Resource Guide for Physics and Whitehead

This Process Studies Supplement provides a scholarly resource for studies in Whitehead and modern science and serves as a complement to our book *Physics and Whitehead: Process, Quantum and Experience* [Timothy E. Eastman and Hank Keeton, editors, Albany: State University of New York Press, 2003].

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Physics and Whitehead Workshop, International Whitehead Conference, August, 1998.

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Introduction

Why focus on Whitehead?

Whitehead's academic career spanned more than five decades from 1880 well into the 20th century, covering a variety of fields from mathematics and symbolic logic, to philosophy of nature and philosophy of science, to epistemology, cosmology and metaphysics. During his early work in mathematics and logic (1880-1912--generally the years at Trinity College, Cambridge) he clearly enlarged his specific concentration on mathematics to include applications for other more physical sciences. As he gradually generalized those early investigations more into the foundations of broader science, he began expressing his evolving insights using more philosophical language and categories (1912-1924--generally the years in London at University College and the Imperial College of Science and Technology). This more philosophical discourse led to even broader categorical investigations that resulted in the challenging cosmology of his mature thinking (1924-1947--generally the years at Harvard University's philosophy department, and retirement).

Whitehead began at a place quite foreign to most scientists during the early part of the century. Rather than focus on the "things" which were being measured and tested (whether massive objects or massless objects), Whitehead choose to focus on the "events" which constituted or included those "things" instead. Other thinkers (e.g., Alexander, Bergson, James, Pierce) track parallel paths through similar issues, and together help constitute an emerging field within philosophy focusing on *relationality* and the *process* nature of the universe. This philosophical field was described as *process philosophy* by the 1960s and found institutional support at Harvard and the University of Chicago.

Whitehead is unique among major process philosophers in terms of his in-depth knowledge of science, mathematics, and logic. Although process thought generally has developed many fruitful strands other than Whitehead's, our focus on Whitehead's work and its progeny is warranted by both his impacts on science and the current relevance of his work for inspiring new approaches to numerous topics in science and the humanities.

Resource Guide Description

First Section

Mutual impacts of Whitehead on science and mathematics are first presented, which demonstrate why Whitehead is a worthy subject of contemporary research. Then we list a broad array of internet resources. After that, we provide a comprehensive bibliography of physics and process thought, and an extensive bibliography in other areas of science and process thought. This includes papers and books that address scientific issues to some extent and that are not focused exclusively on philosophical issues. A glossary of terms completes this first phase of the resource guide.

Second Section

This section provides materials complementary to our book *Physics and Whitehead,* published by SUNY press, including book information, bibliographic sketches for major contributors, and complete dialogues. Due to length limitations, the book contains only part of the dialogue from the Physics and Whitehead Workshop held in 1998 as part of the International Whitehead Symposium in Claremont, California. This PSS entry now contains the entire dialogue material subject only to the limits of the recording and transcribing process.

Appendices

We conclude with several Appendices containing items of special relevance to our topic. Appendix A contains notes on process-oriented physics developments, with a special focus on possibilities for generating basic physics from information. Many contemporary physicists use process-oriented language in their work and some specifically call attention to linkages with process philosophy. For example, Reginald Cahill refers to his approach as "Process Physics." Appendix B contains reprints from special focus sections of *Process Studies* published in 1997 and 1998 and edited by Timothy Eastman on the topic of "Process Thought and Natural Science." Appendix C provides a reprint of the special *Process Studies* issue, edited by Dean R. Fowler, on Whitehead and Natural Science (*Process Studies* 11/4, 1981). Appendix D features a previously unpublished paper by Christoph Wassermann on C. F. von Weizsacker's work on quantum theory and lays out several fundamental connections between process thought and von Weizsacker's interpretations. Appendix E provides previously unpublished material by Robert Russell and Christoph Wassermann on converting Whitehead's Theory of Relativity into modern notation, on how Whitehead's theory meets all the basic observational tests for a general theory of relativity, and then raises some questions about how Whitehead's formalism may yield some advanced results previously thought to be unique to Einstein's approach. Appendix F features a paper by Lawrence Fagg that emphasizes the importance of electromagnetism.

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Mutual Impacts of Whitehead on Science

Topics

Impacts of Whitehead on Physics
Impacts of Whitehead on Mathematics, and Logic
Impact of Whitehead on Other Areas of Science
Impact of Whitehead on Philosophy
Impacts of Science on Whitehead's Philosophy
Suggested Revisions to Whitehead
Rejection of Whitehead

[Note: Detailed references are given in the Comprehensive Bibliography.]

Impacts of Whitehead on Physics

Natural ontological basis for quantum and relativity theory – A modified Whiteheadian theory of events provides a natural ontological basis for quantum theory in light of recent developments in the quantum theory of measurement, Bell's Theorem, and relativity theory.

For quantum theory (Stapp, Finkelstein, Malin, Shimony)

For relativity + quantum theory (Papatheodorou & Hiley, Finkelstein, Tanaka)

"it should be clear why such avowedly post-Whiteheadian thinkers as Bohm, Stapp, Wheeler, and Prigogine acknowledge an explicit influence, as well as an important intellectual indebtedness, to Whitehead himself. They have not followed Whitehead; they have treated him as a rich historical resource for novel philosophical insights …this is precisely the perspective that philosophers in general should come to adopt in their assessment of Whitehead's significance." [Lucas, 1989, p. 199]

Unification of geometry and physics – Whitehead's 1905 Memoir "undertook the unification of geometry and physics by means of …symbolic logic--which was forged by Whitehead and Russell between 1900 and 1910. The paper constitutes a synthesis unique in the history of ideas at that time. Not until 1916, in the *General Theory of Relativity*, did Einstein express the unification of geometry and physics." [Schmidt, p. 4]

Impact on mainstream gravitation research - In working on Whitehead's theory, Eddington stumbled upon a previously unknown form of the Schwarzschild metric, a form thus discovered a full 36 years before Kruskal's famous singularity-free coordinate systems of 1960. "Thus, far from being a useless relic of an obscure philosopher, Whitehead's theory has actually contributed significantly to the progress of gravitational research during the past thirty years." [Hyman, p. 389]

Simplicity and pedagogical attributes of Whitehead's relativity theory - Whitehead's theory is analogous to the Lienard-Wiechert formulation of classical electrodynamics, the pedagogical attributes of which have been especially stressed by Feynman [Hyman, p. 387]. "Einstein's theory is nonlinear and therefore not susceptible to such a simple formulation." [Hyman, p. 388]; "Whitehead's law of gravity is manifestly Lorentz covariant, rather than generally covariant. However, it could be written in generally covariant form if one wanted to go to the trouble." [Hyman]

Disproof of Whitehead's relativity theory may be premature - Clifford Will's work does not constitute a disproof of Whitehead's theory of relativity and further work is needed. [Fowler, 1974, 1975a, 1975b]; Whitehead's theory is equivalent to the Schwarzschild solution of Einstein's theory; it passes standard experimental tests; Will's claimed disconfirmation is premature; a slight generalization of Whitehead's theory permits the Kerr solution for rotating holes [Russell and Wassermann, see Appendix E].

Whitehead has inspired recent work on possible quantum foundations for consciousness – "Whitehead, for example, described the universe as being comprised of occasions of experience. To examine this possibility scientifically, the very nature of physical reality must be re-examined" [Hameroff and Penrose]. [Also see Shimony, 1997; and Stapp, 1993.]

Algebra of events inspired by Whitehead - "We formulate Suppes predicates for various kinds of space-time: classical Euclidean, Minkowski's, and that of 'general relativity'. Starting with topological properties, these continua are mathematically constructed with the help of a basic algebra of events; this algebra constitutes a kind of mereology, in the sense of Lesniewski. There are several alternative, possible constructions, depending, for instance, on the use of the common field of reals or of a non-Archimedian field (with infinitesimals).
Our approach was inspired by the work of Whitehead (1919), though our philosophical stance is completely different from his. The structures obtained are idealized constructs underlying extant, physical space-time." [Da Costa]

Fundamental entities as events - "In his 1959 essay entitled 'My Present View of the World,' [Russell] argued that the fundamental entities are discrete but overlapping 'events', that the fundamental entities of mathematical physics are 'constructions composed of events', and that entities like conscious minds and 'selves' are best understood as collections of events 'connected with each other by memory-chains backward and forwards'." [Lucas, 1989, p. 124] [For examples of physicists who conceive of fundamental entities as events, refer to books and papers by Stapp, Malin, Finkelstein, Shimony, Papatheodorou & Hiley, and Whipple.]

Impacts of Whitehead on Mathematics and Logic

Emergence of Mathematical Logic – “To Frege and Peano, Whitehead and Russell one is indebted for the full formalization of these abstract ideas. This is a new mathematics as well as a new logic.”
[Ghose]
“…a knowledge of the symbolic logic of Russell and Whitehead is still a necessary prerequisite for understanding contemporary studies in logic, in the foundations of mathematics, and the philosophy of science.” [*Runes*]

Foundations of Symbolic Logic – “Working independently of Frege, Alfred North Whithead and Bertrand Russell created another version of this kind of logic. In *Principia Mathematica* (1910-1913), they utilized an easily readable notation invented by Giuseppe Peano that led to the widespread dissemination of the new logic. Their system became the main symbolic tradition until Frege’s neglected writings were rediscovered after the Second World War.…As general systems, both have been superseded, but certain parts of each …are still widely accepted today. Because of its earlier canonical status, we shall focus on Whitehead and Russell’s system. It is difficult to overestimate the importance of Whitehead and Russell’s notation [Note by Eastman: based on other references, such notation was primarily the innovation of Whitehead.] in making the new logic accessible to scholars.…The revolutionary nature of this work becomes even clearer in comparison with Scholastic logic, which began with Aristotle.… It was an inferential system, designed to draw valid conclusions from premises. It was not an axiomatic system of the sort that Whitehead and Russell developed but instead consisted of a large number of ad hoc rules.…These rules apply to the only type of argumentation that the system recognized: the syllogism.” [Popkin, pp. 607-608]

Relevance to modern mathematical discourse - “History on the whole vindicates Whitehead’s concern with the notion of perspective. In fact, the discovery...that logical paradoxes infect the very basis of modern mathematical discourse (i.e., the language of sets) ...illustrates well the dangers and perplexities that result when the importance of perspective is not taken into account.”

[Code, 1985, p. 204]

Impact on 20th Century Mathematics - “There is one major mathematical legacy of *Principia Mathematica* in which it is referenced in the title of perhaps the most significant paper that affects mathematics and its foundation of the twentieth century...written by Kurt Godel in 1931. In the article he proved...that the thesis of *Principia Mathematica* is false. One cannot deduce arithmetic, much less mathematics, from logic.” [Mays, 1977, p. 31]

Defining points and lines in terms of regions - “...the essential thing about Whitehead’s approach is not his objection to operationalism, but the fact that Whitehead bases his discourse upon regions or ‘lumps’ of space, and in terms thereof defines points and lines. And *just this* approach has been developed in mathematics.” [Seaman, 1975] “Whitehead, in his famous book *Process and Reality*, proposed a definition of point assuming the concepts of ‘region’ and ‘connection relation’ as primitive. Several years after and independently Grzegorczyk, in a brief but very interesting paper, proposed another definition of point in a system in which the inclusion relation and the relation of being separated were assumed as primitive. In this paper we compare their definitions and we show that, under rather natural assumptions, they coincide.” [Biacino and Gerla]

Promising foundation for contemporary philosophy of mathematics – “That Whitehead’s early attempts at a philosophy of mathematics were inadequate, does not mean that his empiricist position was wrong. We believe that his mature philosophical position, an extension and modification of his earlier empiricism, is an adequate and satisfactory foundation for a contemporary philosophy of mathematics.” [Henry and Valenza, 1993, p.

24] “We wish that we could have asked Whitehead in his later years about his earlier passion to objectify mathematics to the detriment of its relation aspects [revealed in later mathematics research]. His mature philosophy was so thoroughly relational.” [p. 25]

Recovery of induction in Principia Mathematica proof *89.16 - “In his new introduction to the 1925 second edition of “Principia Mathematica”, Russell maintained that by adopting Wittgenstein’s idea that a logically perfect language should be extensional, mathematical induction could be rectified for finite cardinals without the axiom of reducibility. In an Appendix B, Russell set forth a proof. Godel caught a defect in the proof at *89.16, so that the matter of rectification remained open. This paper shows that while Godel and Myhill are correct, Russell was not wrong. A new proof for *89.16 is given and induction is recovered.” [Landini, 1996a]

Current developments in type theory and typed lambda calculus – “Our formalization is close to the ideas of the ‘Principia’, but also meets contemporary requirements on formality and accuracy, and therefore, is a new supply to the known literature on the ‘Principia’ (like Sections, 25, 19, 6, and 7). As an alternative, notions from the ramified type theory are expressed in a lambda calculus style. This situates the type system of Russell and Whitehead in a modern setting. Both formalizations are inspired by current developments in research on type theory and typed lambda calculus.” [Laan and Nederpelt]

Automated theorem proving - “The paper describes and contrasts two approaches to automated theorem proving applied to portions of Russell and Whitehead’s ‘Principia Mathematica’ (PM). The Logic Theory Machine by Newell, Shaw, and Simon tried to duplicate the reasoning behind the proofs as a human mathematician might do. Wang’s approach uses sequent logic and the computer to prove the theorems. The paper describes both methods in detail. It also resolves an error in PM and in the correspondence between Simon and Russell. The paper concludes that the Logic Theory Machine approach is more satisfying in its attempt to understand the human endeavor that is the basis for PM.” [O’Leary]

Point-free topology - “The idea of point-free topology, which can be traced back to Whitehead, is to take the notion of open-set as basic and to consider the notion of point as derived. In this paper, it is shown that Tychonoff’s theorem, classically equivalent to the axiom of choice, has a direct inductive proof if it is expressed in a point-free way.” [Coquand]

Method of Extensive Abstraction and theory of congruence – [See Palter, 1960, Chapters 5 and 6]

Laguna-Whitehead procedure in geometry – “…counter-example to the primacy of non-symmetrical relations is the de Laguna – Whitehead procedure in geometry of defining one-way relations, e.g., inclusion, in terms of a symmetrical relation of ‘extensive connection’.” [Hartshorne, 1970, p. 208; also see Palter, 1960, Chapters 5 and 6; Laguna; Lowe, 1962, p. 82]

Impact of Whitehead on Other Areas of Science

Major influence on Laszlo’s General Systems Theory - “...I found...that the organic synthesis of Whitehead can be updated by the synthesis of a general systems theory, replacing the notion of ‘organism’ and its Platonic correlates with the concept of a dynamic, self-sustaining ‘system’ discriminated against the background of a changing natural environment.” quote from *Intro. to Systems Philosophy* [Laszlo, 1972, p. viii]
“Whitehead offers a unified system of thought which is based upon the concept of organizations within structured organizations, beginning at the very basis of physical reality and extending upwards into increasingly complex structures...a hierarchy of organisms with a base level of purely physical organism underlying all complex organic organisms...this hierarchy is characterized by various degrees of ‘organic unity’.” [Code, 1985,

p. 140]
"Systems theory (in all the versions I have ever seen) is classical, a theory of reality. The general systems theorists I have read don't even recognize this limitation, they are so immersed in it. Organism has clear quantum aspects, brought out in the paper. It would diminish organism to call it systems theory."[Finkelstein, private communication, 3-29-02; also see Finkelstein, 1997, available in Appendix A]

Constructive logic and its application in computer science – "This interpretation, especially as refined in the type-theoretical work of Per Martin-Lof, puts the system on par with the early efforts of Frege and Whitehead-Russell. This quite recent work, however, has proved valuable not only in the philosophy and foundations of mathematics, but has also found practical application in computer science, where the language of constructivism serves as an implementable programming language and within the philosophy of language." [Sundholm]

Formalizing 'internal relations' as binary operators rather than as classes - "Logic's standard practice of treating relations as classes of ordered pairs of terms has the advantage of simplifying the calculus of relations by making it amenable to set-theoretic treatment, but this practice also has the disadvantage of emasculating the idea of relation by identifying it with what Bradley called 'external relations.' This paper formalizes 'internal relations' by not considering them as classes but rather as binary operators which generate a new term from a given ordered pair of terms, thus distinguishing between related and unrelated terms - internal relations being essential to the terms related, according to Whitehead." [Asenjo]

Self-identity of compound entities in chemistry – "...a compound individual should be considered to be one 'actual entity' if, and to the extent that, particular percipients interact with that entity as a unified source of effective action [Early, p. 253—available in Appendix A].…Some, but not all, compound entities have the property of retaining self-identity while engaged in action, and therefore have an ontological status that is different from the status of those nexus which lack that property.…For physics, the thing itself is what it does." [pp. 254-256]

Impact of Whitehead on Philosophy

Overall impact – "Whitehead's work …anticipated and …contributed in important ways toward framing many of the most significant themes at issue in the current mainstream of Anglo-American philosophy." [Lucas, 1989, p. 5]
"…important work in the fields of contemporary philosophy and history of science, epistemology and the sociology of knowledge, modal logic, action theory, and philosophy of mind." [p. 7]
"Whitehead's summary contribution to the history of Western philosophy is an attempt to complete the revolution initiated by Copernicus, by offering a metaphysical account of the nature of things that can simultaneously take seriously both nature and human experience." [p. 132]
"Whitehead probably belongs less in the linguistic tradition of analytic philosophy (which he himself did much to foster) than he does in the wider literary, interpretive, and speculative traditions of European or Continental thought." [p. 203]

Chief figure and founder of process philosophy – "Whitehead is the chief figure and in many ways the founder of process philosophy, a contemporary philosophical movement in vigorous development in America, and more recently in Europe." [Lucas, 1989, p. 6]

Facts and values – "With Whitehead's assistance, we may at last find a way to move beyond the pervasive relativistic distinction between facts and values." [Lucas, 1989, p. 6]

"While he shares the interests and concerns for a broader interpretation of facts and values, he denies the fundamental distinction of scope or method between the scientific and humanistic disciplines … and offers a close parallel to the challenge posed to the conventional understanding of hermeneutics in European thought by advocates of a 'universal hermeneutics', including Rorty, Mary Hesse, and Foucault." [p. 204]

Impact on Wittgenstein - "Wittgenstein, who wrote *Tractatus Logico-Philosophicus* partly to address problems in *Principia Mathematica*, was so pleased with this book that he gave up philosophy, because he thought that he had solved all the philosophical problems that could be solved." [Henry and Valenza, 1993, p. 31]
"Like Whitehead, Wittgenstein was 'born again' philosophically, and also, like Whitehead, repudiated the fundamental thesis of *Principia Mathematica."* [Mays, 1961]

Importance of Whitehead's defense of speculative metaphysics - "The advocacy of systematic or speculative thought as an antidote to cultural or professional tunnel-vision, however, does not require that its advocates embrace what Rorty decries as a 'foundationalist stance'. In fact it is quite conceivable for systematic thought to remain sensitive to its own ingrained matrix of self-reference, as well as to the circularity inherent in any such form of cultural and historical interpretation." [Lucas, 1989, p. 4]

Limits on the scope of scientific laws - "For Whitehead, scientific laws are spatially and temporally restricted and only support counterfactuals whose conditions are within the scope of the law. Kneale and others (e.g., Popper, Pap, Carnap) believe this account mistaken, because they think nomological generalizations are universally quantified statements which are omnitemporally and omnispatially unrestricted in scope. But Whitehead's scepticism about the epistemic grounding of such claims is more plausible than these philosophers have believed. Their omnitemporal and omnispatial requirements are gratuitous and unjustified." [Beauchamp]

Reconceiving teleology and rejecting vitalism- "…for Hegel, as for Whitehead, teleology is the cornerstone of what Whitehead later called the 'Reformed Subjectivist Principle'…. Hegel rejects, as Whitehead later does, the alternative of a pure vitalism." [Lucas, 1989, p. 101]

The **philosophy of organism** provides

(1) an ontological basis for causal connection
(2) a basis for vectors in physics
(3) a foundation for the notion of energy
(4) an interpretation of the quantum character of nature
(5) an interpretation of vibration and frequency
(6) a foundation for induction
(7) a relational theory of space-time
(8) a basis for the notions of rest, motion, acceleration, velocity, and simultaneity
(9) an explanation of the relation of geometry to experience
(10) a foundation for the biological notion of an organism and the sociological notion of a society

[from Schmidt, pp. 173-174]

Concept of Prehension [link of field theory to a generalized concept of experience]

- perception in the mode of causal efficacy
- doctrine of symbolic reference
- unified theory of perception

"Sixteen ways of thinking that are more or less obviously unfavorable to the understanding and acceptance of the concept of prehension. They go far to explain why Whitehead's philosophy is even yet not well assimilated--in many circles not even discussed--by the profession. They also furnish a measure of his originality." [Hartshorne, 1979, pp. 253-264]

1. Subject-predicate logic and the neglect of relative predicates.

2. Thing-structure vs. event-structure of reality.
3. Common sense and ordinary language (fallacy of the perfect dictionary?)
   Suspicion of new concepts.
4. Fascination with symmetry.
5. Three alleged simultaneities: perceiving and perceived, memory and its data, mental events and their bodily conditions.
6. Determinism: the symmetrical view of causal necessity.
7. Hume's axiom: What is distinguishable is separable.
8. Continuous becoming, denial of quanta.
9. Three confusions: the given with the believed or known to be given; the remembered with the believed or known to be remembered; data experienced as apparently single or non-composite with genuinely single things.
10. "Neutral" or non-emotional, sensory qualities.
11. "Inextended" mind and its natural results: dualism, materialism, or skepticism.
12. "Pathetic (anthropormorphic) fallacy."
13. God as unmoved mover knowing the world.
14. Truth as "timeless."
15. Nominalism.
16. Non-intentional, non-modal logic.

Solution to problems of induction and causation - "Whitehead's epistemology, stressing causal efficacy, presentational immediacy, and perception in the mixed mode of 'symbolic reference', provides a credible alternative to both Kant and Hume on the relation of causality to experience. His account of causality and his decisive justification of the empirical grounding of inductive reasoning thus emerge as Whitehead's most significant (and insufficiently appreciated) contributions to Western epistemology and philosophy of science." [Lucas, 1989, p. 9]
"Whitehead's integration of these dimensions of experience [bodily feeling and emotions] into a unified theory of perception, recovering the experience of causal efficacy, ranks in my view as his chief contribution to the Western philosophical tradition." [p. 91]

Logic of relations and the importance of relative predicates – "…alongside the logic of relations, the stress on the importance of relative predicates, and the novel theory of 'prehensions'--a list Charles Hartshorne quite rightly cites as Whitehead's 'revolutionary' contributions to Western thought--I would add the doctrine of symbolic reference, and particularly the notion of perception in the mode of causal efficacy. Karl Popper … is generally given all the credit for 'solving' the problem of induction through the deductive notion of 'falsification'. Notwithstanding, I believe that it is Whitehead who provides the only account of induction and causality that can respond to Hume while preserving a genuine role for empiricism, for experience, and for that stubborn grain of realism that remains deeply and perhaps forever imbedded in the scientific enterprise. In any case, there is a kind of originality here that Russell, to my mind, never quite emulates." [Lucas, 1989, p. 114]

Influence on Russell's theory of descriptions – "Russell credits Whitehead with having 'awakened' him from his 'dogmatic slumbers' by devising the mathematical technique, called 'extensive abstraction', for deriving such presumably fundamental notions as point-instants and material particles from sets of events. Russell claimed that his technique provided the insights that led to his own theory of descriptions and the application of Occam's razor." [Lucas, 1989, p. 114]

The first-order logic and first-order semiotic of R. M. Martin – Introduction of Richard M. Martin's philosophic logic "to those interested in the logico-linguistic underpinning of philosophic theology and systematic theology. The first part of the article consists of an exposition of Martin's theory of first-order logic and first-order semiotic, augmented by the calculus of individuals and an event logic. The second part of the article consists of a discussion of Martin's application of philosophic logic in process theology as well as a further extension of that logic to several crucial problems in process theory." [Power]

Internal relatedness and time - "The notion of internal relatedness in both Prigogine and Whitehead is integrally related to the reality of time. A genuine evolutionary paradigm cannot exist where time is dismissed as a subjective phenomenon...time is real because systems construct themselves in it ...one must develop a theory of organism by which internal experience is explicable...the categories of permanence and flux in Whitehead are transposed in Prigogine's works to 'order' and 'chaos'."
[Kirk, p. 60]

Grounding the concept of scientific progress - "Whitehead's clearest discussion of 'progress through revolutions' in science is to be found in FR. There he maintains that the two aspects of reason, practical (scientific method) and speculative (metaphysical systems) are interrelated in such a way that progress results." [Plamondon, 1979, p.139]
"...systems of both science and philosophy develop in interaction. Successive theories in both science and philosophy involve a widening of explanatory categories...to catch ever more experience....This constitutes the meaning of the 'cumulative' aspect of scientific theories." [p. 140]

Experiential grounding of science - "The task of science is not to explain nature through an appeal to a conceptual representation of it, but rather to explain a conceptual representation through an appeal to experience." [Folse, 1974, p. 39]
"Just as Whitehead argues that our scientific knowledge involves a high degree of abstraction, which removes us from the concrete real things of nature, so Bohr argues that our conceptual interpretation of experience is like a 'projection' onto one of many different possible 'conceptual planes' of the fullness of experience, not captured in any single conceptual picture. These different conceptual 'projections' or 'pictures' of nature are often, among themselves, inconsistent, but together they *complement* one another so as to form the fullest possible conceptualization of experience....Thus Bohr also sees the problem in epistemology as essentially a critique of abstractions and would be in natural sympathy with Whitehead's program." [p. 39]
"This crucial role of activity in experience is the cornerstone for the compatibility between Bohr's Copenhagen position and Whitehead's view." [p. 41]

Paradigm functioning in science – "Thus, over thirty years in advance of Thomas Kuhn's seminal study, one finds already set forth, in Whitehead's meticulous historical and philosophical analysis of the rise of modern science, a surprisingly contemporary analysis of many of the salient features of paradigm functioning in 'normal', in revolutionary, or in pre-paradigm scientific disciplines …[but] Whitehead, unlike Kuhn, does not wholeheartedly embrace the relativistic implications of this analysis. Rather, he holds fast to a critical realist epistemology reflecting the prevailing experience and working assumptions of practicing scientists." [Lucas, 1989, p. 133]

Popper and the logic of scientific discovery – "Popper stubbornly adheres to a realist epistemology, sharply rejects the logical empiricists' version of verification, and advocates a kind of recursive method--requiring ever more precise assertions, precise testing, and the construction of hypotheses that can unify ever greater and more disparate realms of observations. All these, and especially the last, map with striking precision onto Whitehead's canons of philosophic method…" [Lucas, 1989, p. 135]

Rorty and the failure of the foundationalist linquistic program – "Whitehead, even more than Dewey, has already blazed the path that Rorty presently wishes to pursue. At several points, for example, Whitehead issues a stinging critique of the inadequacy of linquistic and logical foundationalism. He also decries the more general tendency toward epistemological foundationalism that he, like Rorty, traces back to Descartes." [Lucas, 1989, p. 139];

"This is the vision of systematic philosophy which Whitehead advocates--one which is, I firmly believe, immune from Rorty's criticisms of the modern metaphysical and epistemological tradition." [p. 140]

Misc. notes on influences:
"…no evidence whatever that Whitehead knew of Peirce's views or was in any way influenced by them." [Lucas, 1989, p. 62]
"…remarkable absence of reference in Whitehead's work to evolution, to specific evolutionist theories, or to specific evolutionary cosmologies or cosmologists." [p. 58]
"Whitehead…seems unwilling to endorse anything that would smack of a dualistic or vitalistic theory." [p. 63]
"Bergson's influence on Whitehead is quite similar to the influence of William James, the influence of both pertaining almost entirely to Whitehead's radical reconceptualization and extension of the very notion of experience itself." [p. 64]
"The Whiteheadian school represents a form of cosmology influenced principally by mathematical physics (primarily relativity theory and, to a lesser degree, quantum mechanics), and only to a minor degree by evolutionary biology (which is more or less presupposed)." [p. 70]

Impacts of Science on Whitehead's Philosophy

Whitehead worked to develop a metaphysics that is perpective invariant even as physical laws should be coordinate independent - [Stolz, 1995]
"...relativity...is plausibly near the heart of the evolution of process metaphysics." [p. 379]
"...Whitehead's relativity principle ('it belongs to the nature of every being that it is the potential for every becoming') is a full metaphysical generalization of the physical principle (that all inertial reference frames are equivalent)" [p. 380]
Stolz asserts that a metaphysical version of covariance is manifest in the deep structure of the reconstruction of Whitehead's thought. [p. 380]
"...a covariant metaphysics would manifest a set of dynamic objects in processive flux against an invariant background of unchanging forms. These notions map beautifully onto Whitehead's actual entities and eternal objects, and more generally onto any theory of organism." [p. 380]
Stolz "stresses physical covariance more specifically as a principle of formal homogeneity or symmetry and, correspondingly, he claims that Whitehead had implicitly imported this notion into his philosophy to develop a metaphysics that is perpective invariant even as physical laws should be coordinate independent." [p. 380]
"An analogous transition of the search for invariants in the description of natural processes in general is characteristic for the 'natural philosophy' of Whitehead. The idea of a field theory of cognition is one result of this transition to the search for covariant representations of epistemic processes." [p. 380]

Impact of 1905 Memoir work on Whitehead's later philosophy of nature - "...some connection between the method of speculative philosophy in PR and the axiomatic method used to construct the various concepts of the material world in MC....It might indeed be argued that Whitehead's philosophy of nature with its emphasis on the 'principle of relativity', is largely a development of Concept V of MC, to which an experiential dimension has been added." [Mays, 1977]

Treatment of time - From 1915 forward ("Space, Time, and Relativity" address to British Association for Advancement of Science) "Whitehead treated time as an integral component of a four-dimensional space-time manifold." [Hurley, 1979]

Indefinite diversity of modes of ingression - "...while Whitehead's process metaphysics is a triumph of dynamic relationality over mere substance, something all too inert seems to persist in his conception of eternal

objects." (Henry and Valenza, 2001, p. 55)
"...the ordinary conception of a predicate or property answers nicely to the Whiteheadian notion of an eternal object, and our appeal to fuzzy predicates is anticipated by Whitehead's corresponding 'indefinite diversity of modes of ingression.' An so, what we find here--and explicitly--is both that the relatedness of eternal objects is ontologically paramount and that this relatedness is held or, in a sense, maintained by [the primordial nature of] God." [p. 74]
"...our categorical examination shifted the difficulties in the ontology of predicates to the priority and provenance of their mutual relations, which in turn Whitehead explicitly ascribes to the primordial nature of God." [p. 75]

Suggested Revisions to Whitehead

"Whitehead, a mathematician of note to his contemporaries but of small consequence to his successors, never scented a relational approach to mathematics....He seems implicitly to have accepted a condition of ontological stasis for the mathematical world. All the more remarkable, then, that Whiteheadian metaphysics explicitly countenances the occasions of actual entities through the dynamic, relation process of concrescence, a process remarkably similar to the dynamic evolution of mathematical forms. The holism of functoriality is the holism of process thought. We stand in amazement that Whitehead saw this so clearly in his adopted field of philosophy but not in his native field of mathematics." [Henry and Valenza, 1997, p. 34]

"In UA Whitehead sought to achieve what he calls generality by trying to unify by a common interpretation apparently disparate algebraic systems.... In PM he sought to unify mathematics by logic. Both attempts failed. The supposed common interpretation of generalized spaces in UA was not satisfactory. When his system of logic with its assumption of the theory of types was objectified and compared with other mathematical systems, it was shown to be paradoxical. Further, Godel showed that it was incomplete for arithmetic." [Henry and Valenza, 1997]

"His mathematical research tended to two extremes: applications and foundations....For Whitehead...abstraction is foremost a tool of science, and UA takes this view to the limit. Hence, when he surveys the field with a unifying eye, he sees on the one hand, symbolic logic... and, on the other hand, real or complex linear algebra and its extensions. The vast middle ground (including number theory and algebraic geometry, for instance) is lost in the deep shadows cast by rational, empirical science. The resulting formalism is too enfeebled to support the objects and methods of twentieth century mainstream mathematics, and the great irony of Macfarlane's criticism becomes this: the failure of UA lies not in relentless, arbitrary abstraction and formalization but in the narrowness of its extensive base." [Henry and Valenza, 1997, p. 27]

"The view of mathematics set forth in PM is irrelevant to the working mathematician. It is simply the wrong level of description for the activity in question. In our opinion, this, and not Godel's Incompleteness Theorem, is the basic functional failure of logicism...one does now eschew logicism for its incompleteness but for its ineffectiveness." [Henry and Valenza, 1997, p. 33]

Misunderstanding of Kant - "Witness, for example, his deficient historical understanding of German idealism and his misappropriation of Kant, a deficiency Whitehead shared with many of his English and American contemporaries, including Bertrand Russell." [Lucas, 1989, p. 8]
"…despite Whitehead's complete ignorance of Hegel." [p. 9]

"…there extends throughout all of Whitehead's published writings a virulent anti-Kantian polemic…it is simply inconceivable that one should propose to 'do philosophy' as though the likes of Kant and Hegel had never existed!.…Whitehead's stated desire to effect 'a recurrence to pre-Kantian modes of thought' (*Process*

and Reality, vi/xi) has, in addition, made his work virtually inaccessible (not to mention inexcusable!) to contemporary Continental philosophers bred in the cultural heritage of Kant and Hegel.…I will suggest that this alleged departure [from Kant] is not nearly so great as both disciples and critics have imagined ….[Whitehead's] own thought is both intelligible and congenial to contemporary philosophers, particularly those involved with recent trends in European thought ….Whitehead was not so much ignorant of Kant as he was by and large a prisoner of the Anglo-Saxon philosophic climate of opinion, in which Kant's philosophy is customarily appropriated (in a very narrow and simple-minded fashion) as purely an anti-metaphysical epistemology of Newtonian science. Within this intellectual climate, for example, there is no attempt to comprehend Kant's own systematic and synoptic philosophical project ….To the shock of most historians and Continental philosophers, such material is simply overlooked in the conventional English-language appropriation of Kant that has reigned until quite recently ….To [Whitehead's] lasting credit he, unlike [his Anglo-Saxon contemporaries], rejected this anti-metaphysical epistemology as philosophically inadequate ….It is fair to say that Whitehead read Kant as having enshrined in a peculiarly idiosyncratic way an epistemology grounded in Newtonian-Euclidean cosmology.…In the early twentieth-century climate of opinion, Whitehead would almost inevitably have been led to 'get Kant wrong', as virtually all his contemporaries did as well …[however] many of the views he espouses about actuality, subjectivity, and the nature of experience can be shown to be extensions of certain Kantian doctrines, rather than (as Whitehead himself thought) inversions of them." [Lucas, 1989, pp. 75-79]
"If Whitehead can trace a "destructive" subjectivist tendency from Descartes through Kant to Bradley, we may also with even greater credibility, trace a constructive tendency toward the reconception of experience from Kant, through Hegel, Morgan, Bergson, and others to Whitehead himself ." [p. 86]
"…Whitehead …adds that reasoned, organized consciousness, in turn, presupposes experience …the notion of 'experience' is quite broadly construed for Whitehead, as it is also for James and Bergson." [p. 87]

"Stanley Klein: I think you are correct that there are discrepancies between Whitehead and modern quantum theory and I recommend to anybody a chapter in Penrose's book by Abner Shimony [See Bibliography: Shimony, 1997], who's a big Whitehead fan but who advocates an augmented Whiteheadianism… what Shimony is talking about is an augmented Whiteheadism and maybe that's what we should be talking about. Let's not take Whitehead of the 1920s too seriously, but imagine an augmented Whitehead, as if he were around now with knowledge of Bell's theorem and modern issues. Would it just be augmented or would it require a fundamental transformation of some or all of his categories?" [Eastman and Keeton, p. 188]

"John Wygant: Whitehead does need to be modernized in the light of what has happened in the past 70 or more years… the nature and method of metaphysics is really very different from the nature and method of science, so in revising I think one also has to look at what's happened in the last 70 years in metaphysics as well." [Eastman and Keeton, pp. 267-268]

Rejection of Whitehead

"…the current irrational prejudice against Whitehead among a majority of analytic philosophers must be traced to Whitehead's own advocacy, during his career, of controversial and unpopular philosophical themes and positions. Ford specificallly cites three of these positions: (1) Whitehead's belief in the legitimacy of speculative thought; (2) his presumed commitment to panpsychism; and (3) his willingness to embrace a version of theism.…Whitehead's philosophical isolation stems at least as much from the subsequent co-opting of his philosophy by followers whose exegetical and theological interests differ sharply from Whitehead's own explicitly philosophical agenda." [Lucas, 1989, p. 131] "There is nothing inherently objectionable about these subsequent neo-Whiteheadian developments; but it is high time to return Whitehead's own, more philosophical interests to center stage." [p. 132]

"…Whitehead has fallen victim to precisely the same set of forces that has polarized the field generally and driven a wedge, in particular, between so-called analytic philosophy (qua philosophy) and so-called Continental philosophy, in which the less quantifiable and less logically rigorous contributions of literature, art, history, and cultural anthropology are allowed to play a significant role.…Such speculative and systematic philosophy is once again in resurgence on the American philosophical scene, at least.… Philosophical theism was decidedly a secondary issue with Whitehead.… This whole matter of panpsychism or pan-subjectivism in Whitehead's thought has been radically miscast." [p. 131]

"Whitehead's odd reading of Kant, his ignorance of Hegel, and his simplistic understanding of subsequent trends in post-critical idealism--to which his sophisticated recasting of 'critical realism' is not so much opposed as allied--are formidable obstacles to his serious reception on the European philosophical scene." [p. 203]

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Internet Resources - Science and Process Thought

Center for Process Studies at Claremont
[http://www.ctr4process.org/]

International Process Network
[http://www.alfred.north.whitehead.com/IPN/ipn_homem]

The Australasian Association for Process Thought
[http://www.alfred.north.whitehead.com/]

European Society for Process Thought
[http://www.espt.de]

Japan Internet Center for Process Studies
[http://pweb.cc.sophia.ac.jp/~yutaka-t/process/index.htm]

Papers online from *Process Studies* (selections up to about Vol. 15, 1986)
provided through religion-online.org by Ted and Winnie Brock.
http://www.religion-online.org/cgi-bin/relsearchd.dll/listcatitems?cat_id=109

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Cahill, Reginald T., Papers on his process physics
[http://www.socpes.flinders.edu.au/people/rcahill/processphysics.html]

Fimmel, Peter, Notes and links on process physics
[http://cygnus.uwa.edu.au/~pjf/index.html]

Finkelstein, David, Research and publications
[http://www.physics.gatech.edu/people/faculty/dfinkelstein.html]

Prigogine, Ilya, Links by Shu-Kun Lin on his Dissipative Structure Theory
[http://www.mdpi.org/entropy/entropyweb/prigogine.htm]

Stapp, Henry P., Current papers online
[http://www-physics.lbl.gov/~stapp/stappfiles.html]
Notes and links about Stapp's book, by Piero Scaruffi
[http://www.thymos.com/mind/stapp.html]

Tanaka, Yutaka, Papers on process philosophy
[http://pweb.cc.sophia.ac.jp/~yutaka-t/process/papers.htm]

General Resources on Philosophy of Physics:

About Physics – Philosophy of Physics
http://physics.about.com/cs/philosophy/index.htm

A Brief History and Philosophy of Physics
By Alan J. Slavin, Department of Physics, Trent University
http://www.trentu.ca/academic/physics/depinfo/history_895.html

History and Philosophy of Science and Mathematics on the Internet, UK
http://www.herts.ac.uk/humanities/philosophy/intersci.html

The Net Advance of Physics – Philosophy and the Foundations of Physics
Prepared by Norman Redington, MIT
http://web.mit.edu/afs/athena.mit.edu/user/r/e/redingtn/www/netadv/founds.html

Open Directory Project – Links in Philosophy of Physics
http://dmoz.org/Society/Philosophy/Philosophy_of_Science/Philosophy_of_Physics/

PhilSci Archive, an electronic archive for preprints in the philosophy of science
Sponsored by: Philosophy of Science Association, the University Library and Center for Philosophy of Science, University of Pittsburgh
http://philsci-archive.pitt.edu/

References for the Philosophy of Physics
Professor Uchii's Online Articles, Kyoto University
http://www.bun.kyoto-u.ac.jp/~suchii/physics.index.html

Stanford Encyclopedia of Philosophy, Edited by Edward N. Zalta
http://plato.stanford.edu/
[Note entries on Alfred North Whithead by A. D. Irvine and on Charles Hartshorne by Daniel Dombrowski]

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Metanexus Institute, Philadelphia
Online Forum on Science and Religion
http://www.metanexus.net

Meta Library - science ethics, philosophy and religion
www.meta-library.net

Research News & Opportunities in Science and Theology
http://www.researchnewsonline.org/

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Glossary

Action Principle. Action is the integral of the Lagrangian of a physical system with respect to time. Of all possible motions, the dynamical motion of a system of particles and fields is one for which the action is stationary (not always a minimum).

Actual Entity. In Whitehead's metaphysical system, the category of *actual entity*—also termed *actual occasion* or occasion of experience—is the basic metaphysical genus of existents. The other metaphysical genera of the system consist of existents that either are generic operations, features, or relationships of actual entities [see *contrast, nexus, prehension, proposition*, and *subjective form*] or are uncreated ontological presuppositions of all actual entities [see *creativity, envisagement, eternal object,* and *extension*]. Actual entities are the final real constituents of the actual world. They are discrete and interconnected, and their generic properties are those Whitehead deemed essential to any discrete moment of *experience,* human or non-human. Actual entities are "drops of experience, complex and interdependent" (A. N. Whitehead, *Process and Reality*, 18).

Actual Occasion. See *Actual Entity*.

Asymmetry. Vulnerability to a possible change.

Atomism. The view that there are discrete irreducible elements of finite spatial or temporal extent. For propositions, the view that relations are external and that some true propositions are irreducible (Logical Atomism).

Autocatalytic (Chemical) Reaction. A (chemical) process that increases in speed as it progresses. Non-autocatalytic reactions generally become slower as time passes. However, if a chemical substance produced by a reaction happens to increase the speed (rate) of the chemical reaction that produces it, then that product is said to be 'an autocatalyst' - and the reaction rate increases without limit, unless some necessary reactant other than the autocatalyst becomes depleted. This sequence of events (mechanism) is called 'product activation' or 'direct autocatalysis'. Several other relatively simple chemical mechanisms (e.g. inhibition by a reactant) also yield autocatalytic behavior ('indirect autocatalysis').

Baryon. An elementary particle formed of three *quarks*, for example, a proton or a neutron.

Bell's Theorem. A mathematical proof, assuming locality, that determinate projections for the spins of electrons are incompatible with spin correlations predicted by quantum theory. Observational tests supporting Bell's result suggest that reality must be non-local. These results appear to resolve the *EPR argument* of Einstein's, which indicated a necessary incompleteness to quantum mechanics [derived from John Bell (1928-1990)].

Boolean Algebra. An algebraic system that treats variables, such as computer language elements or propositions, with the operators AND, OR, IF, THEN, NOT, and EXCEPT [derived from George Boole (1815-1864)].

Bootstrap. The notion that the nature of matter reflects self-consistency rather than arbitrary "elementary" constituents. See *S-matrix Approach.*

Bose-Einstein Statistics. See *Quantum Statistics*.

Causality. The relationship between a cause and its effects. There are determinate, statistical and other types of causal relations. The causal principle, roughly that the same cause always produces the same effects, is essential to science.

Change. In considerations of *symmetry* or *asymmetry*, the production of something different.

Classical Logic. See *Logic, Quantum and Classical*.

Closure. Completion of a collection of items or relationships in such a way as to yield a set that is, in some sense, complete.

Collapse of a Quantum State. The change in a quantum state as a quantum system undergoes a transition from the potential to the actual during a measurement.

Concrescence. In Whitehead, the process of *concrescence*—or the microscopic process—is the second stage in the becoming of an *actual entity.* The first stage is the process of *transition.* In the stage of concrescence, the process of becoming, though conditioned by the determinations of transition, is self-determining. The process of concrescence is thus a process of self- causation. Since concrescence is guided by the actuality's *subjective aim*, it is also a process of *final causation*.

Contrast. In Whitehead, *contrast* is the most encompassing category of existence, excluding only existents belonging to the category of *eternal object*. A contrast is any synthesis of items in an *actual entity*.

Copenhagen Interpretation of Quantum Theory. A synthesis of Bohr's complementarity interpretation and Heisenberg's ideas on the uncertainty principle. Sometimes referred to as the "orthodox" interpretation of quantum mechanics.

Cosmic Background Radiation (CBR). The total radiation from outer space that is not associated with specific, identifiable sources (considering photons but not particles). The equivalent blackbody temperature of the CBR is approximately 3°K.

Covariance. See *Relativistic Invariance*.

Creativity. In Whitehead, *creativity* is that eternal aspect of the universe by reason of which there is an endless becoming of *actual entities*. It individualizes itself, and thus manifests itself, in the becoming of every actual entity. But it is never exhausted by such individualized manifestations.

Debye Screening. Within a *plasma* there is a redistribution of space charge to prevent penetration by external electrostatic fields. The length scale associated with such shielding is called the Debye length and shielding clouds of this dimension are called Debye spheres. See *Plasmas*.

Decoherence. Environment-induced loss of interference terms in quantum solutions that can contribute to resolving some problems in *quantum measurement theory*.

Diachronic. Covering events at different times.

Dielectric. Material placed between plates at different electrical potentials (capacitor).

Dissipative Structure. An arrangement of processes, taking place in an open system (a defined spatial region that can exchange material and/or energy with its environment), such that any alteration in that arrangement (whether internally or externally generated) engenders a response that tends to restore the original arrangement (see *limit cycle*). Dissipative structures contrast with 'equilibrium structures' - self restoring arrangements of items that persist in closed (isolated from the environment) systems. Interaction with the outside world tends to break up equilibrium structures (such as an ice crystal), but such interaction is necessary for persistence of dissipative structures (such as a flame in the tip of a gas jet).

Dualism. In *metaphysics*, the view that for any given domain there are two independent and mutually irreducible substances (e.g., the Cartesian dualism of matter and mind). In *epistemology*, the view that there is a duality of the content immediately present to the mind (e.g., sense datum) and the perceived object.

Dynamic System (in Chemistry). A collection of inter-related processes--states of affairs that change as time progresses. Such combined interactions may lead to a unique equilibrium state--a condition that maintains itself indefinitely (without changing the surroundings) by means of the balance of countervailing changes. Alternatively such combinations of changes may produce one or more non-equilibrium steady states--conditions that maintain a particular set of properties, while exchanging material and/or energy with the environment. Non-equilibrium steady states may be either stable (self-restoring after disturbance) or unstable (destroyed by any disturbance). In the condition known as bistability, two stable non-equilibrium steady states exist, as well as a third, unstable, steady state. The condition of the overall system will correspond to one or the other of the two stable steady states, depending on the past history of the system.

Dynamics. The analysis of energy, force and associated motions. See *Kinematics.*

Electromagnetism. See *Force Fields.*

Electron. A point-like particle that contains one unit of negative charge and has a mass of 0.5 Mev/c2. Electrons form the component of atoms outside the nucleus.

Entelechy. In Aristotle's philosophy, the mode of being of a thing whose essence is completely realized or actualized, in contrast to potentiality or the form.

Envisagement. In Whitehead, *envisagement* is that eternal aspect of the universe by reason of which every individualization of creativity is in part a function of the state of the universe correlative with the initiation of that individualization.

Epistemology. One of the two main branches of philosophy, which is devoted to studies of the origin, methods, structure, and validity of knowledge. See *Metaphysics (Ontology)*.

Epochal Theory of Time. Whitehead's theory that temporal process is a discrete succession of epochs, each having the duration needed for the emergence and completion of *an actual occasion*; also called a cell theory or atomic theory of time.

EPR Argument. An argument by Einstein-Podolsky-Rosen (EPR) that quantum mechanics is necessarily incomplete. It is based on two metaphysical principles, the separability principle and a locality principle, and derives an inconsistency between these realist principles and predictions of quantum mechanics. Einstein appears to have lost this argument (*see Bell's Theorem, Nonseparability).*

Eternal Object. In Whitehead, the only category of existence whose members are not created by the becoming of *actual entities*. A geometrical form, a shade of blue, an emotion, and a scalar form of energy are all examples of eternal objects. Basically they are qualia and patterns whose reproduction within, or ingression into, an actual entity render determinate the latter's objective and subjective content. Thus, relative to actual entities, they are said to be forms of definiteness or pure potentials for the specific determination of fact. But, in themselves, eternal objects are each an existent with a unique individual essence conjoined with a non-unique relational essence that it shares with some other eternal objects. Apart from their joint ingression into an actual entity, eternal objects are isolated from one another

Euclidean Geometry. See *Geometry, Euclidean and Riemannian.*

Experience. In Whitehead, *experience* refers both to an experiencing-process and to the experience-product generated by that process. The experiencing-process is one and the same with the becoming of an *actual entity*; and the experience-product is that same actual entity as a being, or as already become. The essential features of experiencing do not include *consciousness or sense-perception*, but do include receiving, taking account of, and responding to, data that are primarily actual entities already become and eternal objects. The receiving of data constitutes the objective side of experiencing, whereas the responding to data constitutes the subjective side. A completed actual entity is a determinate synthesis of objective data and subjective responses. Such a synthesis is both the aim and product of the actual entity's process of becoming, or experiencing.

Extension. In Whitehead, *extension* (or extensive continuum) is a technical term with a variety of related meanings. In the metaphysical theory, extension is an eternal aspect of the universe: it is an infinite, indeterminate continuum differentiable into potential finite regions that only become actual when embodied by the becoming and being of individual actual entities. The finite region embodied by an *actual entity* is its extensive standpoint, is uniquely its own, and does not overlap with the extensive standpoint of any other actual entity. Extension, in this sense, is neither physical space nor physical time; rather, the becoming of actual entities effects the spatialization and temporalization of extension. In the cosmological theory, under the influence of relativity physics, it is assumed that actual extensive standpoints contingently constitute an ever-expanding four-dimensional continuum of spatio-temporalized extension. This assumption is in no way necessitated by Whitehead's metaphysics.

Extensionality. In the logic of classes, there is an axiom of extensionality which effectively assumes that everything is a class, and treats the words 'set' and 'class' as synonymous.

Extensive Connection. See *Topology and Extension*.

Fermi-Dirac Statistics. *See Quantum Statistics*.

Feynman Diagram. In quantum field theory and especially for quantum electrodynamics, simple diagrams can effectively replace complex mathematical terms of the field equations.

Feynman Paths. Classical *action*-carrying "potential" paths in spacetime whose aggregation determines *wave-function* propagation.

Final Causation. See *Concrescence*.

Fine Structure Constant. A fundamental dimensionless constant of physics, the fine structure constant α (=1/137) derives from studies of closely spaced groups of lines observed in the spectra of the lightest elements.

Force Fields. Four fundamental interactions are distinguished in modern physics: gravitational, electromagnetic, weak nuclear, strong nuclear. The characteristic strengths of these force fields are 10^{-39}, 10^{-2}, 10^{-5}, and 1, respectively. Both gravity and *electromagnetism* are long-range force fields whereas both nuclear forces are very short range (10^{-13} cm or less). See *Gauge Theory*.

Gauge theory. Gauge invariance is central to current theories of the fundamental interactions. Derived from Weyl's work in relating scale changes and the equations of electrodynamics, gauge theories constructed to embody various *symmetry* principles have been very successful in representing the fundamental interactions. See *Force Fields*.

Geometry, Euclidean and Riemannian. Geometry is the mathematics of the properties and relationships of points, lines, surfaces, and solids. The system of geometry that dominates our practical affairs is a modified version of the assumptions of Euclid of Alexandria (325-265 BC). Georg Riemann (1826-1866) introduced a new system of geometry to handle curved surfaces and curved spaces. Einstein used this *Riemannian Geometry* to develop his general relativity theory, providing a quantitative representation of both gravity and accelerated reference frames.

Gluon. A virtual particle that is exchanged between quarks that constitutes the strong force. Gluons not only interact with *quarks*, but with each other.

Grand Unification Theory (GUT). A theory that seeks to provide a common derivation for the color and electroweak forces and for *quarks* and *leptons*.

Hermeneutics. The science and methodology of interpretation; a discipline initiated through biblical analysis in the 19th century.

Hilbert Space. A vector representation space for the properties of quantum systems. A finite-dimensional Hilbert space is a finite-dimensional Euclidean space in which vectors are represented as complex numbers instead of real numbers.

Holism. The theory that the world is composed of organic or interrelated wholes which are more than their constituent parts. See *Particularism*.

Hyperfine Structure. A slight shift in the frequency of radiation from atoms due to the interaction with the atom's nucleus.

Hypothetico-Deductive Method. This method is used in factual sciences as well as in *metaphysics*. It is constituted, according to Whitehead, by a balanced mutual relationship between three elements; (i) the creative element which accounts for a imaginative construction of hypotheses and theories and as such is free of all kinds of restrictions; (ii) the rational element which secures the coherence and internal consistency of the hypotheses forming the theory and the possibility of deduction of consequences from this axiomatic base; (iii) finally the empirical element calls for at least the possibility of indirect empirical testing of metaphysical theories through the integration of mediating scientific schemes.

Idealism. Any philosophical framework whose basic interpretive principle is that of Idea, Mind, or Spirit. Process philosophers generally avoid traditional *dualisms* such as idealism/materialism and mind/body. See *Realist*.

Implicate order. Physicist David Bohm introduced a distinction between an explicate order, comprising the given world of experience, and a holistic implicate order, which is a fundamental causal order in parallel with and underlying the explicate order.

Indeterminacy Principle. For particular observable pairs (e.g., position and momentum; energy and time), precise measurement of one observable necessarily causes uncertainties in possible knowledge of the complementary observable.

K Meson. One of the strongly interacting elementary particles with baryon number 0. Observations of K Mesons first indicated an intrinsic time asymmetry in high energy physics interactions.

Kinematics. The study of motion excluding the effects of mass and force. See *Dynamics*.

Lagrangian. The difference between total kinetic energy and potential energy for a dynamic system of particles expressed as a function of generalized coordinates and their time derivative.

Lamb Shift. A small change in the frequency of the light emitted by an hydrogen atom due to the existence of virtual pairs.

Lattice Field Theories. Theories where spacetime, rather than being continuous, consists of a discrete set of points at which fields are defined.

Leptons. Elemental fermions, which have spin-1/2 statistics (see *Quantum Statistics*); *electrons*, muons, neutrinos, and tauons are all leptons. See also *Quarks*.

Linguistic Turn. The point of view that meaning is constituted by linguistic practice of a community and that there is no external standard for such practice.

Limit Cycle. A unique sequence of states of a dynamic system, each described by two or more variables (say, x and y), such that the sequence traces out a closed curve in the x, y plane which encloses a single point (x', y') that corresponds to an unstable steady state of the system--and furthermore, that any deviation from that sequence of states (the limit cycle) engenders a response that tends to restore the system to one of the states of the limit cycle. All trajectories of the system eventually reach the limit cycle, irrespective of their starting conditions. Autocatalysis is necessary (but not sufficient) for existence of a limit cycle.

Logic, Quantum and Classical. Logic investigates the structure of propositions and deductive reasoning by focusing on the form of propositions instead of their content. Classical logic derives from Aristotle and is captured in modern *boolean logic*. In contrast, some physicists argue that quantum theory requires a non-Boolean or quantum logic. The basic logical structure for deductive reasoning is the syllogism wherein one can infer, for example, from major premise "If A then B" and minor premise "A" that "B" is true. Similar logical implication is obtained through disjunctions. For example, one can infer the truth of "A" from combining the major premise "A or B" and minor premise "not B."

Logical Conjunction, Disjunction and Implication. See *Logic, Quantum and Classical*.

Logicist. The claim that all mathematics can be derived from logic. Implementing this reduction was the goal of Whitehead and Russell's *Principia Mathematica*. This claim, however, was proven false in 1931 by Godel's famous Incompleteness Theorem.

Metaphysics (or Ontology). One of the two main branches of philosophy, which is devoted to studies of the nature of being or *ontology*. See *Epistemology*.

- **plain**: a theory of the most general features of reality and real entities.
- **exact**: a theory of the most general features of reality and real entities which makes explicit use of formal sciences (logic, mathematics, game theory) in theory construction (reducing the ambiguities of ordinary language by defining the basic terms explicitly and making explicit the relations between the basic notions and axioms) and theory criticism (testing internal and external consistency).
- **scientific**: an exact metaphysical theory which further takes into account the (main) results of contemporary scientific research.

Metaphysics and Sciences, relations between. See *Sciences and Metaphysics*.

Metasystem level. Level of description embracing both experimenter and system under study.

Neoplatonism. Arising in the 2nd century A.D. as extensions of Platonism, the view that ideal patterns or universals are existent substances and that body and soul are independent substances.

Nexùs. In Whitehead, any set of *actual entities* is a *nexùs*. The term "does not presuppose any special type of order, nor does it presuppose any order at all pervading its members other than the general metaphysical obligation of mutual immanence" (A. N. Whitehead, *Adventures of Ideas*, 201). The mutual immanence of discrete actual entities is an apparently paradoxical doctrine that receives consistent explanation in terms of Whitehead's theory of metaphysical *extension* (See Nobo). Nexùs are classified into various main types according to the specific contingent forms of order they exhibit. A social nexùs, or *society*, is by far the most important type of nexùs.

Nonseparability. The supposition that *Bell's Theorem* results on spin correlations indicate a fundamental connectedness between occasions, including some regions outside the normal causal light cone of relativity theory. However, nonlocal correlations depend on a common initial event at the source of the associated particles or photons.

Objectification. In Whitehead, *objectification* refers to the manner in which one *actual entity* is immanent in another actual entity. There are three modes of objectification: causal, presentational, and anticipational. The different natures of the three modes cannot be understood apart from the properties of metaphysical *extension* (See Nobo).

Occasion of Experience. See *Actual Entity*.

Ontology (or Metaphysics). The theory of being qua (as) being. For Aristotle, ontology is the science of the essence of things. See *Metaphysics.*

Particularism. The view that all apparent wholes are mere aggregates of discrete, separable parts. See *Holism*.

Phenomenology. The descriptive analysis of subjective processes. Roughly, pure phenomenology and pure logic are mutually independent disciplines. Modern usage of the term derives from Husserl (1859-1938).

Photon. The particle aspect of light, or more generally, electromagnetic radiation. Photons have no rest mass and carry one unit of angular momentum in units of h-bar. Each photon has an energy which is Planck's constant, h, multiplied by its frequency.

Planck Scale. An exceedingly short distance, equal to 1.6×10^{-35}m, based on combining Planck's constant, the speed of light, and the gravitational constant.

Plasmas. Plasmas are an electrically conducting interactive mix of uncharged particles, positively charged particles, negative electrons, electric fields and magnetic fields. The fraction of uncharged particles in a plasma varies dramatically, from more than 95% in the lower ionosphere to less than 1% in the solar wind, the continuous stream of plasma from the Sun. In contrast with neutral gases and liquids, plasmas are noted for their highly interactive properties and collective effects. They comprise more than 99% of the visible universe. See *Debye Screening* and the plasma web site at http://www.plasmas.org.

Prehension. In Whitehead, the activity of prehending is the most concrete creative operation involved in the becoming of an *actual entity*. Its created product is the most concrete component of an actual entity already become. Each prehension is analyzable into a subject, an objective datum, and a *subjective form*. The subject is the actual entity insofar as it autonomously decides its own final subjective definiteness. The objective datum is any entity—such as another actual entity, an *eternal object*, or a *nexus*—that is taken into account and responded to by the subject in its process of self-formation. And the subjective form is the definiteness with which the subject clothes itself in response to that datum. The subjective form is how the subject defines itself in response to that datum.

Proposition. In Whitehead, a *proposition* is the prehensible *contrast* of an *actual entity* or *nexus* with an *eternal object*, or a set of eternal objects, expressing a possible determination of that actual entity or nexus. A proposition may serve as the datum for a propositional *prehension*. The prehension of a proposition does not require consciousness. However, in a high-grade actual entity, a few propositions may be consciously prehended against a vast background of unconsciously prehended ones. Self-referential propositional prehensions are possible, and one kind, termed the *subjective aim*, is generic to all actual entities.

Pulsar. A rapidly rotating neutron star that emits radiation in pulses linked to its rotational period.

Quantum Logic. See *Logic, Quantum and Classical*.

Quantum Measurement Theory. The analysis, for different interpretations of quantum mechanics, of what observables can have determinate values in a given *quantum state*.

Quantum State. A mathematical entity which contains all the available information about the probabilities of all possible measurements on a quantum system.

Quantum Statistics. Statistical physics endeavors to deduce information about macroscopic properties of a system based on analyzing statistics of its microscopic constituents. In application to quantum systems, a basic distinction is found between particles having half-integer spin or Fermi-Dirac statistics and integer spin systems with symmetric quantum wave functions, which display Bose-Einstein statistics. Since electrons have spin ½, Fermi-Dirac statistics apply and no two electrons can simultaneously occupy the same quantum state. The resulting Pauli exclusion principle forms the basis for generating the periodic table of the elements.

Quark. A point-like constituent of neutrons, protons, and mesons. The quarks contain all the nucleon mass and are indivisible as far as we know. Three quarks form a *baryon*, such as a proton, neutron, and other short-lived particles. Two quarks form mesons. See also *Leptons*.

Realism. For *ontology*, the theory of the reality of abstract terms or universals in which universals exist before things, in contrast to nominalism for which universals have a being only after things. In *epistemology*, realism holds that it is possible to have faithful and direct knowledge of the actual world. Process philosophers generally avoid traditional *dualisms,* such as *idealism*/materialism and mind/body. If one insists on the idealism/

realism pairing, it can be argued that Whitehead was both an idealist and a realist. See *Idealist*.

Reductionism. Reduction is the subsumption of one conceptual scheme by another. In metaphysics, reductionism holds that there are systematic identities between entities of a higher level to those in a lower, reducing level. In epistemology, reductionists typically point to semantic equivalences between propositions in the higher level to those in a lower, reducing level. Reduction in science is the effort to systematically explain one scientific theory by laws and phenomena in another lower-level theory.

Relativistic Invariance. Properties of a system are invariant if they are unchanged during a change in the frame of reference. The Lorentz transformation needs to be applied to length and time measurements to achieve relativistic invariance. In comparison, the classical Gallileian transformation is a good approximation at low speeds but differs noticeably from the Lorentz transformation at high speeds, especially those approaching the speed of light. Applying relativistic invariance enables the laws of physics to have the same form for any system of coordinates; this is called the principle of *covariance*.

Riemannian Geometry. See Geometry, *Euclidean and Riemannian*.

S-Matrix Approach. Theory based on the general principles governing particle collisions (such as frame independence, causality and probability conservation), rather than on arbitrarily-specified field equations.

Sciences and Metaphysics, relations between

- **stimulation**: On the one hand, a scientific metaphysics provides a most general scheme of reality from which (with the help of additional specifying hypotheses and limiting conditions) specific notions can be logically derived, which may function as basic concepts in a science and thereby throw new light on old scientific problems, transform them and initiate new scientific research strategies and experiments.
- **criticism**: Sciences are the critics of metaphysics. The schemes of the sciences mediate between the abstract and general metaphysical scheme and empirical fact as disclosed by experimentally guided observation. If a scientific approach that is initiated by a metaphysics does not lead to fruitful new insights issuing in new experiments yielding positive, i.e. confirming results, not only this scientific approach must be modified or even abolished, but also the initiating metaphysics has to be reconsidered.

Screening. See *Debye Screening* and *Plasmas.*

Semantics. The study of the meaning of signs and symbols.

Society. In Whitehead, a *society* is a *nexus* made up of successive generations of actual entities exhibiting a common form of order that the members of each generation inherit from the members of the preceding generation. The common form of order is the society's *defining characteristic*. Societies, or their defining characteristics, are the enduring objects of nature.

Space Plasma. See *Plasmas*.

Spin Network. A quantum-theoretic network of coupled spins used by Roger Penrose as an atomistic geometry of the surface of the sphere.

Spinor. A vector describing spin of the electron.

State Vector. Polarization and other quantum states are represented by matrices called state vectors. See *Wave Function*.

Steady State Model. A model of the cosmos in which hydrogen is steadily created so that the cosmos would continue in a steady state.

Subjective Aim. In Whitehead, the *subjective aim* of an *actual entity* is what guides its process of becoming. It involves a *proposition* prehended by the actual entity with the *subjective form* of purpose to realize it its process of becoming. The actual entity is itself the logical subject of the proposition, and an *eternal object*, or set of eternal objects, is the logical predicate of the proposition.

Subjective Form. In Whitehead, a particular subjective definiteness gained by an *actual entity* by reason of its *prehension* of some datum or other. The definiteness of each subjective form is due to the ingression of an *eternal object* or set of eternal objects.

Substantialism. The view that all reality is basically composed of substances whose change of configuration constitutes change without reference to any fundamental process as in process thought.

Supersession. In Whitehead, *supersession* is a technical term standing *both* for the process constituting the becoming of an *actual entity* and for the chronological relations generated by that process. The relata of supersession are either actual entities or phases in the becoming of each actual entity.

Supervenience. The relationship between the characteristics of a collection and the properties of the components that compose that collection. For ordinary macroscopic objects (shoes, ships, sealing wax) the mass of a collection is simply the sum of the masses of the components. However, much of the energy produced by the Sun derives from the circumstance that the mass of the nucleus of the helium atom is somewhat less than the mass of four hydrogen nuclei (protons) that may be taken to compose it. The standard philosophical treatment of wholes and parts ('mereology') treats parts as being unaffected by their aggregation into larger units. This approach may not apply to all composites of philosophic and/or scientific interest. To the extent that the existence of a composite changes the characteristics of the components, the properties of the aggregate may not correspond exactly to ('supervene on') the sum of the corresponding properties of the parts of that aggregate.

Symmetry. Immunity to a possible change.

Synchronic. Covering all events at one time.

Syntactics. Formal (content free) analysis of the linguistic forms of languages.

Topology. The study of geometric spaces that are invariant under deformation.

Transition. In Whitehead, the process of *transition*—or the *macroscopic* process—is the first stage in the becoming of an *actual entity*. The second stage is the process of *concrescence*. In the stage of transition, the process of becoming is determined by the state of the universe correlative with the initiation of the process. The process of transition is thus a process of efficient causation.

Uncertainty Principle. See *Indeterminacy Principle*.

Uranium. A silvery-white metallic element of atomic number 92, which has 14 isotopes of which U-238 is the most abundant. The isotope U-235 is fissionable with slow neutrons and, in a critical mass, is capable of sustaining a chain reaction that can proceed explosively.

Vector. A quantity having both magnitude and direction. See *State Vector*.

Venn Diagrams. Classes can be diagrammed as overlapping circles, which can help test the logical consequences of given *Boolean* propositions. These were developed by John Venn (1834-1923).

Virtual Particle. A particle that is formed for a very short period of time and then ceases to exist.

Virtual Particle Pair. A pair of particles produced spontaneously in the vacuum as a result of the Heisenberg uncertainty principle. For example, an electron and positron can be produced and exist for a very short time arising out of nothing.

Wave Function. The state of motion of a particle can be described by a complex wave function $\psi(x, y, z; t)$. The probability of finding the particle in a volume element dV at point (x, y, z) and time t is equal to $\psi^*\psi$. Wave functions are commonly represented by linear operators or matrices called vectors; examples include what are termed ket, bra, and state vectors.

Wave Packets. Groups of waves, traveling at the group velocity, which are combined disturbances of a set of sine waves with a limited range of frequencies and wavelengths. The pure sine waves used to define phase velocity do not really exist because they would require infinite spatial extent.

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Capsule Description

Exploring the rich interface of contemporary physics and Whitehead-inspired process thought, this book features papers and discussions by prominent scientists and philosophers sharing the conviction that quantum physics not only corroborates many of Whitehead's philosophical theses or insights, but is also helpfully illuminated by them.

Promo Copy

Exploring the rich interface of contemporary physics and Whitehead-inspired process philosophy, this multi-disciplinary work is partly based on papers presented and discussed at a three-session workshop on "Whitehead and Physics" held in August 1998 as part of the International Whitehead Conference in Claremont, California. The work's editors and contributors share the conviction that quantum physics not only corroborates many of Whitehead's metaphysical theses or insights, but is also helpfully illuminated by them. Thus, though differing in perspective or emphasis, the papers by Geoffrey Chew, David Finlkestein, Henry Stapp and other prominent scientists smoothly dovetail in subject-matter or conceptuality with those of Philip Clayton, Jorge Nobo, Yutaka Tanaka and other leading process philosophers. Excerpts from the workshop's discussions among presenters, panelists, and audience capture the excitement generated by the papers' theses and arguments. In addition, to facilitate further research and creative work in the field, the editors have collected an extensive bibliography and created a well-structured website. Not incidentally, the bibliography and website jointly document the rapid growth of contemporary interest in Whitehead exhibited not only by physical scientists, but also by ecologists, biologists, psychologists, systems theorists, theologians, and philosophers.

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SUNY Series in Constructive Postmodern Thought

Summary of Key Ideas and Concepts

Preface and Part I. Physics and Whitehead

The preface and Chapter I provide a systematic introduction to the key ideas and concepts that recur throughout. An exceptionally clear and concise introduction to process thought is given by Clayton; this is complemented by Nobo's in-depth concluding work in Chapter IV. Within process thought there is a focus on events and process versus objects, and emphasis on experience as paradigmatic, and the development of concepts such as prehension, concrescence, and supersession. Eastman weaves together all contributions in the volume by providing a systematic comparison of concepts in the classical, quantum, and process frameworks. It is shown how the latter two frameworks both illustrate the theme of "duality without dualism." The process-relational tradition represents a balanced perspective, a middle ground, between the extremes of Parmenides' substance monism and the 'all is change' doctrine of Heraclitus. This middle ground does not set up a simple equivalence between each pair of concepts, such as being/becoming or symmetry/asymmetry, but a complex symbiotic relationship, illustrated by the physics of symmetry and asymmetry as shown by Rosen. Keeton covers Whitehead's early works and demonstrates his roles as mathematician, logician, and mathematical physicist. Jungerman then shows how signatures of process permeate modern physics with a focus on interconnectedness, evolution without exact predictability, and specific illustrations of process in physics.

Part II. Order and Emergence

Earley demonstrates the relational basis of chemistry for which entities formerly thought to be simple substances are actually networks of processes. He finds a wide class of unit-determining closures in relations from chemistry to ecological systems. Malin shows how the rise of fields of potential out of actual events reveals a literal dance occurring between actuality and potentiality. In a model discussed by Geoffrey Chew, the non-material content of the vacuum impinges on the propagation of the actual-potential matrix resulting in scalar differences, which appear as 'object' manifestations similar to classical physics. The discrete happenings emerging from this actual-potential activity are the focus of the formalism. They serve as a bridge between purely conceptual events and purely physical events. In this actual-potential interplay, Stapp describes how an irreducible choice for all quantum systems arises from how "a particular question must be posed." Important insights into the brain and consciousness are gained as Stapp evaluates how the freedom pertaining to such questions and the need for these choices persistently remain when the brain is included in the system.

Part III. Fundamental Processes

Rosen shows how symmetry principles, so important for modern physics, reveal an important complementarity between symmetry and asymmetry. He points out that "the possibility of a change, which is a necessary component of symmetry, is contingent on the existence of an asymmetry of the situation under the change." Thus, the inevitable possibility of a change indicates that the assumed symmetry of classical formulations is incomplete. Embedded within the actual-potential interplay is a fundamental asymmetry, which produces the capacity for the process itself. Rosen's work illustrates a duality without dualism in physics, which is shown by Eastman to be closely mapped to key philosophical categories, especially as developed in process thought.

From the standpoint of spacetime, Hansen shows how the paradoxes of defining unique local 'present' reference frames within special relativity are resolved by the actual-potential matrix, producing unique extended regions within which measurements can occur. Concrete temporal facts are then not global but local - a 'local temporalism.' Actual-potential rhythm exhibiting such local temporalism becomes the fundamental application of relativistic physics, which is then understood as an application of process ontology. Classical matter and Minkowski spacetime become cogredient aspects of this process structure. This allows alternative topologies to appear as spacetime within the process structure.

Tanaka shows how quantum logic applied to the extended actual-potential matrix yields a broader understanding of the 'individuality' of events and the 'singularity' of actuality. Durations within the flux of spacetime become related to scale and the appearance of particular singularities. S-matrix type theories, which do not distinguish between space and time, assume the fundamental connection between them within the event. Thus spacetime is manifested in the event itself, and the operators representing the events include the spacetime parameters.

Finkelstein explains that "I have passed through four successive stages of belief concerning universal law:
Polynomism: When I began to teach physics, I told my students that physics was the search for the laws of nature.
Mononomism: After I read more of Einstein I taught that physics was the search for *the* Law of Nature. I thought this was an inspiring insight.
Anomism: Then I suspected that there was no law.
Pannomism: Now I think that there actually is a law, but an evolving law like Newton's and Peirce's rather than an absolute one like Laplace's, and that is all there is."
In the Part III Dialogue, Professor Finkelstein elaborates as follows: "I suspect that the things we call laws today are simply phenomenological descriptions of the quantum fine structure of the vacuum. That, I'm sure, is a condensation phenomenon. The limited number of possible laws is the result of a limited number of possible phases. And so the apparent constancy of law is because there are jumps between them just as there are between the various crystalline forms of ice. You don't have a smooth variation from one to the other. It takes a real disaster."

Part IV. Metaphysics
Riffert shows how a purely scientific metaphysics can be seen to emerge from the fundamental shift from 'objects' to 'events' that has occurred in contemporary physics. The specific requirements for an adequate and applicable metaphysical system are explored from the standpoint of Mario Bunge's formal methodological criteria. What results is an incorporation and suggested expansion of Whitehead's cosmology conceived as a theory of events.

In 'Whitehead and the Quantum Experience,' Jorge Nobo argues the need for speculative philosophy and develops an experientialist principle. He then systematically moves from human experience to experience in general, to speculative metaphysics, to speculative cosmology. Nobo then builds on Whitehead's metaphysical experientialism to show how concepts of causal objectification, supersession and extension, prehension and transition, among others, help us to understand some recent developments in quantum physics.

Bibliographic Sketches for Major Contributors

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creator of the plasma page: http://www.plasmas.org

Timothy Eastman has carried out basic research in plasma physics and space physics for over 25 years and has been national coordinator for space plasma research for six years while at NASA headquarters and the National Science Foundation. Working with QSS Group, Inc., Dr. Eastman is a consultant in plasma science and applications, and Group Manager for space science support at the Space Science Data Operations Office located at NASA's Goddard Space Flight Center. He is well known for discovering the low-latitude boundary layer of Earth's magnetosphere and other research results important to solar-terrestrial relations and space weather. In addition to space physics research, Eastman has pursued philosophical interests through extensive reading and graduate level studies, conferences and publications, especially in the area of process philosophy.

He has given formal responses in conferences to Hilary Putnam and Henry Stapp, and edited special issues on process thought and natural science in two issues of the journal *Process Studies* 26/3-4 (1997); 27/3-4 (1998). In collaboration with Dr. Keeton, he has created the present comprehensive guide to physics and Whitehead published in *Process Studies Supplements* ("Resource Guide to Physics and Whitehead," *PSS* 2003; http://www.ctr4process/publications/pss/).

Editor - Hank Keeton

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Hank Keeton became interested in Whitehead's thought after deciding to do graduate work in philosophy, rather than physics. But his inclination toward particle physics led him to work on the Alvarez experiment at the Lawrence Berkeley Laboratory in the early 1970's. This combination of interests led him to complete his Ph.D. under Bernard M. Loomer at the Graduate Theological Union in Berkeley, concentrating on Whitehead's evolution from theoretical physics into philosophical metaphysics. Keeton explored the mathematical development of Whitehead's theory of extensive connection in his doctoral work. Since then, he has continued to be active at the interface between process thought and the philosophy of science, with an emphasis on current developments in theoretical physics. His greatest hope is that the evolving ideas of process philosophy will assist current developments in relativity and quantum mechanics. Hank owns a general contracting firm in Oregon specializing in commercial and industrial construction. (See Hank Keeton, *The Topology of Feeling: Extensive Connection in the Thought of A. N. Whitehead, Its Development and Implications*, Ph.D. Dissertation, Berkeley: Graduate Theological Union, 1984.)

Philip Clayton

Philip Clayton is Ingraham Professor of Theology at the Claremont School of Theology and Professor of Philosophy at the Claremont Graduate University. He holds doctoral degrees in both philosophy and religious studies from Yale University. Clayton is author *Explanation from Physics to Theology: An Essay in Rationality and Religion* (Yale University Press, 1989), *God and Contemporary Science* (Eerdmans, 1998); and *The Problem of God in Modern Thought* (Eerdmans, 2000), and co-editor of seven volumes, including *Quantum Mechanics: Scientific Perspectives on Divine Action* (University of Notre Dame Press, 2001) *In Whom We Live and Move and Have Our Being: Panentheism and Science* (Eerdmans, 2003), *Evolutionary Ethics: Human Morality in Biological and Religious Perspective* (Eerdmans, 2004), and *Science and the Spiritual Quest: New Essays by Leading Scientists* (Routledge, 2002). Professor Clayton is a leading scholar in the science and religion field and is principal investigator of the *Science and the Spiritual Quest* project at the Center for Theology and the Natural Sciences in Berkeley, California. His specializations are in philosophical theology, the interface between science and religion, and the history of modern metaphysics; he also publishes in the philosophy of science, systematic theology, epistemology, and the philosophy of religion. Clayton won the Templeton Prize for Outstanding Books in Science and Religion and the first annual Templeton Grant for Research and Writing on the Constructive Interaction of the Sciences and Religion.

Joseph E. Earley, Sr.
Dr. Earley is Professor Emeritus of chemistry at Georgetown University; he has specialized in far-from-equilibrium chemical systems. In addition to his forefront work in modern chemistry, Professor Earley is active in the emerging field of philosophy of chemistry. He is the editor of *Individuality and Cooperative Action* (Georgetown University Press, 1991) and the editor of *Chemical Explanation: Characteristics, Development, Autonomy* (New York Academy of Sciences, 2003).

John A. Jungerman
Dr. Jungerman is Professor Emeritus of the University of California at Davis. His research has been primarily in nuclear physics. He was Founding Director of the Crocker Nuclear Laboratory there. He studied process philosophy with Dr. Rebecca Parker, President of the Starr King School for the Ministry. Most recently he has authored *The World in Process, Creativity and Connection in the New Physics* (State University of New York Press, 2000).

Shimon Malin
Professor Malin teaches at Colgate University in New York. His research is in various aspects of quantum field theory, relativity and cosmology and has authored two books, *Representations of the Rotation and Lorentz Groups* [Dekker, 1976] and *Nature Loves to Hide: Quantum Physics and Reality* [Oxford University Press, 2001].

Geoffrey F. Chew
Dr. Chew of Lawrence Berkeley National Laboratory is a leading theorist in fundamental physics. He originated the famous S-matrix theory, which has been very influential in high energy physics. The book of essays related to his work *A Passion for Physics* (World Science, 1985) was prepared in Dr. Chew's honor. Most recently, he has been developing an historical quantum cosmology.

Henry P. Stapp
Dr. Stapp of Lawrence Berkeley National Laboratory is a leading theorist in fundamental physics, especially the quantum theory of measurement. His most recent work *Mind, Matter, and Quantum Mechanics* [Springer, 1993] has moved into issues of the origin of mind and consciousness, always with solid roots in the physics.

Joe Rosen
Professor Rosen is former chair of the Department of Physics and Astronomy at the University of Central Arkansas. A distinguished contributor to the study of symmetry, he is the author or editor of eight books, including *Symmetry in Science: An Introduction to the General Theory* (Springer, 1995) and *The Capricious Cosmos: Universe Beyond Law* (Macmillan, 1991). Dr. Rosen is now a consultant and resides in Rockville, Maryland.

Niels Viggo Hansen
Dr. Hansen is with the Department of Philosophy at the University of Aarhus, Denmark. His current research work focuses on formulating a modern concept of organic time, inspired by Whitehead, Hegel, Løgstrup and Latour, including linkages with contemporary science and technology.

Yutaka Tanaka
Dr. Tanaka is professor in the Department of Philosophy at Sophia University in Tokyo. He is director of the Japan Internet Center for Process Studies, editor of *Process Thoughts*, and director of Touri-Kadan (forum on classical Japanese poetry). Dr. Tanaka has written *From Paradox to Reality Kouro-sha* (Kyoto, 1993) and *Whitehead Koudan-sha* (Kyoto, 1998).

David Ritz Finkelstein
Professor Finkelstein of the Georgia Institute of Technology is a leading theorist in fundamental physics. He is the author of *Quantum Relativity: A Synthesis of the Ideas of Einstein and Heisenberg* (Springer, 1996). He is currently developing a quantum theory based on elementary processes rather than elementary particles.

Franz Riffert

Dr. Riffert is a philosopher and psychotherapist with the Institute for Education at the University of Salzburg, Austria. He has written three books, including *Whitehead und Piaget: Zur interdisziplinaren Relevanz der Prozessphilosophie* (Peter Lang, 1994), and he has a work in progress (with Michel Werber) titled *Searching for New Contrasts: Whiteheadian Contributions to Contemporary Challenges in Psychology, Neurophysiology, and the Philosophy of Mind* (Peter Lang).

Jorge L. Nobo
Dr. Nobo is professor of philosophy at Washburn University in Topeka, Kansas. He is a leading scholar of metaphysics, process philosophy and Whitehead, and is the author of *Whitehead's Metaphysic of Extension and Solidarity* (State University of New York Press, 1986).

Lawrence W. Fagg
Dr. Fagg is research professor in nuclear physics at The Catholic University of America (Emeritus). He is the author of *Two Faces of Time* (Quest Books, 1985), *The Becoming of Time* (Scholars Press, 1995) and *Electromagnetism and the Sacred* (Continuum, 1999).

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Physics and Whitehead Workshop

Process Thought and the Common Good

Silver Anniversary International Whitehead Conference

August 4-9, 1998 at the Center for Process Studies

Claremont School of Theology, Claremont, California

Physics and Whitehead Workshop, August 5-6, 1998

Session I: Order & Emergence

Moderator: Lawrence Fagg (Catholic University, Emeritus)

Theme Setters: Geoffrey Chew (Lawrence Berkeley Laboratory), *A Historical Reality that Includes Big Bang, Free Will, and Elementary Particles*, and John Jungerman (UC Davis, Emeritus), *Evidence of Process in the Physical World*.

Discussion Panel: Murray Code (University of Guelph), Stanley Klein (UC Berkeley), Jorge Nobo (Washburn University), Harry Papatheodorou (Birkbeck College, University of London), and Robert Valenza (Claremont McKenna College)

[Note: Harry Papatheodorou was unable to attend.

Henry Stapp took his place on the panel.]

Session II: Fundamental Processes

Moderator: Philip Clayton (Sonoma State University--now at Claremont)
Theme Setters: David Finkelstein (Georgia Institute of Technology), *Physical Law as Physical Process*, and Henry Stapp (Lawrence Berkeley Laboratory), *Whiteheadian Process and Quantum Theory of Mind*.

Discussion Panel: Geoffrey Chew (Lawrence Berkeley Laboratory), Lawrence Fagg (Catholic University, Emeritus), Shimon Malin (Colgate University), Stanley Klein (UC Berkeley), and Yutaka Tanaka (Sophia University and Editor of *Process Thought*)

Session III: Philosophical Implications of Modern Physics

Moderator: Tim Eastman (Plasmas International)
Theme Setters: Lawrence Fagg (Catholic University, Emeritus), *Electromagnetism, Time, and Immanence in Whitehead's Metaphysics*, and Yutaka Tanaka (Sophia University), *Bell's Theorem and the Theory of Relativity*.

Discussion Panel: David Finkelstein (Georgia Tech), Geoffrey Chew (Lawrence Berkeley Laboratory), John Jungerman (UC Davis, Emeritus), Stanley Klein (UC Berkeley), Henry Stapp (Lawrence Berkeley Lab), and Robert Valenza (Claremont McKenna College).

Session I: Order & Emergence

Keeton This workshop is organized into three sessions, each three hours long and divided into three sections. The first section is devoted to the two primary theme setters who will set the basic themes for the overall session. The second section will be a dialog between the discussants and the theme setters. The third section will involve audience participation. Each session will have a moderator and Lawrence Fagg (Catholic University, Emeritus), will serve that role for the first session. He will introduce the theme setters and the discussants.

Fagg The first theme setter will be Geoffrey Chew (Lawrence Berkeley Laboratory) and the second will be John Jungerman (University of California Davis, Emeritus). Our panelists consist of Murray Code (University of Guelph), Stanley Klein (University of California Berkeley), Jorge Nobo (Washburn University), Henry Stapp (Lawrence Berkeley Laboratory), and Robert Valenza (Claremont McKenna College).

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Geoffrey F. Chew   Quantum Cosmology on a Whiteheadian Lattice

My report this morning will be tailored to a conference that has been designed to promote Whiteheadian thought, but it would be wrong for you to suppose me a Whitehead scholar. I'm not - as you will quickly appreciate when exposed to my clumsy use of Whitehead's carefully-crafted terminology. I am a renegade theoretical physicist seeking redemption on terms whose relation to Whitehead remains murky. There is, nevertheless, a connection.

For the last decade, motivated by puzzles encountered during four earlier decades of activity in particle theory, I have been attempting to find a quantum model of the expanding universe that spans all the scales recognized so far by science. Henry Stapp caused me to stumble upon a mathematical structure that looked promising. The structure is generally characterizable as "Hilbert space spanned by coherent states on a lattice." This general structure is specialized through an operator algebra associated with the group of complex 4x4 matrices - a group that defines both the Hilbert space and the coherent-state lattice. Earlier work with the Rumanian topologist, Poenaru, relating dual models to thickened graphs, had led me to regard the group GL(4,c) as promising for the enterprise at hand. Eyvind Wichmann, a mathematical physicist at Berkeley, showed me how GL(4,c) relates to the conformal group.

For the bulk of my decade-long effort I ignored Whiteheadian ideas, attempting to blend coherent states with the S matrix in a generalization of a program outlined earlier by Stapp. But the S-matrix is based on the concept of particle, and my chosen mathematical structure resisted a direct particle interpretation . Then, two years ago, a visit to Berkeley by Rudolph Haag reminded me that in S-matrix theory the event concept is as fundamental as that of particle.

Particle theorists, both those who use the S matrix and those who use local fields, have since the early work of Feynman developed the knack of thinking in terms of graphs – i.e., in terms of vertices connected by arcs. Arcs correspond to particles and vertices to events involving particles. The two notions are self-supporting; neither stands alone.

Although my mathematical structure was resisting a correspondence with graphs, I noticed that certain physical parameters, commonly associated with either Feynman-graph vertices or S-matrix-graph vertices, might be represented in my model by complex 4-vectors - mathematical vehicles characterized by 8 parameters (Complex 4-vectors represent the complex Lorentz group, a subgroup of GL [4,c].) Oversimplifying somewhat, these 8 parameters can translate to a pair of Lorentz 4 vectors, one vector locating the vertex in space-time and the other prescribing a momentum transfer or impulse. The available structure could represent a discrete sequence of impulses, each with a space-time location, even though there was no immediate representation of particles.

Any particle-theory graph blends discrete and continuous notions in a semiclassical-semiquantum pattern. Arcs represent continuous particle propagation through spacetime while vertices represent discrete happenings that affect particles. Classical physics is entirely continuous and might be thought of as "arcs without vertices" - particles without happenings. The model I was contemplating was entirely discrete vertices without arcs, i.e., happenings without particles.

In my semantically-amateurish effort today, I shall be using more or less interchangeably the terms "particle", "matter", "substance", "object", and "localized energy", with "arc" being a mathematical representation of the enduring quality implied by any of these terms. It was this enduring quality that was missing from my model's foundation. I was stuck for the foundation with a discrete sequence of happenings.

Since the development of quantum mechanics, physicists have been aware that matter depends for its meaning on happenings; but can a happening, e.g., an impulse, have meaning without concomitant meaning for "that substance affected by the happening"? The physicist trained to see the universe as material (as substantial) can, in contrast to Whitehead, only respond to this query in the negative. It's easy for a Whitehead scholar to recognize occasions as taking precedence over substance, but for me, trained as a student by Enrico Fermi, it was not easy. Abandoning substance as a priori means giving up localized energy as a primitive concept - removing a cornerstone of physics.

Despite the powerful influence of Fermi, thirty subsequent years of puzzling had prepared me to find that physics provides no more than an approximate representation of certain phenomena at intermediate scales of the universe, totally losing validity at both extremely-high and extremely-low scales. On the low side there is abundant indication of failure for usual physical ideas at the so-called Planck scale, which is given by 10^{-43} sec. or 10^{-35} meters - a scale defined by combining the gravitational constant with the velocity of light and the quantum constant. On the high side there is the Hubble scale or age of the universe, about 10^{17} sec. Physics by its nature cannot deal with the entire universe; this is the domain of cosmology.

Is it possible that, even though matter is meaningless at Planck scale, patterns of Planck-scale impulses build a larger scale that provides approximate significance for localized (enduring) energy? Although Whitehead had no doubt, I needed to be convinced.

I set to work seeking, through my lattice coherent-state model, a special pattern of Planck-scale impulses - a pattern of some scale far above Planck scale while far below human scale, that could be interpreted as elementary-particle propagation. I was asking whether the continuous arc of a Feynman graph might be an approximation to a huge pattern of discrete Planck-scale impulses?

It quickly became apparent that, if localized impulses with Planck-scale separation were to be called "events", physicists would misunderstand my model. To a physicist the simplest meaning for event is something that happens to an elementary particle (like creation or annihilation of a photon.) To avoid confusion I coined the term "pre-event" and only later became aware of Whitehead's term, "occasion" (whose distinction from actual occasion I have yet to grasp). I am open at this meeting to persuasion that I should forget pre-event and employ some Whiteheadian terminology. I welcome your suggestions.

However the mathematical structure of my model requires a pre-event to be characterized by more than location and impulse; also carried is electric and magnetic charge. The 16 elements of a 4x4 matrix accommodate four 4-vectors; two of these represent dual electric and magnetic charges. The model Hilbert space is labeled by pre-event chains that I call "histories". Any history is a finite, although extremely long, sequence of 16-parameter pre-events. The notion of a "history lattice" associates to a collection of constraints on this huge set of parameters.

Model constraint on pre-event location is of a type that might well have been envisaged by Whitehead. For example, each pre-event has an age measured from the big bang, and spacing in age between successive pre-events is by a fixed Planck-scale unit that may be either positive or negative. Whitehead might even have imagined the causal constraint determining the impulse at a pre-event from the electricmagnetic parameters and locations of other pre-events. Further readily-appreciated lattice-defining constraints correspond to charge conservation and quantization.

Unavailable to Whitehead in 1929, however, was a subsequent deduction by Dirac that quantum principles require elementary magnetic charge to be large if (as is the case) elementary electric charge is small. Dirac's rule is essential to the square-tower pre-event particle-scale pattern I am proposing for propagation of massless particles such as photons or elementary electrons. The pattern - giving structure to a Feynman arc - comprises on the order of 10^{17} pre-events, corresponding to a particle scale that is larger than Planck scale by a factor of about 10^{17}. Endurance of such a pattern depends on huge confining (attractive) impulses generated by large elementary magnetic charge that appears with both positive and negative sign within history patterns corresponding to matter propagation. Representation of energy, furthermore, depends explicitly on the magnetic charge carried by individual pre-events. In the model, following a suggestion made by Schwinger 30 years ago, magnetic charge is centrally responsible for creating enduring objects.

In any "material pattern of history," total magnetic charge vanishes - i.e., there is magnetic screening - magnetic charge never being observable. In contrast, small elementary electric charge need not be screened and facilitates history patterns interpretable as the "observation" of one enduring object by another. A typical observation pattern, on a scale a factor 10^{11} larger than particle scale (about 10^{28} times larger than Planck scale), involves particle-scale sub-patterns that represent events in the usual physics sense, sub-patterns where photon square-towers originate or terminate.

In other words Feynman-graph vertices, as well as arcs, are approximations to pre-event patterns. Vertex patterns are large on Planck scale but not huge- each comprising roughly $e_m / e = 1028$ pre-events; where e_m is the elementary magnetic charge and e the elementary electric charge. Vertex patterns, even though involving fewer pre-events than arc patterns, are more complex - merging with the “tops” and “bottoms” of square towers. I am only now beginning to think in detail about vertex history patterns.

I remark that, although Whitehead (without the benefit of Dirac) could not have envisaged the magnetic-occasion pattern I am proposing for all matter (including photons), he seems to have appreciated already in 1929 that electrons cannot be elementary. They must already, somehow, be extended systems. I’m grateful to Peter Mutnick for pointing out a relevant passage in *Process and Reality*. What status Whitehead accorded photons I cannot guess; perhaps someone here knows.

A mathematical model feature I should like to elaborate here, but cannot in the time available, attributes to each pre-event a 2-valued index, T or S, that controls whether or not direction of age change (increasing or decreasing) is allowed to reverse along that portion of the history chain where the pre-event is located. (Location along the chain has significance distinct from spacetime location.) Along a T portion of the chain, age is monotonic - unequivocally increasing or decreasing; along an S portion, age may either increase or decrease from one pre-event to the next. Because matter depends for meaning on event patterns of history and because event patterns invoke local reversal of age-change direction, in material patterns of history only S pre-events appear. Any history chain, however, includes both T and S portions, so how are T pre-events to be interpreted?

My proposal is that most pre-events build vacuum or, if you prefer alternative terminology, “ether”. I have found a magnetically-robust, magnetically-neutral pattern that pairs T and S pre-events - a pattern incapable of representing energy flow but related to the cosmological Hubble flow that associates a preferred Lorentz rest frame to each location in spacetime. (The special rest frame of our location “here and now” is not quite the frame in which this room is at rest but it is not very different. Our room velocity is less than 1% of light velocity.) The candidate vacuum pattern, in contrast to a square-tower material-flow pattern, has a random-walk aspect that leads nowhere - standing still in the special frame. The great bulk of any model history is vacuonic; material history constitutes a tiny fraction of the total.

Presence of S pre-events within vacuonic history patterns allows the patterns to interact with material patterns (although of course without energy transfer) and I conjecture some such vacuum-matter interaction to be responsible for the rest mass carried by most particles. Whether vacuonic history has other local impact on material history I cannot presently guess, but vacuonic history has a global impact associated with model meaning for the present. This latter meaning, brought out by discussions with Henry Stapp, links to a notion of “universe center”.

I am obliged now to invoke certain quantum-mechanical notions not represented in Whitehead’s scheme. The (Hilbert-space) state-vector of the universe, which I denote by $\Psi\tau(H)$ is a function of history H - the meaning of H having heretofore been given as a chain of pre-events. The symbol τ represents an evolution parameter of time dimensionality that associates with the age of those pre-events located near the universe center. What is meant by "center"?

For mathematical reasons related to the T, S index, history (at fixed τ) is confined to the interior of a spacetime doublecone whose forward-lightcone boundary associates with the big bang and whose backward-lightcone boundary has a neighborhood interpretable as the "present". In a mature universe, such as one that accommodates human history, width of the present, i.e. extent of the backward-lightcone neighborhood - encompasses only a tiny fraction of the doublecone interior, so most history lies in the past (although after the big bang). My guess for width of present is -10^{-15} sec, large on particle scale, while small on the scale of human consciousness; I call this new scale “observer scale”. History patterns classifiable as an observation manifest observer scale.

“Center of universe” coincides with doublecone center so the 4-vector displacement between doublecone vertices has magnitude 2τ. As τ increases, the size of the doublecone increases and there is room for new history to develop. New history develops in the present.

Change in wave-function dependence on history represents new history developing in the present as τ increases. Although important questions about change of wave-function history-dependence remain currently unresolved, discussions with Stapp leave me optimistic that the model will not founder here. (I count on Henry to connect these questions with the Copenhagen puzzle he has long contemplated.) New history is constrained by the "immediate past" but not determined thereby. The entire history of the universe (which, remember, is mostly vacuonic) is involved, as τ moves to $\tau+\Delta$, in the development of new history.

Besides the unobservable and poorly understood vacuonic component of history, present model understanding fails to exclude magnetically-neutral electrically-charged "loose" pre-event strands building "undisciplined" history patterns classifiable neither as material nor as vacuum. Such strands, free from the constraints of magnetically-robust history fabric, could not interact with material history in the familiar (physical) sense of matter influencing matter or even in the sense by which vacuum generates rest mass, but there nevertheless would be influence. You are free to speculate how such influence might be manifested.

In extremely-early universe, with τ below observer scale, the spacetime doublecone is too small to permit distinction between present and past. I refer to such a youthful phase as “immature.” Below particle scale furthermore meaning for localized energy disappears. Only with sufficient age does the model universe have a chance to develop a mature history whose material past reveals itself (by observation) in the present. (The model’s immature universe might be likened to inflation in standard cosmology.)

As I approach my conclusion I need to report that any history chain, in order to conserve charge, comprises a succession of closed loops around a closed 4 manifold representing the maximal compact subgroup of GL(4,c). The closed manifold divides into 8 portions (4S and 4T) each of which projects onto the spacetime doublecone. Each closed loop passes in succession through 4 different portions, 2S and 2T. The region of transition between S and T portions is “the present”.

A loop passing close to this morning’s meeting contains - 1060 pre-events, whereas at τ = 0 ("big-bang") each loop contains only 2 pre-events (both of zero age.) There is nevertheless, a huge number of loops and thus a huge, although finite, number of pre-events already at $\tau = 0$. The parameters of these initial pre-events provide the model’s initial condition. The model allows the universe even at its beginning to be complicated. Certain special initial conditions may be required if the model universe is to have a chance of reaching maturity in the sense experienced by humanity.

In conclusion, let me recap the scales so far recognized by the model – see table below. The smallest is that of Planck, giving the spacing between successive pre-events (actual occasions?) along the history chain. Next is the scale of history patterns corresponding to Feynman graph vertices--the most elementary events recognized by physics; the Feynman vertex scale is about a hundred times larger than Planck scale (Physicists call the Feynman vertex scale “grand unification scale.”) Following a factor 10^{15} larger is the particle scale characterizing magnetic charge dominated history patterns that represent endurance of matter. Particle scale patterns provide meaning for localized energy. After yet another huge factor--this one perhaps 10^{11}--comes observer scale for the electric charge dominated history patterns featuring photon arcs, that underlie knowledge. This is the scale that provoked the famous but controversial Copenhagen interpretation of quantum mechanics. Width of present is on observer scale. Finally there is Hubble-scale age of universe - which must be huge on observer scale if the universe is to be knowable. The enterprise here is to think of the emergent evolution associated with the expansion of the universe that causes different patterns to develop and, quantitatively, to think about this by associating different numerical scales to the different phenomena.

Sample Time Scales w ithin Historical Reality

Our present age (here and now, since the big bang)	10^{17} sec
Human lifetime	10^{9} sec
Scale of human consciousness	1 sec
Period of atom	10^{-15} sec
Minimum duration of elementary particle	10^{-25} sec
Age step between pre-events along history chain	10^{-43} sec

[Note: The formal paper associated with this oral presentation is published as "A Historical Reality that Includes Big Bang, Free Will, and Elementary Particles" in *Physics and Whitehead: Quantum, Process and Experience*, ed. by T. Eastman and H. Keeton (Albany: State University of New York Press, 2003).]

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Questions from Panelists:

Klein - What seems to be needed is to add the subjective element of experience to quantum mechanics, which doesn't seem to have such a subjective thing. Something panexperiential has to be added. I have a feeling that the photon and electromagnetism is essential to this. Thermostats for example have some of the needed characteristics, sensitivity to the environment and being able to act on the environment. When the temperature changes, bi-metallic strips start stretching accompanied by interactions of virtual photons. Photons considered generally may be the extra ingredient not only for measurement but also for the extra elements that arise in process thinking.

Chew - Measurement is electromagnetic. There could be no such thing as measurement without the very special properties of electromagnetism, such as the extremely small mass of the photon and the small charge of the electron. The matter which is built out of these ingredients has to have certain characteristics or you couldn't imagine measurement. But, all these discussions about collapse of the wave function and all the puzzles of quantum mechanics, which go along with notions of measurement, almost always are carried out without any recognition or attention to the fact that this is an electromagnetic process. That seems to me to be a deficiency. I've always believed that if you could really understand how these special characteristics of electromagnetism are essential to measurement, you would make more progress in the puzzles and paradoxes of quantum mechanics.

In the particular model that I've been pursuing there are two distinct meanings for time. There is the global time, which applies to the whole universe, and then there is the local time which applies to what I call pre-events or histories within the universe. Again, if there really are two meanings for time, you better pay attention to that when you start struggling with these tricky issues. In particular, there is a double cone in which the history of the universe is located for a given age of the universe and the size of the double cone is parameterized by the age of the universe. But the history is the interior of the double cone so, as the universe keeps expanding, the size increases and the present keeps moving forward and it's in the present where measurements are being made. Remember, the present has a width so you still have to specify those local times inside the width of the present to have a complete specification of what's going on.

Klein - How, from your 4x4 complex matrices, do you get the structure of quarks or colors?

Chew - That I have not succeeded in doing and the model is tentative, but there is the possibility that the way space-time is represented comes first through a compact space which then projects on to a double cone in physical space-time, but there is an eight-to-one mapping. The compact space I set up into eight center portions, each of which projects onto the same physical space-time. So you have this eight-valued index associated with the compact space and it's there where I am hoping to find representations for things like color.

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John Jungerman Evidence of Process in the Physical World

I greatly admire people like Geoffrey Chew who are struggling to incorporate Whiteheadian ideas directly into the language of physics. I think it is very exciting and wish you good luck. It's a pretty tough project that you have. My discussion here is a more of an overview of evidence for process in the physical world as we know it. From the world of the extremely small atoms and nuclei and their constituents to nonlinear, self-organizing systems on a human scale and finally to the vast regions of the cosmos itself. At every level we find interconnectedness, lack of predictability, creativity and increasing order. These are also fundamental tenets of process thought through which descriptions of events or occasions of experience, which Whitehead assumes are its basic entities. Process philosophy asserts that an event or a society of events is influenced by or connected to previous events. The event harmonizes this information with its goals and makes an unpredictable, "subjective" decision that may lead to creativity and novelty. Now I am going to discuss, in turn, each one of these in some detail. Let us begin with interconnectedness.

First of all the general theory of relativity that came into being early in this century interconnects time, space, and matter as concepts whereas they were separate concepts in classical physics. As professors Griffin and Fagg have pointed out, time itself is characterized by becoming; it is a process. Wave-particle duality was forced on physicists early in this century by experience. They were separate ideas in 19th century physics. So we see things getting connected in terms of ideas but we also see connections directly. In quantum mechanics we have supraluminal correlations at great distances, what Einstein called spooky interactions at a distance. He had the vision to see this back in 1935 and did not like quantum mechanics because it had this possibility, and yet in 1972 at Berkeley Lab, John Clauser made the first experiment to show that in fact that is the way the world is and lately some Swiss physicists have found these correlations over distances greater than 10 km, so it does not seem to have very much of a limitation in terms of distance over which the connection is made. It is rather mysterious from our normal way of looking at things. We see connections among quarks to form protons and neutrons that form our atoms.

Now, on a human scale, we have complex, nonlinear systems that are far-from-equilibrium and show connections among trillions and trillions of molecules. I would like to just speak briefly of an example. If you take a thin layer of oil and you heat it, say, from below. First you get just a convective pattern. The oil just circulates. But if you increase the heat source, and increase therefore the thermal gradient in the layer of oil so the system gets further and further from equilibrium, which would be a state where the oil is not moving at all and where there would not be any thermal process happening in it. As you get farther and farther from equilibrium, suddenly the oil breaks up into exquisite hexagonal cells called Benard cells and each cell has oil rotating within it, clockwise or counter-clockwise. We have no way of predicting which way that manner of rotation will go and yet we have this incredible connection happening spontaneously. That is an example of one system that is simple enough for us to understand, at least a little, such that we can reproduce it in a laboratory.

In the cosmos we see gravitational connections, masses producing galaxies and stars from dust, the dust in turn collected by gravity from molecules. In fact, we are all connected together. We are all stardust from the supernovae that some 6 billion years ago created the heavy elements in own bodies. So we are all connected in a very fundamental way. That way, and also if you believe in the big bang idea, we all started 15 billion years ago or so from a common source.

I would like to turn now to the idea of lack of predictability that we again see at these three levels – microscale, human scale, and macroscale – of the cosmos. In quantum mechanics we have a statistical theory that can tell us about probabilities of things happening but has nothing to say about individual events - what an individual particle is going to do. One of the things that physicists like to talk about is the double-slit experiment where you have two slits - imagine electrons going through the slits and forming a pattern of interference on the screen subsequent to the slits. The pattern is predictable by quantum mechanics but where an individual electron is going to land - which fringe the electron is going to be found if it is measured - we have no way of predicting. One could say that the electron [more exactly, in Whitehead's framework, the electronic occasion] makes itself an individual decision. I know that is pushing matters and most physicists would not like to hear it that way but from a Whiteheadian point of view it is an example, it seems to me, at a very elementary level of a decision being made. You could certainly speak in that language if you wish. Again then we have a lack of predictability there. The electron makes its own "subjective" decision in a Whiteheadian kind of language.

At the human scale, as I mentioned before, we have the rapidly heated oil, we have a non-predictable situation if the nonlinear system proceeds through time sufficiently. For example, if you try to predict even the motion of the planets over thousands of years you will find that you get chaos, i.e. predictability vanishes even though we are used to very fine astronomical predictions. If pushed for a sufficiently long period of time, nonlinear effects come in and precise prediction vanishes. So even then classical physics gets nonlinear and we get a chaotic situation resulting.

Whitehead said that novelty proceeds near chaos. I think we see that in the study of complex systems. They are often self-organizing and create novelty, but they do it on the borders of chaos very much as Whitehead said a long time before we discovered this just a couple of decades ago.

Again, at the level of the cosmos, we find lack of predictability. We know that in a certain volume of space, statistically a supernovae will appear but we have no idea which star is going to become a supernovae - there is a certain lack of predictability even at the very large scale.

Turning finally to the third idea of creation of order and novelty. We find at the microscopic level trillions of gluons being exchanged per second to hold the quarks together that constitute the protons and neutrons, which constitute the nuclei which constitute the atoms. In the atom itself, the electrons in the atom are held to the nucleus by again an exchange of what physicists call virtual photons. These are packets of energy exchange happening again by the trillions in the kind of field theory, which seems to be the way the world is. So we have a birthing and dying of events that are happening just to create the forces that hold the nuclei and atoms together. In addition to this, within the vacuum itself, there is no such thing really as a "vacuum" because in a vacuum we have spontaneous creation of virtual particle pairs again by the billions and trillions per second. These particle pairs exist for a very short time, on the order of some 10^{-23} seconds. The particle pair, electron and its positive electron companion, are constituted - birth and then die - in that time. It is like a short-term loan that has to be paid back - conservation of energy is violated but over a very short period of time. Quantum mechanics allows that but the loan has to be repaid within about 10^{-23}. But in the meantime these virtual particles are there. One of the most accurate theories that we have in physics, Quantum Electrodynamics, deals with that and predicts, for example, the levels of the hydrogen atom to one part in 10 billion and if you do not include the virtual particle pairs you do not get the right answer. So physicists are convinced that these are real. We ca not see them directly but we infer them through experiments.

Getting to the level of the cosmos, we find again creativity on a grand scale. We start, if we believe in the big bang theory, with a sea of radiation. We form quarks, the quarks form nucleons, nucleons form nuclei, atoms form after 2 million years, and then stars, galaxies and all the rest. After about 11 billion years we begin to get into biological evolution on our own planet. So we see the universe characterized by ever increasing order and complexity. And we can ask ourselves - could it have been otherwise? But instead we find physical laws that remain really constant - to within a few percent of present values back to a time less than 35% of the age of the universe. With such order, creation of novelty is possible. As kind of an aside, Hartshorne argues for asymmetry to make change possible to produce order, which is characterized by its distinguishability and irregularity. If everything is symmetric then there is no possibility of change. So Hartshorne argued that for order to happen in a Whiteheadian view, nature has to be asymmetric. He did not know too much about physics but in a recent paper by Joseph Rosen in a recent issue of *Process Studies* (26/3-4, 1997; see also J. Rosen, *Symmetry in Science*, Springer, 1995) he argues that physics too is asymmetric. We have had a wake-up call in the 1950s. There was such a thing called non-conservation of parity, which was discovered. That is, the universe is not the same when we look in a mirror, as assumed before. Another example of that asymmetry which is very important from our perspective is that there is just a slight bit more matter in the universe than anti-matter. From a physicist's perspective, in the big bang just as much matter as anti-matter was formed and when they got together you end up just with radiation again. In fact it's a very close call. There are about a 100 million photons for each material particle in the universe. We are here because of that 1 part in 100 million, you might say. We have a fundamental interest in this asymmetry - that there is more matter than anti-matter.

All of this underlines what physics has shown to be, and especially in modern physics, is the primacy of events over substances. We need to talk about substances, but to think of them as primary is a limitation of our senses. What we know now is that if we look at an atom it is made of point electrons, so far as we know an electron has no size, and if we look at where more than 99.9% of the atom's mass is in its nucleus we find that the nucleus is made of quarks. And if we ask how big are the quarks, we find that their diameter is less than 10^{-16}. That is, less than 100 millionth of the size of an atom. And that's where all the mass is - the rest is just exchange of gluons happening. Which again are particle and event happenings. And so, if we ask what is the volume of the atom where the matter is, it is one part in 10^{24}. It's a huge number. If you ask how many grains of sand there are in all the beaches of the Earth, it is the number 10^{20} – 10,000 times less. It is a huge number and all the rest is where events are happening. So substance is really an illusion - a very huge illusion - a lack of being able to see what the universe really is. This underlies the idea of re-thinking the idea of substance as being primary, which began a long time ago but was especially emphasized by Descartes.

I would like to conclude by asserting that a good theory gives us an explanation of present experience but a superb theory, such as relativity, predicts or anticipates new phenomena. Whitehead's process metaphysics, I think, is somewhat in that latter category. It is remarkable to me that it is so compatible with discoveries made in physics decades later, such as Quantum Electrodynamics or of the whole sub-nuclear domain, which, as I have just described, is full of events and is not substance oriented at all. So, in my opinion, process ideas have a firm foundation in the physical world.

[Note: The formal paper associated with this oral presentation is published as "Evidence for Process in the Physical World" in *Physics and Whitehead: Quantum, Process and Experience*, T. Eastman and H. Keeton, eds., SUNY Press, 2003. Please refer also to Professor Jungerman's book *World in Process: Creativity and Interaction in the New Physics*, SUNY Press, 2000.]

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Dialogue among Panelists:

Stapp - At the beginning of your talk, you mentioned increase in order whereas the normal idea is that entropy increases and that, on the whole, order decreases. Although local increases in order may occur compensated by decreases in order somewhere else in the universe, but overall that represents a decrease in order and not an increase. In your opinion, is there any evidence against the normal idea that entropy increases, hence order decreases on average, based on the things you have talked about?

Jungerman - The laws of thermodynamics still apply so far as I know. On the other hand, we in this room are all evidence of order, a particular order that goes against the second law. We use the low entropy from the Sun and the plants and animals that we consume to create order in our bodies. We are indebted to those low entropy sources for our own existence. You can ask where that came from and for that you will have to go back ultimately to the big bang, which itself must have been a low entropy source so that we could exist and be in accord with the second law of thermodynamics. I am certainly not proposing to abolish that 'sacred' law of physics. Remember as well that the second law only applies to closed systems and most natural systems are not closed. We do see elements of order and we ourselves are examples of that; it's what Gregory Bateson called the 'sacramental' or what Schrodinger called 'negative entropy.'

Stapp - Do you then see evidence for a process that works against disorder?

Jungerman - It seems to me that self-organizing systems create order against the second law, but that does not mean that overall the second law is violated, but locally it is in these systems. If you look at it globally the second law works, but if you look at it locally there is order being created, so it depends on your perspective.

Chew - In my model, which I take seriously, although you might consider it 'pretty far out' there, is this huge component of what I take to be Whiteheadian history which is not 'material' - all these pre-events building patterns and a meaning for matter. Physicists only think about the material portion; they really do not think about anything else. So the second law of thermodynamics is involved in the notion of energy and energy is not primary, it is a feature of the material universe and not a feature of this huge component which I call 'vacuum.' At least in this model, there is ample opportunity for something else to happen.

Stapp - Let me ask about your vacuum. In Whiteheadian thought you do have the impression that experiential or objective events are at work here so I might ask, is there any possibility then that experience as we know it would be perhaps understandable and explainable as a property of your vacuum. Ordinarily, physicists think of the vacuum as just certain kinds of particles without any experiential quality. Would you say that your vacuum could be something different?

Chew - Yes. I am coming more and more to believe that it could be.

Nobo - Well first of all I'm very excited about Professor Chew's paper because it brings physics closer to features of Whitehead's thought that are generally neglected among Whitehead scholars. These are features having to do with a theory of extension which is metaphysical – there is something prior to the becoming of actualities, prior in a supersessional sense, and which gets structured as a result of the becoming of actualities and those structures, in some cases, can be construed as spatio-temporal. The internal structure of the occasion or the pre-event mirrors certain extenso-genetic relationships in the becoming of eventities. [see J. L. Nobo, *Whitehead's Metaphysics of Extension and Solidarity*, SUNY Press, 1986]. I will come back to that in a moment. But the immediate issue is the business of entropy or disorder increasing as a function of particles. We are talking about a different kind of information, if I read Chew right. It is an information regarding the history and relationships of pre-events. So you could have order increasing there that is not manifested in the decreasing order of particles.

One of the things I am interested in is that what you are calling the historical element seems to correspond to what Whitehead called supersession and a supersessional order is much more primitive, more basic, than temporal order. It gives rise to it and is connected to the theory of extension in that the supersessional order is encoded into the very structure of the extensive standpoint of the pre-eventities or the actual occasions. The whole history of the universe up to the becoming of that pre-eventity is projected into its internal structure so that the information about that history is in that event: the complete history of the universe up to that point.

Where temporal dimensions or durations arise presupposes already, not only patterns of pre-eventities, but their interaction. We can correlate those patterns that we can measure as so much physical time, but the supersessional relation is much more basic.

Anyway, for me, this is exciting and now I feel an obligation to formalize what I am talking about so that physicists can make use of it.

Klein - My comments are inspired by a conference in Berkeley some six months ago on Science and Religion. It's very clear to many people that religion has a powerful role in shaping human behavior and influences the way the culture is going to go. It is my feeling that with a stronger coupling between knowledge of science and its images and expressions of spirituality the world would become a better place. And, it seems to me that Whitehead's process thinking can play an important role in that.

Now, let me get back to Geoff Chew's comment, which I was very impressed with because it reminded me of exactly where I was 30 years ago at Lawrence Berkeley Laboratory. In those days, Geoffrey was doing very adventuresome thinking. Those were the bootstrap days, and one of the things that came out of the S-matrix approach that he pioneered was that it got coupled into the popular domain. Fritof Capra's books and a number of others linked bootstrap theory with Buddhism and eastern ways of thinking and that actually had some influence on the big world, on theology, and how people thought about the universe. What I want to hear more of is, what are the images that physics can bring forth to the theologian? Physics has some amazingly beautiful understandings, incredibly beautiful symmetries, that have not made it to the outside world. It might be that the Whitehead intermediary, process thinking, is enough - it might be other things. What is it that we physicists can do to connect more with philosophy and theology?

I do not think that we need to go to your complex 4x4 matrices and your pre-events to get a very strong sense of how physics has a strong non-material aspect. I am a very firm believer, in fact my California license plate is "duality," that the present quantum mechanics that we know and love so well, as Henry has pointed out many places in his writings, has a dual structure and a non-material element. The public needs to see better images than what we have gotten across. What has gotten across is that there is confusion, only different interpretations and the physicists are fighting. I do not think that is true. Again, coupling Whitehead with quantum mechanics is the avenue to link physics better with philosophy and theology.

Fagg - I heard a talk a few months ago by Freemon Dyson on the subject of entropy. The second law of thermodynamics applies to a closed system and, as John was talking about, if you make the system global it still applies even though locally you can get these negative entropy results. Dyson subscribes these days to an open universe. If so, on a really global or cosmic scale, the second law cannot really apply.

Code - Whitehead in *Science and the Modern World* points out that there are two abstractions which we must use if we are to explain both matter and spirit and that puts me in mind of the kind of duality here and this seems to be reflected in professor Chew's talk. Materiality and spirituality are a typical duality here. The problem of language keeps coming up here whether or not our understanding keeps improving as we become more and more knowledgeable about smaller and smaller things. To be more specific, I was intrigued by Professor Chew's comment about what it is that causes patterns to have duration. This implies to me that communication is in some sense a fundamental part of the world, which makes me wonder whether you have ever thought about Peirce's semiotics in terms of trying to understand the vacuum and what is going on in the non-material side. In this non-material world communication appears to be going on but the language for this is missing.

Chew - I do not have any language yet. I agree with you completely that that is an extremely important issue.

Jungerman - I would like to get back to professor Fagg's remark about the open universe. I think there is some data now from looking at supernovae (the Berkeley group has been looking at supernovae at large distances) and the evidence seems to be that the universe is actually open. Perhaps that is an answer to Henry.

Valenza - In your pre-material, pre-event world, is there some identifiable aspect of your theory? Some parameter lurking in the sixteen slots of that matrix that says in the non-material world why pre-coherence, if that is the right word, even emerges - this is why a larger time-scale reality evolves in such a way that human biological systems find it very effective to use particle and substance ontology in conducting hunting and fishing and shaping each other.

Chew - There is in the model, as presently formulated, need for a huge dimensionless parameter, of the order 10^{30}, and I do not know where that parameter comes from. I have speculated about some possible connections with number theory, but I do not have a clue yet where that huge parameter comes from. But it is essential for the universe to manifest the qualitative features that it does, that there be some huge parameter that sets the big ratio between scales that is so essential. You would not get anything like the universe that we know if you did not have that huge parameter built in and I do not know where it comes from. I a m hoping that some beautiful discrete mathematics will say that a number like that is picked up. I have heard of a possible candidate but it is pure speculation.

Fagg - Is that at all related to the cosmological constant?

Chew - No, it's not – it's related basically to what sometimes people say is the smallness of the gravitational constant expressed on particle scale, but in the picture I was showing you it is simply the ratio of the particle scale to the Planck scale where you get that huge gap.

Nobo - In Whitehead the universe, theoretically from the metaphysical point of view, is an open universe. Regarding Klein's issue about theology and so forth, it is certainly possible within the Whiteheadian metaphysical scheme to have God be the cause of what is interpreted as the big bang. I have just published an article on how that might be done. [see *Process Studies* 26/3-4] But it is not strictly Whiteheadian since I take an aspect of the universe to be eternal, supersessionally antecedent to any becoming, and out of that there is spontaneous becoming which is the primordial actuality. But it's not God until it makes the decision by which it constitutes itself into a creator of the first set of what we might call worldly occasions. It's partly a self-constituting decision and partly a transcendent decision which uses the same conceptuality which afterwards we would use to see how one actual occasion can be, in an important sense, the determining cause of why another occasion comes into being or is begotten by the universe. The interesting thing is that you don't need a concept of an infinite density. You just need eventities, a finite set such that each member of that set gives rise to an indefinite number of other eventities so you have a quick expansion of the members of this growing history of eventities, which not too much later would give rise to particles and enduring entities.

Fagg - When you're talking about infinite densities you're talking about the initial event?

Nobo - Physics has to read an infinite density into the big bang because it has to have those particles come out of that infinite density, but I'm saying that in Whitehead that is not necessary.
You have a finite set alpha of eventities but they very quickly, in a few generations, can expand at an indefinite rate and account for the expansion of the universe.

Chew - This morning at breakfast I was told somewhat smugly that a feature of this model that I have been telling you about, which physicists typically find very puzzling, is totally obvious from the Whiteheadian point of view so I will just mention what it is. It was emphasized in my own consciousness only fairly recently as a result of discussions with Henry Stapp and that is that there is an important meaning for the present. That the present has a width - not precisely defined here as a width. In the model, as I am understanding it, this width is more or less what I call the observer scale. So if you want to associate a number with it it's something like 10^{-15}; that's a huge interval in terms of the basic step size, which you remember is 10^{-43} , so you can get all sorts of patterns within the width which is the present, but it's still very, very tiny on the scale of human consciousness. So it's perfectly consistent with the normal idea that the present is well defined but at the same time there being lots and lots of room for complicated patterns to develop. In the model all the new history develops in the present - there's a definite region. You've got all this past history and there's a little strip there - that's where new history develops. However, if you push the age of the universe back too far, you will cause the distinction between past and present to disappear. If you try to talk about an age of the universe that is less than 10^{-15} seconds (cosmologists often do this) there isn't any distinction between past and present in that region - normal psychological time at least is blurred.

Klein - A quick comment on putting this middle width, the present, between two dualities. I recommend a wonderful book *Zen and the Art of Motorcycle Maintenance,* written by Robert Persig almost 30 years ago, which was all about this duality thing and then he puts in this middle width and then he goes crazy. It's just marvelously written.

Eastman - What about time width? This seems very analogous to a notion that David Finkelstein introduces in his book *Quantum Relativity*, which he refers to as a chronon. Does this relate directly to what Geoff has brought out here?

Finkelstein - There is a quantum of time. There would be a technical present if there were such a thing as 'the present'. Of course, relativity makes the idea of the 'present' very observer dependent, particularly for systems in motion. I'm sure that's taken into account in all these discussions. But there is a large difference in size and since the philosophy of organism is a cell theory of actuality it makes sense to ask if the cells have any sizes associated with them and, if so, what is this typical size? I'm astonished how many physicists think that the fundamental cell has a size and it's roughly the Planck length or the Planck time. If you look at any operational way of actually measuring fields at points determining locations of events and so on, you never get down to the Planck length. There are many, many effects. Even black hole formation cuts off 12 orders of magnitude above the Planck length. If you consider the Compton effect and limits on the cell size, the only way that anyone could possibly think that the Planck length was the fundamental cell size is to imagine a universe as nothing but gravity - the Planck length and time or the numbers just made from Planck's constant, gravity and the speed of light - and that would be a totally inconsistent picture of nature because there would be nothing to measure gravity with. Gravity is the one theory that can't be everything - magnetism might be but not gravity. So, if there are cells, they're much bigger than the Planck length. And then the question of where the Planck size comes from might have been answered by Weisskopf in his very first paper on renormalization where he points out that the Planck length is e (note: e = 2.71828...) to the power -137 times typical particle sizes (137 comes from the coupling constant of electromagnetism). It looks like a thermal effect - it looks as if gravity might be a statistical phenonenon as many other physicists have suggested.

Eastman - What would be more fundamental?

Finkelstein - I'm not sure that the idea of 'fundamental' is fundamental.

Chew - Jorge Nobo's comments remind me of two features, again coming out of this model, which we're commenting on. One is that relativity is not a feature of the model. The universe has a center in the model and relativity is an illusion associated with these huge scales. To put it crudely, it's like saying that the portion of the universe to which we are accessible is such a small portion that even though the universe has a center there's no way of us discovering that because we're confined to looking at a relatively small part of it. But it's quite essential in this model that relativity not be an exact idea; it's only an approximate idea, which is based on the huge ratios. The second feature is that gravity is not a priori either. The notion of gravity depends on a notion of energy and the notion of energy doesn't arise until you get patterns which are big enough to show this persistence. So on that picture which I flashed, I put a question mark with gravity - where does gravity first sit? My guess is that it is between what I call particle scale and observer scale. It's somewhere in that region that gravity begins to have a meaning, but certainly not at the lower scales.

Klein - Do your pre-events have dynamic properties? How does one maintain causality and how do pre-events become real events?

Chew - Well those are constraints on what I call the history lattice. There are electrodynamic constraints which have the usual ideas of causality built into them.

Klein - Is there a Lagrangian for pre-events?

Chew - Lagrangian is a notion related to energy so there is no Lagrangian.

Klein - So how do you maintain causality?

Chew - As a constraint on the lattice. There has to be a certain relationship between the pre-events and the lattice that is causal - causally consistent. There is 'time.' If you look at my preprint on magneto-electrodynamics, you will see a detailed description of this.

Stapp - If gravity only comes in later, why is the Planck scale defined earlier?

Chew - In the model, I would say that there is a unit which is the spacing of the pre-events along the chain and that is a basic constant of the model. I'm hoping that it will turn out later that that unit is related to gravity. But it's wishful thinking that the model will describe gravity.

Stapp - My second question is in regard to the remark by Murray Code. He says that physicists, on the whole, deal with the physical and that's certainly true. On the other hand, the very point that Stanley Klein was making is that quantum mechanics, in the way it's really formulated, brings in an observer. There has been a lot of effort to get the observer out of quantum mechanics. The founders of quantum theory found it necessary to bring the observer in. It is true that Bohr then kind of dismissed the observer in a certain sense by saying that we can't deal with biological systems and therefore diverted the attention of physicists away from the observer and experiential aspects of reality. It seems somehow to be in the works since the beginning, as Stanley was stressing, and at least a few physicists are concerned particularly with this question of how the observer plays a role in the whole thing. Quantum mechanics certainly opens the door for this in a very natural way that I will be talking about this afternoon.

Code - Well Whitehead did place experience, understood broadly, as central to his thought. It's very difficult to see the interrelationship of subject-object without dividing. Coleridge said it this way "if you distinguish, you do not divide and if you divide you get into trouble."

Klein - But here's the problem. The equations of physics are reductionist and so scientists, if you go outside this room and ask typical scientists about what is causing me to raise my hand, they will give you a chain of arguments that is mechanistic based on how neurons are processing. Very deterministic because quantum effects are quite negligible. And we have a story of me raising my hand that has no free will and that is 'science.' And so the big question facing this science-theology connection, the subject-object, that I don't think Whitehead himself achieved, is how do you get a totally reductionist ontology to also allow total free will? That's the problem. If you can tell me that Whitehead achieved that, I would love to know where to read that. To have total reductionism and still have total free will. And I think that quantum mechanics does that and some of the things that Henry Stapp and Abner Shimony have done - I have to advertise Shimony. In Penrose's latest book, Shimony has a major essay on an augmented Whitehead - one combining Whitehead and quantum mechanics to address this very tricky business of how you get a reductionist theory to be not reductionist.

Fagg - So you're saying that quantum mechanics qualifies the idea of a total reductionism?

Klein - Yes, the rules for quantum mechanics are very precise except that you have this funny duality. My theme, as Henry well knows, is that the split in quantum mechanics (I'm a Copenhagen type person because I think that it's so beautiful.) can be moved anywhere. You can move the split up high so that the equations of quantum mechanics and biology apply to my moving my hand. Actually you can do this with neurons - pretty reductionist.

Finkelstein - I would like to qualify the remark that quantum theory is totally reductionist. Indeed, it's the least reductionist of our physical theories in that for the first time, for example, one could know everything possible about the history of particles and know nothing whatever about the position of any particle in the system. This is totally unthinkable in classical physics. In classical theory, every property and symbol is simply a collection of ‘and’ and ‘or’ combinations of properties of individuals. This expresses the reductionism of classical physics. And that’s just not the way it is in quantum theory. If you have a Benzene ring, you don’t know where the bonds are.

Klein - You’re mixing up levels above and below the split if you start out with a Schrodinger equation and don’t have the collapse event. I’m the biggest proponent of how quantum mechanics solves this but it’s a tricky business.

Finkelstein - But it isn’t the split that solves it - it’s no longer reductionist.

Fagg - When you say ‘split’ do you mean the split between the observer and the experiment.

Klein – Yes.

Nobo - Quite often the indeterministic aspect of quantum mechanics is dismissed as irrelevant to the free will issue in philosophy because statistically it just about cancels out. But that assumes already that our stream of experience is nothing but neurons and ultimately particles interacting. The advantage of this approach is that our stream of experience is analyzable into the same basic types of entities that Professor Chew is talking about. Here I identify pre-eventities with pre-events. That argument doesn’t hold if at the quantum level we can speak of individual events that are in principle unpredictable. If our experience-events are, in some sense, exactly at that same level then they are, in some respects, self-determining. We have to attribute self-determination to ourselves (what Griffin calls hard-core common sense) but we can also attribute some measure of self-determination to more elementary, less complex, occasions. Reduction is also somewhat of a sham - there are a lot of promissory notes in the reductionism of science.

Klein - I study vision - vision science - so I know most about that and we’re very successful at reducing everything about vision to neurons.

Nobo - Well, I would put it the other way. Give me an example of where you don’t loose something in the reduction and dismiss it as subjective.

Klein - Very important distinction. The issue of subjective, of consciousness or feel, is where I think quantum mechanics, by working between consciousness and events, has a place for the observer, the subjective. But what I’m talking about is more the objective. Is there anything that happens that can be measurable that isn’t reductionist?

Nobo - You already threw the baby out with the bath water - you said anything that is measurable. Why does everything have to be measurable in reality? Obviously there is reduction in the sense of reducing higher level to lower level laws or properties, but I don’t think that you can do this across the board, even for measurable things.

Klein - Are events measurable for Whitehead?

Nobo - It depends on whether you are talking about actual occasions, societies of actual occasions, or interactions of these. I think that they have measurable features but not all the features are measurable.

Valenza - For a moment, let’s shift our measure of order away from the classical physicist’s notion of entropy.

Another notion of order is provided by an information-theoretic notion. If I sit in front of my computer screen, black-and-white, say it has a million pixels on it. A state vector for that system would mean a million bits of information - a string of ‘on’ and ‘off’ states. On the other hand, if one of Dr. Jungerman’s hexagons is on my screen, I could say that I need a million bits of information to specify it but I could also say that with just a few bits of information a generative mechanism could be specified from which the pattern evolves and, in that sense, there is a very high level of order on that computer screen. That notion of order is not equivalent to entropy (or negative entropy) and in a completely deterministic system that measure of order becomes an invariant. With that idea of order, is the order of the universe increasing or decreasing?

Chew - I can only venture a guess based on my model. If you consider the universe to include all this non-material history then there is a sense, a quantum-mechanical sense, in which it may be that nothing changes, but I’ve got this huge non-material component and this tiny material component and any question you ask will almost surely be focused on this material component. Thus things could look very different from this statement that nothing is changing.

Jungerman - I don’t have much to add except you mention determinism and those little cells are not determined. We can’t specify initial conditions enough to determine whether they’re going to circulate one way or another.

Valenza - That’s what generated my question. Those little cells - is that the spontaneous appearance of order in this information-theoretic sense?

Jungerman - Yes, I think that self-organizing systems do that. But there’s a limitation in terms of predictability.

Finkelstein - If we’re going into these borderline areas far outside ordinary experience then we must be very careful in carrying our concepts along. I want to insist that the concept of entropy makes sense for systems in equilibrium and in no case is it really meaningful to speak of the entropy of the universe. To determine the entropy of a system you have to be able to carry out a thermodynamics cycle on it or, if you put it in informational terms, there has to be someone outside the system getting the information and the universe, by definition, therefore does not have an entropy. You speak poetry to speak of the entropy of the universe.

Stapp - This is in regard to this question of reductionism. As we see, it can be defined in different ways and depending on the definition you might get different conclusions. Let me just advertise my talk this afternoon by saying that it ought to have been entitled “Is mind slave to body”? Is there some possibility that it is not slave to body? That there is something, given a complete description of the system’s universe, that is not determined. In quantum mechanics there are two simple answers. If you have statistical laws perhaps mind could bias the statistics. But that would be outside quantum mechanics. If you want to stay with quantum mechanics, it says that there is no bias in these laws, you should stick with these laws. There is another way that you might evade this question by saying “well, if you have only statistical predictions as to what is going to happen, you have some possibility for an intrusion of some choice from outside quantum mechanics which is nonetheless controlling the way things should go.” But I would also regard that as outside the bounds of quantum mechanics. That’s essentially another way of saying that this freedom you want to give is not a true freedom. But in my talk this afternoon, there is a place for something outside the physical universe that can come in and change the physical system.

Dialogue open to full audience:

Clayton - Geoffrey, the interesting result this morning is that your discussion brings you closer to Whitehead than many of the Whiteheadians in the room. From your comments this morning and from previous discussions I understand that you question the future of duality - you do not want to have a place for an observer or something outside the model. That would mean that whatever you finally say about quantum mechanics, it wouldn't be Copenhagen or any interpretation with an observer outside. Whitehead didn't have such dualism either. That makes you two allies against a neo-Whiteheadian rationalism that seeks to incorporate such dualism.

Chew - I think that's fair. Let me now be more explicit with this phenomenon that is called Everett branching, which is the 'bug-a-boo' of quantum mechanics. If you try in quantum mechanics to say that there is nothing beyond quantum mechanics then you get stuck with the crazy 'many worlds' picture. So how do I imagine how this might be dealt with in the model. I hope it will turn out that many worlds means many physical worlds. If you insist on writing your wave function just in terms of Hilbert space parameters, which have to do with matter or substance, then you get stuck with these puzzles. But imagine that the complete wave function includes all these things, which I vaguely call 'vacuum,' which play a part in the whole dynamic. All these things could be built up of Whiteheadian actual occasions, which have the same set of 16 parameters as actual occasions that form matter, but they just form different patterns and these patterns don't fall into the categories that science has so far been able to deal with, characterized by this persistent matter. Maybe the wave function will finally exhibit the feature that the influence of all this non-material history picks out, one of the usual Everett branches, and by some interference effect gets rid of the other ones thus ending up with just one material branch, which you will never understand if you insist on working with a Hilbert space that only has material labels on it. You have got to use these non-material aspects into the Hilbert space or you'll never have a chance.

Clayton - That's an important clarification because the vacuum comes out now as non-material and the word 'vacuum' might be misleading.

Chew - Yes, physicists do talk about vacuum and to that extent it could be misleading but the meaning of vacuum here is quite different than usual.

Klein - Geoffrey has done here something very much like David Bohm. Finding a different language in which this non-material component has the flavor of this probe that knows where the two slits are in the Swiss experiment involving far apart, non-material, entanglements to guide this pre-event, so it sounds kind of "Bohmie."

Noemie Kenna - I was originally in physics but am now working in theology and religion. I think that the Whiteheadian concept of experience is very pertinent to this discussion because in material sciences we know that fluctuations in thermodynamics have a distinct impact on atomic structure at the finest level. Each fluctuation causes permanent change in the material which forever alters the future of the process. This relates to what was said about the universe becoming more ordered and that everything in the universe is an accumulation of all of the past experiences that have had physical impacts on the matter. This means that you have creativity in which suddenly new forms come into being. This idea of experience is where science and philosophy are coming together.

Marcus Ford - If Whitehead were here how would he respond? Might he say that Professor Chew is allowing the Eliatic camel to get his pugnacious nose under the Heraclitean tent and Dr. Chew has missed the main point of *Process and Reality* that I, Whitehead, have tried to say there that the least bits of the universe are not bits at all and the building blocks are not blocks. We're talking about events and the glue that holds them together is known as prehensions and when prehensions occur there is an interpenetration so that there are no distinct lines between self and other, this and that. We start with an event which remembers a past, anticipates a future, and is part of a society of other events that interpenetrate. Every individual has a temporal as well as a spatial dimension. Would he say that you've missed the point in *Process and Reality* or would you say that I've missed the point.

Chew - I couldn't detect anything in your list of Whiteheadian principles that my model doesn't satisfy. The model starts without any meaningful endurance or substance and has to build meaning for both out of patterns and change. My understanding is that that's ok with Whitehead.

Derek Vondrat - As a preliminary point, the idea that quantum mechanics is totally reductionistic is qualified. I would also qualify the idea of total freedom. I don't think that Whitehead every subscribed to that notion. All actual entities are internally related so freedom only occurs within the boundary conditions that gives rise to each actuality and experience. Perhaps that provides a middle ground to understand freedom versus reductionism. The other point is one that relates to what Griffin said last night about organizational duality. Whitehead would expect that for very simple, microscopic systems not involving complex, emergent societies, for example photons hitting the retina and that information being transferred to the brain, you would expect that would occur in a very reductionist, orderly, non-free manner, but even if you can reduce the mechanism can you reduce the response that the mind will have to the information brought to it by the eye?

Klein - I would recommend reading some experimental papers by Bill Newcomb of Stanford on the behavior of monkeys in response to visual stimuli and the finding is that it is possible to predict behavior in some detail. With these results, the question is whether anything fails to fall into the reductionist fold.

Barbour - It seems to me that Whitehead and Hartshorne put considerable emphasis on differences in the organizational levels of the world as noted by Griffin last night as organizational duality, or better, organizational pluralities, not just two kinds of organization. I'm not sure that Whitehead would expect the kind of action at the sub-quantum level or pre-event that Geoffrey was talking about. I'm very sympathetic with emphasis on the event character of objects, but what I think is the way that Whitehead protects against reductionism is not by positing something going on at the very, very bottom, but by positing rather radical differences in the way that patterns of events at higher organizational levels work to exert causitive influence, you might say, from the top down. In other words, to provide a lure whereas I get the impression from Geoffrey's presentation that some of these non-physical elements can be explained from the bottom up.

Chew - That's not clear. In the model, there is a big bang boundary condition. Even at the big bang, there already are a huge number of pre-events; the history chain is already very long. It is simple in a sense that has to do with loop structure but it's also complex. There has to be built in this huge factor that I talked about so the boundary condition at the big bang has to know about these huge gaps in scale that are going to develop. Thus, it is not entirely building up from the bottom. You must have built in already considerable organizational complexity and anticipation in the boundary conditions for all this complexity.

Stengers - When does the Hilbert space enter into your model - at the very beginning?

Chew - Yes, so far I have been unable to not include a Hilbert space at the beginning. But you are not committed to material labels on the Hilbert space. And at this stage there is no commitment to stationary states, which is a completely separate question. What I have is basically the direct product of 16 simple Fock spaces.

Finkelstein - Probably your coupling to Hilbert space is more general than that.

Tanaka - There is a sharp distinction between events and actual occasions in Whitehead's philosophy. 'Actual occasion' is a metaphysical concept whereas event has a physical, experiential basis. How should one think about temporal possibility?

Chew - One needs to distinguish at least two concepts of time in this scheme. I talked about the age of the pre-events. I mentioned that they don't have to keep advancing along the chain. There is a sequence so that the chain has a sense of always advancing, but as you move along the chain the age doesn't have to keep moving forward and, in fact, the characteristic that distinguishes matter as opposed to vacuum is that to describe matter you need the notion of event, already a cluster or pattern of pre-events bouncing back and forth. Otherwise, you cannot represent matter. All of that takes place at particle scale, which is way, way below observer scale where measurement first arises. You can't have a notion of measurement at particle scale; you must have huge patterns that are much, much bigger, and then when you get to those very big patterns there is a second time which controls this 'present' idea. Remember I said that there is a width to the present and the whole band keeps moving forward and that's the time in which the age of the universe, if you like, keeps moving forward. But within that band you still have all that bouncing back and forth which is building the meaning of individual events. Although not a direct answer to your question this illustrates the complexity of the issue.

Clark Smith - While working on my dissertation on mental healing or faith healing, I was studying a lot of David Griffin's work where he mentions materialist philosophers who try to shoot down dualism on the basis that mental causation finally reduces to matter and energy. What one physicist told me is that we study things as they are. Whitehead might say that physics is a science of the past and deals with things as they are, but Whitehead was trying to move into a general cosmology which addresses how things come to be with a general theory of causation and in doing so was forced to develop a general theory of creativity. Both in cosmology and Whitehead there is direct reference to the future and an effort to see how physics along with freedom could lead to novelty in the patterns.

Klein - Causation is of course central to physics and there is some exciting recent work on this, for example the work of Andre Linde on the creation of universes.

Chew - A partial response, always in the context of this model. When the age of the universe moves forward one step opens up some room for new history to develop. Question - what controls that new history, what limits it? And there is an influence from the immediate past reflected in the constraints, the lattice constraints - causal electromagnetic constraints. You are just not allowed to have histories which violate these, but there are still plenty of possibilities which obey these. There the model goes along perhaps naively with the standard quantum mechanical idea that there is a unitary operator which acts on the wave function that is there before the step is made and that tells you how the wave function will be in the new step. This involves the entire history, including all this vacuum stuff, and it is not controlled by the purely material component and certainly not by the immediate past.

Smith - From what you have said so far, what you are describing is quite in line with Whitehead. The past constitutes the occasion up to that point but novelty of some sort is always possible. The influence of the past can't be denied and is stubborn fact but there remains an openness to novelty.

Audience Member - What I think Professor Chew is doing is to approach asymptotically the notion of creativity.

Klein - Every single level of this heirarchy, so far as I know, is understandable.

Clayton - What about a modern theory of causality which goes beyond Whitehead? That's an insightful critique of Whitehead trying to take into account self-organizing systems and it is a response to your precise question "what about a broader theory of causality?"

Jungerman - I think that different levels of nature can have their own laws and all is not reducible to elementary particles.

Session II: Fundamental Processes

Clayton - Introductory remarks for session - Let me take one minute to talk about content. How would you structure an encounter between physics and Whitehead's thought? You would have to do it in a way that showed the major characteristics and interests of physics. The terms and theories would have to be drawn from physics. We have to pay concern to the mathematics, to forms of theories, data, and most of all to the contemporary state of physics today. That means we have to avoid the sort of generalizations that run roughshod over important distinctions within physics. That concern for carrying out the process with careful attention to the contemporary state of work in physics should characterize this session, as I believe it characterized the last. That should give this particular set of sessions a slightly different flavor or tone than many of the other sessions here in Claremont, but one that I think complements them as well. What themes would you take for an encounter between contemporary physics and Whitehead? Order and emergence - our morning session? Fundamental processes - this session?
Or philosophical implications of modern physics - the session for tomorrow afternoon? You will note of course the intentional choice of this title - "fundamental processes." One normally speaks of 'fundamental particles' and here already you see an attempt to bring process-oriented categories into dialogue with contemporary physics. We hope that much of what you hear today will be the sort of discussions that might go on within a research group on fundamental particles.

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David Finkelstein Physical Law as Physical Process

I would like to thank Tim Eastman and Hank Keeton for giving me this chance to acknowledge my indebtedness to Whitehead. It's been quite a few years. When I was in high school I was, for an important brief time, a devotee of science fiction and the novels of L. Sprague deCamp, a graduate of Stevens Tech where I also worked. Equations of symbolic logic appear and the idea of an arithmetic of thought so fascinated me that I ended up reading the three volumes of *Principia Mathematica,* which has stunted my growth forever. As a high school student you can get into the stacks of the New York Public Library and fortunately the Harlem branch of the library had volumes 1 and 2 of the *Principia* and I spent many happy hours there scanning them. Later on I learned the importance of projective geometry in physics and…I came across the aphorism 'geometry is cross-classification,' which helped me to understand quantum logic when I came across that. This is because quantum logic is really projective geometry interpreted as cross-classification. Clearly Whitehead did not make a sharp distinction between mathematics and logic. That would have been totally against the aims of his *Principia* efforts. And of course this led me on to read books like *Process and Reality* which made it that much easier for me to understand modern physics when I began to despair of ever doing so.

If desired, one could discuss the question of the relation between modern physics and Whitehead completely in Whiteheadian language - that's the whole point. What Whitehead had set out to do was founded not on the intuitions of Newton but on the latest state of our information about the world, which means the basic ideas of relativity and quantum theory, and I have no problem finding them all the way through his work. One of the problems, however, is that while relativity has a fairly uniform mode of expression in physics, it really swept the field within a few years after its pronunciation, somehow quantum theory has split up into a great many dialects. A great many people are saying the same thing about their experiences in remarkably different languages. This is very confusing to physicists in the first place. How can you tell when you disagree with someone? Even when they agree they sound different, and it is certainly confusing to the general public. I must say that I account for the difference by the fact that when Einstein made his discovery he went out and announced it to the world boldly, and when Heisenberg made his he went to work for Hitler. If he had really said what it was he was thinking he would have ended up on a meat-hook. I think of quantum theory as a holocaust survivor. Even as it was in Germany he was accused of doing Jewish physics. And as a result various dialects of quantum theory sprang up. In France the thought of Count Louis de Broglie had very great influence and he never really accepted Heisenberg's view in the first place. In this country Wigner found a totally different way for expressing the ideas of quantum theory in which the emphasis is shifted from the wholeness and non-objectivity that Heisenberg emphasized to the idea of a wave function as the fundamental variable of the system. Now Bohr and Heisenberg made it perfectly clear that the wave function is not the system. That the wave function describes the whole process of observer and system. This is a very new thing in physics. In classical physics one forgets the observer. One talks about things 'as they are.' I heard someone earlier say that physics is about things 'as they are.' And of course the first thing you learn in relativity is that there is no 'are' and the second thing you learn from quantum theory is that there are no 'things.' Aside from that, the idea is true. [Note: This modern perspective was well expressed in Whitehead's earlier works in natural philosophy, including *Principles of Natural Knowledge* (1919), *Concepts of Nature* (1920), and *The Principle of Relativity* (1922).]

Remember that Heisenberg formulated the quantum theory in the city of Munich in the decade in which Kandinsky was operating. It was Kandinsky who coined the phrase 'non-objective art' and Heisenberg seized it and called quantum theory non-objective physics. Perhaps it would have been better to have called it object-free physics. The whole idea of quantum theory is to talk about what you do - you talk about the whole process. Heisenberg set up a so-called algebra in which the fundamental elements, operators, could just as well be called processes, they are the things you do. Later on, as a result of Schrodinger's point of view, it became convenient to factor these general processes of Heisenberg into two parts, one is creative, one is anti-creative, one begins the experiment when you inject something, one ends the experiment when you read out what you have. There is a temptation to call these input and output. That's not a good idea because the system doesn't 'put' anything out. You have to take it out, you extract, so it's better to call it input and outtake. And these are special cases, I believe, of Whitehead's general concept of process. And it was to cover the operational foundations of field theory and modern physics, which is so powerful in relativity theory and quantum theory, that Whitehead was led to take the idea of process as fundamental. It's in modern physics that we learned to do this. The event is a very, very tiny process and the measurements of quantum theory are larger processes. So the idea of a wave function of the universe has to be regarded as an anachronism in which you give up the idea of describing the observer and imagine that you can talk about things as they are. There must be some way to do a cosmology that takes into account the facts of quantum life, but the idea that you can do it just by imagining the application of ordinary quantum concepts means implicitly that you're putting an observer, an all powerful, all-knowing observer, outside of the universe looking at it. Now this is totally alien of course to Whitehead's philosophy and totally alien to Heisenberg's physics, and Bohr's. So I really think that there are important problems involved in understanding the whole universe that Whitehead has faced more seriously than most physicists.

I have tried to draw up with Bill Kallfelz a table relating the vocabulary of present day physics to that created by Whitehead in the late '20s and it works pretty well - there are a few blank spaces of not-so good correlations [D. Finkelstein and W. M. Kallfelz, "Organism and Physics," *Process Studies*, 26 (1997): 279-292]. I think it's expressing the extent to which theology influences physics - it's not gotten across in our courses. But if you look back on the development of physics, you begin with Newton's brand of theism and for Newton the idea of a closed physical theory is absurd. He takes for granted that God steps in now and then to keep things working in a reasonable way and the idea of one single dynamical law is totally alien to Newton. This is so important I want to read it.

Since Space is divisible ad infinitum and matter is not necessarily in all places, it may also be allowed that God is able to create particles of matter of several sizes and figures and in several proportions to Space and perhaps of different densities and forces and thereby to vary the laws of nature and make worlds of several sorts in several parts of the universe. At least I see nothing of contradiction with all this. (Newton, 1730, Query 32).

What I want to talk about most in the time I have left is the controversial, hard question of the non-creativity that we see in nature. If the fundamental elements are creative how come so much of nature goes by rote, like the ball that falls? In Leibniz's time, this was expressed by saying that things move in such a way that this is the best of all possible worlds and over the years we have managed to quantify what makes some worlds better than others. There is this thing called 'action' - things move in order to make the action a maximum or minimum. It's a matter of signs, stationarity is the important thing. And so gradually the search of the physicist began to be a search for 'the' action - 'the' fundamental law. Newton doesn't speak of 'the' law of nature. When I learned physics, I thought physics was the search for the laws of nature and then I read Einstein. That's where you find the idea that there is 'a' law and immediately I was converted. Physics is the search for 'the' law of nature. I thought this was a great insight.

Now as I get older I must admit that I'm either atheist (there is no law) or pantheist (there is nothing but law). There's not too much difference between these two positions from my point of view. But the older ones no longer make sense to me so I want to dredge up this remark of Newton which starts it all off. I will read a fairly extended quote to avoid slanting.

> Since Space is divisible ad infinitum and matter is not necessarily in all places, it may also be allowed that God is able to create particles of matter of several sizes and figures and in several proportions to Space and perhaps of different densities and forces and thereby to vary the laws of nature and make worlds of several sorts in several parts of the universe. At least I see nothing of contradiction with all this.

And then there's a hiatus of a hundred years or two during which we're led to believe that there is one fixed law. Now if you look down the list of the fundamental concepts of classical physics, they have been relativized since then. One of the few survivors of the mechanical doctrine in today's physics is the idea that there is 'a' law - 'the' law. The grand unified theory is one expression of it. The 'theory of everything' is another expression of it and so forth. In quantum theory one has to be a little suspicious of this idea because surely the law for a system depends on what the system is and the system cannot be the whole universe in quantum theory. There are therefore many systems and so, at the beginning, there are many laws. What can it possibly mean to say there is only one? It must mean somehow that you have a way of figuring out what the law is that goes with each system. That's not impossible by any means, but it's quite different from what people are searching for at present. Where does the concept come into mechanics in the first place? The point I want to make is that the idea of a separate dynamical law, separate from every other element of physical theory, is actually a byproduct, an artifact, of the separation of space-time into space and time. A truly relativistic theory, relativistic in all its formulations, could see no difference between kinematics and dynamics. By kinematics I mean a theory of the description of motion; kinematics is the linguistics of physics. It sets up a formal language, a syntax, usually disgustingly mathematical, with a dictionary relating it to the experiences that go on and don't go on with all the measurement you could make, the experiences you could have in principle, and then there's the question - what determines the experience you do have? What is it that distinguishes the actual from the possible? And Whitehead is perfectly clear about this - it's the aim of the organism. Well organisms change their aims. So this sounds a little as if Whitehead is giving up the idea of an immutable natural law. Certainly Peirce, an intentionally evolutionary thinker, ridiculed the idea of an absolute law. He insisted that the law had to evolve and he described the process by which it happened. He spoke of the first flash whereas today we speak of the big bang.

I was really gratified at this meeting to discover that I'm not crazy to think that Whitehead imagined the law itself as mutable, something that probably everyone here knows. And here it is on page 27 in the Whitehead exam from 1927 Harvard, the last question, #10:

> Potency refers to the continuum of nature. Act to the community of atomic creatures.
> Potency is a character of the creativity due to the creatures. [and now begins the question]
> Explain this doctrine pointing out its bearing (a) on this (b) on the doctrine of an evolution of laws of nature.

So Whitehead too had the feeling that there is no definite law of nature. That law also is part of the creative process. I suppose in modern physics Wheeler is among the first to insist that the laws of nature are mutable; as he put it, “there is no law except the law of averages.” To which I would add the comment ‘that is not a law of course.’ It doesn’t tell you what is going to happen on each occasion.

Let me get back to my remark about the separation between dynamics and kinematics - dynamics is kinematics plus law. I have claimed that this separation is a remnant of the old distinction between space and time. The fundamental variables that we take in classical mechanics are positions, then we ask how the positions change in the course of time and the rate of change of position is frozen at a certain moment in the concept of momentum or velocity. We ask how positions and momentum change in the course of time. In quantum theory, correspondingly, our fundamental variables, position and momentum, change only the position variables but have no affect on time. Earlier, the idea of a Hilbert space was mentioned as a framework for physics. But Hilbert space does not contain time. The original formulation of quantum theory is timeless in its kinematics, it deals with states at one moment. It is fundamentally non-relativistic therefore as has been pointed out by all the founding fathers of relativity from Bohr to Wigner and on through modern times. So how do we correct for this? After we have worked out the matrix elements, the transitions, between different positions, we add in information about how to get from here now to here later. We set changes of position which are handled by kinematics and changes in time which are handled by dynamics. If you set up a true network theory in a ways Geoffrey has described this morning, you will describe processes in a completely spacetime way. I don’t mean spacetime in the ordinary sense, but you certainly will not introduce a distinction between space and time. You’ll talk about processes or events or transitions which do not necessarily connect things at the same time, but like the actual processes that go on in nature, it takes time to cover space. You’ll not assume propagation faster than the speed of light, you’ll not assume rest, you talk about what actually goes on, which means that you will link space and time in the kinematics. Once you describe a physical process by giving, let’s say, the operators that couple different space and time together, there’s nothing else to do. Each such description assigns an amplitude to every other description. There is simply no place in such a theory for a separate law of nature.

The description of the process also contains the information about what the probability of a happening is and assigns probabilities to every other process, relative probabilities. Given that your preparation is so and such, if you look for this what is your chance of finding it? Quantum theory is set up to answer such questions. That’s my main point. That Whitehead was a little bit ahead of us. The search for ‘the’ law which has evoked considerable criticism within physics already, really is an absurdity, it’s a relic of the last century. Whitehead simply saw that a little earlier than the rest of us.

[Note: The formal paper associated with this oral presentation is published as “Physical Process and Physical Law” in *Physics and Whitehead: Quantum, Process and Experience*, ed. by T. Eastman and H. Keeton (Albany: State University of New York Press, 2003). Please refer as well to the following works by Professor Finkelstein: “A Process Conception of Nature,” in *The Physicist’s Conception of Nature*, ed. by J. Mehra (Dordrecht: D. Reidel, 1973): 709-713; “All in Flux,” in *Quantum Implications: Essays in Honour of David Bohm*, ed. by B. J. Hiley and F. D. Peat (London: Routledge, 1987): 289-294; *Quantum Relativity: A Synthesis of the Ideas of Einstein and Heisenberg* (Berlin: Springer-Verlag, 1996). Finally, see Finkelstein’s article written with William Kallfelz, “Organism and Physics,” *Process Studies* 26 (1997): 279-292.]

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Henry Stapp Whiteheadian Process and Quantum Theory of Mind

This morning the title was suggested “is mind slave to body?” - this is a basic ontological question, a necessary part of any ontological theory of the universe. What is the nature of the interplay between the subjective or experiential aspects of nature and the objective or physical aspects? And by subjective or experiential, I will mean theories, ideas, thoughts, sensations, things that seem to come into being and then perish and then are replaced by a successor. Opposed to that we have the idea of the objective or physical aspects. These are things that continue to exist, like a particle. The particle is a paradigmatic example of one of these bits of the physical universe that persists and carries on. So the question is "what is the relationship between these two parts of the universe?" In classical physics the physical aspects are self-sufficient, they themselves determine their own unfolding in time. In this sense, the subjective aspects of nature are slave to the physical. In so far as the psychological aspects could contribute, they must themselves be determined by the physical aspects. In that sense there is no real freedom, the physical aspects would control everything and in that sense they are not free. The physical controls them. To the extent that they control anything physical, they must themselves be completely controlled by the physical. This is a consequence of the deterministic character of classical physics.

On the other hand, I would say that a basic idea of Whitehead's is that it is the subjective aspects of nature that are somehow primary. He wants to build his universe out of these subjective occasions. They seem, and he claims and often emphasizes, that these are the real realities, the basic entities of nature. It would not seem that his intention is to make them slave to the physical in the same way that happens in classical mechanics. So the question is "is that idea correct? Are they slaves or are they not slaves? In fact, is the idea even well defined?" So according to classical mechanics you can make the idea well defined and the answer is 'no' or the answer is that the experiential aspect is slave to the physical. My theme today is that according to quantum theory the idea can still be made well defined and in this case the experiential aspect is not slave to the physical.

First let me tie this into Whiteheadian process thought. I will tie quantum theory and Whiteheadian process together with just a few words to indicate my take on what this connection is. In Whiteheadian ontology you have these actual occasions, which at least originally were like experiential events. They somehow had a psychological aspect - they came into being, they perished, and they left some potentialities for the future. These were then taken up by later occasions and you have the process of a switch between actual occasions which had a certain psychological element and the potentialities that link them. For these actual occasions, even in his later *Process and Reality*, he talked about appetite and satisfaction, they had some psychological elements. In his earlier works, these things were really much more like human conscious experiences. Later on he wanted, I'm sure, to make a theory that would hold even before human beings were around and so he went on to more elemental notions of these occasions, but some psychological aspect survived.

As far as quantum theory is concerned, Heisenberg also talks about the probability function as representing 'tendencies' for events, objective tendencies for events to occur. He talks about transitions from the possible to the actual where the actual were events. The tendencies were essentially imbedded in the wave function and the state of the universe represented potentia for events to occur so there was a very clear similarity there. In the Copenhagen interpretation, or the original interpretation of quantum theory, which was an interpretation with a very pragmatic orientation, these events that were the foundation of the theory were increments in our knowledge. In order to be a practical theory, you had to tie the theory into what experimental physicists do. They set up experiments in order to probe nature in some way and they experience some increment of knowledge. They find out something, and so the events in the Copenhagen interpretation, in the final analysis, were increments of knowledge and hence experiential type elements. So we have some close similarities and that's the basic reason why many physicists, quantum physicists, find Whitehead attractive. The basic ontology seems to have some natural links that might be exploited.

The question that I'm addressing, just to state it again, is "can a subjective, experiential aspect of nature control a physical aspect but not be controlled by the physical aspect?" This is a question of freedom in some sense. Now there are two simple ways that people might use quantum theory to say that there is freedom. These are both ways that I am not going to allow. One is the idea that if you have some statistical laws maybe mind can come in and bias these laws in some way - but that means you're throwing out quantum mechanics. Quantum mechanics - these are the basic laws seen, if you'll permit me, in this epoch. Whitehead talked about different epochs, laws as different habits, existing for a while. And at least at the moment, we have some rules we can use that work very well. That's the sense I am going to talk about laws - these rules seem to be working in our neighborhood of the universe at least. So a biasing of the laws would be basically a rejection of quantum theory from my point of view. But that's not what I'm talking about. There's another similar idea that you could talk about, which is to say that the statistical laws are in place but you have the individual choice and maybe the individual choice could go this way here and that way there and so, in that way, mind could come in and influence the course of events within the quantum picture, but I regard that also as outside. If you have something controlled by a statistical law, then you don't want to refer to something outside - then you have a lot of trouble keeping track - how does it know what happened earlier? In any case I'm rejecting that. I'm not talking about either one of those two ideas of how mind could come in and influence the course of events, but a different idea.

I'm going to give you kind of a two-minute course in quantum mechanics. Quantum mechanics is built around the idea of an experience. Ultimately, as Bohr talked about, our experience, how we set up the apparatus and what the experience of the observer would be. Quantum mechanics is a mathematical formalism, Hilbert space and a lot of things like this. So there has to be a correspondence between experience on the one hand and something in the mathematical formalism. I'm representing that by this arrow - the experience corresponds to something in the mathematical formalism, it's called a projection operator. It's the projection operator corresponding to that experience. This is just a pictorial way of letting you know that there has to be this correspondence between experience and something in the formalism. The next thing you have here is a state of the system. A fundamental idea in quantum mechanics is that if you ask a question and get the answer 'yes,' the state changes. You have more information, therefore you can't expect the state, in so far as it represents knowledge, to be the same. It's got to change and make itself consistent with the new knowledge and that's represented by this symbol here. The original state, if you perform an experiment and take out some information and get the result say 'yes' - the experience does occur - the state changes to a new state that is compatible with the new information that you have. And there's a formula which tells you the probability that if you ask that question you'll get the answer 'yes', experience 'e' does occur. There is a way within quantum mechanics to give you a statistical prediction and that's the famous statistical element of quantum theory.

Now I must draw a sharp distinction between the Copenhagen interpretation which I talked about just now and the von Neumann interpretation. The Copenhagen interpretation, as I said, was based on a practical approach. It was not an ontology and was not designed to be an ontology. It was designed to be a practical set of rules that would avoid metaphysical and ontological questions and allow physicists to do their job without getting embroiled in such matters. From that point of view this system 's' was kind of a tiny little thing such as one electron or one photon and you prepared the system in some way, you probe it and take some information from it, and it will reduce to this new form which represents the new information or the change in the state reflecting the fact that you have new information about the state. So this is not designed to be an ontology. There's another approach, which is von Neumann's approach, and the idea here is that the quantum laws seem to cover both individual atoms and any conglomerate of atoms, at least in idealized form. That's what the laws seem to say. They should cover any system of atom, so von Neumann's idea was to take that seriously and say 'well these apparatuses are part of the quantum system, even the human observer and his brain, they're all made up of atoms, the quantum rules should cover that whole physical universe.' From this point of view, experience and words should be associated with what's going on in the brain of the observer. So what we have, in this reduction of the state, should take the brain to be a state of the brain that is compatible with the experience. If I'm looking at something that could be this or could be that and I see the second then there should be a reduction of the state of the brain to be compatible with that new information. So von Neumann's work essentially showed how the pragmatic rules could, in a sense, be deduced from this bigger picture, and how the whole universe, and the projection operator, which in the Copenhagen view acted on this little system, could now be regarded as acting on the state of the brain. So now we have a more complete picture, at least what would purport to be a more complete picture, where we have the usual causal chain from what's happening out there to something in the brain and, in an experience, rather than this kind of jump in the Copenhagen interpretation (where we basically said one shouldn't talk about brains and biological systems, that's too complicated). You kind of jumped from experiential things to what was going on in the world here. You say 'no', the experience should be associated with events happening in the brain and so that what was his idea. So that is the idea that I am going to pursue. Not every physicist would like to pursue that. In fact, most physicists probably would like to keep mind out of physics and would not approve of this von Neumann approach.

The key point of my talk is that there are two choices involved in applying quantum theory to a system.

There's a Bohr contribution to the Schilpp volume of *Einstein, Philosopher-Physicist* where he's discussing the Solvay Conference of 1927, which was kind of the marking point in the formulation of modern quantum theory; he said the following:

> An interesting discussion arose about how to speak of the appearance of phenomena for which only statistical predictions can be made. The question was whether as to the occurrence of such individual events we should adopt the terminology proposed by Dirac that we are concerned with a choice on the part of nature or, as suggested by Heisenberg, we should have to do with a choice on the part of the observer constructing the measuring instruments and reading their recordings.

So we have this quote and the point is, in quantum mechanics, you need both. Before you can apply the quantum formalism you first need a choice of what question is going to be posed. David Finkelstein emphasized that too. You take some particular thing from quantum theory, you ask a particular question, and it's only if you ask the question that quantum theory will give you a statistical prediction about what the answer to the question will be. In other words, you ask a certain question, ultimately the question is 'will a certain experience occur?' When you set up an experiment, you are designing an experiment such that if you get this result, some pointer to the right, it will tell you something, give you more information, answer your question yes or no, but first you have to ask a particular question. Then the question is basically 'will such and such an experience occur?'

Now I want to take a little deviation here and suggest that the nature of the interaction of mind with brain is through coherent states of the electromagnetic field. There are many reasons why physicists would like that. These are very classical ideas and our experiences seem to be classical. These states are particularly robust, they are not very easily disturbed by all of the noise going on in the brain, and indeed decoherence effects tend to leave these states pretty much unchanged. They are the most robust of the states and they are quite easily described by neat mathematics. When I say a Gaussian wavepacket, that has a certain mathematical meaning. It's a wave packet which essentially describes the state, say, of one particular simple harmonic oscillator. Once you take a coherent state decomposition of the electromagnetic field in the brain in terms of these states, each of the particular oscillator states is represented (in the coherent state representation) by a simple wave form here. You can imagine that this is kind of a cloud of potentialities or possibilities for what that state classically would be. Classically you would say it's here or here; quantum mechanically you have this smeared-out set of possibilities for what it might be that acts as a unit, as a potentiality for the occurrence, the answer to some question. For example, if this state which is centered around 'q' is the state of the system, the observer could ask the question "is my experience this?" Is the experience the one that corresponds to the state q prime? Quantum mechanics gives a statistical answer to that question. It doesn't say 'well maybe' and it doesn't say it's kind of a blurred out 'yes and no,' it says that either it will be 'yes' or it will be 'no' and it will give you the probability of those two options. So it will jump if it was in this state to begin with and if you asked the question 'is it in this state?' it might say 'yes' or it might say 'no.' It will give you one of those two answers. If it says 'yes' it means you jump to the new state - that's the quantum jump. In this particular case, and this is going to be important to what follows, there is a formula for the probability and, at least for small separations, this has a quadratic term, 1- (something that becomes very small), when the distance between them becomes very small and this quadratic dependence will be important to what I have to say.

You don't ask in quantum mechanics "where it will be?" You ask 'is it here?' and then quantum mechanics will say 'yes' or 'no' and, if it says 'yes,' it means a jump, a change from what it was before, so the experience 'e' must be chosen before nature can choose the answer. So there is then this freedom of the choice and as David kind of said, once you make the whole universe described by the quantum mechanical formalism the observer is somehow pushed outside. This question has got to be asked in order to make sense of the formalism, but the state of the universe does not answer that question. It does not even tell you what question you're going to ask. And that's the point. Therefore there is a freedom within quantum theory as to what question is going to be asked. This is a basic question in quantum theory. How do you determine what the question is? In the present state of quantum mechanics there is freedom there - freedom as to what question is going to be asked.

Now suppose we have a state of the brain, which I'm schematically representing by this Gaussian wave packet. It corresponds to a certain experience happening. Suppose we had this experience and now the brain is in this state. And suppose that if you look at the Schrodinger equation, which is the quantum mechanical analogue of the equations of motion of classical mechanics, and suppose you look at the normal equation of motion, then the system would tend to move. There are some forces acting on this; it has a tendency to move in a certain direction. Now, on the other hand, and this is the famous quantum Zeno effect, suppose you ask in very rapid succession 'is my experience this same experience?' and you keep asking it over and over again, there's freedom to choose whatever question you want to ask. If you should choose to ask that question over and over again at a rapid pace, the effect in quantum mechanics is to freeze the motion. Instead of moving in a way that the ordinary physical forces would have it move, in some direction, it's frozen in place. That means that the freedom that you have within quantum theory to choose the question does give you some control over how the wave function is evolving. If you should choose to repeatedly ask this same question over and over again, it would change the motion of the brain. It would cause the brain, in this case, to freeze in place. Now, I would like to suggest that maybe there is a connection between this freedom of choice as to what experience I will have and your psychological freedom to attend to one matter or another. There is a question of psychology 'what is it that chooses what you're going to attend to?' You have the freedom to attend to this or that. I can ask this question or that question. If I look out of the room, I can focus on what I want. So, if you do make this correlation between freedom to attend to what you want and the asking of a question of the brain, what state is the brain in, you would say that your freedom of attention can control the activity of the brain. It can cause it to be different from what it ordinarily would be under the action of physical laws. That's the so-called quantum Zeno effect. If you keep asking the same question rapidly enough, you freeze the motion in place and don't let it evolve as it would normally.

Suppose the system was originally over here. And suppose you just ask the question 'is it over here?' Well the answer would be almost surely 'no.' These things are so far apart that if it's here and you ask whether it's over there the probably is very, very tiny that you would get the answer 'yes' - it's almost certainly 'no.' Suppose you do the following. Suppose you break this interval, this length, between the centers of these two wave packets, into a bunch of N tiny intervals. Suppose I ask a succession of questions. Is it here? Shift a little bit. Is it here? Shift again and ask a whole sequence of questions. Applying the quadratic dependence shown earlier, the answer is this, that the probability that you could move the thing over there by the amount 'L' is given by this formula and as N becomes bigger that quantity becomes 1. In other words, if you could focus your attention in this way you could actually move something which wanted to just sit here, and had no tendency to move at all, you could move it over here just by asking the right sequence of very closely spaced questions.

So that's the bottom line. There is this freedom within quantum theory in conjunction with the freedom to choose the question which is not answered within the quantum formalism and is not answered by the wave function. Let me say that the wave function represents the physical aspects of the universe, that's the generalization of the classical description of the physical world which goes over into the wave function in quantum mechanics. There's nothing within the wave function that answers this question of 'what question is going to be asked next.' This is something that is somehow outside the system, and there is therefore an element of freedom within quantum theory. The point of this is to exhibit that the exercise of that freedom can actually, according to the quantum formalism itself, change the quantum state to something different from what it would be if you were not attending to things in this particular way.

[Note: The formal paper associated with this oral presentation is published as "Whiteheadian Process and Quantum Theory" in *Physics and Whitehead: Quantum, Process and Experience*, ed. by T. Eastman and H. Keeton (Albany: State University of New York Press, 2003). Please refer as well to Dr. Stapp's book *Mind, Matter, and Quantum Mechanics* (Berlin: Springer-Verlag, 1993).]

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Dialogue among Panelists:

Chew - I want to make some remarks about this notion of measurement or observation which has taken on such importance in quantum mechanics thus far and was very important for the previous presentations and comment that, from the historical point of view that I am currently favoring, there's nothing special about an observation. It's just simply a particular pattern of history, a localized pattern of history, a collection of events, which have certain characteristics. Among them is the characteristic that the sub-pattern which corresponds roughly to the observer and the sub-pattern which corresponds roughly to that which is observed. And although they get interlocked, they don't mess each other up so much that the identities of the two gets spoiled. You can qualitatively say this, you can imagine it, but to quantify that, to say exactly how much messing up you will allow in an observation is pretty obscure, and I'm certainly not in a position to do that. But, in order for such patterns to exist at all, it is non-trivial. For example, the material component of the universe has to be rather dilute.You happen to be over there and I happen to be over here in order for me to be able to look at you and not completely get entwined with you and mess you up. And that depends on the fact that this is an extremely dilute phase of the universe that we're functioning in. That diluteness by the way is specifically related to what I said was the relatively small component of history which is material, most of it being non-material. Most of the rest of the universe, which isn't matter, dominates the total of whatever we have available to put history into. So diluteness is one essential characteristic and that isn't present in the very early universe. It has to expand a great deal before you can even begin to talk about observation.

The second requirement is the smallness of the elementary electric charge. Henry Stapp emphasized that brain activity is electromagnetic but certainly any pattern of history which you could call a measurement is electromagnetic. It is mediated by photon arcs and at the ends of the photon arcs you have these very tiny electric charges, which are causing those photon arcs to either be born or die without disturbing terribly whatever it is they're running into. So observation and measurement, which is the cornerstone of a large part of Copenhagen ideas, is not obvious. It's a very special feature of our portion of the universe. And of course if it weren't there we couldn't accumulate knowledge which depends on such local conditions.

Stapp - The two of us did of course ask whether your vacuum was physical or mental and it seemed that it could very well be mental or have mental aspects. The endeavor that I am involved in is actually using quantum mechanics as it exists today, looking at the simple ontology (von Neumann I do believe), where the mind is kind of left out of the part of nature that is normally regarded as being described by a wave function and the evolution of the wave function. It may be that in your other picture it's there and that's quite possible. The idea that something could come out of nothing at all, it seems to me, is an absurdity. The idea that this chance decision comes out of nothing at all I certainly reject. So I tried to carefully pose the question not in terms of total freedom of the universe, but freedom of the part that we associate with experience from the part that is well defined in quantum mechanics as it exists, which is this evolution of the wave function of the physical part of the universe. So I could formulate the question in a particular way by identifying the physical with the evolving wave function as it's understood today in quantum mechanics and ask about freedom relative to that. So it's freedom relative to that particular physical framework that I'm talking about.

Klein - Since Geoffrey picked up on this photon business, I would like to go along with that in the context of the quantum Zeno effect that he brought up. The thing that I would urge everyone to read in connection with the quantum Zeno effect is in this advertised publication (*Process Studies* 26/3-4). On p. 328-330 is a book review of Henry Stapp's *Mind, Matter and Quantum Mechanics* and the last paragraph is very interesting. By the way it's a very laudatory, positive well-written review by Joe Rosen. He goes through this thing that I would also hope that David Finkelstein can do, which is a translation of Whitehead's language, and right next to it is the language of physics. In particular, you go through three efforts of Whitehead's thinking and then exactly parallel to that are three aspects of quantum mechanics, so one is inspired to think that 'wow' here's a very nice coupling. But then in the very last paragraph he says "well let's look at how the brain works." Let's look at how classical mechanics, classical neural networks with feedback, handles this and it has the same exact parallel. He gives the identical structure to Whitehead and to quantum mechanics - global, long-range, coherence, etc. And so let me do that with Zeno and maybe hook in photons.

The idea of the Zeno effect is that if you attend repetitively to a single idea, let's say, you can freeze it. Well, there are easy brain mechanisms involving chemicals and the neural structuring that we know and love so well, without any quantum effects, such as the neural mechanism of attention that are being understood, and it's very easy to make a neural network (classical) that freezes an idea. Similarly, it's very easy to make a neural network with attention that shifts an idea, that shifts the attractor basins if you like, that classical language, so that you can get some motion of something that otherwise, without that attentional shift, would be frozen. And so I would like people first of all to look at that very well written paragraph and I would like Henry, David or others to comment on this translation of Whitehead having parallels with quantum, but then it might also have parallels in classical neural dynamics with feedback.

Stapp - Yes, I would like to answer that because that's just exactly the point of freedom that I was emphasizing in my last talk. That chaos or any of those neural networks, if it's a classical system, then that mechanism whatever it is causing it to freeze in place or to move, was itself controlled by the system just prior to it. The physical in and of itself is doing the whole job. There's no freedom in that sense of anything outside, whereas I claim that in quantum mechanics there's a difference here because if you define the physical system in terms of the wave function or state vector then there is something outside that is not determined by that physical system. Namely, what question is going to be posed… is nonetheless able to change and control the behavior, so I claim there's an essential difference between the chaos mechanism and the one that I'm talking about.

Finkelstein - I will like to hear Joe Rosen's list and compare it with my own.

Klein - There are three lists, the first one is the Whitehead list, the second one is the quantum list, and the third one is the classical list (*Process Studies* 26/3-4, p. 329). There is also a list by David Finkelstein on p. 291 of that journal.

1. classical evolution is, in general, effectively unpredictable.
2. under classical evolution, a system may continually pass through a limited range of states in an almost periodic manner and a tiny change of conditions can cause the system to change abruptly its behavior and settle into a single state; just like quantum collapse.
3. states of complex classical systems can involve long-range patterns and order as emphasized, for example, by those of us doing brain modeling.

I should underline that I'm a big believer in quantum mechanics but more on the metaphysical side; not on the reductionist side.

Tanaka - About these parallels with Whitehead's metaphysics, especially David Finkelstein's idea of the relativization of absolute dynamic roles as it appears in Whitehead's metaphysical ideas and Finkelstein's ideas. Whitehead wrote the book *Principle of Relativity*. The meaning of Whitehead's principles of relativity in physical works is similar to Einstein's but with slight differences, and Whitehead used the principle of relativity in *Process and Reality*. In this case, the principle of relativity has a metaphysical meaning. It means a thoroughgoing relativization or relationality between actual occasions, so in Whitehead's sense the physical world is not absolute, it can change from cosmic epoch to cosmic epoch and dimensions of spacetime are also changeable. The present four dimensions of spacetime are an accidental fact in Whitehead's cosmology. So to Whitehead the relationality of actual occasions is basic, that's in the metaphysical sense, and the physical roles must be deduced from the metaphysical relationalities. But the physical role itself cannot be confirmed on empirical grounds because empirical testing requires a uniform sense in the subjective world. I want to emphasize the meaning of subjectivity, the experiential aspect of actual occasions. Many physicists deny the experiential aspect of elementary particles and elementary events in the physical world. But I think that such events and objects are abstractions from actual occasions, more exactly the relationality of actual occasions. So I am very much inspired by Professor Stapp's ideas of the experiential aspect…so that subjectivity is present also in the microscopic level. But Whitehead only stated this idea in the general, metaphysical sense; he did not separate the mathematical generalizations of concrete physical theory. He did not construct a concrete physical theory as has the particle physicist. So the question I have for David Finkelstein is that I think he must stress the relativization of classical logic. Your main idea regarding the interpretation of quantum physics is that quantum logic cannot necessarily hold in the most basic description of the world so that Einstein's concept of the completeness of physical theories presupposes the classical logic. So classical logic is to blame because the classical logic of classical physics does not accept the relationality of quantum events, so Einstein rejects the competeness of quantum physics. I ask Professor Finkelstein, when you relativize absolute dynamic roles, what is your own background logic - is it classical logic or quantum logic?

Finkelstein - First of all, thank you for your kind remarks about my old work, but I no longer believe it. When I first came across von Neumann's lovely paper, first in his book and then in papers with Birkhoff on the revision of logic involved with quantum theory, I was still rather fresh from going through Whitehead and Russell, and Whitehead, when he wrote *Principia*, was a thoroughgoing logicist. He really thought logic was fundamental and so anything that changes logic must be very important. And it's still true, yes it's important, but that's not the best way to look at it. I think, from the point of view either of organism or of quantum theory, logic is sort of an epiphenomenon, a very high level description of the actual dynamical processes that go on. In fact the von Neumann logic is peculiarly timeless, it's not enough for physics, you can't build a physical theory on Boolean algebra alone. So you certainly can't do a Boolean algebra of things just at one moment so you certainly can't do it out of the von Neumann modifications of Boolean algebra. You need a deeper theory and I'm sure that dynamics or kinematics (I no longer distinguish between the two) is that deeper theory and this is just an early stage that everybody has to go through.

Tanaka - I am very glad to hear that you read the *Universal Algebra* of Alfred North Whitehead.

Finkelstein - No, it's his *Projective Geometry* that I read. I only looked at parts of *Universal Algebra*.

Tanaka - A difference between Bertrand Russell and Alfred North Whitehead, in their attitude towards mathematics, was that Russell wanted to reduce mathematics to logic, but Whitehead on the contrary reduced mathematics to algebra. Whitehead was more of an applied mathematician so he majored not in pure mathematics but in applied mathematics and theoretical physics. He constructed a new theory of gravitation which is different from Einstein's theory, thus Whitehead was also a theoretical physicist. Algebra is more to the center than logic so I think there is commonality between Whitehead's ideas of mathematics and Finkelstein's ideas of quantum logic.

Finkelstein - I hadn't realized that, thank you very much for pointing it out.

Malin - I would like to comment and ask you about the laws of nature. The idea that the laws of nature are habits of nature is something which Whitehead believed in and it's certainly very attractive. Now, if it's true, the way we would expect it to manifest is to see that the constants of nature are variable and so far as I know there is a very precise measurement that they are not variable to 1 in 10 to the 12th power or something like that - very accurate. How do we deal with that? Well, one way is to say that Whitehead is wrong. Another way is to say that they do vary but they have not detected it yet. And another possibility is that there is an inter-consistency between the different laws of nature that we haven't realized yet, which brings about the fact that they cannot change, some self-consistency condition. So what do you think about that?

Finkelstein - I associate the idea that natural law is just a habit with Peirce more than Whitehead. Did he share that idea also? (Malin - Oh, yes) Ah, yes. Thank you. The idea that things happening tends to increase their probability of happening again, of course we don't call it habits any more in physics, we call it Bose-Einstein statistics. That's a guess that natural law is a condensation phenomenon and I'm very much inclined to the view that Geoffrey put forward earlier that really it's all in the vacuum. I suspect that the things we call laws today are simply phenomenological descriptions of the quantum fine structure of the vacuum. That, I'm sure, is a condensation phenomenon. The limited number of possible laws is the result of a limited number of possible phases. And so the apparent constancy of law is because there are jumps between them just as there are between the various crystalline forms of ice. You don't have a smooth variation from one to the other. It takes a real disaster.

Malin - My question to Henry is the following. You spoke about freedom in what I think were two phases of which one was the freedom to ask the question. This seem to imply that the collapse of the wave function comes from the consciousness of the observer. If you're implying that, you must be aware of the well known objections to that position.

Stapp - No I'm not implying that. I tried to draw a very sharp distinction between two kinds of choices. First, there's a choice that seems to be assignable to a small system, like a human being or a brain or something like this. Quantum mechanics seems to allow that choice. The choice of what question to ask is to be assigned to this small system. Since it's a choice of basically what experience I'm going to look for, it's very much like directing your attention. Basically when I direct my attention to some extent it's asking "is it this?" so I'm making a close alliance between the choice of asking the question and the choice of a small system to attend to. But the answer to the question for large systems is apparently far from local. It's not connected with the observer and that's the quote that I had. It's connected with nature so nature answers the question, but maybe it's the small system that has the option to ask which question nature will answer. So there's a division of labor.

Malin - Let me make one more comment. If we say with Dirac that nature makes a choice then of course the question that people have been working on for seventy years or so is how does nature make the choice and is there a mechanism? And it seems to me that, if we believe in Whitehead, we must say there cannot be a mechanism or least not a mechanism that completely determines it because, if there is, there is no place for creativity, which is one of his most fundamental concepts.

Stapp - The importance of what I have said today, is that you can answer the one question without answering the other. This question of how nature chooses is really a big question, but maybe we can tie the question of how we human beings pose the question to something that is much more accessible to study, in fact scientific study.

Clayton - Do you agree with Malin that there can't be only mechanism and still have creativity?

Stapp - I believe in the law of sufficient reason. There has got to be some reason behind every choice. Nature in its totality must have some mechanism for answering these questions, but it doesn't have to be local. According to quantum ideas, the whole universe can be involved in that choice. So that's a big, big question. But if we can focus on another question, the observer's choice, and make that associated with a local human system or some other local system, then we have something we can attack.

Nobo - I was struck by the fact that Whitehead does use the phrase "organic mechanism" in *Science and the Modern World*. It may be an unhappy phrase since mechanism has the connotation of complete determinism, but I think you can interpret it to mean a partial determinism. That the earlier partly determines the later but leaves elbow room for self-determination and so there is a mechanism and this is the wholistic aspect: It's the universe as a whole determining earlier phases of an event but leaving later phases open….It is a mechanism of sorts but not a complete determinism.

It strikes me that there's a parallel to the business of asking a question. It may be that one event puts a question to the next event. It's a question and an imperative. Do this if you can. In Whitehead, an 'experience' really cuts across what you were calling subjectivity and what Whitehead calls physical experience. The physical experience is the more mechanical, deterministic, earlier-to-later; the subjective experience is where the freedom is, but that freedom puts a question to the next event, so to speak. I'm playing with an idea here. If we think of every event being partly informed by the past and partly self-informing or self-forming, then that self-formation together with the earlier information, can put a question to the future, as it were. In Whitehead every subjective aim has a transcendent component. The aim is at intensity of experience in the present and in the relevant future so that that this transcendent element is the question being put to the future. His answer is partly mechanical and partly creative. This is very vague and it may not make any sense to you but it's something that Professor Stapp's comments have got me to thinking.

Stapp - Let me first say that the events that I'm talking about, that you can call occasions or actual occasions, are more in line with Whitehead's earlier thinking where what he was talking about was like a human experience, which is associated with a large organism and not these tiny little things that are even smaller than particles. Once you start with the idea of a human-type experience, of course, you realize that that's not enough to build a whole world out of because we weren't always around and so you have to have some generalization of it and it's natural to go the route that Whitehead did go down to these little tiny things. I'm not at all sure that's really the way you need to generalize, in fact I see a lot of problems with it which I won't go into, but I don't like that way at all. I think the events are a much higher level thing even if they're not human. The way it works at that level, as both Whitehead and Heisenberg were saying, is that as this event or occasion occurs, it creates potentialities for the future.

Nobo - That's Whitehead's intent.

Stapp - I'm thinking of things at this higher level and not at the mechanical level where it has these powers which are almost rigidly formed. That's a way to go too but I'm certainly not focusing on that level….So I think that you can draw a distinction between physical and non-physical on the basis of quantum mechanics. In other words, the physical is the part that is represented by the quantum mechanical wave function and that only represents potentialities, but there's got to somehow be a bigger, deeper reality that finally decides it and it's the whole universe somehow that's coming into play, but that's a big problem.

Nobo - For Peirce, matter was mind hide-bound in habit. In Peirce and in Whitehead, there's a possibility of thinking that one level of reality becomes habit-ridden, so now you have constants; then you have a level that builds on that and which for a while has freedom, indeterminacy, novelty; but it too becomes hide-bound and then you go to a higher level and, if we can make that hierarchy of levels meaningful in theory, then you could have your constants at one level, and your tendencies, trends and so forth at another level and, once something becomes a constant, always a constant. That's a possibility, but there's always a level where you wouldn't have the determinacy, mechanism and so forth. My question to Professor Stapp is, how would you answer someone who says that the question that you're posing is itself determined by earlier states of the brain?

Stapp - The way I'm answering that is that if, by earlier states of the brain, you mean the quantum mechanical description of the brain in terms of the wave function and the state then it's not. There has to be something outside the quantum mechanical system that poses the question to the quantum mechanical system. That's how it works. Quantum mechanics by itself doesn't determine what the question is going to be - there's something outside. That doesn't mean it's outside of nature but it means outside this narrow definition of what is physical, namely what the physicists kind of call physical and the generalization of classical physics to these wave functions. It's outside that 'physical.' That's a physical that is local and evolves according to local deterministic equations. It's outside that narrow definition of physics although it's broad in the sense that it covers all of quantum mechanics except for the decision and experiences of the observer. If you call those things as being outside the physical, which is kind of natural to do, then these choices are not made by the physical brain.

Fagg - I have questions for David Finkelstein and for Henry Stapp. First of all, you talk about no law and I was wondering how congenial your ideas on this were with Wheeler's talking about commutability of law, law without law, and so forth.

Finkelstein - I think he simply came to this conclusion before I did; I have no problem with it at all.

Fagg - The other question is, I guess, a little deeper, and that is that I too have a problem that, if you're dealing with the entire universe, then where is the observer? It's outside the universe for which there is no physical outside. I'm not up to date on Jim Hartle and Murray Gellman, but the last I remember reading about their work they're talking about a coarse-graining kind of quantum mechanics in which they were able to average over parts of the wave function of the universe that are insignificant and they invoke the idea of decoherence and so forth and they seem to feel that they can proceed with this without the necessity of an observer. As I say, I'm not up to date about this, but I am wondering what thoughts you have about that.

Finkelstein - At the beginning of one's encounter with quantum theory, there really are two roads, probably more than two, but I want to confirm one particular junction. If you look at Kandinsky's paintings, you can say there are no objects on the canvas because he's a bad painter or you can say he didn't think there are objects and he wanted to express this in his work. Likewise if you look at the quantum theory of Bohr and Heisenberg, you can say they left out an ontology because they're not great physicists, they had to get the experiments working and so on, they just wanted the answers. Or, if you actually read what they say, you see it's a matter of principle that they didn't give an ontology. They really thought in terms of process as primary. It's not that something is left out. He called it non-objective physics because he didn't think there are objects. Now, if you take that road then you work algebraically with the processes themselves, but if you insist on objects, if you insist on an ontology, rather than a kinematics, you'll have to run around desperately for something these operators can act on. And Schrodinger provided you with wave functions. You have to ignore the fact that von Neumann is very careful about indicating that a quantum system does not have a wave function.

A quantum system does not have a state. When we take up quantum theory we make a list of the questions we can ask of a quantum system. The question "what is your state?" is not in that list. You can ask about the energy, the momentum, etc., but nowhere are you allowed to ask "what is the state?" so, in an important sense, there is no variable corresponding to the state. You put one in because it's suggested by the mathematics and because we're desperate for an object. And if you do that then you have to wonder about the crazy things a state does. To ignore the fact that it doesn't exist then you have to make it 'collapse.' The whole business of collapsing states obviously depends on retaining the idea that a quantum system has a state. Remember that in von Neumann's book the wave function is something that describes not one quantum system, but what he calls a 'reiner Fall' translated in an excellent translation as a homogeneous case. You just need to have some way of making quantum systems and you make a lot of them all the same way. So when Dirac and others say it's the way you make the quantum system as described by the wave function, or the psi vector or what have you. That's the process. I like that very much but then you don't pull one member out of the ensemble and say it has a state, which somehow tells you what the whole ensemble is. You cannot look at a quantum system and see how it was made. It doesn't have enough information in it. You can ask any question, but unless you ask the right one you will not find out how it was made. So it's totally un-operational, totally counter-experiential to introduce the idea that a quantum system has a state. There's a huge variety of states representing questions we choose and the system will come up with either a 'yes' or a 'no' depending on, in part, its past and, in part, on a decision that's made on the spot. That's the other choice that Henry Stapp speaks of. There really are two choices. We decide the question and nature or the system or a collective decides 'yes' or 'no.' But all you get from the experiment is one bit. You put in a huge amount of information, rotate a polarizer or you tune a particle detector, and all you get out is a 'yes' or 'no.' To imagine that the system is carrying an infinite amount of information besides this 'yes' or 'no' doesn't agree with our experience.

Fagg - Dr. Stapp, in the early part of your lecture, you mentioned a whole list of subjective things like thoughts and feelings and so forth as arising and then dying. Let me note that there are some feelings that go on for a whole lifetime - traumatic experiences and so forth. The other thing is that I simply did not really get this business of repeated observations as developing a freezing. Is this a freezing in the brain or in the system that the brain is occupied with observing?

Stapp - Yes, I was suggesting that our experiences are associated particularly with certain aspects of the brain which identify the electromagnetic properties, electromagnetic field, of the brain, and I list a number of advantages of it. An individual particle is so tiny it's hard to think that it's affecting thoughts very much so the states of the electromagnetic field somehow average over lots of things and when you look at it in this way you're getting a nice averaging that seems to be more closely connected to our experiences. So there's this particular feature of the brain that I'm focusing on and saying that's the particular feature that's connected with experience and so then you're able to talk about these gaussian wave packets, for example, that I was talking about and so the suggestion was that by focusing your attention, asking a particular question repeatedly, that that translates into "is this particular gaussian wave packet here?" - in other words you're asking some particular question about that wave packet. Now the rest of the brain can be doing all sorts of things while you're asking this particular question. This is a particularly important feature of the brain which is controlling lots of other things that are going on, by your freezing that particular aspect of the brain in place. The example is, if you're holding up a heavy weight, at least the feeling that you have is that by focusing your attention intently on some particular thought you are working against some sort of force that is wanting to do something else and you're holding it in place. So I'm suggesting that you are holding in place some particular aspect of the brain that's in charge of lots of other things and it's not the whole brain that's being frozen, it's just a particular aspect of the brain that's being frozen.

Fagg - One last point and this admittedly brings in religion concerning creation *ex nihilo*; of course, you know that according to most mainstream Christian theology, the *ex nihilo* creation is their position. Henry was talking about not subscribing to the idea of creation out of nothing which of course makes a lot of logical sense I suppose, but I just wanted to bring up the point that there is this other theological position that, according to mainstream Christian theology, the universe was created by God out of essentially nothing. If you believe that God is this omnipotent creator.

Finkelstein - There's also a French philosopher who created something called "integralism." He was inspired by the integers and especially by the natural numbers, and he saw that zero could give rise to one, could give rise to two and so forth, and he founded a philosophy in which things come out of nothing in that way.

Klein - Speaking of numbers, everybody should go to the movie **Pi** which is all about how everything comes out of numbers.

Finkelstein - I saw **Pi** just the other day and of course it's greatly made, incredible what a man can do on a small budget, but the thesis I found to be incredibly irritating. From my metaphysics it's a bad movie. It's based on the idea that there is one law, in fact it's the name of God, the 216 letter Hebrew word or Hebrew sentence which can be converted into an integer of 216 places, which answers all the questions of nature and I regard that as a reductio ad absurdum of the idea that there is a natural law, the law that we're all searching for, and why not 215 letters?

Klein - I don't want to give the theme of the movie away but I strongly recommend it. Until the very ending I thought that's what the movie was all about, but of course the ending was different. Could I ask Geoff Chew on this same topic on whether there are absolute laws of nature. I spent a number of years of my life following your S-matrix, bootstrap program which I thought was just wonderful that one could derive some of the basic properties of the masses, the coupling constants from logical principles of unitarity and causality. But it is my present understanding, and this is what I would like to hear, that all of that is now out the window because of the anthropic principle whereby our present laws are kind of unique for our universe. That is, if you change the electron-photon coupling ($\alpha = 1/137$) a little bit or if you change the nucleon mass a little bit, you wouldn't get life, you wouldn't get our universe. My only understanding of how that can happen, how you can have our universe get just the right constants, is by one of these Linde mechanisms of creating lots and lots of universes, lots and lots of laws, and we just happen to live in a universe with the right kind of laws. Is the bootstrap out because of the anthropic principle?

Chew - I tend not to think in that bootstrap way any longer largely for the reasons that you are posing, and I wanted to introduce a word to the discussion which I haven't heard which I feel is an extremely useful word that natural science has come up with which philosophers don't seem to like. I've always felt that this was a defect in most philosophy but I thought that maybe Whitehead was an exception but I've never seen Whitehead use this word either. He probably had some much more sophisticated way of expressing this same idea. The word is 'approximation.' He does use it? (audience - Oh yes) Oh, I'm glad to hear that and just to relate this to the points that David and Stanley have made, if you start thinking from a physical science point of view, you realize that no statements about the universe can be absolutely exact. They must all be approximate because, for example, I talked earlier about the nature of measurement. Measurement is inherently an approximate idea. There is no such thing as exact measurement and since all of our ideas are based on observation, observational knowledge and so on, it's difficult to believe that there are any statements that humans can make about the universe that could be exact statements. And this connects up to these various ideas that have been thrown around; for example, the smallness of the elementary electric charge. It appears to be very, very important but because you depend on it, the fact that it isn't zero means that all these lovely statements you make based on its smallness are not quite exact. They are all approximate because it's not zero and the same thing can be said about the largeness of the age of the universe. We have all these scientific concepts that are based on the notion that tomorrow is pretty much the same as today. Anything that happens today could be reproduced tomorrow and that's what natural science is based on, but that is based on the idea that the age of the universe is infinite. That the universe is not expanding. But it's changing. Tomorrow is not the same as today. There is no exactly reproducible experiment. There is no statement about the universe that you can make that is absolutely exact given the fact the age of the universe is finite. You can go down the list with many other parameters. Science has come up with these huge ratios which we call dimensionless numbers which give you some understanding of why certain approximations can be extremely accurate. When you have a ratio as big as 10 to the 17^{th} power it makes certain approximations so accurate that humans don't bother to keep remembering that this is only an approximation, the human lifetime isn't long enough to make it worthwhile to worry about the fact that the age of the universe is finite. In any case, I believe that it's important to keep this word 'approximation' in the vocabulary and I'm very please to hear that Whitehead does this. I hope he consistently agrees that no word that he defines so carefully can have an absolutely precise meaning. It has to have an approximate meaning.

Clayton - Well, he does, roughly.

Finkelstein - I'm delighted by the lovely things that Geoffrey was just saying; I'm glad he said them.

Dialogue open to full audience:

Eastman – Announcement made that Harry Papatheodorou, a colleague of Basil Hiley's at Birkbeck College, University of London, is unable to attend; everyone then signed a special copy of the *Process Studies* journal for Harry.

[Reference: C. Papatheodorou and Basil Hiley, "Process, Temporality and Space-Time," *Process Studies* 26 (1997): 247-278.]

Joseph Bracken - I have two quick comments. Larry I would be wary of being too literal about creation *ex* *nihilo* because, if you look into the history of Christian dogma, it is designed primarily to eliminate some of the dualism that was present in the early Christian world. As a result, it might not be creation out of absolutely nothing but only eliminating creation out of preexisting matter which would equivalently set up a dualism. For Henry Stapp, have you thought about this? It's easy to confuse what I would consider two terms, the one are 'reasons' and the other are 'causes.' Reasons are not the same thing as causes. Causes work within a context where the cause determines the effect; the reason influences the effect but the effect in a curious way is its own cause. In other words, I can have reasons for doing things and, as a result, it would be totally irrational for me not to have some reason but I don't have to say that the reasons, even the series of reasons that motivate me, in the end determine me. The determination in that altered context comes from the part, curiously enough, of the effect that, in a sense, is causing itself. It's kind of like reversing the classical cause-effect relationship that I think could be useful, as I see it, for your own project.

Jungerman - I would like to address to Henry Stapp the same question that he asked me earlier. Is there anything in this work that illuminates the idea of emergent order against the second law of thermodynamics?

Stapp - If you look at a quantum system, and Von Neumann points this out, the quantum system, if it evolves according to the Schrodinger equation, it doesn't change its entropy, the whole entropy doesn't degrade. You're not doing any fine gradient or anything. You have to look at the whole Schrodinger state. Basically the system doesn't change. It's just a unitary evolution to something else and the entropy does not change. On the other hand, if you have a collapse of the wave function, the entropy does change and in fact you are jacking up the negentropy. ['Negentropy' denotes negative entropy, which is a measure of order.] You have the potential of putting a lot of order into the universe because you're picking out of a lot of possibilities something that's very special and hence you are putting negentropy into the universe. Every time a collapse occurs there is this apparent pumping up of the negentropy of the universe and I find that a very attractive idea because then the universe could start in a very uniform state, without this tremendous neg-entropy that ordinary thermodynamics would require, and it would really be put in bit by bit as these collapses occur and so, yes, there's a possibility that these collapses, if they really occur, are really the things that are responsible for the fact that negentropy can run downhill all the time because it's being jacked up all the time.

Audience Member - Are you saying that at some level consciousness plays a major role in the unfolding of events? Or perhaps it's more like the maps that we create of events. Perhaps it's basically just a map, like Whitehead would say 'the map is not the territory.' He was not that invested in the way that we explain natural laws but rather would say that the territory itself is much larger than our map of it. The map does not create any event in the territory. What happens when we as human beings do something which is "unprecedented and impossible?" I'll give you an example. When John Kennedy announced that we were going to the moon in ten years. This was something that we as human beings had never done; we had no map, the territory was unknown to us and yet what we did in that process is that we imagined ourselves being successful doing it and entered into an experiential acceptance that we were successful and then looked at each other and said, in the wisdom of hindsight, what the moon looked like. So essentially we went from an acceptance of an accomplished fact, an event that was pulling us towards it, and we then allowed that event to organize not just our thinking but our action that led to that event and led to the consequence we had desired to achieve. How do you explain that? Where does that fit in the logic of science and the logic of physics.

Stapp - It seems to me that it fits very naturally and easily into this point of view. This point of view really is saying that our experiences are creating tendencies for future things to happen and if you have a certain structure of your experience, if you're talking about a human experience, it has a lot of the future in it. Most experiences have an intentionality in them. I'm about to raise my hand or I'm intending to raise my hand. So there's always this looking forwardness of your experiences and of course they can look a long way ahead to being on the moon and you put into action that whole sequence. That sort of thing fits beautifully into this view of the universe.

Audience member - So you don't think that there's an element that comes in there that is not anticipated by your experience? I think that our experiences are not a very good future because all our experiences can tell us is what we have already done. They can only give us a limited outcome and if we had never done something before, our experience would not lead us into doing things that we have never done before.

Stapp - I think the human brain has the capacity to pull together ideas from different sources and combine them in different ways and you do get new ideas no one else has ever had before and you could make it a mystical thing if you want but I'm not sure that's really so necessary. It seems to me that the human brain creates these potentialities that might account quite naturally for the way new ideas come up. This idea that I just told you today, I didn't have several months ago but a lot of tendencies were there and I talked to some people and I think it ultimately emerged out of a confluence of influences acting on me.

Lango - The question I have is about the relevance to Whitehead's metaphysics. Whitehead is primarily interested in relativity theory; primarily in influence by relativity theory, a subject he worked on, and only tangentially influenced by quantum theory. Many of the radical developments of quantum theory were going on in the 1920s while he was writing *Process and Reality* so it's understandable why he would be less influenced by them. It seems to me that there are real problems with squaring his metaphysics with quantum theory. Let me just focus on what seems to me an obvious one, a view that Prof. Finkelstein explained twice. Your interpretation of Heisenberg is that he talked about processes, the process of interrogating nature or experimenting with nature, whereas *Process and Reality* reflects the metaphysical vision of Plato's *Timaeus* where the whole universe consists in processes and what physicists do in questioning nature through experimentation is just one subset of those processes. So it seems to me that what Heisenberg is doing is more naturally understood in terms of the idealist tradition of Hume and Kant and that it squares much less with more objectivist ancient Greek-like approaches to the process of Whitehead.

Finkelstein - Certainly Heisenberg formulated his quantum theory in terms of very special processes - measurements - but he continually imagined that's what the universe was constituted of. I'm sure that what Geoffrey said earlier that measurements are not that different from other processes, they're not that special, is something that most physicists take for granted including Heisenberg.

Stapp - It's certainly true that Whitehead was a great scholar in relativity theory and he wrote books on it and had his own variation. But I think it's probably likely that he was aware of quantum jumps, that was 1915 when Bohr came up with that idea, and I think that fed into his idea that there was an event-like or a jump, this actual occasion, of things happening. These happenings or actual occasions, a world based on happenings, probably was given a lot of support by his awareness of the rudimentary developments in quantum theory even before the late 1920s. There was a lot of quantum theory in the air and he must have known about it and been influenced. And he does mention quantum theory now and then.

Klein - But I think you are correct that there are discrepancies between Whitehead and modern quantum theory and I recommend to all a chapter in Penrose's book by Abner Shimony who's a big Whitehead fan but he advocates an augmented Whiteheadianism. There's a lot of similarities that Henry has pointed out. It's very close. Whitehead comes close and as David has pointed out with potentialities, etc. Very close matches but it's missing something and what Shimony is talking about is an augmented Whiteheadism and maybe that's what we should be talking about. Not taking Whitehead of the 20s too seriously but imagining an augmented Whitehead as if he were around now with knowledge of Bell's theorem and modern issues. Let's not get too stuck on the old Whitehead, then we kind of say well he didn't do this or that, and just talk about an augmented Whitehead. Would it just be augmented or would it require a fundamental transformation of some or all of his categories?

Clayton - Let me turn that back to the two speakers. It has often been said that Whitehead didn't take into account much of quantum theory, understood at least according to the Copenhagen interpretation. Are you trying to augment or transform Whitehead and/or rethink some of the standard sayings of quantum theory to bring them together. On the face of it, the questioner is right, there's a prima facie incompatibility between the two. Can you clarify the common ground in the two projects that you're involved in?

Stapp - Well I just had a discussion at the end of the earlier session with John Lango and he pretty much convinced me that Whitehead's idea of, for example, Platonic ideals is maybe not a good thing. You don't need Platonic ideas. The Aristotelian idea of forms as potentialities is much more useful for the quantum view of the universe so I think that you probably do want to sort out what you want to take out of Whitehead. Certainly as a physicist, he didn't have the benefit of a lot of experience that we have and so you take from him what you want. You don't regard him as 'the' authority.

Clayton - And at the same time you're breaking with some standard interpretations of quantum mechanics when you bring in dialogue with this new Whitehead.

Stapp - Well, what is standard? There are so many interpretations and in most interpretations physicists want to keep mind out. I mean that was the idea that most physicists have, you know, that mind is something we better get out of the system. So, on the other hand, if you want an ontological interpretation and the simplest view is based on von Neumann's idea that there is a state of the universe that collapses and has certain structures. That is, ontologically speaking, a very simple way to develop quantum theory. From that simplist view you automatically get these things. The observer is pushed out somehow and his or her questions have to remain.

Finkelstein - I tried to line up the ideas of Whitehead with those of quantum theory and it doesn't work too well. The concept of the concrescence of occasions is a problem. Whitehead indicates that an occasion can be resolved into concrescences of other occasions in a non-unique way, it's variable, that sounds very much like the resolution of a vector into components in several different ways and that makes concrescence sound like quantum superposition. But then there's nothing anywhere in the structure that sounds like the other important operation in quantum theory which is multiplication - the combining of a proton and a neutron to make a deuteron or the building up of an atom, etc. And of course that's necessary.

Lango - Between concrescence and quantum superposition, I think with concrescence there's final causation. I don't think there's final causation in quantum superposition and so that leads me to think that there's a radical discrepancy between Whitehead and a quantum picture of the world. In fact, during this whole discussion I never heard the term final causation mentioned, and that's an essential ingredient in Whitehead's metaphysics. It's a strange ingredient and it's one thing that prevented Whitehead from being the philosophy of the 20th century and may yet prevent it from being the philosophy of the 21st century as mentioned in David Griffin's speech. That's another example of where it's difficult to square quantum theory with Whitehead without transforming Whitehead.

Finkelstein - By all means, I would like to transform him. I'm sure that Whitehead is the last person who wants to stop the process and in quantum theory there is something that could be called final and initial causation. In Dirac's language they're called kets and bras; the ket represents the process by which you begin an experiment like putting a photon into a polarizer and the bra represents the action you carry out at the end of the experiment when you have an analyzer and see whether the photon gets through to your eye. That ends the experiment so it's quite final.

Malin - Schrodinger in a wonderful little essay called the "Principle of Objectivation" makes the point that all of science including quantum mechanics works under the assumption that the perceiver, or what he calls the subject of cognizance, is kept out of the picture. That's how science starts and I think the best fit of Whitehead into physics would be to consider physics as a projection of Whitehead's idea into the objectivized domain. In other words, if you do that, if you remove the subject of cognizance from the picture, then the objectivized picture you are left with gets to be very close to quantum mechanics.

Bracken - I don't think that I would agree that Whitehead doesn't have a way of multiplying. I think that concrescence is the bringing of the many into one, once you have the one, that one is open to many simultaneous concrescences from that point on, so it does multiply I think into others. But I would like a clarification about the comments that you, David Finkelstein, and also Geoffrey Chew, made about laws being many physical laws. I think that there's general agreement that, yes, Whitehead could go along with that quite well but there's another side to Whitehead.

Finkelstein - I didn't say there are many, I said they're changing. I'm sure there's only one.

Bracken -There's only one?

Finkelstein - and it's a variable, I would also say it's the only variable. I think that's all there is.

Bracken - I thought that it was you who said at each level that there would be a different law that would apply to that level of reality.

Finkelstein - That's an interesting idea but I don't think I support it today.

Bracken - In any case, whether the law is changing, in other words, there was a comment that the laws or the law are not absolute and I think that Whitehead would say that. If we're talking about the physical or the actual world, the major category in Whitehead's metaphysics is called the category of the ultimate and the question I would like to ask, perhaps Geoffrey Chew here, is that you seem to have made the statement twice, no statement about the physical world can be exactly true, or you also said it a second time, that no statement about the world with the word "physical" in there can be exact so it seems to me that statement itself either applies to itself and therefore is not a true statement or it does and therefore you have a true statement.

Chew - I would prefer to restrict myself just to the former statement about the physical world.

Germain - Neurologists and psychologists point out that, in terms of talking about the brain, there is an empirical datum that we can look at. Two things that seem to support professor Stapp's ideas as they were presented today. One of them is that the intentional matrix is actually the place in the brain where consciousness can be most uniquely located. The intentional matrix is primarily in the brain stem and slightly higher and if you have stroke or damage to any part of the brain you will recover complete consciousness, you will be completely awake. You might have less to be conscious of because you've lost that portion of the brain but you still would be completely conscious. But if the intentional matrix is examined at its more fundamental levels then the loss shows and you can literally see this in people floating in and out of consciousness, on the basis of the way some things press on this part of the brain. There is a lot of theory and evidence that I don't want to get into that supports this idea of attention being the basic control parameter in conscious process. The other thing relevant to Professor Stapp's model is that there are actually discrete brain states. That the brain goes through sorts of chaotic process for the most part and that there's a period of change in the state of the brain that is followed by a relative period of stability and then change from stability and so on, so you can break down these discrete states. As to what extent they might correlate to states that Professor Stapp introduces that would have to be determined experimentally, and I think that a lot of things that he's saying can be flushed out experimentally because they do have correlates with what is actually happening.

Clayton - And yet this changing focus of attention is not identified with any particular brain state. That's not a way of speaking that a neuroscientist would be comfortable with, is it?

Germain - Well, the intentional matrix basically raises the brain to a certain energy state, it's called activation, and the activation in terms of energy can be thought of in a lot of different ways. Neuronal matrices form basins of attraction and the state then is drawn in to a basin of attraction based on an energy minimum. For instance, when a rabbit sniffs it has this process of activation which forms attractors that represent different orders of what things are. Along the lines that Professor Stapp has said, then you have the experience and you have to match the experience with the brain state and that's the process by which the states actually go into one of these specific attractors which match the order.

Audience Member - What do we do about individuals with multiple personalities or persons under hypnosis?

Germain - There's a process that leads to consciousness and states are the end product of that process, but that process can vary, for example in someone who has multiple personality. Each state is actually the becoming of an identity. Reality is discontinuous in a Whiteheadian sense so the identity is actually matched with the brain states in the same way that experiences match with the brain state. If you act in a certain way with your multiple personality and if that's personality A then personality A will be the one that comes into play. There's a lot more complex process theory involved with that and how identity works and how it relates to brain states. As far as hypnosis goes, hypnosis is basically bringing down the activation energy of the brain state. You're more or less in a state of quietness. The directions of your questions is coming from the therapist who is leading you along in the process. So in that case, the executive if you will, the one asking the question, is actually outside of you.

Keeton - Geoff Chew was indicating that in his current model for quantum mechanics and relativistic explanations of the world of experience that there is a very small component related to matter and a very large component that is non-material and so the model includes elements which, from a classical standpoint, had explanatory meaning or content relative to the material aspects of the model but for the non-material it's a little more difficult to talk about, for instance, their causal relationship to experiences. What I think I'm hearing you say in explaining the rise of consciousness, and locating consciousness, immediately Whitehead would say this is committing the fallacy of misplaced concreteness. How would you describe the non-material, non-physical aspect of consciousness?

Germain - Actually I think I tend a little more towards a subjective model that reality is basically units of experience and experiences are all interrelationships which occur on a hierarchy. In other words, electrons have very little experience and it builds in larger and larger systems which then can express a higher level of experience. So it's something that may be in the structure of matter itself, an external thing, but actually to me it's more on the inside, something that perhaps is coming out of the zero point field or something along those lines.

I think you can dispense with dualism and subjectism, although I'm not absolutely sure that I could justify that, but to me the events are subjective. There is no concrete collapse of the wave function. That the actual event is subjective and that we are subjective entities. In a sense, almost like the many worlds idea except that there is only one mind.

Clayton – When you've heard these comments here do you say 'yes that's what I'm trying to say' or are you resisting the points?

Stapp - Well I thought I was in agreement with him until this last remark. I am certainly thinking that we are not living in a many worlds situation. That there are these actual occasions that collapse the wave function to some particular form. That's certainly the basis of the way I've been talking and I think it's quite compatible with Whitehead, that an actual thing occurs and it somehow uses up the potentialities in one particular sort of way and the other incompatible possibilities are no longer possibilities, of course they would be potentialities for other events. There are definite decisions that are made. That it happens this way and not that way so it's not a many world interpretation - that just all of the things that quantum theory says are possible and are all existing and there's no choice anywhere.

Germain - Those are two ways of looking at it and I don't know how to describe what's in between them, but if you look at the view that there is this sum of all possible worlds then it really wouldn't be possible for part of the wave function to perish. It has a primordial existence in some sense.

Eastman - You mention now about the Everett many-worlds interpretation and it seems to me that for Everett and others taking that interpretation (from their point of view the simplist and required by the physics) they are implicitly making a philosophical claim that, in terms of the distinction between real actuality and things actualized that there is no real potentiality, basically a denial of real potentialities. You have the wave function propagating and creating all of the multiple worlds, basically actualizing every one of them, in other words, taking the potentiality as itself multiply instantiated and multiply actualized and implicitly making the philosophical claim that there is no real potentiality. Whitehead wants to say that potentiality is real although not actual. Taking a position regarding the reality of multiple worlds necessarily involves making a philosophical claim, whether the philosophical claim is made by Everett in terms of one option or by Whitehead for another option. But physicists who buy into that I think implicitly make such a philosophical claim, perhaps without knowing it.

Finkelstein - For me the whole business about multiple universes is the result of a graduate student who never really met quantum mechanics. He met this collapsing theory and wants to do something about it. He didn't think of giving up the idea of objects altogether. It's a very Whiteheadian, Heisenbergian, Einsteinian idea. So he took this other road. I can't make any sense of it. I can't follow the road. I don't see the point. It seems to me ignoring the real point of quantum theory. I agree completely with your analysis. In fact, I was very informed by what you said.

Eastman - that there is effectively a denial of real potentiality in many-worlds interpretations.) Thank you very much for pointing that out.

Bracken - I would like to ask Henry Stapp about the relationship between electromagnetic events going on in the brain area and what is usually called the mind. You were saying that the interaction goes on at the electromagnetic level in there and you didn't say much about brain cells. Is it your feeling that brain cells don't produce their own results to influence us and the only feedback is at the electromagnetic level?

Stapp - My idea here was that these neurons with calcium and potassium ions and all of these charged particles moving in and out at a very rapid rate, gates opening and closing, there's a tremendous amount of activity in every individual neuron even and then with all these billions of neurons there's a tremendous amount of electrical activity. This electrical activity produces an electromagnetic field and this field is kind of a way of integrating and getting a picture of what all these things are doing. It's a consequence of what they're doing. It's not that you're leaving them out, you're saying that there's a higher level description that is a consequence of what all those neurons are doing. The suggestion was that consciousness really interfaces with that higher level description rather than going directly down to individual ions that are going through some microchannel in some neuron, but that's too low a level. Consciousness doesn't directly interface with that, only indirectly, by virtue of the electromagnetic field that it has created.

Bracken - I think I follow that, but I'm just wondering whether you felt that there isn't another level in which cells as a whole produce a result, a field or a concrescence, in addition to the general electromagnetic field produced by their parts?

Stapp - Well that's a good question. The point is that in quantum mechanics as well as in classical mechanics there is a question of the choice of variables and, for example, if you have two particles you can choose to talk about this or that particle or you can choose to talk about the center-of-mass of these two particles, two ways that you can talk about the same system, and sometimes it's useful to do one thing or the other. When you are talking about the collapse, there is a question about what variables in which the collapse is going to occur and, if you say that these collapses that I'm talking about are at this very high level of integration, it's kind of like saying that the center-of-mass of something is at some place where there's still a tremendous amount of other processes that could conceivably be going on that are dealing with a kind of relative coordinate. There's so many ways to slice the process up into what variables you're going to use so, yes, it's quite conceivable that there could be lower level events going on that are not incompatible with the high level events so they occur basically in higher level variables like the ones I'm talking about, namely, the electromagnetic field which is more overall.

Clayton - And indeed these lower levels could serve the same function that consciousness serves?
Stapp - I think you have to say that, if you want to follow this idea that experience is a real thing, and you want to say it has this role in the world that quantum mechanics, in this simple point of view, gives to it, that it basically makes a choice that this happens, then you also need something, an amoeba or something further down the line. Other things are possible that won't have this experiential quality and if it can happen in simpler systems you can certainly ask the question, 'well, can't these simpler sort of collapses occur in our brain also?' I can't see a reason why it couldn't happen and not be incompatible with the higher level kind of events that we are conscious of.

Audience member - I would just briefly say, Henry, that you find that if you take a muscle cell and put it into a pancreas within a couple of replications, those cells become pancreatic cells, that the field organizes the expression of the identity of a cell and not the other way around.

Stapp - I really was puzzled by your earlier statement that was attributing to me what seemed to me just the opposite. I was saying that consciousness is controlling the brain and you seem to be saying that I was saying the opposite.

Audience member - What I understood you to say was that experience was the ground out of which thoughts took place and my background says that I operate as if consciousness creates the reality.

Stapp - That's my position too.

Audience Member - If you can simulate a consciousness that you have never experienced, if you can imagine yourself doing something that's impossible, then what I said was that consciousness will organize you into becoming the one who can do that. That is non-continuous, it breaks the laws of physics, it's not supposed to show up this way, that this abstract, non-physical idea is actually organizing the field.

Stapp - Let me answer that. Here I am and I suddenly say 'I'm going to raise my hand or lower my hand.' Within this scheme that I'm proposing it's quite possible that an experiential event says 'raise' and it raises because an experiential event actualized a certain state of the brain and that has consequences just following through the mechanisms of the brain, which will cause these neural impulses to go out. So it's just exactly as you say. The conscious thought is organizing the brain in such a way to make this thing happen, that's at the very simplest level.

Audience Member - It also could be argued that because your arm was raised and lowered before you have the experience of that and from that experience you have an intention, a continuation of that previous experience.

Bracken - I found a real connection that wasn't noted between this notion of real potentiality and finality because efficient causality organized into an overall system tends to reduce everything to actuality. If there's a system that is somehow actual, you can go backwards and forwards in time because it already has a certain actuality as a system of thought. Only when you introduce final causality and subjectivity, do you really get real potentiality, the opportunity for real creativity and novelty to emerge, and that's where there really is a clash between classical science and Whitehead because he's going back to a 'pre-modern' understanding of science where final causality played a very important role, but he's not doing this in the relatively unsophisticated way that was practiced by Aristotle and Aquinas.

Clayton - A genuinely excellent discussion. We should give ourselves a round of applause.

Session III: Philosophical Implications of Modern Physics

Eastman – Session introduction - I would like to share with you some reflections about the relevance of the process-relational vision and process thought that may go unnoticed among many circles. This is because we often think of process thought as being on the periphery, as perhaps having rather exotic and perhaps not relevant kinds of ideas, as with its purported use of panpsychism (it's really pan-experientialism and not panpsychism) or other kinds of misinterpretations of Whitehead's thought. I would like to provide you with a broad characterization that also illustrates the point made by Marjorie Suchocki this morning in her discussion on pragmatic pluralism where concepts can become separated from grounding in their experiential base, thus giving rise to the 'fallacy of misplaced concreteness.'

Physics, chemistry and engineering have been so productive for modern society because of their substantive experimental capability, and very rugged and excellent testing of models and theories. A synergism of theory, model, simulation and experiment made possible the success and progress of relativity, quantum theory and contemporary understandings of field theory that have transformed our understanding of the world around us. Let me suggest a broad characterization of the key elements in classical versus contemporary science. In contrast to classical physics where you would have some concept or term A only, contemporary physics gives a more nuanced understanding of both A *and* B, as a duality but a 'duality without dualism.' For example, you might consider substance only, treated as self-identical, immutable and enduring philosophical atoms that might be considered to make sense in classical physics, but in contemporary physics the particles themselves are interrelated with the fields of which they are a part. Thus, what we really have is both particle *and* event-oriented descriptions. Where before we talked only about external relations, we really have both external *and* internal relations in contemporary scientific understanding due to the impact of modern field theories. "Continuity only" made some sense in classical field theory, whereas now there is both continuity *and* quantization. In contrast to "symmetry only" we now recognize the need to talk of both symmetry *and* asymmetry as demonstrated by Joe Rosen [*Process Studies* 26 (1997): 318-323]. Or consider just "determinism only" but modern science now leads us to treat predictability *and* determination in a more nuanced way and indetermination, in some sense. And the complementarity principle in quantum theory, which brings out how you have not just "particles only" but both particles *and* waves in the wave-particle duality that is fundamental to modern physics. In every case, there has developed a more inclusive understanding that has emerged that is very consonant with the basis of the process-relational vision.

This comparison is shown clearly by a table of philosophical pairs, adapted from a table by Hartshorne in Chapter VI of his major work *Creative Synthesis and Philosophic Method* (LaSalle, IL: Open Court, 1970):

> dependent/independent, internally related/externally related, whole/part, later/earlier, becoming/being, temporal/atemporal ....

These are pairs in philosophy. It's fascinating to see how Hartshorne laid out this table and tried to represent a comprehensive set of philosophical pairs or dual relations - he called them polar opposites. In physics we also have dual pairs. In quantum theory we talk about the system *and* the episystem, the observer's role in preparing the system as well as the system itself, nonlocal versus local, kinematic versus dynamics, absorption/emission, initial acts/final acts, actuality/possibility, asymmetry/symmetry, discreteness/continuity ...

With these physics pairs, I ask in which cases do we have an overlap with the philosophy pairs? In those cases, there may be some useful insight for the benefit of philosophy of dual relations that have emerged from contemporary physics. I do not have time to discuss the implications of these overlaps at this time, but share them briefly here for future research and our present dialogue.

[Reference: Timothy E. Eastman. "Duality without Dualism." In *Physics and Whitehead: Quantum, Process and Experience*. Ed. by T. Eastman and H. Keeton. Albany: State University of New York Press, 2003.]

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Lawrence Fagg Electromagnetism, Time,
and Immanence in Whitehead's Metaphysics

As with Geoffrey Chew, I'm not a card-carrying Whiteheadian, although I have some familiarity with it. I felt that since this is a session on Whitehead's thought and physics, and that since included in Whitehead's thought are a lot of religious complements, I felt it might be worthwhile to inject a little bit of religion into this discussion.

As far as we know today there are four different physical forces in nature, the strongest of these is the nuclear force, next in order of strength is the electromagnetic force which is the fundamental physical mechanism that makes possible the operation of us and most of the world to which we usually relate, the third is known as the weak force, and the weakest of the four is gravity. Despite their difference in relative strengths, the electromagnetic and gravitational forces are both distinguished by the fact that they are both long range forces in contrast to the other two which have very short ranges. The electromagnetic and gravitational forces can lay claim to some kind of universality if only because their range can be so extensive; indeed, in the case of gravity, it is this great range that renders it the dominant force cosmologically. The distribution of gravitationally-interacting masses in the universe defines the limits of the universe and space. It's also the mutual gravitational attraction that slows the universe's expansion and controls the interaction of planets, stars and galaxies. It's also true that the other two forces, the weak and nuclear, although very short range, play a vital role in sustaining the balance in cosmic nature that makes possible our existence. For example, if the nuclear force were approximately 1% weaker, deuterium (heavy hydrogen) could not form to go on to make helium and the result would be a universe made up of hydrogen only and we would not be here. If it were only 1% stronger, there would be too much helium and we wouldn't be here either. The nuclear and weak forces drive the processes that form the heavier nuclei in supernovae explosions, which later lead to the formation of second and third generation stars such as our Sun. It is such heavier nuclei that are at the core of the atoms and molecules making up our bodies. So while the gravitational, nuclear and weak forces are unquestionably vital, in this presentation I will focus attention solely on characteristics of the electromagnetic force because this force and electromagnetic radiation or light, its carrier, are by comparison with the other forces so much more intimately dominant and omnipresent in all aspects of our lives in the way we sense and relate to the world.

This omnipresence of the electromagnetic force became more apparent with the development of quantum electrodynamics (QED), which showed that the electromagnetic force between electrically charged particles is carried by unobservable photons called virtual photons. Although they cannot be directly observed, their existence is certified by the fact that without including them, QED calculations could not yield their results, which are in such incredibly accurate agreement with experiment. In part because of the accuracy of QED, but also because of the wide technological application of electromagnetic processes, the electromagnetic force is known far better than the other three forces. Its effect and presence in all aspects of our life and relations with the world is ubiquitous. At the microscopic level, electrons are constrained to orbit around the nucleus of an atom by the electromagnetic force via its virtual photons. It is the same interactive glue that keeps atoms together within molecules so that all of chemistry and biology, at root, operate via the electromagnetic force. For example, this force makes it possible for bacteria, which have the smallest living cells, to exhibit the purposeful mobility, coherent collective action, and remarkable sophistication they do in their growth and survival. We are at the other end of this biological chain so that we ourselves and all our organs are run by this mechanism. From the interaction of blood cells to the activities of neurons in the brain. It is the same force with its photonic rule that governs the incessant interplay of molecules in air and water that collectively unite their motion to give us sound and ocean surf, respectively. While it is gravity that keeps us, all earthly objects and the atmosphere attached to the earth, it is the electromagnetic force with its mediating photons binding the atoms and molecules tightly together in solid objects that is a prime factor, along with certain quantum effects, in keeping the table lamp from falling through the table and the table from falling through the floor. It is this force that makes possible all modern communication, telephone, radio, TV, satellite and so forth. Virtually all experimental studies of the other three forces, whether in the microscopic realm using particle accelerators or the cosmologic realm using telescopes, are conducted through an electromagnetic filter. This of course includes the operation of all the computers and complex electronic instruments that store and analyze the data and that make calculations based on the data.

In this presentation, however, perhaps the most relevant property of electromagnetism and its mediating photons are a host of very low energy, subtle electromagnetic interactions that Geoffrey Chew has called 'gentle quantum events.' [Chew, Geoffrey. "Gentle Quantum Events as a Source of Explicate Order," *Zygon 20 (1985): 159-164] These make possible the life of humans and their consciousness. The extreme subtlety of these events is quantified in recent experiments in microbiology which show that voltage gradients as low as 10 to the -7 volts per cm and frequencies between zero and 100 cycles per second are involved in the interaction between cells and living creatures. All plant and animal life is bathed in and interacts with a sea of such very low frequency radiation that envelopes the earth. This is independent of radiation superimposed by technology. With electromagnetism underlying virtually everything in our world from the dynamic states of rocks to the operations of our brains, it begs consideration as a primal factor in the full understanding of the nature of an actual occasion. An actual occasion acquisitionally feels or prehends data from previous occasions as well as eternal potentialities to realize its concrescence. But it is the subtle interaction of quantum electrodynamic events involving a multitude of mostly very low energy photons, real and virtual, that execute the orders in the prehension process. Whitehead's concept of actual occasions involves some rather specific views also about time and space. For him actual occasions define a spatial-temporal domain and thus manifest a finite temporal duration and a spatial extent in their becoming in the display of their uniqueness and maturation. It is this uniqueness that directly implies the irreversible nature of time. No two actual occasions are exactly the same, they are irreproducible and once having occurred are irrevocable as is time.*

There are a number of microscopic, electrodynamic phenomena that may be of use in learning more about the structure of an actual occasion and its role in revealing the irreversible nature of time. Probably the best known of such phenomena is the emission and absorption of electromagnetic radiation by atoms and molecules. These particles can be excited to a higher energy state via a collision or the absorption of radiation. Then, in turn, they decay to a lower energy state with the emission of radiation. This kind of exchange of radiative energy is proceeding constantly around us all the time. Another equally relevant radiative phenomenon is known as Bremmstrahlung (collisional radiation) in physics. It occurs in all electric, electron, atomic and molecular collision processes. Whenever an electrically charged particle is deflected in a collision, it undergoes an acceleration. Whenever such a particle is accelerated, it emits radiation whose energy varies, depending on the kinetic energy of the particle and the angle of deflection. Such emissions can also occur not just between charged particles but between neutral atoms and molecules, among other things, by what is known as van der Waals forces which have considerably less strength than the ordinary one over r-squared (r^{-2}) of electromagnetism, but nevertheless they're there. And they come into play if the atoms or molecules have a non-spherical distribution of orbital electrons even though totally the atom or molecule may be electrical neutral. But a lack of sphericity can also be induced in a collision between two neutral atoms, which are ordinarily spherical, also resulting in radiation. Such photons as well as high energy photons from more energetic collisions are effectively lost in the medium. This collision between two spherical neutral atoms generates some radiation because actually in the instant of collision there is a distending of the electron distribution and that generates some radiation. The collision by the amount of this loss, however small, is irreversible. And this behavior of collisional photons is in addition to that of photons emitted and absorbed by atoms and molecules via transitions among their energy states, which I mentioned earlier, and these photons are also lost in the medium. Now I say this as an effective phenomenon that actually happens even though in principle, according to the theory, individual collisions are time symmetric or reversible. In any case, I suggest that this incessant energy exchange via photons, whether due to collisions or due to excitation and decay of atomic or molecular energy states, plays a fundamental role in the ultimate concrescence of an actual occasion and in characterizing the irreversible nature of time.

Just as cognizance of the pervasiveness of electromagnetism here on earth can inform us concerning the temporal aspect of actual occasions, so also such cognizance may be useful in realizing a fuller understanding of the religious dimension of Whitehead's metaphysics. One salient feature of this dimension is his contention that an actual occasion is influenced but not determined by God in its process of concrescence. This omnipresent influence on all, even microscopic, actual occasions clearly suggests a perception of divine indwelling or immanence as opposed to transcendence. But it is a myriad of electrodynamics events in the form of real and virtual photons that execute the spiritual order and the exercise of that immanence and that underly our ability to be aware of that immanence. Intimately related in the sensing of that immanence is the presence of light, electromagnetic radiation. The importance of light as a physical agent in the realization of divine immanence is abundantly apparent in religious history worldwide. Indeed, light has served as a primary symbol for the spirituality of men and women since the dawn of human consciousness. Moreover, in mystical experience, it has actually served as a medium for relating to God. Scriptures of religions worldwide are replete with the use of light to symbolize God's provident and salvational relation to men and women. You can see this in the Hebrew bible, in the Christian gospels, in the Koran, and the Hindu Upanishads. Many of those who have had near death experiences find themselves at the final stage of the episode in the presence of a being of light which exudes unquestioning warmth and love and requires an unequivocally honest response. Thus there is an intimate relation of electromagnetic radiation, light, to a sense of divine indwelling experienced by people of virtually all religious traditions. A comparable apprehension of immanence is apparent in the thought of Whitehead, not only because of the abundant subjective metaphors he uses in delineating his philosophy, but also because of the interactive influence he maintains that God has on the becoming of an actual occasion, luring but not determining it. The fact that light plays such an intimate role in catalyzing yet not conveying God's immanence, along with the universal role played by the electromagnetic interaction in all of earthly nature, prompts me to maintain that it is a meaningful physical analogue for the immanence of God. I base this contention on the logical assumption that at least some of the characteristics of God as creator are transmitted to the created, i.e., us and the world. A total disconnect between creator and creation, between cause and effect, would be difficult to accept. It is one of the methods used by theologians to seek patterns and characteristics in the properties and operations of the natural world that might reasonably be analogous to some attributes of God. In essence, this is the approach followed here by selecting one part of nature, electromagnetism, and arguing that its omnipresence in our world constitutes a compelling physical analogue to the immanence of God.

However, in the context of Whitehead's religious philosophy I suggest that a stronger claim may be made. That electromagnetism is a viable physical correlate to God's immanence. That is, more than simply a paralleling analogue, electromagnetism plays an interactive role in the relations between God and actual occasions. The world is acted on via Whitehead's perception that every actual occasion derives its initial orientation, or subjective aim in Whitehead's language, from God. To the extent then that every actual occasion draws its character from this orientation, God is objectified by each actual occasion. It is therefore, in this way, that God provides an antecedent influence on the behavior and future of an actual occasion. It is through this medicate interaction that the resultant objectification of God by actual occasions that God can be said to be processive. God needs and uses actual occasions, to quote Whitehead "as an intermediate step toward the fulfillment of his own being." Given that it is the electromagnetic interaction that is the workhorse that provides the underlying physical operations that help bring about the fruition of an actual occasion, I suggest it also plays some role as a physical conveyor of the interaction between God and the actual occasion, an interaction that influences both the occasion and God. The electromagnetic interaction is the physical component of this reciprocal interaction and, in this sense, may be said to be a physical correlate with the immanence of God.

What I am trying to emphasize here is that among the four forces electromagnetism is special. The other forces play a supportive but a relatively passive, inanimate bystander role. On the other hand, it is reasonable to claim that beyond this earth, at the cosmic level, all four forces may jointly constitute a physical analogue for God's immanence. However, this vast firmament in which the four forces are active may be considered as the fertile soil from which at rare localities in the universe electromagnetism blossoms forth and realizes its full potential in terms of intelligent life and consciousness, making it possible for the universe to be conscious of itself and God. So I say that electromagnetism is not God nor is it God's immanence, but I do see it as a physical analogue of that immanence and, in a Whiteheadian context, a correlate of that immanence.

In conclusion, it must be understood that this presentation has been given in the context of classical Whiteheadian philosophy and does not deal with any subsequent related work in process philosophy or theology. I also wish to emphasize that what is described in this presentation I consider to be only reasonable suggestions for further explorative thought. It's admittedly speculative, conjectural and 'far out.' I make no claims for exhaustive philosophical rigor; accordingly the ideas expressed here are intended to stimulate continued study, research and dialogue in this area.

[Note: The paper associated with this presentation is given as Appendix F of this *Process Studies Supplement*. Also, please refer to Dr. Fagg's book and *Process Studies* paper.

Fagg, Lawrence. "Electromagnetism, Time, and Immanence in Whitehead's Metaphysics." *Process Studies* 26 (1997): 308-317.

Fagg, Lawrence. *Electromagnetism and the Sacred: At the Frontier of Spirit and Matter*. NY: Continuum, 1999.]

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Dialogue among Panelists:

Eastman - Thank you Larry for a presentation in the very best spirit of Whitehead's defense of speculative philosophy contained in the preface to his *Process and Reality*.

Jungerman - Thank you for a very thoughtful paper from my perspective. It illuminates a lot of things for which I had only vague feelings about, the electromagnetic interaction having to do with what's going in our world and, in particular, in our bodies. There's just a peccadillo (small sin or fault) in terms of Whiteheadian thought. The subjective aim is partly influenced by the initial aim of God, but it is also influenced by all our previous prehensions of the past and so evil can result because, you know, we don't always follow the initial aim. So, if I understand you correctly then, you suggest that the electromagnetic interaction is used as a manifestation of the initial aim - is that right? Is the electromagnetic interaction used, in your view, to manifest the initial aim of God in an occasion?

Fagg - No, that's too strong a statement. Electromagnetism plays a role as one of the components in the subjective aim and that component is the influence of God. I agree with the initial part of your statement that it's not just God who is involved in the subjective aim.

Jungerman - What is the connection between the electromagnetic interaction and the initial aim of God in the occasion? There's some connection presumably.

Fagg - The connection is that electromagnetism is a creature of God and that's only a part of the picture of

God's influence, but it is the physical part of whatever influence God has on the subjective aim.

Valenza - If I think of electromagnetism as providing a communications channel (perhaps I'm making a category mistake here with engineering) is there a modulation on this signal, a bandwidth, is there some information being transmitted?

Fagg - Modulation? You really are thinking like an engineer. I think that you're abstracting and over-specializing from what I've said. I'm not talking about any specific transmission of information. I'm just saying that electromagnetism is a physical analogue, or in Whiteheadian thought, a physical correlate. But it is a physical analogue that helps us to understand something about God and God's attributes.

Valenza - So it in no sense carries a signal.

Fagg - No, I didn't mean to imply that.

Chew - I totally subscribe to your basic position and I sometimes like to say that reality is 'electromagnetic.' A particular feature of electromagnetism which you didn't mention, which has often impressed me, is the role of electric screening in creating boundaries for objects. For example, the fact that I can think of this can as a separate object is due to the fact that the can has a huge amount of electric charge but it's almost exactly equal and opposite amounts of charge and the electric fields as a result don't leak out very much. So that when I approach that can I don't feel it until I touch it, and there's the boundary. So that boundary effect which is so much at the root of the way we look at the world - see the world as made up of separate objects - that basic notion is rooted in electromagnetism.

Fagg - That's a very good point. Because of this screening, that's why electromagnetism isn't quite cosmologically as influential as gravitation.

Eastman - As an addendum to this point about screening, let me note that in high-density, collisional neutral environments like the can the scale of the screening is very small and boundaries are sharp. In a space plasma where I do my own research, in a location say about half way to the moon within the earth's magnetotail, the Debye length or screening distance within the collisionless space plasma there is on the order of one to five kilometers. The plasmas there are highly interconnected and that gets multiplied because of the overlapping of Debye spheres. Thus you have long-range interactions going on from earth radii scales to 100's of earth radii in which you have rather substantial coupling. So the spatial scales of both electrical screening and electromagnetic coupling between different systems can vary dramatically.

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Yutaka Tanaka, Bell's Theorem and the Theory of Relativity.

I met Dr. Tim Eastman about 14 years ago while attending a Claremont Whitehead conference in 1984 (*Physics and the Ultimate Significance of Time*) and I remember that Tim said to me that Whiteheadians should recognize that Bell's theorem is of vital importance to understand the philosophy of organism - do you remember? The theme of my presentation is the Bell's theorem and the theory of relativity. I also met Professor Finkelstein about ten years ago in Atlanta when attending the AAR meeting and I remember that he stressed the importance of quantum logic, especially if we analyze the quantum paradoxes. I was very impressed by his work and began to study the quantum logic. So I will mention the importance of quantum logic in my presentation. Because of limits of time I will only discuss the first paper "Bell's Theorem and the Theory of Relativity: An Interpretation of Quantum Correlation at a Distance based on the Philosophy of Organism" [*Annals of the Japan Association for Philosophy of Science*, March, 1992]. So first I will read the abstract of my paper and then just those parts that are closely related to Whitehead's philosophy of organism.

The combination of the so-called EPR argument and Bell's theorem reveals one of the most paradoxical features of quantum reality, that is, the non-separability of two contingent events. If we accept the conclusion of the revised EPR argument together with Bell's theorem or experimental verifications of Bell's inequality then we are necessarily led to the denial of local causality. Now the concept of local causality is the cornerstone of Einstein's theory of relativity.

We next consider the problem of compatibility between the background theory of relativity and quantum physics. A proposal by Karl Popper, German philosopher of science, going back to Lorenz theory is examined and rejected because the quantum correlation of EPR is not to be interpreted as an action-at-a-distance, which we can control and use as an operational definition of absolute simultaneity. An inquiry into something like aether as hidden reality behind the theory of relativity is considered as retrogressive. A similar situation exists with the so-called hidden variable theory of quantum physics. Acceptance of the non-separability of local elements of reality is the undeniable fact.

We discuss the possibility of a realistic interpretation of quantum physics which transcends scientific materialism and classical determinism. As an example of such a project, Professor Stapp's theory is examined with the structure of Whiteheadian process philosophy, which provides the metaphysical background of his realistic interpretation of quantum physics. Finally, I present another version of quantum metaphysics, a new version based on Whitehead's philosophy of organism which is broad enough to include both observer and observed, local causality and non-local relations, space and time, potentiality and actuality, and the inseparable unity of physical reality. So I want to skip the first part of my paper because it provides just historical background. The conclusion is that we must accept non-locality, so I will now read the second section on quantum correlation and the theory of relativity.

Quantum Correlation and the Theory of Relativity

Some philosophers and physicists, facing the breakdown of locality, proposed going back to the problem situation before Einstein. Bell himself suggested a possibility of the restoration of the absolute framework presupposed by Lorentz's theory of electrons and aether, because behind the scenes something is going faster than light. Popper more explicitly stated this possibility [Karl Popper, *Quantum Theory and the Schism in Physics* Hutchison (1982): 30] :

> It is only now, in the light of the new experiments stemming from Bell's work, that the suggestion of replacing Einstein's interpretation by Lorentz's can be made. If there is action at a distance, then there is something like absolute space .... If we now have theoretical reasons from quantum theory for introducing absolute simultaneity, then we would have to go back to Lorentz's interpretation.

Moreover, there are several arguments against the restoration of the absolute frame of reference. The simultaneous correlation in quantum physics is different from a Newtonian type of action at a distance. The former is probabilistic and non-controllable whereas the latter is deterministic and controllable. So we cannot send information with a superluminous speed on the basis of the distant simultaneous correlation in quantum physics. We cannot acquire information through the random sequence of measured values at one side without comparing them with the results of the other side. As the coincidence of two contingent events cannot be used for sending information with a superluminous speed for the purpose of synchronizing two clocks at a distance, the empirical test of Bell's theorem does not make Einstein's theory of relativity invalid through the alleged discovery of prohibited action. We may theoretically introduce absolute simultaneity, but we do not have any experimental arrangement to detect the existence of the absolute frame of reference.

Instead of the restoration of an abolished classical theory, Stapp made a radically progressive trial of introducing something like absolute time by supposing the deep structure below Lorentz invariant phenomena. This structure was described by him as that of events which have the absolutely linear order of "coming into existence." Stapp's theory had an ontological background provided by Hartshorne's version of process metaphysics, according to which the ultimate realities are events and the whole universe has a cumulative structure of creative advance with a cosmic simultaneous "front" of actuality. The purpose of Stapp's theory was to ensure both the macroscopic causality properties with Lorentz-invariance and all of quantum theory on the basis of his metaphysics of events. We may say that Stapp replaces the classical concept of aether with the absolute world of events which are logically prior to space-time. The main characteristic of Stapp's theory was that he adopted the absolute and universal concept of existence in which what comes into existence does not depend on a space-time standpoint, whereas Einstein's theory of relativity relied on the relative and local concept of existence in which what comes into existence depends on a space-time standpoint. As the breakdown of the Bell inequality requires some events to depend on other events whose positions lie outside their backward lightcones, Stapp postulated that the sequence of actualized events should be well-ordered even in the case of spatially distant events.

Though I agree with Stapp that the ontological framework of events is necessary for the unified picture of the world, I do not think he is justified in introducing the absolutely well-ordered structure of events. Einstein's theory of relativity, which only admits the partially-ordered structure of events, seems more plausible even in the consideration of the Bell-Aspect experiment.

In the simplest cases of Bell's phenomena there are four events E0, E1, E2, and E3, whose locations L0, L1, L2, and L3 lie in four well-separated experimental areas A0, A1, A2, and A3.
If all events lie in the well-ordered sequence of occurrence, as Stapp assumed, there must be an unambiguous temporal order between El and E2: one of the two events must be prior to the other.

Suppose El is the prior to E2. Then E2 depends on what the experimenter in A1 has decided to do whereas E1 is independent of what the experimenter in A2 will decide to do. So he reduced the "simultaneous" correlation between E1 and E2 to the unilateral influence of one upon the other. The difficulty of the above picture is that there does not seem to be any experimental apparatus to determine which is prior, E1 or E2. Though we guess that an influence or superluminous transmission must have gone from L1 to L2, or from L2 to L1, we do not know yet which one is the cause of the other. There is the remnant of classical causality in Stapp's model in which the mutuality or interdependence of quantum phenomena totally disappears. In other words, Stapp's model does not seem to consider the "individuality" of a quantum system which Bohr emphasized in his doctrine of complementarity between space-time coordination and causality. This "individuality" can be expressed as the organic interdependence between parts of the quantum system: the whole may be in a definite state, i.e. may have as definite properties as quantum theory permits, without its parts being in a definite state. The two particles of the imaginary experiment in the EPR argument and the two photons of Aspect's experiment are examples of the inseparable parts of an "individual" organism. In this organic unity there cannot be a determinate causal order among all parts of the whole. In the above case there remains the essential ambiguity of causal order between E1 and E2 because their correlation is symmetrical and not detectable until we monitor and record it in L3, i.e. the common causal future of L1 and L2. This ambiguity is characteristic of the relativistic framework of space-time, and any attempt of restoring the absolute framework tends to violate not only the principle of relativity but also the principle of complementarity between space-time coordination and causality.

In the next section I will present another model which aims at synthesizing the principle of relativity and quantum correlation on the basis of the philosophy of organism. In this model events are, as in Stapp's and Hartshorne's process metaphysics, basic ontological categories from which material objects and space-time are derived. The background philosophy of organism is more similar to Whitehead's own cosmology than Stapp's and Hartshorne's revised version, for the fundamental vision of Whitehead's philosophy is, as Nobo clearly explicated [Jorge L. Nobo, *Whitehead's Metaphysics of Extension and Solidarity* (Albany: State University of New York Press, 1986): 205-248], the mutual immanence of discrete events regardless of their temporal relationship whereas "process" philosophers seem to stress only the immanence of earlier events in later ones. We will find that the immanence of later events in earlier ones and of contemporaries in each other are indispensable for the understanding of quantum correlation. The "organic" model of quantum reality is also similar to the Hua-yen Buddhist doctrine of simultaneous interfusion and interpenetration signifying unity-in-multiplicity, for it rejects the notion of independent self-existence which Hua-yen Buddhists called svabhava in their doctrines of praitya-samutpada (interdependent origination) [Steve Odin, *Process Metaphysics and Hua-yen Buddhism* (Albany: State University of New York Press, 1981): Introduction]. The concept of the absolute frame of reference should be replaced with the idea of thoroughgoing relativity: we need not postulate the absolutely unique temporal order. Even the absolute world of four-dimensional space-time as prefixed reality in Einstein's theory of relativity should be abolished if we take into account the complementarity between space-time coordination and causality. If we are, as Bohr aptly stated, simultaneously actors as well as spectators on the great stage of life, the image of a scientist as an outside spectator should be replaced with that of a participating observer inseparably involved in the objects to be observed.

Quantum Correlation viewed from the Philosophy of Organism

The peculiarity of quantum correlation is caused by the so-called "collapse of the wave function." One of the unsolved problems of quantum mechanics is the nature of this discontinuous phenomenon. The usual framework of quantum theory does not describe the process of collapse itself but simply accepted it as the result of measurement in the statistical data of observation. In other words the collapse of the wave function belongs, not to the object-language of quantum formulae, but to the meta-language of quantum mechanics which correlates mathematical formulae and experimental data. Many physicists tried to enlarge the framework of quantum mechanics enough to give a unified description of observer and observed, i.e. the microscopic measured system and the macroscopic measuring apparatus, but there seems not to be an unanimous resolution of this conundrum.

d'Eespagnat pointed out the enigma of the "collapse of the wave function" as follows [Bernard d'Espagnat, *Conceptual Foundations of Quantum Mechanics* (W. A. Benjamin, Inc., 1976): Ch. 8]:

> The puzzle with which we have to struggle is constituted by the fact that, since the wave function is a non-local entity, its collapse is a non-local phenomenon. According to the formalism, this phenomenon propagates instantaneously. In that sense we may say that the wave packet reduction is a non-covariant process. Again, this would create no difficulty if, like the reduction of probabilities in classical phenomena, this collapse were of a purely subjective nature.

But we have seen quite strong arguments in favor of the thesis that it is not. d'Espagnat's comment that the wave collapse is not to be solved by a subjective interpretation of probability is important, for it excludes an easy "solution" of the conundrum by appealing to our ignorance of initial conditions. Certainly, if we get new information about the system, then the probability distribution of quantities that characterize the system changes discontinuously. The discontinuous change of quantum physics cannot be explained away by this kind of probabilistic argument. Such general arguments are unsatisfactory because they do not take into consideration the peculiar characteristics of a quantum mechanical algorithm of probability. The probability wave and the probability amplitude represented by a complex number were totally unknown before quantum physics. They behave… as if they violated classical logic. For example, the famous double slit experiment shows that even in the case of only one particle, say a photon, the interference occurs between two mutually exclusive possibilities, i.e. the possibility of the same particle's going through one slit A and the alternative possibility of its going through another slit *B*. So if we represent the third event, say the effect of the photon on the photographic plate with C, the (AvB)^C=(A^C)v(B^C) has been experimentally confirmed, which violates the distributive law of classical logic. Finkelstein stresses the need of quantum logic as a non-Aristotelian logic in the description of the microscopic world just as we need a non-Euclidean geometry in the theory of general relativity. [D. Finkelstein, "Matter, space, and logic," *Boston Studies in the Philosophy of Science* (1964): 199-215]. I prefer to say that if we need quantum logic, then it must be a kind of modal logic with the distinction of real (objective) possibility and actuality. In the above example of the double slit experiment, (AvB) describes not an actuality but a real possibility whereas both (A^C) and (B^C) describe two actualities which are mutually exclusive. In the Whiteheadean terminology, the transition from the disjunctive many to the conjunctive one does not follow classical logic because the interference of alternative possibilities really occurs. This phenomenon of probability interference shows that we have to face objective probability reflecting the experimental situation rather than the subjective one reflecting only our ignorance of the determinate fact. In other words, real possibility and actuality are inseparable with each other in quantum physics, and we must treat the collapse of the wave function as the objective transition from real possibility to actuality.

The next problem is about the quantum transition itself. If the collapse of the wave function is an objective phenomenon, then is it "an action at a distance," i.e. a non-covariant phenomenon which happens instantaneously? This problem is crucial to our consideration of the Bell correlation and the theory of relativity. We confirmed above the fact that quantum correlation and the principle of relativity are compatible, and we need not explain quantum correlation as the unilateral causal effect with superluminous speed. Einstein's theory of relativity was more progressive than Lorentz's theory of aether in that Einstein introduced into physics a radically new perspective in which space and time are non-separable from each other.

It is regrettable that many discussions of physicists about the collapse of the wave function presuppose only a non-relativistic framework. The "simultaneous" correlation would be meaningless in the relativistic framework, because such a terminology implicitly assumes that there exists only one time system of classical physics. The non-relativistic quantum physics does not treat space and time in their non-separable unity. Time appears only in the form of a parameter and does not take the role of an operator corresponding to an observable quantity, whereas in the relativistic framework spatial coordinates are permitted the status of operators which characterize the quantum system. So if we describe the collapse of the wave function in the non-relativistic framework, we must say that it happens instantaneously, i.e. non-locally with respect to space. The dubious scenario roughly runs as follows: if the quantum system prepared at the time t1 is measured at t2, it changes its states continously and causally between $t1 < t < t2$ according to Schrodinger's equation, but at the moment of t2 the discontinuous irreversible event called "the collapse of the wave function" happens and its effects propagate instantaneously with the super-luminous speed.

The above picture is not relevant to the relativistic concept of space-time, because the very concept of simultaneity and instantaneous transmission does not make sense. The non-separability of time from space means that non-locality of the collapse should be accepted, not only with respect to space but also with respect to time. The reason why temporal non-locality, more exactly spatiotemporal non-locality, has been ignored may be simply that the collapse of the wave function has been discussed mainly in the non-relativistic framework.

Einstein himself seemed to anticipate the problem of spatiotemporal non-locality in his criticism of the indeterminacy principle, for he pointed out that "if we accept quantum physics, then it becomes impossible to restrict the indeterminacy principle to the future; we must admit the indeterminacy of the past as well [A. Einstein, Tolman, E. C., Podolsky, B., "Knowledge of past and future in quantum mechanics," *Physical Review* 34, 780-781, 1981]. This criticism was not so famous as the EPR argument, but it is of decisive importance when we discuss the collapse of the wave function as a non-local phenomenon in space-time.

I think that Einstein's concept of completeness presupposes the classical world where the relation of divisibility follows. In the quantum logical world, they are incommensurable and no mutually divisible events exist. The very concept of completeness does not follow so we can conclude to non-locality, but we cannot conclude the completeness or incompleteness of quantum physics because the very concept of completeness does not follow. This is because the concept of a complete description of the world by Einstein presupposes the classical logic. We cannot make a complete Venn diagram concerning quantum events so in quantum logic the concept of complete description is meaningless.

[Note: The formal paper associated with this oral presentation is published as "The Individuality of a Quantum Event," in *Physics and Whitehead: Quantum, Process and Experience*, ed. by T. Eastman and H. Keeton (Albany: State University of New York Press, 2003). Please refer also to references at Professor Tanaka's web site, the **Japan Internet Center for Process Studies** http://pweb.cc.sophia.ac.jp/~yutaka-t/process/index.htm]

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Dialogue among Panelists:

Valenza - I would like to ask Professor Tanaka to repeat his argument against this linear ordering underlying actual events as, for example, in the Bell-Aspect experiments, followed by a response by Professor Stapp.

Tanaka - For events E1, E2, E3 and E4 at locations l1, l2, l3 and l4, if all events lie in a well-ordered sequence of occurrence, as Professor Stapp assumes, there must be an unambiguous temporal order between events E1 and E2. One of the two events must be prior to the other. ... A difficulty of the above picture is that there does not seem to be any experimental apparatus to really determine which event is prior, E1 or E2.

Stapp - It is well known that there is, in one sense, complete compatibility with the theory of relativity. There is what Abner Shimony called peaceful coexistence between the one aspect of quantum mechanics which is completely compatible with the ideas of relativity, namely that there is no way of communicating a real signal faster than light. Everything is compatible with the idea that there is no ordering and that there's no possibility of sending a signal to determine which comes first in this situation. So at a practical level there is no problem. One is left to try the idea that what happens in one region cannot depend on what an experimenter decides to do in another region. So we're talking about a decision by an experimenter to form one experiment or another experiment. That seems to be something that is outside the system. You are imagining in this whole theoretical discussion that the experimenter is free to choose what experiment he's going to do and then you're supposed to say, well, that choice shouldn't influence the outcome that appears in another region that could be even earlier in time, that in a relativistic sense, can be regarded as already having happened. This is a theoretical idea and, if you impose that theoretical constraint, you arrive at a logical contradiction. You arrive at a funny situation which is called 'peaceful coexistence.' On the one hand, if you ask at the empirical level there is no contradiction with the ideas of relativity but, if you go one step and impose the logical idea that there should be no dependence backward in time based a free choice, then you arrive at a logical contradiction. In answer to your question, no, I can't give you an experiment that will tell you one or the other and that's exactly what is captured by Abner Shimony's phrase 'peaceful coexistence.' It's a logical contradiction and not an experimental fact.

Tanaka - So your full theory operates at the ontological level and not just the physical level. Your model is very welcome to Hartshorne's type of process metaphysics so I try to give another version more faithful to a Whiteheadian, ontological framework.

Stapp - Hartshorne certainly liked the idea that things come in a well defined order. The Whiteheadian idea of an actual occasion is that an actual occasion, in its coming into being, fixes where it is. In my understanding of Whitehead, he talks about this actual world, which I interpret as being the events that have already occurred in the backward light cone and that are fixed and settled. So this is fine if you have a well defined idea of coming into being. Something is fixed and you know its backward light cone, its actual world, the world upon which it can draw causally in the Whiteheadian point of view. If you had these two events and you're not saying which event is first, then you don't know. This event might decide to locate itself in the backward lightcone of the other one, so you seem to arrive at some sort of logical problem in making the Whiteheadian idea work if you don't apply a sequential order. Now that is just reading Whitehead literally. Now I heard something that you were saying about each event being immanent in the other, and that was the way you were going to get out. I did not really understand that very well.

Eastman - Jorge Nobo has referred to a certain range, width or duration, applicable to these space-like separated regions other than ones in the backward light cone. Does the concept of duration help in this discussion?

Stapp - For Whitehead, in order to deal with this sort of problem, he gets into the idea of 'presentational immediacy.' That is, as you experience something it has the effect of happening 'now' even if you access to the past and are causally influenced by the past. Nonetheless, you perceive it as happening 'now' so you don't really have causal access to those things out there. You have an indirect access because of access to the past to other things that will propagate into the future. Somewhat like the human brain works, the brain automatically accounts for real delays in events and makes a nice picture as though things are all happening 'now' reconstructed from various things that actually happened in the past. That's what Whitehead meant by 'presentational immediacy.' Experiential events appear to be 'now' in spite of the fact that you only have access to the past. I understand that all in a causal way. It's somewhat of an illusion that experience is in the 'now.' I don't think that allows for causal influence of the type that Bell's theorem seems to require. The Whiteheadian concepts of presentational immediacy and coming into being don't seem to satisfy the picture. Now if you have another idea of Whitehead's where events can in both ways be immanent in each other within an evolving universe, then I will listen to it. There seems to be a problem there.

Tanaka - Whitehead distinguished between space time and an extensive continuum, the latter being a proto-spacetime. Since Whitehead discusses the extensive continuum, he drops the dimensionality of space time. Dimensionality is a physical concept….In the extensive continuum there is mutual immanence of pre-events despite the fact of temporal order in the physical world. Whitehead explicitly says that every event is immanent in other events regardless of the causal order. My paper is a tentative formulation of Whitehead's extensive continuum as a proto-spacetime.

Finkelstein - Since I may be involved a little in getting you started on this project, I feel that I should point that there's a limit to how much satisfaction you can get out of quantum logic of this kind. If you think of the letters A, B, and so on as representing processes, then a simple way to combine two processes is to do one after the other. That goes on in the laboratory all the time. You put one polarizer after another, for example, but that's not what occurs here. Here you have the cap (1) and the cup (c). To verify that A cap B equals C, it really takes an infinite number of experiments of the kind I mentioned, the simple juxtaposition type, so that doesn't mean anything here is wrong or inadequate, it just suggests that it can't be fundamental. The fundamental thing is the dynamical composition of processes in terms of which this can then be expressed. The other, for me, unsatisfying feature of this quantum logic concerns extensionality, which again doesn't mean it's wrong, it just means that more work has to be done. With classical logic there's an important kind of extensionality. Each property corresponds to a set of individuals, those having that property, and each set corresponds to a property belonging to that set. I understand there are problems when you get to infinite sets and problems of self-reference that (we know how to take care of these nowadays, in fact, von Neumann is one of the pioneers in doing this, but I point out that he only did this for classical logic) cannot really be done for this system because there isn't the quantum set theory to go with this quantum logic to make it an extensional theory. To make a set theory requires a further algebraic structure which is still lacking here. You require it to go to the higher order logic. This is all first order logic and you can't do physics with a first order logic. You need the whole apparatus, the hierarchy of statements about statements about statements, and that's still lacking.

Eastman - You're saying that current quantum logic is intrinsically incomplete?

Finkelstein - At any rate the quantum logic that we have seen used today is a small part of it.

Tanaka - I think that quantum propositional logic is rather simple. It has a modular structure. There are many difficult problems with quantum predicate logic so I cannot resolve these problems, especially as one applies quantum logic to infinite structures. Classical logic is very straightforward and we can easily use it as a tool of infinites, but quantum logic cannot be used so easily as a tool of infinites, so when we deduce many things we easily use the classical logic, but in this diagram I want to say that the fundamental principle of classical logic does not hold necessarily in this world - the world we live in. So the conclusion of my quantum logic paper is that in the quantum logical world, the analytical truths of the classical world do not necessarily hold, so we can say that we live in the quantum physical world after the experimental disproof of Bell's inequalities.

Finkelstein - I agree completely. We need a more quantum logic.

Klein - I would like to get back to a topic of interest to the general group about seeing what we can do to connect Whitehead's process thinking to quantum thinking. One way of approaching it is to read Whitehead's text carefully, try to figure out what the words meant for him, try to figure out what they might mean in the modern age, and get into lots of linguistic battles about who thinks he meant this or that. That's one approach. To stay close to Whitehead and maybe make some changes. The other approach is kind of to abandon Whitehead's writing and to understand the spirit of Whitehead. Since quantum mechanics as we have seen has many, many ingredients in common with process thinking, why don't we just take up quantum mechanics as the basis of process thinking rather than the Whitehead text and let's try to discuss what is missing from present quantum mechanics that needs to be augmented. Is that a topic of interest? I will claim that nothing is missing. I personally believe that quantum mechanics is sufficiently rich for the task. (Henry Stapp in a lot of his writings talks about subjectivity and actualizations when measurements are made.) I think the mapping is probably pretty good but there may be some things missing and let's find out what they are. Thus, let's take quantum as the basis and then let's find out whether there is something missing in quantum mechanics that we need to augment it to make it the basis for process thinking.

Jungerman - That's an interesting idea. Do you have any ideas how you would put the divine into quantum mechanics? I would like to hear about that.

Klein - I'm giving a paper on Saturday afternoon entitled "Will Robots Sin?" I think you can get religion/theology out of quantum mechanics - that is the beauty of quantum mechanics, it gives subjectivity, it gets the subject into it, and that's what classical mechanics leaves out.

Jungerman - I can see the subject getting into it, but how you do you get God in there?

Klein - Talk to John Cobb - is there a theologian here? I come from a Jewish theology and I carry around with me a book by Rabbi Schulweis (*For those who don't believe*?) that's trying to make God understandable to academics like me and he does an incredibly good job of what is prayer, what is suffering, how come there is evil, and looking at the Bible. So he goes to the Torah and is doing standard biblical interpretations of the various faces of God. Such efforts could revitalize theology and make it more humane.

Eastman - A question of clarification - are you saying that you would use quantum theory as a key tool in developing some robust metaphysics that would go beyond Whitehead or are you saying that you would essentially take the needed metaphysical formulation and essentially reduce it to quantum?

Klein - I'm missing the distinction. Whatever is going on here with the Center for Process Studies, that's what I want to do. The problem is that it's based on Whitehead and Whitehead has lots of flaws, and so I'm wanting to keep many of the connections that a very nice theology can be based on and see whether quantum could provide that process basis because it's so close, but there's something missing.

Eastman - Clearly the panel and others here are open to modifications of Whitehead's metaphysics. We're not just into what has sometimes been referred to as Whiteheadian scholasticism. Using the best of contemporary physics and philosophy, we can be carrying out the cutting edge of such a program. So what's missing?

Chew - I was going to ask you to clarify your use of the term 'quantum mechanics' because at least two ambiguities have been identified. One has to do with whether the notion of measurement has to be part of quantum mechanics or whether you can somehow define what you mean by quantum mechanics without talking about measurement? And the second has to do with how many different times there are that are supposed to be described by quantum mechanics?

Klein - We have a proposal. I don't know whether Henry or David are into this enterprise. A big problem is measurement and this is what Geoffrey is pointing at. One of the critiques of quantum mechanics is that every single quantum mechanician has his or her own interpretation of what the meaning of it is and that's going to be confusing if you want to talk to the outside world, philosophers, theologians and the public, so there's a lot of discussion about what we mean by measurement, etc. I think that it is possible to all sit down and come up with the basic elements, some very simple things. A few of us had lunch together and we kind of agreed upon the first two pages of Dirac or something like that as what is necessary. Let's make it very simple what I'm talking about. We would like to provide some substrate to process thinking and, if you look at the first chapter of David's book, I suspect that you'll find some agreement. We're not going to answer some subtle questions like where's the measurement made, but it's going to be a hell of a lot better than what's in Whitehead's writings on this issue. It might be a little "Copenhageny," but maybe not; we're kind of agreeing on the Heisenberg picture. But anyway we don't know the answers to your question. I sure hope that we don't need more than one type of time. You'll have to convince me why you need more than one. I'm presuming that one time is plenty good.

Stapp - Not to expand upon it, but to ask a question. The outline that I gave of quantum mechanics in my talk left open two questions and I took it right out of Bohr's discussion of Dirac's idea that nature chooses and Heisenberg's idea that an important part of quantum mechanics is the observer's choosing of what question is to be asked. So I think that quantum mechanics in its present form - let's say the project is to start with quantum mechanics, use Whiteheadian ideas to add whatever more is needed. At least you have a foundation that is based on scientific evidence and that there's a coherent, logical structure grounded on scientific evidence, and then to use Whitehead to enrich it to the extent that's needed to bring it up to Whiteheadian standards of completeness. Let's say that's the project as I would understand it. So I see what's missing at the moment in the quantum description is how these two questions get answered. How does nature answer the question of what's actually going to happen and what is going on in the observer's formulating his or her question of what question he's going to pose. There's a lot still missing in my view from quantum mechanics. Neither answer to these questions is known.

Whitehead is basically suggesting, the way I read him, that the mechanism of answering those questions or the process by which those questions get answered are to some extent psychological in nature - that there are things like appetite and final cause and satisfaction. You have to bring psychological type criteria and evaluations into the mix in order to get answers out. I think there is something missing in quantum mechanics, apparently Stanley disagrees.

Eastman - David, would you share with us your reflections on the Quantum-Whitehead Project?

Finkelstein - Well, first I must admit I'm a little flabbergasted; I didn't think that we would go public today. And I would not have included in the prospectus a promise that we're going to do better than Whitehead because he covers a lot of territory.

Klein - No, maybe I wasn't clear. I want to add to quantum mechanics what is needed. I think Henry said it just as well. I want to find out what is needed to be added to quantum mechanics to bring it up to Whitehead, but at least, as a basis, start with quantum mechanics.

Finkelstein - I had to say those things just so that I could stop blushing.

Eastman - It sounds like you have a synergism here of a possibility of going beyond both quantum and Whitehead.

Finkelstein - The possibility exists, yes. One of the elements in Whitehead is a uniform way of looking at organization at all levels. Nowadays it's called systems theory. I think that we can say that Whitehead anticipated systems theory by a few decades and we don't have a systems theory that's founded on quantum theory. It seems to us today that systems behave very differently at the quantum level, at the macroscopic level, and so on. I suppose there's a uniform way of looking at all these levels, but I haven't seen it and I certainly wouldn't swear to produce one but I am interested in setting about trying especially with such pleasant people to work with as a fun interaction, a delightful process, and we'll have to see what comes out of it.

Chew - This is unfair because I can see that you three have not really agreed yet, but do you all share the belief that the observer has to be recognized explicitly in any statement of what quantum mechanics amounts to?

Stapp - Certainly at the practical level that's what quantum theory is.

Chew - Now do you agree that that condemns this formulation to be approximate?

Finkelstein - Yes, definitely - as any other. Any statement usually is stated by somebody. Usually there's a speaker and a speaker isn't able ever to have maximum information about the speaker and so since all the little details about where my left toe is right now have some impact on distant stars, there's no way that I can make an exact statement about the world. The bigger the speaker and the smaller the system, the more chance there is of making reasonable statements about the system, but as the world gets bigger, eventually I get to look pretty small, and the idea that I can make a perfectly accurate statement about the rest of it is lunacy, it's futile.

Eastman - Well for a decade if not centuries, the general public has thought about physics as being the exemplar of exact understanding in the details and now we have some of the most eminent physicists of the country agreeing that it's necessarily approximate.

Finkelstein - I think that it was an hallucinatory phase, roughly from 1750 to somewhere in the last part of the 19th century, and now we have reached the end of this little island, we're getting into our boats and joining the rest of humanity.

Eastman - And perhaps with that getting into some of the murkiness of the real world and not just in the ether of our concepts - there is that interplay.

Finkelstein - That blooming confusion.

Chew - Would you include an estimate of the accuracy of the information in the formulation?

Finkelstein - I think that could be done actually, but it won't be an exact estimate.

Klein - Was your earlier comment of whether the observer would be included a suspicion that maybe it shouldn't be? Because if it's going to connect to process thinking the subject, the subjectivity, has to be put in there at the very beginning, which is this observation aspect as I think it has to be if we want to pursue this enterprise of connecting with Whitehead.

Chew - It seems to me that then you want explicit recognition of the role of electromagnetism…

Klein - Oh, yes.

Chew - So this will be a formulation of quantum mechanics which explicitly speaks about electromagnetism.

Finkelstein - Actually I am very impressed by your brilliant exposition, in the past also, of how fundamentally electromagnetism shapes our perceptions of the world. But that leads one to speculate, suppose it didn't exist? Could we still have a world? And Feynman pointed out that you could still have atoms, they might be a light year in Bohr orbit instead of what they are now, gravitational atoms, and these could form some kind of van der Waals structures. I can imagine brains on the order of galaxies in size operating according to gravitational

interactions. It might be a fantasy because gravitons are pretty evanescent creatures compared to photons. It's not clear to me that the world has to be just the way it is. The idea of measurement ordinarily just means a three-phase operation in which you have two systems initially separated, then they come together and interact in such a way that some quantity in one is correlated with some quantity in another and then they separate and then one knows something about the other. And there's this really beautiful theorem by Kochen and Specker which says that any unitary operator that isn't trivial can be written as a measurement, as establishing correlations between some variable of one system and a suitably chosen variable of the other system so measurements are not going to be that hard to get.
[Note: For a reference on the Kochen and Specker 'no go' theorem, see chapter 3 of Jeffrey Bub, *Interpreting the Quantum World*. Cambridge: Cambridge University Press, 1997.]

Chew - I was going to ask you about this remark of Feynman. Did he believe that in the absence of the screening, which you can't have with gravitational effects, you could have enough separation to define the distinction between the observer and the observee?

Finkelstein - No, all he did was to replace Coulomb's law by Newton's law and look at how big the atoms are. He didn't go on to build 'people' out of them.

Chew - I'm a little skeptical that you could have the distinction that you would need.

Finkelstein - Right, the shielding is important, isn't it?

Valenza - Do you gentleman have any first impressions on whether or not this other vague component of eternal objects that plays an essential role in Whiteheadian metaphysics is required in what you propose?

Klein - Well, fermions might last eternally.

Valenza - I didn't mean physically eternal. I mean eternal objects specifically as the term is used in Whiteheadian metaphysics.

Eastman - Analogous to universals versus particulars; like conceptual entities.

Klein - Are they in the subjective world, how do they make themselves manifest?

Valenza - Through the primordial nature of God, it's a hell of a trick.

Eastman - In Whitehead there are real potentialities. The process of becoming involves an incorporation of both previous actualities and these potentialities, or eternal objects in Whitehead's scheme, so there is both the incorporation of previous actualities and a range of possibilities that are part of the prehensive unification that constitutes any actual entity.

Klein - How necessary is that to process philosophy and theology?

Eastman - It's an essential part of the basic Whiteheadian metaphysics but there is debate about particular ways of constructing eternal objects. Robert is in mathematics and some others are more concerned about how to construct reference to conceptual forms, and Whitehead, as a logician and mathematical physicist, wanted to incorporate this into his overall scheme.

Stapp - Are these Platonic or Aristotelian?

Tanaka - I want to explicate the meaning of eternal objects. Whitehead says that there is pure potentiality. If something happens it becomes a real potentiality. Physicists always presuppose that there are real potentialities in the actual world but eternal objects are pure potentiality which may be actualized but they are not conceptual possibilities.

Eastman - It's not like Platonic objects, which have always existed, whereas Whiteheadian eternal objects require a certain embodiment, an exemplification. This is a detail we should not get into here.

Klein - It might be important.

Finkelstein - I think it's important. We're really speaking of real potentialities which are crucial I think in the Whitehead system and also in quantum theory. Heisenberg spoke about this quite early on in the game. It's one of the items within the table in my paper. Wave functions, psi vectors, are examples of potentialities that may or may not become actualized.

Klein - But I thought there was a difference between these potentialities, that's the wonderful matching of quantum to Whitehead, but then I thought there's this new thing called an eternal potentiality.

Finkelstein - Remember when we're doing quantum theory we only ask where wave functions come from, we treat the observer as eternal. You always have these possibilities available to him. That's part of the approximation for us. You don't look at those changes so we might pretend they don't happen.

Eastman - I might note that some physicists might wish to entirely avoid real potentialities and one example of this would be to take the many worlds interpretation that the collapse of the wave function and its possible alternatives are all actualized in a multiple of realized worlds so that there is no real potentiality, whereas Whitehead would say that there is real potentiality where things may become either A versus B.

Stapp - I think that's the sort of quantum mechanics we're talking about - with real potentialities. David said the other day that the other one is nonsense. Didn't you say something to that effect?

Finkelstein - I probably did - I get carried away.

Klein - It's not clear that it won't work.

Eastman - It's sounds like there are many very interesting new possibilities coming out of this workshop on Whitehead and physics. The synergism of the discussion here has been very fine.

Nobo - When you talk about virtual photons be kind to them. I've been a virtual panelist today and it's been hell with many virtual comments that nobody can listen to and have not been actualized. I have enjoyed this tremendously. On the issue of an actual entity deciding where it comes to be, that may be Hartshorne but it's not Whitehead. It's determined by the past and specifically by at least one actual entity in the immediate past.

Stapp - Some entity in the past decides where this entity is going to be?

Nobo –Right, so what's the past?

Stapp - Whitehead as I interpret him has a cumulative theory of actuality. Once a region of this continuum becomes determinate it remains determinate. Because of that it can function in later occasions where this wholistic process projects the information of that entity into later entities. It's a very redundant system because the information that has been accumulated is constantly being projected into every new eventity or actual occasion which then contributes to all future occasions. But part of its process of becoming involves a structural determination that has a causal effect on where in extension, as far as where in a supersessional order, it's the next.

Stapp - So an event itself has no input into where it's going to be; it's already fixed where it's going to be?

Nobo - That is correct. The event is begotten by the universe with a partial determination and a complete succession and, in the act of completing itself, it anticipates at least one successor but it can anticipate more than one so you can have splitting of world lines and you can also have coalescences of world lines. I would like you to consider the possibility that there is such a thing as a metaphysical double cone of which the light cone is a subset and that, until quantum physics, the metaphysical cone has been irrelevant. But when you have to deal with quantum physics there's a possibility that now the metaphysical cone becomes important. It's just like the light cone. It's got a past, a future, and an elsewhere region for contemporaries. There has to be a frame of reference. Relative to that frame of reference there will be events such that one is earlier than the other but they are all contemporaries with the frame of reference. You have the same thing but it doesn't depend on light which is a special case depending on local causation. I do agree with what you said about modifying Whitehead and this is one of the modifications that we need to make. There's a difference between causal objectification and conformation that tends to be ignored in the interpretation of Whitehead, but going beyond that I think Whitehead goofed when he said that an actual entity has to conform to every entity in the past. If it only conforms to some, then that conformation relation is what is going to give you local causality requiring contiguity and so forth. But the relational causal objectification is going to give you what appears to be, what is in a sense, instantaneous communication. And there is a way in which we can have some information about contemporaries metaphysically because they are anticipated by their antecedent events. I'm very excited about this but now I have to go on to formalize it.

Eastman - I suggest that the Quantum-Whitehead project people might think about incorporating Professor Nobo in your discussions. He's on the leading edge of Whiteheadian work.

Dialogue open to full audience:

Eastman - It's been our hope that pulling together our panelists as well as the broader group of those of you interested in the synergism between process-relational thought with recent developments of physics from which could emerge to life new possibilities and actualizations. With that, I would like to first call on one audience participant, Proessor Jorge Nobo, who earlier made a comment just before the break.

Nobo - When Professor Tanaka spoke, the way he put it that I disagree with is that it's not the case that determinate actual entities in the future are immanent in earlier actualities. It's the extensive regions from which they will arise that are immanent in earlier actualities. In *Science and the Modern World*, Whitehead is talking about spatial relevance and he says this applies to temporal stretches and then he says it applies to spatial-temporal regions. I've taken it one step further and apply it to eternal extension as necessary for making his system coherent and explaining many problems in his system and making them then fit.

Stapp - How about *Process and Reality*? Doesn't he make it explicit there?

Nobo - He talks all the time about mutual immanence and he is very explicit in *Adventures of Ideas* where he says 'any two actualities, regardless of their temporal relation, are mutually immanent' - now that's careless because he uses the term 'actuality' and it's not that any two 'actualities,' it's that any two 'extensive regions' are mutually immanent. Relative to a frame of reference, one region may be occupied by a determinate actuality (which is past), one region may be the potential locus for a future or a contemporary actuality relative to that frame of reference. So it's really the mutual immanence vis-a-vis extensive regions that become the loci of actualities. That is the mutual immanence and that enables some information about contemporaries to be possible and there's much more to the theory than that. But I don't want anybody thinking that I am holding that future actualities are determinate, immanent in their actuality, because that would be as un-Whiteheadian as you can get.

Tanaka - I really prefer Professor Nobo's interpretation of Whitehead. I think that there is a vital difference between Whitehead and Hartshorne. Whitehead explicitly says that future events are immanent in the present and that two contemporary events are immanent with each other, especially in *Adventures of Ideas*. Hartshorne only stresses immanence of the causal past in the present. There is no passage that Hartshorne wrote that the future is immanent in the present or that two contemporaries are immanent with each other. On this there's a lot of difference between Hartshorne and Whitehead. So my interpretation of quantum physics is based on Whitehead's original version, not Hartshorne's version.

Nobo - My interpretation is based on Whitehead's but we disagree as to whether he means determinate actuality or their potentialities.

Stapp - You're saying that the regions are predetermined though, right? Where the event is going to occur.

Nobo - No, they're not predetermined until an actual event determines where a successor is going to be.

Stapp - No, but once a bunch of things have occurred they're going to determine, for example, where the next events are going to occur, not necessarily what's going to happen but where they're going to occur, at least in a projective sense

Nobo – Yes.

Laszlo Forizs - Although I got my PhD in physics I am now active in Buddhist philosophy. I have lots of comments here, eternal objects for one. I agree with Professor Tanaka completely that the extensive continuum is something like a proto-spacetime. What is very important in Whitehead is the relational complex. There are many such models of relationality in Buddhist philosophy; models of correlation but not of spatio-temporal correlations. For Whitehead, this relational complex is prior to external relatedness. Let's take the example of a bubble chamber. There is a particle coming to this bubble chamber and in quantum mechanics it's described by a wave function and it's a unitary evolution and we find something there and it collapses. Again, unitary evolution, propagation, collapse. What is really there for us is a completion. In a sense it's a measurement, but now a question arises 'is it anything to do with consciousness?' - no. What is more important, the spatio-temporal external relation or the completion? In a sense it's a collapse, but in another sense it's a completion because a decision was made. You can interpret it as an everlasting question that nature questions itself and then there is an answer. There is something there so it collapses, and this is irreversible in principle.

Klein – There is collapse if the bubble chamber was the measurement device. It's a Schrodinger cat problem.

Barbour - I was asked to be on the panel but previously committed myself to presentations elsewhere and am sorry to have missed part of the discussion. What I would like to do is to pose some questions from a more theological perspective but with a physicist's perspective in mind (I was once a physicist and became a theologian). Physicists want to start from and stay as close to physics as possible. Whitehead in his more metaphysical stage particularly was very concerned about a system that would include religious sensitivities as well as scientific ones and, if one looks at that side of Whitehead, I'm wondering if one isn't pushed to extend Henry Stapp's position to ask 'isn't God asking the question in some situations?' Both before there is a human observer and, if you extend the von Neumann scheme to include the whole universe, because there can be no observer outside it. It seems to me that this opens another dimension.

I don't think that Whitehead would have approved of those theologians today who are exploiting quantum mechanics by saying that God intervenes at the quantum level to determine one of the potentialities. That's certainly a possible way to go and it certainly doesn't violate the laws of physics. God is not pushing electrons around. He would be actualizing one potentiality among other potentialities. Again there are all kinds of problems theologically - the problem of evil for example. I think that most contemporary theologians that do want to make use of quantum indeterminacy want to say that it must be a rare kind of event and it must be subject to the statistical distributions that we know are not violated and so forth.

There is one other problem and I am wondering if anybody would want to comment on it. Hartshorne was quite concerned about the problem of when one talks about God's relation to the system. I would be interested whether Bell theorem in your eyes throws any new light on this. The problem is namely that for us it's fine to say that E1 and E2 are events that are out of communication with each other. The interval is longer than a signal at the velocity of light could be communicated. At the practical level, we could remain agnostic about which event is first and accept the destruction of absolute simultaneity for human observers. But now if God is related to all of this, presumably God's omniscience isn't subject to that kind of limitation of the transmission of information at the velocity of light. One has to get beyond Hartshorne and say that God is presenting initial aims relevant to the particular event that God is relating to. If you ignore relativistic time effects and the destruction of simultaneity, you could say that God presents an absolute frame, but most physicists would resist that. Several people have tried to reply to this problem following Hartshorne's work in having raised it…. Does that throw any light on that aspect of Whitehead's attempt to relate God to each event? What I'm asking, if anyone wants to do it, is obviously more speculative and won't come out of the physics alone. It will come out of a concern for relating a God who may be known in other ways, for Whitehead is known in other avenues of human experience. This is a big agenda, but are there any particular points that anybody would want to respond to, whether what you have been saying throws any light on God's interaction with the world that is clearly a part of the process conceptuality?

Stapp - Well, first let me talk about things in physics before getting to God. I realize that your emphasis is on God, but first there is a small point but maybe an important one. You said that no physicist would prefer a special frame and now you must remember though that the basic thing about the theory of relativity is that the laws are supposed to be invariant under certain transformations, and the general laws are supposed to be frame independent. That's a very different statement from saying that the world is independent. The world is not independent. The world is one particular way and so a big distinction has to be drawn between the nature of the world and the nature of the general laws. Now, as far as the world is concerned, there was a big bang apparently and experiments are done and, amazingly enough, you look back in all directions and it seems that there was a preferred frame. These things have moved out in all directions and it looks like the big bang had a preferred frame in which it occurred. This is the background radiation and this is measured with great accuracy - 1 in 10^5 - so when you look in all these directions there's this common rest frame of the electromagnetic radiation. So there is then in nature itself a preferred frame. Now another thing along the same line. There is this book, the Schilpp volume *Albert Einstein: Philosopher, Scientist*, and in that book Kurt Godel of Godel's Theorem fame has a chapter. He points out (I don't know if it's still true but it probably still is true) that in every cosmological model there is, in fact, a natural sequence of 'nows.' A natural sequence built into the cosmological models. There are two reasons then for saying that we don't necessarily have to think the order of coming into being has to be relativistically invariant. We have a very good reason for saying that maybe it's not that way. That there is a preferred order for coming into being so that is one point. In other words, there's nothing really contrary. What relativity theory says is two things - that the laws are invariant under relativistic transformation and that no signal should be transmitted faster than light. Those requirements are both satisfied in quantum theory and there's no problem with either. If the laws are correct, there's no possibility of sending a signal faster than light so that's this peaceful coexistence. So there's no real logical contradiction. Bell's theorem on the other hand seems to say that you have to have - if you believe that the experimenters have a free choice - you don't get anywhere unless you are willing to say imagine, at least, that the experimenters have a choice to do this or that - it turns out that you cannot impose a condition that their choices only affect the future. If you try to put that condition in, the actual outcome, only effects in the forward light cone, then there's a logical contradiction. So that seems to be saying that somehow there is some faster-than-light influence in spite of the fact that there is no faster-than-light signal. So you might want to say that's God's doing, you know maybe God has his view of the universe, the big bang frame, and he has no problem with having these faster-than-light influences that don't lead to faster-than-light signals.

Klein - I think you get into a major problem which is the one Ian actually mentioned, which is the problem of evil. For the same reason that you don't want God to have omniscience in collapsing wave packets in general you sure don't want God to have the omniscience to do these little micro things, because then you'll have the problem of evil. Most theologies that I know of don't give God that kind of influence.

Tanaka - I would like to give some comment about the theological implications of Bell's theorem. The difference between Whitehead and Hartshorne is that, for Hartshorne, God is a society of divine occasions with personal order, so Harshorne needs the cosmological now. Hartshorne is very much annoyed by the general theory of relativity, in the usual understanding of the general theory of relativity, where we always must say 'here-now' - not a cosmological now, which does not have an objective counterpart in the general theory of relativity. We can accept Professor Stapp's model and say that there is something like a cosmological now. In my Whiteheadian model, the theoretical relation between God and the world is something like this. Max Jammer, the Hebrew historian of science, wrote *Concepts of Space* and pointed out that the Newtonian concept of absolute space has an origin in the Hebrew idea of God. So Newton says that absolute space is an *sensorum dei*, a sense organ of God. One possible reading of Whitehead is that the extensive continuum is something like an absolute space in the Newtonian sense so God is omnipresent with everything in the extensive continuum.

Klein - How does Whitehead deal with evil?

Tanaka - That's another question. Whitehead distinguished creativity and God. There is a metaphysical concept called creativity which is more fundamental than God as an actual entity. If God is omnipotent being, Whitehead says that then there is a very serious problem with the actual existence of evil in this world, but this is a different problem from that of the extensive continuum.

John Wygant - I think that Whitehead does need to be modernized in the light of what has happened in the past 70 or more years, but in doing that I think that it is important to distinguish between his metaphysical scheme that's outlined in the second chapter of *Process and Reality* and the applications that he makes of it in Part II. Now when someone commented on how erroneous he was about Darwin, that's an application and he may need a lot of correction there, but it seems to me that the more important question is, how do the metaphysical categories need to be modernized? Those categories are very, very abstract and general and are compatible with a lot of different scientific theories. I think they're compatible with action-at-a-distance theories, they're compatible with contact theories, they're compatible with different versions of quantum theory. The point is that the nature and method of metaphysics is really very different from the nature and method of science, so in revising it I think one also has to look at what's happened in the last 70 years in metaphysics as well. Now, as to the problem of universals, which was raised by the topic of eternal objects as a case in point, a lot has been said about the problem of universals, about the issue of eternal objects, in the intervening 70 years. No one here has mentioned the topic of societies, but that's how Whitehead makes the connection between his categories and ordinary objects, and his concept of societies is an essential concept. A society perpetuates a defining characteristic from occasion to occasion, that defining characteristic is an eternal object, a kind of Aristotelian form. It's not clear to me that anything you say in quantum theory can be relevant to that, maybe it will be, but what's more relevant is the past 70 years - especially the discussion of substantialism in metaphysics since the rapid development of modal logic in the 1960s. Since the 1960s there has been a terrific discussion of substantialism in metaphysics and that's relevant to a re-evaluation and interpretation of what Whitehead says about societies, eternal objects, and so on. As you engage in your project, I think you have got to think through what the nature of metaphysics is, how it relates to physics (it's not as obvious as some of the things you've suggested), but also to take into account what has happened during the intervening 70 years in metaphysics as well.

Stapp - That probably sinks the project.

Eastman - Perhaps those in the Quantum-Whitehead project are getting into more than they had every imagined.

Forizs - I would like to respond to your question about the problem of evil because it was avoided. But I think it's unfair because Whitehead solved that problem. I like the solution, the best I've ever heard of. It is connected with the problem of objective immortality. There is no such thing in Whitehead's philosophy as God isolated from the metaphysical scheme which defines a primordial nature of God and there are lots of things about the consequent nature of God. The primordial nature of God is actually deficient, conceptually abundant, and unconscious; on the other hand, the consequent nature of God is actually abundant and in a sense conscious. It is related to the problem of evil. There is a beautiful sentence in *Process and Reality* that God is in a sense a sufferer, so he suffers, and his suffering converts the ruin. It uses the ruins of the temporary world and converts this ruin into his own nature so in a sense events as terrible as the holocaust are also a part of the consequent nature of God, but it's difficult to understand this transformation

Eastman - You're saying that what's difficult to understand is the process of redemption.

Forizs - Yes.

Klein - I don't know enough about process theology to know whether the God of love, which I think God is, can avoid this problem of evil. Isn't God always present on these process decisions, which include the creation of evil?

Forizs - That is God's function in the old fashioned sense. For Whitehead God is a process, God is an actual entity, in the making.

Klein - That's totally compatible with quantum mechanics. That's the God that is always with nature, and there's a process and interaction with humans and things. I see no problem with quantum mechanics being a basis for that type of God.

Forizs - There is no other possibility for God if you apply the ontological principle. Is there any other possibility?

Eastman - That's the self-transcending God - ever more inclusive.

Fagg - Were you aware, Stanley, in your discussion of evil of Whitehead's statement that the limitation of God is of goodness and the strength of God is of an ideal. This is somewhere in *Religion in the Making*. There is a limitation to God and it is his goodness.

Audience Member - In process theology, the nature of God is coherent, is always essentially a positive vector, it never goes against itself, and what evil is is an act against itself. The divine would never enter into that. We make judgements that something bad or good is happening. We call things evil but at some level, some "God's eye view," even if humanity intends something for evil, it's assumed that the divine intends it for good. Somebody mentioned the holocaust. As a minister, I get into discussions on inter-faith council about the nature of God and religion. One of the things that Rabbis have said to me is to thank God for the holocaust because what it did is that it awakened Jews in this world to their own theology, to their own necessity to maintain spiritual identity, and that without it Judaism would have disappeared from the planet within one or two generations. I can't say that but I can tell you that there are people in Judaism who will say that kind of thing about the holocaust. So judgements about things that happen to us are judgements of a generation. They are not ultimate judgements and I don't think that you can involve the divine in making those judgements.

Klein - Yes, I think the holocaust is a bad example because decisions by deranged human agents were involved. A much better example in my mind is a cancer that strikes your child, a rock, a random thing from nature, a meteor, coming and killing your child, because now we have a real problem if God is involved with collapses that lead to these consequences. Quantum mechanics has no problems, and process theology, as I understand it, has no problem with that but it does put limits on God.

Barbour - I think the process answer to the problem of evil involves a number of elements. David Griffin has written two very good, recent books on it, and it involves the whole idea of divine self-limitation. The fact is that in the Whiteheadian system, no event is entirely deprived of God's action, and God is not the God who coerces anything to happen. In fact, God can't make anything happen alone. God introduces elements into what's already there and is bound by those structures and usually respects the lawful character of things; no act is purely the act of God. God is the fellow sufferer who understands and participates in the world. However, this is a problem in traditional theology. Whitehead strongly reacted to the monarchial God, the sovereign, omnipotent God. For him, God doesn't know the future because the future can't be known. Omniscience is very restricted and omnipotence, in particular, the traditional notion of omnipotence, is very strongly rejected in Whitehead's writings. While there is a problem of evil, I don't think it's a problem with a God as lure, a God of persuasion if you want to use an anthropomorphic term.

Klein - That's exactly the point I was trying to make. It came up in the context of Bell's theorem…. God isn't down there manipulating every little collapse.

Bracken - I would like to introduce one distinction that I don't think Whitehead always makes. That is to distinguish when you talk about evil as a deliberate attempt to produce negative results, from what I would call tragedy, that is the confluence of freedom with nobody making a decision. I think it's important to make that distinction when we talk about evil because in a world in which you have free creatures, even with good intentions and with as much knowledge as you possibly could have, the future is somewhat open and you can have destructive events happening with no bad intent; then evil would be the bad intent to produce the negative result.

Forizs - I still think that the holocaust is a good example and it shows the real power of the Whiteheadian scheme, the categorial scheme. Every single decision is part of the consequent nature of God. You cannot explain away the holocaust. It's not a matter of blame and it's not a shame on God; it's a shame on us.

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Clayton - It's interesting to look back over the three sessions now, over nine hours that this group has met. The title of this session was "The Philosophical Implications of Modern Physics." That suggests a unidirectional move. We take modern physics, which we can all agree on of course, and then we work on its philosophical implications. What has actually occurred in this session, as with the earlier ones, has been far from that. In fact, we found ourselves in a bi-directional dialogue, right? Drawing on philosophical resources to interpret quantum mechanics, relativity and so forth and we've made little sorties out from portions of physical theories, but certainly not in a massive way. Geoffrey is developing a physical model but he comes to a conference like this and to similar ones in the past to look for ideas, terms and frameworks that would help in doing his physical modeling. The themes of the earlier two sessions, order and emergence, and fundamental processses, showed that same sort of bi-directional move. The one difference was the way that Stanley announced the 'project' and that was announced as if we could agree upon Dirac pages 1 and 2 and then move outward from that. But then in his subsequent formulation, it became, let's take that as a starting point, maybe more adequate than a 1929 text, but let's see how it might need to be augmented by Whitehead (already there is bi-directionality there), in turn augmented by this other perspective. So I just want to reflect back a little bit on the nine hours and see what statements we might make empirically on our own progress or lack thereof.

Eastman - In terms of reflecting on the sessions here since we have begun, I suggest now that each panelist reflects on follow-on possibilities, new insights that came to them, something that you saw out of it, or just any reflection on this past nine hours.

Valenza - I have always accepted Whitehead as a hypothesis and had a lot of intellectual fun trying to chase out the consequences of it. I've always been astounded by the man's depth and intelligence but have always felt ill at ease with the grounding of process metaphysics. That it either isn't well grounded or threatens an infinite regress and it disturbs me that that happened in these meetings to the extent that we get into trouble with language referring to certain categories such as whether something is physical or proto-physical. That still hasn't been sorted out. As our discussions have highlighted, they're useful but there are some very deep questions, both physical and metaphysical, to be asked about the whole process system and I think unless they're asked or at least a coherent conversation emerges that we are in each other's way in terms of making progress.

Eastman - As it was brought out before with a comment in the back about important developments in metaphysics, metaphysical propositions as well as the issues of scientific propositions, that each of these has to be attended to.

Chew - One of the questions I was hoping to get an answer to at this meeting was whether or not Whitehead's cosmological scheme was based in some way on a notion of matter. I know that it's based on a notion of process, there's no question about that, but does Whitehead's notion of process carry with it some implied, a priori meaning for matter. I still don't know the answer to that question but I'm persuaded that it doesn't matter for me. I will proceed in a Whiteheadian spirit and, as Phil indicated, I have been inspired by this discussion. I don't know why but I feel more motivated, even more than I was, to try to develop this idea that a cosmology can be based on a notion of history where the history doesn't start with some notion of matter, but the notion of matter is emergent from certain patterns of history and that there is, however, a much larger component of history which is non-material and I hear here all sorts of possible relevance for this idea of non-material history. I'm going forth determined to find some ways.

Tanaka - There is no traditional notion of matter in Whitehead's metaphysics. Whitehead criticized the concept of matter in *Science and the Modern World.* In the conceptual scheme of *Process and Reality* there is nothing like matter, so instead Whitehead proposes a creative process. Whitehead says that material particles are complex enduring objects or societies of actual occasions.

Eastman - Whitehead does a critique of the notion of self-identical substance, the classical type of substance or the philosophical concept of substance, and that this is set aside. What we refer as matter, as substance, are things that emerge in this ongoing process of becoming and being. It's in this dialectic of the prehensive unification of things into actual entities and then into sequences of occasions (the being of any actual entity is constituted by its process of becoming, its prehensive unification of past particles, fields and its own immediate past self). From that whole process you get what we refer to as substances, the physical world, the table and everything, so there is a notion of substance, it's just not the classical notion.

Jungerman - I think that the fact that we're meeting here exemplifies that even after 70 years Whitehead has a lot to offer in inspiring us and, at the same time, it seems clear from our discussions that he certainly isn't the last word. It actually is 70 years ago so we need to update it. I'm very encouraged and excited by physicists here who might actually develop some models based on physics that could provide a firm foundation for the metaphysics. It's a great start but it seems to be terribly ambitious when you think about religious experience or feelings, emotions, trying to incorporate those things into quantum mechanics. I'm glad I'm not doing it.

Fagg - I must confess that relative to my contribution I feel like a freeloader here because I've learned so much. I think that the discussion of the EPR problem has really stimulated a lot of thought in my mind and I really appreciate that. I'm especially interested in what the 'three muskateers' will come up with and I am going to go back and read the first page of Dirac. Also, I'm especially interested in what Geoff Chew is trying to do with his model and even more interested in his statements how quantum theory must come to grips with electromagnetism, especially in the problem of measurement. He's absolutely right. It's very rarely ever mentioned whenever any discussion of quantum theory and its interpretation comes into play.

Tanaka - I will give some comment on the concept of metaphysics. Metaphysics originally comes from Aristotle with his book written after (meta-) physics, thus the term 'metaphysics.' So, Aristotle's metaphysics presupposes the physics. Whitehead wrote books about physics - *Principle of Natural Knowledge, Concept of Nature* and *Theory of Relativity* - so he was well versed in this area of relativity and its vital significance for contemporary processes, and then he began to write his own metaphysics. There is another aspect of metaphysics; that it must be the science of the most concrete elements of our experience. So he shares the terminology in Western philosophies; we must go deeper than usual and he tried to do a phenomenological analysis of our own experience, the deep structure of experience in the world. Experience, considered very broadly, is very important in Whitehead's metaphysics. In one sense, Whitehead is a radical empiricist.

Eastman - Whitehead is effectively a radical empiricist in the strongest sense in that, as Whitehead says, as one tries to work with these metaphysical propositions, you start in the ground of immediate experience and you fly off, as in an airplane, to work with conceptualities and models, but you necessarily must land again and be grounded in immediate experience. The full testing of these high-level concepts includes metaphysics, science, and direct observation.

Klein - Well this has been great fun for me. I haven't had this kind of stimulation for many, many years. I left doing main line physics about 25 years ago and have since been working at trying to understand experience in its psychological aspects. I study vision - how the visual system works - close to how experience works, consciousness, attention, how the brain perceives. Many of the arguments we've been having about experience are part of that understanding…. As my neuroscience colleagues figure out how experience works, emotions, feelings, the chemistry, the biology, when that gets figured out, and we figure out how to make robots with emotions, feeling, before not too long but perhaps not within our lifetime, then the landscape will change. We won't have to worry about how to explain feelings and emotions, and it's going to be more on theological issues of free will - where does evil come from, things like that. I'm sure that Whitehead has many intelligent things to say. Maybe not in our lifetime, but in some future, this vision of having a theology that is compatible with physics will come about. I don't think we will do it in our lifetimes but I'm confident that someday it will be done.

Stapp - … Cross filtration of ideas is a very good thing to happen. We come here as physicists concerned with a certain part of experience about the world. Physicists trying to push the frontier a little bit are always coming up against philosophical questions of one sort or another and so I think it's very good for us to have an opportunity to come in contact with and exchange ideas with people who are working in a philosophical tradition that is close enough that we can really exchange ideas with. Hopefully, since the ideas on the two sides are close enough, I would hope that maybe some of the ideas coming from physics could help along what is probably needed in Whiteheadian metaphysics. I think it's basically the cross-fertilization of ideas that is important here and I look at it as, you know, maybe a significant event in the advancement of our ideas about the world we are living in.

Eastman - With that, let me ask David Finkelstein to provide the last words as a physicist, followed by Jorge Nobo to provide the last words as a philosopher, and finally Ian Barbour as a process theologian as well as physicist.

Finkelstein - First of all it's inspiring to be among so many seekers for the truth or a better way of looking at nature and life. The idea, which has attracted me for decades, has been that of a quantum view of nature since for me, quantum theory is a process theory. Whitehead's attempt at a process theory of nature is particularly important for me as an indication of how such an enterprise might proceed. I certainly didn't imagine getting involved in a search for quantum theology, and I feel that I don't have much to contribute to such a search, but the search for a quantum philosophy strikes me as worthwhile and if God happens to drop in, I'm open. I really did come with some basic questions. I'm trying to get myself to give up the search for 'the' law of nature which has driven me for decades, and so I'm delighted to get reinforcement, from Whitehead himself apparently, even in the bulletin of our meeting. I've gone around asking this question about 'the' law of nature. Let me spell out my full belief, which is based on the precedent of general relativity. Once we used to think that there was a 'right' geometry and then for a century people began waffling and looking around for 'the' right geometry, maybe Euclid was wrong, and then along came Riemann and Einstein and they said no, geometry itself is a variable, and then Einstein came along and said no, geometry is the only variable in the unified field theory. So, nowadays we do these things more quickly and so, from the suggestion that the law is a variable, I go immediately to the inference, of course, it's a quantum variable, everything is quantum. Superposition of the different laws is therefore as good as the laws themselves, and finally, with a variable this complex who needs any other? So probably if the law is a variable it's the only one. That's somehow different from the search for 'the' law of nature. I look around - there it is. I've been looking all my life for it and look, there it is. Right in front of me all this time. But something is still missing. There is this remarkable tendency for events to take a certain course, again and again, and it's not just enough to say look around, that's the way things are, we need more explanation and I'm convinced that this has to do with the structure of the vacuum. I'm searching for those features, which make a vacuum a vacuum, a fit sub-stratum to serve as carrier of the 'law' of nature. The general impression this meeting makes for me is one of great encouragement. There are lots of people looking in this general direction. The hypotheses I make are not being blasted out of the room immediately and thank you very much.

Nobo - As you can judge from my demeanor, I have been extremely excited by the meeting - all three sessions. I have been tremendously stimulated, even challenged. I'm going to go home and start working on some of this. I'm very pleased to see that some ideas of Whitehead that I always maintain have been neglected are precisely the ones that are making an impact or have some use to physicists. Again, that's very encouraging. Papatheodorou unfortunately didn't make it but while I was reading his article (*Process Studies*, 26/3-4), I noticed that he pays more attention to part IV of *Process and Reality.* It strikes me that most people who call themselves Whiteheadian seldom look at part IV of *Process and Reality*. That it's too technical, it's about extension and things like that, and the kinds of things that some Whiteheadians are interested in that have to do with God, experience or aesthetics, they can find in the other parts. But it's there and also in *Science and the Modern World* and in earlier books that you get some of the ideas that are most useful for physics. I'm thrilled that these ideas are being looked at and perhaps some of you will be interested in exploring them further. I'm also very thrilled by the fact that here we have a group of eminent physicists, scientists, and not one of them suffers from what we sometimes call 'scientism,' the belief that you can base a world-view solely on science. Your awareness that that's not the case, and it may be a recent awareness, I don't know, you've expressed this much better than I can. It's exhilarating for me because even in philosophy we have so many thinkers that are slaves to science, what Whitehead called the 'obscurantists of the modern age.' They laugh ideas out of court because they don't fit the current fashionable way of talking or the current fashionable way of thinking. Some of you expressed uneasiness about talking philosophy among philosophers. You need not fear - you're all philosophers. Thank you.

Barbour – I have appreciated being able to attend most of your sessions; I only wish that I could have attended all of them. I respect the careful grounding in the evidence that physical scientists provide, and I agree with the reluctance to move rapidly towards some natural theology. I am concerned as a theologian that the theological community makes use of science in a way that respects its integrity. I don't think that one can derive theology from a scientific picture alone. I am surprised that biological scientists were not represented in this workshop, not one biologist. If we want to make any continuity with the biological world, we have got to further broaden our categories, but I do greatly respect the sensitivity to the limitations of science that have been expressed by several of you. I do think that the connections with theology tend to be more general ones, the kind of elements of wholism and recognition of the interplay of law and chance. These must be taken seriously in any world view, including that of theologians, so I have greatly benefited from what I have heard and am eager to see what further developments might come out of this without expecting that one will be able to develop a metaphysics purely out of quantum mechanics and relativity.

Eastman - Thank you to our panel and to all of the participants. In addition, special thanks to co-convenors Hank Keeton and Philip Clayton. We are looking towards the possibility of doing a book sometime in the future based on all these various inputs, and input is welcome from any of you concerning what you would like to see in such a volume.
[Timothy Eastman and Hank Keeton, eds., *Physics and Whitehead: Quantum, Process and Experience* (Albany: State University of New York Press, 2003).]

Keeton - I also want to express deep personal gratitude to each of you for participating in these three sessions. When Tim and I hatched this idea it really was in our minds as an initial aim and it became a subjective aim, it was an event, we could not control or determine it, we projected into it certain aspects from the past, we knew there was going to be novelty, we knew that, and you all manifested, you all brought that out here, including members of the audience, and I want to thank you. This became more than any of us imagined.

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Appendix A. Process Physics Developments

As demonstrated by the plethora of interpretations of quantum theory over the past century, physics alone does not provide its own unique interpretation. Most philosophical interpretations of modern physics, broadly speaking, can be put into one of two broad categories:

(1) substance as central with relations generally more derivative and, typically, no role for emergence; and
(2) relations as central and a role for emergence.

Classical physics and the many-worlds interpretation of quantum theory are principal examples of the first category of interpretation. The second, relational type is illustrated by many interpretations of modern physics, including mainstream interpretations of quantum physics, relativity theory and quantum field theory. In the broadest sense, such relational interpretations represent steps towards a process physics because of their emphasis on relations and the potential for the emergence of new phenomena and processes. However, in a more restricted sense, interpretations more fully consonant with process philosophy (a "process physics") would provide a key role for time and process in a way that goes beyond treating time as merely spatialized. By some interpretations, for example, the special theory of relativity (SR) is a pure event-communication theory that is fundamentally relational. However, some geometrical interpretations of relativity treat time as spatialized and effectively deny any process.

In this Appendix, we provide references and brief descriptions of several theoretical approaches that go beyond a focus on relations per se and include elements of a process physics.

David Bohm

Author of *Wholeness and the Implicate Order* (London: Routledge, 1980).

In 1950 Bohm wrote a book on quantum theory that many physicists consider to be a model textbook on the subject. In much of his following work, Bohm tried to develop a hidden-variable theory that could more easily fit a realist interpretation than the standard Copenhagen interpretation. Although ultimately unsuccessful in this quest, Bohm was influential in his proposal of an implicate order that grounds the explicate order that represents the everyday world.

David Finkelstein

Author of *Quantum Relativity: A Synthesis of the Ideas of Einstein and Heisenberg* (Berlin: Springer, 1996).

References: http://www.physics.gatech.edu/people/faculty/dfinkelstein.html

The Quantum Relativity Group at the Georgia Tech School of Physics:

http://www.physics.gatech.edu/qr/

Basil J. Hiley

Author (with David Bohm) of *The Undivided Universe: An Ontological Interpretation of Quantum Theory* (London: Routledge, 1993).

Basil Hiley is Emeritus Professor of Physics, Birkbeck College, University of London. For over 30 years, he worked closely with David Bohm on fundamental problems in theoretical physics – work summarized in their book *The Undivided Universe*. Recently, Professor Hiley has been considering how time can be treated in a fully dynamical way by developing algebras, which may lead to a deeper theory from which quantum theory and relativity would emerge as limits. A work of special interest to the process philosophy community was led by Hiley's student: C. Papatheodorou and Basil Hiley, "Process, Temporality and Space-Time," *Process Studies* 26 (1997): 247-278.

John A. Jungerman

Author of *World in Process: Creativity and Interconnection in the New Physics* (Albany: State University of New York Press, 2000).

Shimon Malin

Author of *Nature Loves to Hide: Quantum Physics and the Nature of Reality, a Western perspective* (Oxford: Oxford University Press, 2001).

Ilya Prigogine

Author (with Isabelle Stengers) of *Order Out of Chaos* (NY: Bantam Books, 1983).

Ilya Prigogine received the Nobel Prize in chemistry in 1977 for his contributions to nonequilibrium thermodynamics, especially the theory of dissipative structures. In 1967, Prigogine founded the Center for Statistical Mechanics in Austin, Texas, which was later renamed the Ilya Prigogine Center for Studies in Statistical Mechanics and Complex Systems. Since 1959, he directed the International Solvay Institutes in Brussels, Belgium. Prigogine was a major contributor to the understanding of irreversible processes with a focus on understanding of the role of time in natural sciences. His works with Isabelle Stengers are of special interest to the process community--e.g., *The End of Certainty*: *Time, Chaos and the New Laws of Nature* (NY: The Free Press, 1997).

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Abner Shimony

Author of "Quantum Physics and the Philosophy of Whitehead." In *Philosophy in America*, ed., Max Black (Ithaca: Cornell University Press, 1965); and *Search for a Naturalistic World View* (NY: Cambridge University Press, 1993).

Henry P. Stapp
Author of *Mind, Matter, and Quantum Mechanics* (Berlin: Springer, 1993).
Henry Stapp is a leading figure in interpretations of quantum theory. Most recently, Stapp has focused on applying quantum approaches to the problem of mind and consciousness.
Papers by Dr. Stapp: http://www-physics.lbl.gov/~stapp/stappfiles.html

Information Theoretic Approaches

Professor Cahill's summary of Process Physics – "The older and current physics is appropriately called non-process physics. This new process physics tackles the problem of constructing a model of reality without assuming space, time, matter, etc., but rather by modeling the nature of information and the limitations on such modeling arising from the work of the mathematicians Godel and Chaitin. So far the consequences have been dazzling: a unified theory of space and quantum stuff emerges...but only if we use a new non-geometric modeling of time called process time. This modeling of time matches much more closely the experience of time, namely the present moment effect and the difference between the past and future, something that non-process physics completely failed to model. New results which have arisen recently in the research work are even more startling: it indicated that reality is indeed mind-like...but for a simple reason... both reality and minds process semantic information, that is information which is internally meaningful. This is in contrast to present day physics in which the representation of reality is purely symbolic or syntactical. That method has worked very well but at the deeper levels of reality it is simply inappropriate. In Process Physics semantic information arises as all information is represented by patterns, and these patterns have an infinite fractal depth. Patterns essentially interact by virtue of the structures within the patterns, and not because of some externally imposed symbolic rule. This actual interaction of patterns at all levels essentially corresponds to panexperientialism."

As shown in the paragraph above, Professor Cahill is developing his process physics from a self-organizing neural network model using self-referential noise. Some related information theoretic ways to ground physics have emerged within the past 15 years.

Elden Whipple, inspired by Milic Capek, published a paper in *Il Nuove Cimento* on events as fundamental entities in physics.

More recently, B. Roy Frieden derives some key equations in physics through an analysis of fluctuation spectra. His work yields many advanced and promising results; however, they ground only a Lagrangian approach which appears to be insufficient for many key results in physics [Finkelstein, private communication, 2002].

A similar reduction of physics to information theoretic units is attempted by Edward Fredkin. His digital mechanics is described as a unified, discrete field theory of physics and, like Frieden, he achieves some reasonably advanced results.

Another approach by Stephen Wolfram, founder and President of Wolfram Research, Inc., creator of Mathematica, is based on algorithmic complexity theory and has received substantial press coverage late in 2002. It even received a review by Steven Weinberg in the *New York Review of Books* (S. Weinberg, "Is the Universe a Computer?," Oct. 24, 2002: 43-50). Unfortunately, Wolfram's work with automatons is much less developed for physics relevance than that by Cahill, Fredkin, or Frieden.

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Web Sites

Reginald Cahill
http://www.scieng.flinders.edu.au/cpes/people/cahill_r/processphysics.html
Edward Fredkin http://www.digitalphilosophy.org/digital_philosophy/toc.htm

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Appendix B. Process Thought and Natural Science

Reprint of special focus sections of *Process Studies*, Eastman, Timothy E., ed.,
Vol. 26/3–4, Fall–Winter, 1997; followed by Vol. 27/3–4, Fall–Winter, 1998.
Contents and editor's introductions are given below;
special focus articles in PDF format available at < hypertext link to PDF download >

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Volume 26/3–4 (Fall-Winter 1997)

Special Focus Articles: Process Thought and Natural Science Edited by Timothy Eastman

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Process Thought and Natural Science

(Special Focus Introduction)

Timothy E. Eastman

The ongoing research program of process thought meets some of its most crucial tests in efforts towards a comprehensive philosophy of nature. Contributors to the two special focus issues on natural science for *Process Studies* provide many examples of such tests and commentary that reflect contemporary scientific thought. A core element of modem scientific methodology is the search for invariant, physical relationships that simplify our understanding of complex systems. In addition to a preference for some form of critical realism and inter-subjective testability, scientists search for relationships that are both universal and repeatable. Indeed, the very success of this approach has led to more and more frequent use of "event/process" versus "substance/thing" language in the sciences. In particular, modern physics is much more about interactions and relations than about things and substances.[1] This emergence of process language is presumably related to how "processes are inherently universal and repeatable" and how "any actual process is at once concrete and universal."[2] Of course, we will continue to use both process and substance terms in our language because they reflect pervasive aspects of reality, noting however that their relative usage is a contingency of particular language and culture.[3] Just as process approaches provide a powerful

1 This increase in "event/process" language can be readily checked by reading any of the major physics journals and comparing the frequency of occurrence of event/process concepts and terms in articles published a century ago versus the latter half of the twentieth century. For relativity theory, in particular, Einstein's theory of special relativity can be considered as simply a relational, eventist theory of clocks, light signals and events with only implicit reference to things or substances. For quantum theory, Finkelstein defines "praxic" theories as ones that "take actions as primary entities, and regard states of being as secondary, relative, derivative from actions, and approximations of limited validity." In contrast with classical physics he states that quantum physics "seems irredeemably praxic." (David Finkelstein, *Quantum Relativity* [Berlin: Springer-Verlag, 1996], 26).

2 N. Rescher, "The Promise of Process Philosophy," *Process Studies* 25 (1996), 60.

3 D.L. Hall and R. T. Ames, *Anticipating China* (Albany, NY: State University of New York Press, 1995), 134-141. Hall and Ames argue that correlative or analogical modes displace substance language in classical Chinese.

and elegant way of resolving some age-old problems in philosophy (RW, PM), they are useful tools as well for addressing various problems in the natural sciences as the papers in these two special issues demonstrate.

The first set of papers focuses on physics and the second set focuses on broader issues, including our sense of nature, biological systems and evolution. *Papatheodorou and Hiley* discuss a conceptual and mathematical framework for relativistic physics based on a process ontology. They obtain results that are "very much in accordance with the original notion of process and temporality proposed by Whitehead" including a quantization of time. *Finkeistein and Kallfelz* examine a special self-referential algebra for relating particle structure to spacetime structure and find promising analogues between their quantum network dynamics and Whitehead's philosophy of organism. Developments in quantum physics appear to be an especially rich area for testing and developing process approaches as illustrated by these first two papers and extensive treatments of the mind-body problem and related issues by Stapp[4] and Shimony.[5] Recent developments in quantum measurement theory also suggest a fundamental physical basis for the possibility-actuality distinction that is so central to process thought.[6]

Through a consideration of the work of Faraday, Maxwell and Whitehead, *Athearn* more fully unpacks the modern meaning of physical objects and fields. This sets the stage for *Fagg's* discussion of the electromagnetic interaction which underlies essentially all processes that we directly experience, from rocks to plants and animals because the electromagnetic interaction is the essential physical agent in effecting the concrescence of microscopic events interpreted by Whitehead as "actual occasions." The irreversible temporal character of prehension is explained similarly.[7] Fagg further suggests that "the electromagnetic interaction and light, its radiation, are meaningful physical correlates for the immanence of God."[8] In response to the chapter on "The

4 Henry P. Stapp, *Mind, Matter, and Quantum Mechanics* (Berlin: Springer-Verlag, 1993).

5 Abner Shimony, "On Mentality, Quantum Mechanics and the Actualization of Potentialities," *The Large, the Small and the Human Mind,* Roger Penrose with Abner Shimony, Nancy Cartwright and Stephen Hawking, edited by M. Longair (Cambridge: Cambridge University Press, 1997), 144-160.

6 Jeffrey Bub states that "the actual properties in a classical world evolve in a fixed Boolean possibility space, while the actual properties in a quantum world evolve in a dynamically changing non-Boolean possibility space. Classically, only the actual properties are time-indexed; quantum mechanically, both the actual properties and the possible properties are time-indexed." (Jeffrey Bub, *Interpreting the Quantum World.* [Cambridge: Cambridge University Press, 1997], 239).

7 See also Charles Hartshorne, "Whitehead's Revolutionary Concept of Prehension, *" International Philosophical Quarterly* 19 (1979), 253-263.

8 Fagg emphasizes the speculative nature of his discussion on immanence. Just as with Whitehead, these special focus essays have relatively little theistic reference, recognizing that such issues engender ultimate mystery (see Gordon Kaufmann, *In Face of Mystery* [Cambridge, MA: Harvard UniversityPress, 1993]).

Prejudice in Favor of Symmetry" in Hartshome's major work (CSPM), *Rosen* discusses the importance of symmetry principles in physics, but goes on to demonstrate how asymmetry is a necessary condition for symmetry, in agreement with Hartshome's argument. This grounding of symmetry within an all-embracing asymmetry has profound philosophical consequences as discussed by George W. Shields in his recent paper on the interface between analytic and process philosophy.[9]

The methods and results of classical physics such as classical mechanics continue to be important foundations for modern physics. Certain traditional metaphysical notions such as determinism and materialism are often presumed to be built into it. However, if nonlinear dynamics and collisionless space plasma physics had been part of classical physics when it first developed, then the metaphysical notions of determinism and materialism would have been seen as very problematic and as speculative concepts that should be separately argued as philosophical issues distinct from the essential physics. The apparent determinism of physics, and especially classical physics, arises from the deterministic form of the equations combined with how unique and precise predictions are often possible given exact initial and boundary conditions. Infinitely precise or complete specification of initial and boundary conditions is never possible. In addition, certain nonlinear dynamical systems have chaotic regimes of parameter space which defy exact predictability.[10] Physics involves debating various levels of approximation, precision, and determination whereas the merits and use of the notion of determinism is a distinct philosophical issue. As these special focus papers on natural science demonstrate, when substance metaphysics is not surreptitiously packaged with the physics and forced to compete directly with process metaphysics,"[11] an entirely new

9 If the concept of "symmetry within an all-embracing asymmetry" is sound, "it carries a devastating critique of some still prestigious philosophical contentions in the tradition of Hume. If directional or asymmetrical connectedness is a deep structure of possible worlds" then the "mutual separability of objects or events is not entailed by mere distinguishability." A further implication, Shields argues, is that "tense can be an 'uneliminable' aspect of the semantics of propositions" (George W. Shields, Introduction, "On the Interface of Analytic and Process Philosophy," *Process Studies* 25 [1996], 45-46).

10 Tom Mullin, editor, *The Nature of Chaos* (Oxford: Clarendon Press, 1993).

11 George R. Lucas, Jr, "The Seventh Seal' - On the Fate of Whitehead's Proposed Rehabilitation," *Process Studies 25* (1996), 105-117. Lucas shows here and in *The Rehabilitation of Whitehead* how Whitehead has not been 'refuted' in the history of philosophy and that the often-claimed refutation of Whitehead has depended on avoidance of any genuine dialogue with the process-relational tradition.

and productive approach is opened to interpreting the philosophical implications of contemporary science.

To illustrate the emergence of process modes of description within contemporary science, Table 2 contrasts common interpretations of classical science (first column) with the treatment of the corresponding concept or terms in contemporary science (second column). The table is constructed to emphasize certain dualities which have often been converted into some form of monism or dualism, with one term of the duality taken as fully real and the other term treated as merely derivative or, in some cases, simply unreal. In contrast, contemporary science has come to accommodate the dualities in some form of "both-and," non-dualistic, sense. Capek's classic text (PICP) very clearly describes many aspects of the transition from classical to contemporary physics. Papers of the special issues on natural science provide examples of the dualities listed in the table and their "both-and" accommodation in modern science. Within the process tradition, Charles Hartshorne has provided the most detailed account of such dualities or metaphysical contraries (ZERO; CSPM).[12] The efficacy of such "both-and" constructions in science may arise from the inevitable stages of serial order illustrated in causal before-after sequencing.

Whitehead's work on relativity theory is not discussed in the special issue papers but has received some recent attention. Russell has found that Whitehead's key formulae, when converted to modem notation, contain the Schwarzschild solution for the gravitational field near a spherically-symmetric mass concentration just as the Einstein/Ricci equation for general relativity, which suggests that "either a) Whitehead's free-space equations are actually equivalent to Einstein's free-space field equations (though this has not yet been shown explicitly) or b) they are fundamentally different from Einstein's equation, leading to a new class of predictions and tests of the two theories. In addition the explicit derivation of the Schwarzschild solution from Whitehead's equations showed for the first time that Whitehead's theory … is a robust field theory and not simply an action-at-a-distance theory. As a field theory it could in principle be much more attractive to physicists concerned about gravitational waves and topics in quantum gravity."[13] At this stage, however, Whitehead's approach to a theory of gravity remains quite undeveloped and his basic theory is generally considered as incorrect.[14]

[12] James Bradley, "Metaphysics, Mathematics, and Whitehead," *Journal of Speculative Philosophy* 10 (1996), 233-245.

[13] Robert J. Russell, "Whitehead, Einstein and the Newtonian Legacy," *Proceedings of the Cracow Conference,* 25-28 May 1987. Edited by G.V. Goyne, M. Heller, and J. Zycinski (Citta Del Vaticano: Specola Vaticano, 1988), 176-192.

[14] Crockett L. Grabbe, "Review of Russell, Whitehead, Einstein and the Newtonian Legacy," *Process Studies* 23 (1994), 285-289; reprinted in this current issue *of Process Studies.*

The second set of special focus papers begins with *Schulkin's* analysis of our conceptions of "nature" in which he argues for the legitimation of values and its importance in grounding decision-making in modem ecological economics. *Ahmed* develops a conceptual model of the universe based on chaotic dynamics and contingencies of self-organizing systems. From this basis, he suggests an approach to the emergence of consciousness and sense of moral purpose in humans and links these in a process and ecologically-based ontology of an evolving universe. As noted by *Earley,* both theistic and naturalistic approaches are continually changing and complicate any comparison. With this difficulty in mind, he examines conflicts between these approaches, reviews a novel approach by Stuart Kaufmann towards the scientific understanding of life's origins and explores relationships between this new approach and some contemporary philosophical theologies of creation. *Charles Birch* builds from self-organization in cosmic and biological evolution and internal relations to creativity, feeling and purpose. *Henry and Valenza* start with examining the basic connection between mass and substance from both traditional and process perspectives. They account for the origins and effectiveness of materialist-substance ontology within the context of a process-oriented world and show the advantage of not making materialism ultimate. *Code* argues that both myth and mysticism are an irreducible part of a comprehensive natural philosophy, and he attacks the illusion of scientific super-rationality. By incorporating both myth and rationality, modern science and technology can be practiced with an enhanced sense of ethics and responsibility which is critical as this "rational" animal becomes ever more powerful on a global scale.

The name "process" in process philosophy may suggest that it opts, with Heraclitus, for "becoming" over against "being" or "change" over against "permanence." However, the implication of modern science is that a balance between contraries is achieved but, as with Hartshorne, this balance is not simply symmetrical.[15] Despite its name, process philosophy accommodates these dualities as much as it avoids dualism. Elizabeth Kraus has elegantly described this element of Whitehead's process philosophy:

> it asserts that being and becoming, permanence and change must claim coequal footing in any metaphysical interpretation of the real, because both are equally insistent aspects of experience.[16]

[15] In his logic of ultimate contrasts, Hartshorne pairs r-terms (Peirce's Seconds, Thirds) with a-terms (Peirce's Firsts) and provides two rules of interpretation, proportionality and two-way, asymmetrical necessity (ZERO, Chapter 7).

[16] Elizabeth M. Kraus, *The Metaphysics of Experience* (New York, NY: Fordham University Press, 1979), 1.

Table 2: *Emergence of Process Modes of Description in Contemporary Science*

Classical Science	*Contemporary Science*
Substance only; materialism	Both substance and event-oriented descriptions
External relations only	Both external and internal relations
Continuity only; no ultimate discreteness	Both continuity and quantization
Symmetry only	Both symmetry and asymmetry; asymmetry as prior
Space only; time spatialized	Both space and time; coupled space-time metric
Determinism only	Both predictability/determination and indetermination[17]

Particles only	Both particles and waves; many dualities[18]
Parts only	Both parts and wholes[19]
External only (source for order)	Both external and internal sources of order; self-organization
Efficient cause only	Both efficient cause and other types[20]
No intrinsic parameter limits	Fundamental limits set through relations between parameters (e.g., v<c)

[17] The term “determination” is used here to denote the predictability of causal order as practiced in science, whereas “determinism” is a metaphysical claim requiring philosophical argument.

[18] Edward Witten, “Duality, Spacetime and Quantum Mechanics,” *Physics Today* 50 (1997), 28-3 3.

[19] Collisionless space plasmas provide a clear example of where distinct macroscale processes emerge and where “the large-scale dynamics are immune from the details of microphysics.” In turn, some systems such as superfluid systems exhibiting Bose-Einstein condensation have a close coupling of micro-to-macroscale, and there are other systems that fill in between these two extremes (E. Siregar, S. Ghosh, and ML. Goldstein, “Nonlinear entropy production operators for magnetohydrodynamic plasmas,” *Phys. Plasmas* 2 (1995), 1481; see also T.E. Eastman, “Micro-to-macroscale perspectives on space plasmas,” *Physics of Fluids B* (Plasma Physics) 5(1993), 2671.

[20] Mario Bunge, *Causality: The Place of the Causal Principle in Modern Science* (Cambridge. MA: Harvard University Press, 1959).

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CSPM Charles Hartshorne, *Creative Synthesis and Philosophic Method.* La Salle, IL: Open Court, 1970.

PICP Capek, Milic, *Philosophical Impact of Contemporary Physics*. Princeton, NJ: D. Van Nostrand Company, Inc., 1961.

PM Nicholas Rescher, *Process Metaphysics.* Albany, NY: -State University of New York Press, 1996.

RW George R. Lucas, Jr., *The Rehabilitation of Whitehead..* Albany: State University of New York Press, 1989.

ZERO Charles Hartshorne, *The Zero Fallacy and Other Essays in Neoclassical Philosophy.* La Salle, IL: Open Court, 1997.

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Process Studies
27/3–4 (Fall – Winter 1998)

Focus: Process Thought and Natural Science, II *Edited by Timothy E. Eastman*

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241 JAY SCHULKIN, Evolving Sensibilities of our Conception of Nature
255 A. KARIM AHMED, Causality, Chaos, and Consciousness: Steps Toward a Normative Cosmological Principle in an Evolving Universe
267 JOSEPH E. EARLEY, SR., Naturalism, Theism, and the Origin of Life
280 CHARLES BIRCH, Processing Towards Life
292 GRANVILLE C. HENRY and ROBERT J. VALENZA, The Concept of Mass in Process Theory
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Focus

Process Thought and Natural Science, II

Timothy E. Eastman

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Our sense of nature, biological systems and evolution is the focus of this second of two *Process Studies* issues on Natural Science, the first of which concentrated on physics [PS 26/3-4]. Papers for both issues are listed in Table 1.

The second set of focus papers begins with Jay *Schulkin's* analysis of our conceptions of "nature" in which he argues for the legitimation of values and its importance in grounding decision-making in modern ecological economics. Through a process-relational basis, he argues that values are "real entities of our culture and nature" and often permeate inquiry. Expanding the concept of rights and natural resources to include future generations, fully adequate decision-making then balances rights and relationships to nature, to others, and to our transactions and labor.

Karim Ahmed develops a conceptual model of the universe based on chaotic dynamics and contingencies of self-organizing systems. From this basis, he suggests an approach to the emergence of consciousness and sense of moral purpose in humans and links these in a process and ecologically based ontology of an evolving universe. Ahmed's argument leads to an explicit role for final causation or teleology in biological evolution which he relates in turn to Whitehead's ecological ontology. Following this argument further leads to self-cognition and consciousness where he notes that "Whitehead believed that *conscious and purposive acts are the tip of a 'prehensive' iceberg* that remains below the level of consciousness, yet participates in every moment of concrescence, resulting in novelty and creativity in an evolving universe."

As noted by *Joseph Earley,* both theistic and naturalistic approaches are continually changing and complicate any comparison. With this difficulty in mind, he examines conflicts between these approaches, reviews a novel approach by Stuart Kaufmann towards the scientific understanding of life's origins and explores relationships between this new approach and some contemporary philosophical views of creation.

Charles Birch builds from self-organization in cosmic and biological evolution and internal relations to creativity, feeling and purpose. He presents several arguments to deny the "extreme rejection of final causation from our categories of explanation." Instead, Birch notes two key aspects of internal relations: (1) internal relations with the immediate past or

memory based on Whitehead's concept of prehension and (2) internal relations for an entity's self—constitution "both for immediate 'satisfaction' and for the sake of the anticipated possible future state."

Granville Henry and *Robert Valenza* start with examining the basic connection between mass and substance from both traditional and process perspectives. They account for the origins and effectiveness of materialist- substance ontology within the context of a process.oriented world and show the advantage of not making materialism ultimate.

Murray Code argues that both myth and mysticism are an irreducible part of a comprehensive natural philosophy, and he attacks the illusion of scientific super-rationality. By incorporating both myth and rationality, modern science and technology can be practiced with an enhanced sense of ethics and responsibility which is critical as this "rational" animal becomes ever more powerful on a global scale.

Table 1. Focus Issues on Natural Science

First Focus Issue: PS 26/3-4 (1997)

•"Process Thought and Natural Science": Timothy E. Eastman
•"Process, Temporality and Space~Time": C. Papatheodorou and Basil J. Hiley
•"Organism and Physics": David R. Finkelstein and William M. Kallfelz
•"Whitehead as Natural Philosopher: Anachronism or Visionary?": Daniel Athearn
•"Electromagnetism, Time and Immanence in Whitehead's Metaphysics": Lawrence W. Fagg
•"Response to Hartshorne Concerning Symmetry and Asymmetry in Physics": Joseph Rosen

Second Focus Issue: PS 27/3-4 (1998)

• "Evolving Sensibilities of our Conception of Nature": Jay Schulkin
•"Causality, Chaos and Consciousness: Steps Towards Normative Cosmological Principles": A. Karim Ahmed
• "Naturalism, Theism and the Origin of Life": Joseph E. Earley, Sr.
•"Processing Towards Life": Charles Birch
• "The Concept of Mass in Process Theory": Granville C. Henry and Robert J. Valenza
•"Explanation and Natural Philosophy: Or, The Rationalization of Mysticism": Murray Code

The first focus issues focused on physics and was initiated by *Papatheodorou and Hiley* who discussed a conceptual and mathematical framework for relativistic physics based on a process ontology. They obtain results that are "very much in accordance with the original notion of process and temporality proposed by Whitehead" including a quantization of time. *Finkelstein and Kallfelz* examine a special self-referential algebra for relating particle structure to spacetime structure and find promising analogues between their quantum network dynamics and Whitehead's philosophy of organism. Developments in quantum physics are especially effective for testing and developing process approaches as illustrated by these first two papers.

Timothy Eastman, "Focus Introduction" 239

Through a consideration of the work of Faraday, Maxwell and Whitehead, *Athearn* more fully unpacks the modern meaning of physical objects and fields. This sets the stage for *Fagg's* discussion of the electromagnetic interaction which underlies essentially all processes that we directly experience, from rocks to plants and animals, because the electromagnetic interaction "is the underlying physical agent in effecting the becoming of an actual occasion" (PS 26: 308) The irreversible temporal character of prehension is explained similarly. Rosen discusses the importance of symmetry principles in physics and further demonstrates that asymmetry is a necessary condition for symmetry. This grounding of symmetry within an all-embracing asymmetry has profound philosophical consequences, as discussed by George W. Shields in his recent paper on the interface between analytic and process philosophy (PS 25: 45-46).

One contributor to this issue, *Granville Henry,* has developed a systematic analysis of Whitehead's philosophy with contemporary computer programming methods (FC). In particular, he provides a partial implementation of Whitehead's categorical scheme in Prolog (programming in logic), a contemporary programming language especially well suited to the expression of general logical ideas including the predicate calculus. Henry notes that Whitehead defines mathematics as "the study of pattern" (MG) and that Whitehead illustrates how distinct mathematical-media "may serve as different ways of illuminating the same mathematical eternal objects that function as potential patterns of actual entities" (FC 113). One particular illuminating perspective is that of computational procedures which, in Prolog, can be used to represent any symbolic procedure. Henry creatively applies Prolog to map out and illustrate many concepts in Whitehead's descriptive metaphysics. For example, the "analysis of actual entities is seen to be an analysis of the procedures of prehensions of actual entities" (FC 114). Not only does this 'procedural' perspective help to clarify the relationship of eternal objects, actual entities and other Whiteheadian concepts, it also points to possible ways to refine his descriptive metaphysics by taking advantage of many mathematical developments since Whitehead's time.

In his *Quantum Relativity* (QR), David Finkelstein expertly applies modern mathematical physics to the interface of quantum physics and relativity theory and provides extensive discussion of the associated philosophical implications. His discussion employs a distinctly process–relational perspective, noting for example that for both quantum and relativity theory "each relativizes concepts that used to be absolute (Being: Space)" and "each replaces a static object (state: space point) by a transient process (act: spacetime point)." As with Henry's work, Finkelstein discusses new technical developments that illustrate the prescience of Whitehead's thought, although usually without specific reference to Whitehead. "After we present the usual quantum theory, we explore a quantum network dynamics with a discrete fundamental quantum of time or chronon" (QR 22). Descriptive metaphysics, for Whitehead, "is the endeavour to frame a coherent, logical, necessary system of general ideas in terms of which every element of our experience can be interpreted" (PR 4).

Cosmic and biological evolution, modern physics, mathematics and symbolic procedures all provide powerful new tools to test any possible metaphysical framework but are nevertheless only particular instantiations of such all–inclusive conceptual frameworks.

References

FC Granville C. Henry, *Forms of Concrescence: Alfred North Whitehead's Philosophy and Computer Programming Structures.* Cranbury, NJ.: Associated University Presses, 1993.

MG Alfred North Whitehead, "Mathematics and the Good." In *The Philosophy of Alfred North Whitehead*. Evanston, IL: Northwestern University Press, 1941; also found in *Science and Philosophy.* New York: The Philosophical Library, 1948.

QR David Ritz Finkelstein, *Quantum Relativity: A Synthesis of the Ideas of Einstein and Heisenberg.* Berlin: Springer-Verlag, 1996.

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Appendix C. Whitehead and Natural Science

Reprint of special issue of *Process Studies*, Vol. 11/4, Winter, 1981, Dean R. Fowler, ed.
Contents and editor's introduction given below;
special issue articles in PDF format available at < hypertext link to PDF download >

Process Studies
Volume 11 / Number 4 Winter / 1981

Special Issue on Whitehead and Natural Science

edited by Dean R. Fowler

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JAMES E. HUCHINGSON
226 Organization and Process: Systems Philosophy and Whiteheadian Metaphysics
JAMES E. HUCHINGSON (Ph.D., Emory University, 1977) is Associate Professor and chair of the Department of Philosophy and Religious Studies at Florida International University, Miami, Florida 33199. He is contributing editor to *Zygon* and is currently at work on a manuscript developing a systems view of human nature.

JOSEPH E. EARLEY
242 Self-Organization and Agency: In Chemistry and In Process Philosophy
JOSEPH E. EARLEY is Professor of Chemistry at Georgetown University, Washington, D.C. 20057. In addition to an earlier note in this journal (PS 11:35), he has written more than fifty chapters, articles, and notes dealing with rates and mechanisms of chemical reactions.

HENRY J. FOLSE, JR.
259 Complementarity, Bell's Theorem, and the Framework of Process Metaphysics
HENRY J. FOLSE, JR. (Ph.D., Tulane University, 1972), is Associate Professor of Philosophy at Loyola University, New Orleans, Louisiana 70118. He has authored numerous articles on quantum theory, scientific rationality, atomism, metaphysics, and process philosophy. He is currently completing a book on the philosophy of Niels Bohr.

GEORGE WOLF
274 Psychological Physiology From the Standpoint of a Physiological Psychologist
GEORGE WOLF is Research Professor of Physiological Psychology at New York University, New York, 105303. He was introduced to process thought by Robert Neville and subsequently studied with John Cobb, Charles Hartshorne, and Paul Weiss.

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Editor's Preface

Dean R. Fowler

Developments in twentieth century sciences had a tremendous impact on the formulation of Whitehead's cosmology. Whitehead stated that he arrived at his cosmological position as a result of studies in mathematics and mathematical physics (SMW 152). His methodology involved imaginatively generalizing the factors comprising one discipline, for instance physics or psychology, in such a way that they could be applicable to all disciplines (FR 76, RM 86f.). In order to be faithful to Whitehead's own methodological principles and cosmological vision, we must continually reevaluate the adequacy of Whitehead's vision by studying the foundations of his cosmology in light of ongoing developments in the natural and human sciences.

The essays in this special issue of *Process Studies* assess the adequacy of Whitehead's philosophical vision from the perspective of current theoretical positions within science and suggest directions for modifying his position in light of scientific developments. The first two essays share common concerns. James Huchingson sketches the similarities and differences between the philosophy of general systems theory and Whiteheadian metaphysics. One of the important current contributors to general systems theory is Ilya Prigogine, whose work in chemistry has provided theoretical foundations for the study of the dynamics of interacting systems. The essay by Joseph Earley draws upon the work of Prigogine and others to suggest that Whitehead's notion of the actual entity should be modified to be more consistent with the findings in recent studies of complex chemical processes.

Unlike Earley's essay, which suggests modifications in Whitehead's scheme, the final essays of the issue suggest ways to expand Whitehead's thought. Henry Folse evaluates the metaphysical implications of Bohr's interpretation of quantum theory within the context of Whitehead's critique of the foundations of classical physics. While Whitehead's perspective was primarily influenced by the "old quantum theory" predating 1925, Folse argues that Whitehead's metaphysics is consistent with Bohr's post-1925 notion of complementarity. The final essay of this issue concerns the implications of Whitehead's vision for developing a framework within which current issues in physiological psychology may be addressed. George Wolf develops a model for approaching the mind-brain issue and demonstrates how the scientific implications of such a position, informed by Whitehead's cosmology, have an impact on directing research questions.

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Appendix D. Philosophical Implications of Quantum Theory

Christoph Wassermann, "Philosophical Implications of Quantum Theory: Remarks on C. F. von Weizsacker's Abstract Reconstruction of Quantum Theory in the Light of A.N.Whitehead's Philosophy of Organicism" (first publication of previously unpublished manuscript, 1991) and "Note on the Physical Meaning of Impetus" (1986).

Philosophical Implications of Quantum Theory

Remarks on C. F. von Weizsacker's
Abstract Reconstruction of Quantum Theory
In the Light of A. N. Whitehead's Philosophy of Organism

Christoph Wassermann

(Written November 1991; presented at the Whitehead and Relativity meeting in Kansas City, Missouri on November 26 and 27, 1991, revised in December 1991.)

1. Introduction

a) Relating Philosophy to Physical Theories

In trying to assess the relevance of a philosophical theory, such as Whitehead's, to the understanding of physical theories, such as quantum theory, one can methodically proceed along at least two different directions. The first is to try to construct the foundational concepts and the basic tenets of the physical theory starting out from central elements of the philosophical theory in question, i.e. in our case to try to develop quantum theory out of process philosophy. This task is very difficult, because Whitehead, aside from some dispersed hints, did not explicitly indicate how this should be done. Fortunately there is another possibility. It consists in the confrontation of the philosophical theory in question with philosophical efforts to understand the physical theory under study. In our specific example this would mean the confrontation of philosophical reflections on quantum theory with Whitehead's philosophy. It is this second approach that I will pursue in the following presentation.

b) Philosophical Interpretations of QT

Now I am aware of the fact that, regarding the philosophical interpretation of quantum theory, there are several schools of thought. Some of the more prominent ones have been condensed in the publications of Gunther Ludwig, e.g. *The Foundations of Quantum Mechanics* (first published in 1954), in the work of Joseph M. Jauch from Geneva *Foundations of Quantum Mechanics* (first published in 1968), or in the profound book by Max Jammer *The Philosophy of Quantum Mechanics* (first published in 1974). A detailed analysis would require the confrontation of all these and still others with Whitehead's thought. This is an unfathomable task. To start somewhere, I will concentrate myself on only one such approach, one which in my opinion comes astonishingly close to many of Whitehead's philosophical views, and which is the fruit of several decades of rigorous reflection. I mean the life-work of Carl Friedrich von Weizsäcker, especially as summarized in his book *Aufbau der Physik* (*The Reconstruction of Physics*, first published in 1985 with Hanser in München). If it is possible to show that there are not only some parallels but also equivalent or compatible conceptions between Weizsäcker and Whitehead then it would be much easier to see whether Whitehead's philosophy conforms to quantum theory (and vice versa) or not. The latter is possible because Weizsäcker explicitly reconstructs quantum theory starting out from philosophical propositions.

I do not purport to have understood either Whitehead or Weizsäcker enough to be able to propose definite judgments on equivalences between their thought. This is not astonishing because each of these two philosophical endeavors took decades for its formulation and explication, and I have spent much less than a decade trying to understand them. (In addition both of them diverge significantly from the general trend of interpreting quantum theory philosophically.) But in spite of the immensity of the task, I think that I can already now point to some points of possibly fruitful confrontation, on which future research could be concentrated. This is why the following presentation should not be understood as a presentation of results of rigorous research, but rather as a summary overview on possible points of contact between Whitehead and Weizsäcker in view of motivating others to join in the task of conducting more detailed research in this field.

c) An Overview

After a short biographic and bibliographic overview on Weizsäcker I will basically follow the train of thought as formulated in Weizsäcker's *Aufbau der Physik* (in the following abbreviated with AP) trying to show, on each level of generality, possible similarities to Whitehead's thought, especially as expressed in *Process and Reality* (A.N. Whitehead, *Process and Reality. An Essay in Cosmology*. Gifford Lectures Delivered in the University of Edinburgh During the Session 1927-1928. First published in 1929 by the Macmillan Publishing Co. Citations are from the corrected edition, edited by D.R. Griffin and D.W. Sherburne (Free Press) New York 1978, in the following abbreviated with PRc). It will be my basic contention that in PR Whitehead effected a philosophical paradigm shift that in part was motivated by the physical paradigm shift that took place in the formulation of quantum theory. And my general aim will be to show in some detail which elements of the quantum theoretical paradigm shift can be correlated to elements of Whitehead's philosophical paradigm shift. I do not think that Weizsäcker went as far as Whitehead did in effecting a transformation of the foundations of occidental philosophy, comparable to that envisaged by Martin Heidegger and partially implemented in the latter's only recently published magnum opus *Beiträge zur Philosophie: Vom Ereignis.* But I do think that Weizsäcker was able to formulate the conceptual consequences of the physical paradigm shift of QT in such a way that its relevance for possible philosophical paradigm shifts can be fruitfully discussed.

2. A Biographic and Bibliographic Sketch on Weizsäcker

a) The Weizsacker Clan

The physicist, philosopher and peace researcher Carl Friedrich Freiherr von Weizsäcker belongs to a famous German family. His father Ernst Frhr. von Weizsäcker was a high rank diplomat in the ministry of foreign affairs during the Third Reich, but was deposed in 1944 because of his opposition to Ribbentrop, the secretary of state at the time. His uncle Viktor von Weizsäcker was a well known neurologist and philosopher, who developed the theory of the Gestaltkreis concerning the relationship of an organism to its environment, which influenced Carl Friedrich to some extent. And of course his younger brother Richard von Weizsäcker is currently the president of the Federal Republic of Germany.

b) Carl Friedrich von Weizsäcker

Carl Friedrich himself was born in Kiel in 1912. In 1927, at the age of 15, he met Werner Heisenberg for the first time. The meeting was decisive, because it influenced Carl Friedrich to become a physicist. After studies in Berlin, Göttingen and Leipzig (from 1929 to 1933) he wrote a dissertation with Heisenberg on "The passage of fast corpuscular rays through a ferromagnetic substance" and three years later he completed his habilitation with a publication "On the spin-dependence of nuclear forces". During the war Weizsäcker belonged to the team around Heisenberg and Born who worked on the construction of a nuclear weapon in southwestern Germany (at Haigerloch, not far from Tübingen). After the war and his internment by the British forces he became professor in Göttingen working mainly on astrophysical problems. In 1957 he initiated a motion opposing the implementation of nuclear weapons in the then newly created federal German army, signed by 18 atomic physicists, among them Heisenberg and Born. In the same year he became professor of philosophy at Hamburg university. From 1971 until his retirement in 1980 he created and directed the Max-Planck Institute for Research on Conditions of Life in a Scientific-Technical World (Max-Planck-Institut zur Erforschung der Lebensbedingungen der wissenschaftlich-technischen Welt) in Starnberg close to Munich. Since then he has participated in many ecumenical and interreligious gatherings with the aim of forwarding peace in the world. This reflects his life-long interest in religion, especially the Christian faith.

His list of publications comprises more than 400 items (including 35 books), with topics concentrated in the areas of physics, politics and philosophy (An exhaustive bibliography on C.F. von Weizsäcker can be found in Part IV of my *Struktur und Ereignis* from 1991). I will only quickly mention some publications in the last area, highlighting his efforts to philosophically understand modern physics.

c) Overview on His Publications on the Philosophy of Modem Physics

(i) Before the War. According to his own explication (AP 17), Weizsäcker always wanted not only to practically apply physical theories but also to ask, what one does, when one applies these theories. Therefore it is not astonishing that already as a physicist he published papers of a philosophical character. A number of these articles are gathered in the volume *The World View of Physics* (*Zum Weltbild der Physik*) first published in 1943 (transl. into English in 1951).

Three important and indirectly related articles from this first phase, and which indicate the basic orientation of his ulterior efforts to understand physics philosophically, are entitled: "The second law (of thermodynamics) and the difference between past and future", "The relationship of quantum theory to Kant̤'s philosophy", and "The relevance of logic for natural science". The first paper founds Weizsäcker's interest in the nature of time, and the second his interest in the nature of experience. Later on he combined these two ideas in the assessment that the nature of experience is essentially connected to the nature of time, for "experience is a temporal process (e.g. learning now from the past for the future)" (*Einheit der Natur* 13, "*Erfahrung ist em zeitlicher Vorgang (z.B. jetzt aus der Vergangenheit für die Zukunft lemen)*"). In the third paper it became clear to him that the philosophical penetration of quantum theory implies a reorientation already on the level of logic.

(ii) After the War. This basis of his thought was further developed by Weizsäcker after he switched to philosophy in 1957. An important publication from this time was his article "The problem of time as a philosophical problem". In it Weizsäcker saw that the reformulation of logic necessitated by quantum theory must be a logic of time (cf. AP 17). In the meantime Weizsäcker had gathered a number of collaborators and students who pursued these questions together with him. An intermediary report was published in 1971 under the title "The unity of nature" (*Einheit der Natur*, abbreviated as EN). Here for the first time it became apparent that Weizsäcker was not only interested in the unity of physics but also in the unity of nature. For him "the unity of nature, if it is understood in the unity of physics, (is) the unity of experience" (EN 13, "*die Einheit der Natur (ist), wenn sie in der Einheit der Physik verstanden wird, die Eineheit der Erfahrung*"). This extension reflects his research on Plato and Aristotle. It also provided him with the possibility to pose the question regarding God in the context of his philosophy, without having to go through a jump in faith. For a reflection on the unity of physics, of nature and of experience, understood as the unraveling of the conditions of the possibility of nature, physics and experience, necessitates grappling with the "question regarding the unity of the one" (EN 15, "*Frage nach der Einheit des Einen*"). But "the One is the concept of classical philosophy for God. The unity of nature (therefore) is for philosophy the way in which nature allows God to be seen" (EN 16, "*das Eine ist der Begriff der klassischen Philosophie für Gott. Die Einheit der Natur is (darum) für these Philosophie die Weise, wie die Natur Gott sehen läßt*"). Thus Weizsäckeṛ's philosophical efforts must also be understood as the trial to found a natural theology.

(iii) The Final Synthesis. The most encompassing report on the advance of his own research and on that of related studies by his numerous collaborators is his book *Aufbau der Physik,* published in 1985. It constitutes the first part of a condensation of the philosophical life-work of Carl Friedrich von Weizsäcker. The as yet unpublished second part, to be entitled "*Zeit und Wissen*" (*Time and Knowledge*) has been promised since 1988, but has not yet appeared. Fortunately I have the manuscript, a version from 1989, so that I can assess how Weizsäcker dealt with some of the questions left open in AP. It is to the former magnum opus that we direct our attention now.

3. *Aufbau der Physik* – An Overview

a)The Basic Questions

(1) The Double Vision. There are at least two basic visions underlying AP. The first is that "the complex of physical theories that have come into being during the last centuries is moving towards one unified and encompassing theory" (AP 23), and that QT constitutes the most prominent candidate for such a unifying theory. The second fundamental vision is equally complex. It is based on the assessment that "physics depends on experience (and that) theories formulate laws which are valid in experience" (AP 23). This assessment leads to the philosophical question: "Why can encompassing theories be valid at all?" (AP 23) The Kantian answer to this question constitutes the second fundamental vision underlying AP: "... the foundational general insights of physics always instantiate themselves in experience only because they express necessary conditions for experience" (AP 24). Here Weizsacker differs from Kant in that he does not appropriate this thought as "a certainty, but as a heuristic expectation" (AP 24), and of course also in that he does not formulate the possibly necessary conditions for experience on the background of Newtonian physics but in the context of modern quantum theory.

WHITEHEADIAN REMARK: Whitehead has a similar hesitation concerning the necessary character of his metaphysics (see PRc, "Introduction").

(ii) The Integration of the Two-Fold Vision in the Concept of Construction (Aufbau). This double vision concerning the development of physics and its philosophical imbeddedness is integrated in the purpose of AP, which Weizsäcker describes in the following manner: "The book ... studies the structure (Aufbau) of physics starting from the philosophical question as to how encompassing theories are possible at all and in the expectation of thus reaching a new level of theoretical research within physics itself" (AP 24). The first part of this aim led Weizsäcker to search for concepts in terms of which he could logically and coherently express the most general conditions underlying physical experience. These foundational concepts include the threefold temporal structure of the facticity of the past, the immediacy of the present and the openness of the future as well as the individuality of processes. The second part of the purpose of AP led Weizsäcker to the formulation of his not yet completed physical theory of "*Uralternativen*" (Engl. = primordial alternatives) as a candidate for a grand unified theory in physics.

(iii) WHITEHEADIAN REMARKS: Whitehead's philosophy also understands itself as an encompassing theory of experience. One of the first sentences of PR states this clearly:
"Speculative Philosophy is the endeavor to frame a coherent, logical, necessary system of general ideas in terms of which every element of our experience can be interpreted" (PRc 3). However, he does not, like Weizsäcker, primarily concentrate on physical experiences but aims at including experiences as diverse as those underlying physiology, psychology, sociology, art and even religion. Another difference is that Whitehead did not explicitly use his "speculative scheme" to formulate a "new level of research within physics itself", as is the case with Weizsäcker. These differences could, however, become interesting for the interpretation of process philosophy. For if it can be shown that Whitehead's speculative scheme is compatible with foundational concepts in AP, then Weizsäcker's work could be used to construct QT out of process philosophy.

b) The Structure of the Book

(i) The External Structure. Externally AP is made up of three parts. Part I discusses the foundational concepts of temporal propositions and their logic, of probability and its interpretation, of irreversibility and its relationship to entropy, as well as the concept of information as implied in evolution. Part II is concerned with the construction of a unified physics based on a reconstruction of first abstract and then concrete QT, starting from the foundational concepts introduced in part I. Part III finally is concerned with the interpretation of physics, especially of QT, on the background of the reconstruction of physics as effected in part II. It leads to final discussions on the possibility of going beyond QT and of expressing the whole approach in the language of traditional (Aristotelian) philosophy.

(ii) The Internal Structure. Internally the aim of AP is developed in the context of three concentric types of unification expressing successively the unity of nature, then the unity of physics and finally the unity of QT. In its determination of the most general concepts underlying our experience of nature AP starts with the unity of nature. A discussion of the historical development of the interrelated complex of physical theories towards more and more encompassing theories constitutes the next step: a first discussion of the unity of physics. The innermost circle consists in the reconstruction of abstract QT on the basis of the new foundational concepts, thus founding the unity of QT. In an inverse movement AP then aims at reconstructing all of physics starting from the unity of abstract QT, an effort which understands itself as a demonstration of the unity of physics. The train of thought then finally comes back to its origin in its effort to spell out the new unity of nature constituted by the foundational concepts introduced at the beginning. This is done by utilizing the new interpretative possibilities available after the introduction of these concepts and the ensuing reconstruction of first QT and then of physics as a whole.

In the following presentation I will only treat elements of the first movement of thought from the unity of nature to the unity of quantum theory. A presentation of the inverse movement of thought would constitute at least one other paper, taking us back from the unity of quantum theory to the unity of nature.

(iii) WHITEHEADIAN REMARKS: Whitehead is not only concerned with the unity of nature and the implied unity of physics, but in addition also with the unity of the world, including the world of sociology, of art and of religion. His foundational concepts will therefore most probably be more encompassing than those of Weizsäcker but at the same time in themselves also more difficult to explain physically.

Concerning the structure of PR in comparison with that of AP we may note that Whitehead in PR also starts out with a preliminary determination of the new foundational concepts he introduces to articulate and interpret experience. But he then, in contrast with AP, directly goes over to an interpretation of traditional philosophical concepts in terms of his new conceptuality. Only then does he proceed to rigorously develop the innermost circle, in his theories of prehension and of extension (part III and IV). In their function these two latter parts in PR correspond to the middle part of AP, containing the reconstruction of abstract and concrete QT as well as of SRT. Correspondingly, part II of PR then has an equivalent function in PR to that of part III of AP, both exploring the new possibilities of interpretation furnished by their new conceptuality.

4.FOUNDATIONAL CONCEPTS

a)Time and the Logic of Temporal Propositions

(1) Experience. "Physics is an empirical science (*Erfahrungswissenschaft*, literally a science of experience). What is experience? We call a person experienced if he has learned from the past for the future. The events that he lived through, in a time that has passed, are, strictly speaking, unique, like all events; strictly speaking nothing repeats itself in the world. But nevertheless, such a person has been able to recognize in them those traits that repeat themselves. By knowing these traits, he does not encounter what happens to him today in a completely unexpecting manner. He is also capable of estimating to some degree what still lies waiting for

him in the far future. That his estimations were not completely wrong will become apparent, when that which today is future will have become present. In this way his experience proves (bewährt) itself again and again: the respective present shows that he has truly learned from the past for what then was still future. This justifies his guess that his experience will also prove itself true in a time that today is still future. - All empirical science also has these characteristics, only in a systematic form." (AP 47)

With these opening sentences of the main corpus of his book, Weizsäcker outlines the main vision underlying his whole approach. He is concerned with experience. He is interested in a certain structure of time as disclosed in concrete experience. And he is amazed at the fact that certain characteristics recognizable in concrete events repeat themselves in other such non-repeatable situations. It is on this conceptual bedrock that he will try to rigorously reconstruct quantum theory, and from it most of physics as known to us today.

(ii) How to Speak about Time. Towards this end he first must outline a solution of the formidable problem as to how one must be able to rigorously speak, if one desires to take into account time as thus disclosed in such concrete experiences. Weizsäcker says: "It might appear that the problem of rigorously conceptualizing time could be solved through the introduction of the time parameter. (But) The present book was written, because such is not the case" (AP 48). And he explains: "The results of physics cannot lead to a subsequent definition of what time or the direction of time is ... However, the results of physics can lead us to clarify for ourselves what we had already known in an inarticulate manner before doing any physics at all. In other words, we can agree upon a controllable manner of speech, that we will henceforth use for speaking about time, and we can test this manner of speech to see if it corresponds to our previous understanding of time. With the help of this manner of speech we will then be able to define other physical concepts that need to be explained, or at least to introduce for them also a controlled manner of speech that eliminates certain difficulties previously apprehended. The key concept in this respect is the concept of probability that is fundamental for the interpretation of thermodynamics and of quantum theory" (AP 49).

(iii) The Logic of Temporal Propositions. The "controlled manner of speech" that Weizsacker introduces towards this end is his "logic of temporal propositions". He distinguishes between statements on the past (*perfektische Aussagen*), statements on the present (*prasentische Aussagen*) and statements on the future (*futurische Aussagen*). The main characteristic of Weizsäcker's logic of statements on the future is that they are not accorded the truth values true or false, but the modalities necessary, contingent or impossible. Weizsäcker founds the main logical laws governing the interrelationship of such temporal statements using a dialogical constructivist method of meta-mathematics that he takes over from P. Lorenzen. In this method the truth of a law of this logic is demonstrated, if it can be rigourously anchored in at least one concrete situation or event.

For the purposes of this presentation we need the following definitions and clarifications introduced by Weizsäcker. They also serve as examples as to how Weizsäcker developed his logic of temporal statements:

* "A statement will be called futural (futurisch) if it concerns future facts. An example is: 'Tomorrow morning we will have fine weather" (AP 79).

* A futural statement such as "In the morning of November 30, 1991 there will be nice weather in Kansas City" Weizsäcker calls a "formally perfectual" futural statement (formal-perfektische Aussage), "because it shares the form of the determination of time with perfectual statements" (AP 79).

* He then goes on to say: "In the formalism (of our logic of temporal statements) we will write out futural statements as modal formally perfectual statements: Npt = it is necessary that p at time t; Mpt = it is possible that p at time t" (AP 80). This is the form in which a futural statement can be asserted. "It is not possible to assert a formally possible (temporal) statement as such. If it is asserted, it must be asserted in a presentual, perfectual or modally futural manner, and when it is formulated using a temporal determination, it can be asserted any time at most only in one of these three forms" (AP 81).

* Another important passage states: "The complex nature of what happens is the reason for the introduction of two concepts important for what follows: that of an object and of a question. Strictly speaking, in the world everything is related to everything. Nevertheless, if one wants to decide a prediction Npt or Mpt, one cannot take into consideration all factors acting on the event. In practice one neglects certain influences and puts up with the ensuing uncertainty of the prediction. This restriction of outlook is schematized by the two concepts introduced. We do not consider questions as general as 'what will happen at time t at all?' but only questions, for which a catalogue of possible answers is already presented; these we will call in a terminologically narrow sense 'questions.' The concrete way of setting up such catalogues will be discussed separately for the classical and for the quantum theoretical case ... We will be especially interested in questions that bridge time. These will be questions whose catalogue of answers contains the same possible answers for different times. Such a catalogue of answers bridging time will often be called a magnitude or quantity (*Große*), the possible answers are called the possible values of this quantity. An example of a question that bridges time is: which face of this die will be up at time t? The catalogue of answers contains at any time 6 formally possible answers ... We will call objects certain sections of the world on which we fix our attention and which can be characterized using questions bridging time." (AP 85f.)

(iv) General Remarks on Probability. Against this background Weizsäcker then makes his first specifications on probability. He says: "In what follows we will construct the concept of probability as a mathematical condensation (*Verscharfung*) of the concept of a futural possibility. This will be done in two steps: 1. definition of a type of statement, which will be valued using probabilities; 2. definition of the probability as a quantitative modality of such statements" (AP 88). In other words Weizsäcker "determines probability as an intensification (*Verscharfung*) of the futural modality 'possible' and as such as a predicate of a formally possible statement." (AP 89). Weizsäcker then goes on to show that in classical physics the catalogues of possible answers that physics deals with must be constructed on the basis of the following three postulates: "I. Decideability: Any statement can be decided through a phenomenal exhibition. II. Repeatability: A statement proved true will prove itself in an immediately subsequent repetition of the decision as true, and a statement proved false as false. III. Compatibility of Decisions: Any two simultaneous statements can be decided at the same time." (AP 92). It will be Weizsäcker's contention that all that has to be changed when going from classical to quantum theory will be to abandon the last of these three postulates. By the way, the three postulates necessary for classical physics suffice to structure the set of formally possible statements into a Boolean algebra.

(v) WHITEHEADIAN REMARKS: By basing his approach on the distinction between the factuality of the past, the immediacy of the present and the open possibilities of the future Weizsäcker is implicitly consonant with certain aspects of Whitehead's foundational category of the ultimate: "the many become one and are augmented by one" which could be called the principle of originating unification or of unifying origination. At least the aspect of novelty implied in the openness of the future and the inalterability of past events as factors in the becoming of new events must be mentioned here. We must however keep in mind, that Weizsäcker, unlike Whitehead, does not clearly differentiate between eternal objects and actual entities, and therefore he does not clearly distinguish between the genetic and the morphological mode of analysis of actual entities which their distinction over against eternal objects makes possible. The parallels between Weizsäcker and Whitehead will therefore mostly concern more complex aggregates of Whiteheadian categories of existence. For example, Weizsäcker's concept of a concrete empirical test understood as an in principle non- repeatable event comes close to Whitehead's concept of a nexus of actual entities; and Weizsäcker's concept of an object as a section of the world that can be characterized by questions that bridge time comes close to Whitehead's idea of a complex eternal object finding ingression in the successive members of a corpuscular society of actual entities. And finally I think that it is possible to identify one of the possible answers in Weizsäcker's category of "question," understood as a catalogue of formally possible answers, with what Whitehead calls a proposition. For just as a proposition is a nexus of actual entities openly related to some eternal object that could possibly find ingression into them, in like manner one answer out of a possible catalogue of possible answers is a time bridging entity that can become true in one of a whole set of concrete acts of empirical verifications devised to test the question under examination. From a process philosophical point of view this is probably the main reason why it is not astonishing that Weizsäcker's next step after the elaboration of the foundations of a logic of temporal statements is the discussion of the paradoxes connected with probability. For Whitehead does exactly the same thing. In his chapter IX of part II in PR, entitled "The Propositions," we also find a treatment of the fundamental philosophical problems entailed in understanding probability.

b) Probability

(i) WHITEHEADIAN REMARK: With this preliminary observation we turn to this important concept at the foundations of physics. Weizsäcker has a thorough philosophical discussion of this concept in his unpublished book *Zeit und Wissen*, which I cannot treat here. In comparison with Whitehead it is noteworthy that both he and Weizsäcker are deeply indebted to J. Maynard Keynes' book *A Treatise on Probability,* but each of them interpret his approach in their respective broader philosophical perspective. It would be a very interesting subject to compare in detail how Whitehead and Weizsäcker tackle the main problems involved, and to assess the degree of consonance or dissonance in their respective categoreal schemes that is responsible for a possible convergence or divergence in their interpretations of probability. This question I reserve for a future presentation. Instead I will limit myself to a short outline of Weizsäcker's treatment of probability in view of his abstract reconstruction of quantum theory.

(ii) The Dilemma of the Concept of Probability. "Probability is only the expectation value of a relative frequency (of possible events). But the concept of 'expectation value' usually is defined in such a manner that it already uses the concept of probability. Therefore it looks as though one cannot define probability itself by having recourse to measurable relative frequencies, because this definition, strictly speaking, already presupposes the concept of probability" (AP 102f.). This is the main dilemma underlying the concept of probability. After judging some solutions offered in this situation as only apparent solutions, he outlines his approach to this problem in the following manner: "The origin of the difficulty does not lie in the special concept of probability, but rather generally in the idea of the empirical test of any theoretical prediction. ... The empirical confirmation or refutation of a theoretical prediction is never possible with certainty, but only with a higher or lesser degree of certainty. ... In this sense the concept of scientific experience in practice always presupposes the applicability of some concept of probability, even when this concept has not been explicitly formulated. ... The two concepts of experience and of probability (thus) cannot be subordinated one with respect to the other. ... (For) the empirical test of a theoretically gained probability is only possible within a certain degree of probability" (AP 103ff.).

(iii) The Classical Concept of Probability. Being aware of this vicious problem, Weizsäcker then goes on to construct the classical concept of probability in three steps: "First we formulate a tentative concept of probability. It does not propose to be precise, but wants to be an understandable German (in our case English) description of the manner in which probabilistic concepts are used in practice. Secondly, we formulate a system of axioms of the mathematical theory of probability. In this section we can accept Kolmogorow's system. Thirdly, we give the concepts of the mathematical theory an empirical sense, a physical semantic as it were, by identifying some of its concepts with concepts that are related to the tentative concept of probability" (AP 106). This last step Weizsäcker calls "a study of the consistency of the whole procedure" (Ibid.).

STEP ONE: "The tentative concept is described by means of three postulates: A) A probability is a predicate of a formally possible future event, or more precisely, a modality of the statement which asserts that this event will take place. B) If an event (or the corresponding statement) has the probability of being very close to 1 or 0, then it (the statement) can be treated as practically necessary or as practically impossible. An event (a statement) with a probability not very close to 0 is termed possible. C) If we ascribe a probability p (0 LE p LE 1; LE here means 'less than or equal to) to an event (a statement), then we thereby express the following expectation: From among a large number N of cases, in which this probability is correctly ascribed to the event (the statement), the event will take place (the statement will prove true) in approximately n = pN cases"

(AP 107). In a process philosophical perspective we have to notice that we are here not dealing with a single actual entity, but with a whole class of actual entities for which the question presupposed by the empirical test has a certain sense. Weizsäcker's concept of an event therefore comes much closer to a certain nexus of actual entities than to one actual entity, and the probability is not an eternal object related to such a nexus but rather a complex of eternal objects related to a large set of process philosophical "propositions" which contributes to the determination of the subjective form of a concrete event of testing the probability.

STEP TWO: In the next step Weizsäcker introduces the axioms of Kolmogorow to found the mathematical theory of probability: "Let M be a set of elements x,y,z,... that we call elementary events, and let F be a set of subsets from M; the elements of F will be called events. I. F constitutes a union of sets (with a Boolean algebraic structure). II. F contains the set M. III. To every set A from F we assign a non-negative number p (A). This number p (A) is called the probability of the event A. IV. P (M) = 1. V. If A_1 and A_2 are disjunct, then $p(A_1+A_2) = p(A_1) + p(A_2)$." (AP 108)

STEP THREE: In the last step he then gives this mathematical definition a physical semantic. The mathematical theory of probability then only makes sense physically if a fourth postulate is added to the tentative definition of probability: "D) The probability of an event (a statement) is the expectation value of the relative frequency of its occurrence (of its becoming true). ... (It is important to note that this) expectation value is not defined over the original structure F of events (underlying the mathematical definition of probability). It can (rather) be defined over a structure G of 'meta-events'. ... Then the rules of the theory of mathematical probability allow us to calculate the probability function for elements of G" (AP 109). "What is the epistemological gain of all this? We did not get rid of the tentative concept of probability, we only carried that concept over from events to meta-events, i.e. to large sets of events (in Whitehead's terms, to large sets of large sets of actual entities). The physical semantic of probabilities rests upon the tentative semantic of meta-probabilities. This is a more precise expression of our previous assertion, that a probability can only be tested within a certain degree of probability" (AP 110).

(iv) The Quantum Theoretical Concept of Probability. The next step contains another fundamental decision of Weizsäcker. In this case he proposes an alternative to most philosophical interpretations of quantum theory. Weizsäcker introduces his fundamental decision in the following manner: "If we want to apply an axiomatic system of probability theory to experience, in harmony with the laws of nature known today, then this system cannot be classical probability theory, that up until now was almost exclusively studied by mathematicians as well as by philosophers. The difference between classical and quantum theoretical probability corresponds to the difference between classical and quantum theoretical physics. Most experts in epistemology, especially those from the school of logical positivism, only accorded this difference 'an empirical character,' i.e. a lower level in the hierarchy of concepts as the one on which the sense of such concepts as experience and probability is decided.

"People never understood Bohr's concept of complementarity, because they misinterpreted it as a generalization of a special empirical concept of physics, while Bohr wanted to indicate with it a universal structure of human knowledge, that in quantum theory only found an especially striking example" (AP 303f). In other words Weizsäcker asserts that the difference between classical and quantum physics implies a difference in our basic concepts of experience and of probability. Spelled out in terms of Kolmogorow's axioms this means that not the axioms II to V but already the preliminary definitions and axiom I change when going from classical physics to quantum theory. Weizsäcker says: "It is doubtful whether Kolmogorow's axioms hold in quantum theory at all. The fundamental phenomenon of quantum theoretical probability calculations is the 'interference of probabilities'; the fundamental laws do not refer directly to measurable probabilities but to 'probability amplitudes.' In the system of Kolmogorow this means that the first axiom, which states that the possible events form a Boolean union, must be replaced by another axiom, according to which the union of events are structured by the subspaces of a Hilbert space" (AP 303). And it is exactly along these lines that Weizsäcker will reconstruct QT. The changes that have to be effected to understand and to reconstruct QT thus must not only be effected on the level of derivative and more complex concepts of physics like object, reality, space or time, but already on the level of what for Weizsäcker (and Whitehead) are the most fundamental concepts, namely those of concrete and possible experience as well as that of probability.

c)Irreversibility and Entropy

We can here neither deal with the application of Weizsäcker's approach to the interpretation of the irreversibility of time and the consequent interpretation of entropy and the second law of thermodynamics, nor the construction of the concept of information and its explication in the context of evolution. Instead we will directly go over to the reconstruction of quantum theory, where the results from above will be spelled out more explicitly.

5. THE UNIFICATION OF PHYSICS

a) The Interrelationship of Physical Theories

We also have to skip Weizsäcker's historical sketch, showing how the complex structure of physical theories historically tended towards a theoretical unification; and that QT is the theory that is most prominent in this connection. Weizsäcker uses the results of this historical argument, first, to justify his faith in the impossibility of a fundamental continuum-mechanics, which would be classical, and he derives the consequences of this circumstance for his project, i.e. that QT can now be taken as the candidate for unifying physics. It would be interesting to compare this chapter from AP (chapter 6, pp. 219-280) with the historical sections in Whitehead's SMW. This also is reserved for future study.

b) The Individuality of Processes

(i) Bohṛ's Concept. The conceptual foundations that Weizsäcker introduced so far were all motivated by the Kantian paradigm that the seeming universal validity of a theory can be understood if it can be reconstructed from concepts that express the conditions of the possibility of any experience at all. Of such nature is the structure of time, distinguishing facticity, immediacy and potentiality, as well as the specific understanding of probability outlined above. Unfortunately for Weizsäcker's (or more precisely for Kant's) paradigm, Weizsäcker had to admit that he needs one more fundamental concept to reconstruct QT, which he was not able to understand in the context of this philosophical paradigm, i.e. that could not be understood as a condition for the possibility of any experience. Weizsäcker calls this concept, following Bohr, the individuality of processes. In his book *Correspondence , Individuality, and Complementarity* the current minister of culture and education of the state of Hamburg in Germany, and former doctoral student of Weizsäcker, K.M. Meyer-Abich showed that "individuality is the central and most quantum theoretical concept" (AP 297) that Bohr devised in order to understand QT. "Correspondence and complementarity are relationships of quantum theory to classical physics" (AP 297), but the individuality of processes is the only genuine quantum theoretical concept with no parallel in or relationship to classical physics. It means "indivisibility, especially the indivisibility of processes that can be described quantum theoretically. As such it is the limitation of correspondence and the condition for mere complementary use of classical concepts" (AP 298). This same individuality of processes is responsible for the inability to separate between object and instrument (or subject) in a quantum theoretical measurement situation, especially as it becomes evident in such experiments as produce the EPR-paradox. Weizsäcker's own effort to reconstruct QT must be understood as "a trial to consistently describe individual, i.e. indivisible processes" (AP 299).

(ii) WHITEHEADIAN REMARK: In my opinion Bohr and Weizsäcker here come very close to Whitehead's concept of atomicity, especially the atomicity of actuality and of becoming as reflected in his "cell-theory of actuality" (PRc 219). Since this is a central doctrine of Whitehead it will be very instructive to see exactly how Weizsäcker uses this presupposed concept in his reconstruction of QT and to delineate what categoreal obligations are implied.

c) Reconstruction and Abstract Quantum Theory

(i) The Basic Strategy. To reconstruct QT Weizsäcker proceeds in two distinct steps that are not completely independent. The first step is the reconstruction of what Weizsäcker calls abstract QT, and the second step is the reconstruction of concrete QT. The former deals with any quantum theoretical objects conceivable at all, while the latter is limited to phenomena as experienced in concrete measuring situations. None of the reconstructions has recourse to space or to the path of a particle in space. On the contrary Weizsäcker will deduce the relativistic structure of space-time as well as elementary particles from his concrete QT, which he solely founds on the concepts of temporal structure, probability and the individuality of processes.

(ii) The Concept of Reconstruction. Before outlining these reconstructions we still need to see what Weizsäcker understands by reconstruction and by abstract QT. Reconstructing a theory does not mean the construction of an alternative theory but "its construction out of more or less evident postulates subsequent" (AP 330) to its original formulation in the science which uses it. Weizsäcker distinguishes two kinds of such fundamental postulates: a) epistemic postulates are such as "express conditions of possible experience, i.e. conditions of human knowledge" (AP 330), and b) realistic postulates which are "very simple principles, that we hypothetically presuppose - stimulated by concrete experience - as being generally valid in the realm of reality concerned" (AP 330). The concepts of temporal structure and of probability introduced above are for Weizsäcker epistemic postulates, and the concept of the individuality of processes is a realistic postulate. Alternately one could say, and this is now my own interpretation, that Weizsäcker only had to hold on to the distinction between epistemic and realistic postulates in his reconstruction of QT because he failed to reduce the concept of the individuality of process to a simple condition of possible experience and thus to an epistemic postulate.

(iii) WHITEHEADIAN REMARK: I have not yet made up my mind how this difference between epistemic and realistic postulates of Weizsäcker should be correlated to Whitehead's differentiation between eternal objects and actual entities. It is clear that they cannot be simply identified, because Weizsäcker does not sufficiently distinguish between events and the characteristics that allow the differentiation between events. Maybe one should better correlate them to the Whiteheadian distinction between the mental and the physical poles in the emergence of a new actual entity. The laws implying a physical pole being realistic postulates and the laws implying a mental pole being epistemic postulates. But Whitehead interrelates the two in his category of transmutation, which allows for physical feeling on the basis of conceptual prehensions in an antecedent concrescence, and thus allows for an interrelationship of epistemic with realistic postulates (if the assumed correlation with Weizsacker is correct). This question has to be left open for future study. Perhaps this question signals the limitations inherent to a primarily epistemological and not cosmological approach in philosophy that distinguishes Weizsäcker from Whitehead.

(iv) The Concept of Abstract QT. Let us now turn to the concept of an abstract QT. Weizsäcker defines this concept following John von Neumann and condenses it in four hypotheses. Weizsäcker distinguishes here between hypotheses, which should be self-evident, and postulates, which are more technical and therefore not very evident at all. It will be his effort to construct these non-evident hypotheses, starting only from a certain set of evident postulates. The four hypotheses to be constructed are: A) Hilbert Space: The states of any object are described by vectors in a Hilbert space. B) Probability Metric: the square of the absolute value of the inner product of two normalized Hilbert vectors x and y is the conditioned probability p (x,y) to find the state belonging to y if the state belonging to x is present. C) Composition Rule: Two coexisting objects A and B can be viewed as one composite object C = AB. The Hilbert space of C is the tensor product of the Hilbert spaces of A and B. D) Dynamics: Time is described using a real coordinate t. The states of an object are functions of t, described by a unitary mapping U(t) of Hilbert space on itself. "We call this theory abstract, because it is universally valid for any objects whatsoever" (AP 332).

d) The Reconstruction of Abstract Quantum Theory (Procedures 1-3)

(i) The Four Procedures for the Reconstruction of QT. “Historically quantum theory originated from concrete physical problems. (But) the abstract generality of its final form suggests the possibility of reconstructing this (final) form (of the theory) from postulates, which only formulate plausible preconditions of possible experience” (AP 35). Weizsäcker and his collaborators have devised four procedures or routes for such a reconstruction, “whose sequence denotes an increasing independence of the postulates from historical conditions” (AP 35). Logically all four procedures are based on the definition of the concept of an n-fold alternative (i.e. an empirically decidable question that allows for exactly n mutually exclusive answers), which represents the result of Weizsäcker's analysis of the structure of time and of probability in its appropriation to the specific needs of quantum theory. The first three procedures, in addition, presuppose the concept of an object, so that different n-fold alternatives may belong to one object. In all four procedures the realistic postulate characteristic of quantum theory is introduced under the name of expansion (*Erweiterung*) or of indeterminism. This postulate “states that to every two mutually exclusive states x and y of an alternative there is at least one state z that does not exclude any of the two” (AP 36). The first two procedures in addition presuppose the concept of probability.

In the following we will take up the second and the fourth of these procedures in some detail. The former is a reconstruction of abstract QT and the latter a reconstruction of concrete QT. Concerning the fourth procedure we only discuss the fundamental postulates and not the steps necessary to reconstruct concrete quantum theory. The first and third procedures we will only touch very briefly, by translating Weizsäcker's own compact summary of each. Both are reconstructions of abstract quantum theory.

(ii) WHITEHEADIAN REMARK: It must be noted from a Whiteheadian perspective that as the four procedures mark an increasing independence from the historical form of problems associated with QT, it can be expected that they also mark an increasing consonance with process philosophy. And in fact, detailed analyses are beginning to convince me that this might indeed be the case. Especially procedure three (going back to a suggestion by R.P. Feynman) and procedure four (the most originally Weizsäckerian) contain concepts and categories that come very close to process philosophy and therefore can give an indication as to what parts of PR are of relevance to the inner workings of QT, and inversely, can give hints as to how some dark passages from Whitehead could be scientifically interpreted. It is the wrestling with these procedures, especially the fourth procedure, that has made me wonder more and more if Whitehead should not be credited with having invented main aspects of modern quantum theory all by himself around the same time in which Bohr and Heisenberg invented QT, and if this is not the case, to ask, whether his course of philosophical development had not made him open and sensitive enough to the invention of modem QT so that after its formulation and interpretation by Heisenberg and Bohr he could straight away have indicated in detail what deep philosophical consequences this discovery did have. For as we will see it is especially the genetic analysis of actual entities that will be astonishingly consonant with the foundations of the fourth procedure of Weizsäcker. (NOTE: I still need to study the biography of Whitehead to see of there was any direct interaction between Whitehead and Bohr after 1925.)

(iii) PROCEDURE ONE: Reconstruction via probability and propositional union (M. Drieschner 1970). “The first route starts by reconstructing first the quantum logical propositional union, (then) proving that this constitutes a projective geometry and (finally) introducing Hilbert space as a vector space, over which this projective geometry can be defined” (AP 36).

(iv) PROCEDURE TWO: Reconstruction via probability directly to vector space. I will treat this procedure in some detail. The procedure as outlined in AP consists of two preliminary methodical remarks, three postulates and three deductions. I can however only choose one or two points from each of these categories.

The first preliminary methodical remark is the “definition of an empirically decidable alternative: an n-fold alternative is a set of n statements/states, from which exactly one will prove itself true/present if an empirical test is conducted" (AP 344). A summary of a few explications which Weizsäcker makes in connection with an analogous definition in procedure one is necessary to better understand this notion of an alternative (cf. AP 334f): "All possible observations are described as decisions of n-fold alternatives. (i.e. physics only deals with such alternatives). ...The n-fold alternative fulfills the following conditions: a) the alternative is decidable: i.e. one can bring about a situation in which one of the possible events becomes an actual event and then a fact. b) The events of an alternative are mutually exclusive. And c) an alternative is defined as being complete. Given these three conditions, probabilities can then be viewed as predicates of possible events or of statements, for an alternative is a set either of events or of statements. Both are called its elements. ... The same alternative can be frequently decided. The additional information that Weizsäcker furnishes in procedure two is the following: "We also call an alternative a question and its statements the formally possible answers. (In an n-fold alternative) n GE 2 (GE here means:'greater than or equal to). Infinite alternatives are not empirically decidable. One does not presuppose that an alternative that was not tested is already decided" (AP 344).

WHITEHEADIAN REMARK: (The following remark is similar to the one following Wiezsäcker's concept of 'a catalogue of possible answers.' The reason is that the concept of an alternative is only a special case of such a catalogue.) It is important to note that Weizsäcker's concept of an event corresponds to a type of event in Whitehead's terms (i.e. to a whole set of events with some common characteristics). This is why I think that the elements of an alternative should neither be identified with an actual entity not with an eternal object but with Whitehead's concept of a proposition, i.e. the loose association of one individual eternal object with a certain nexus of actual entities. The former expresses the potential ingression of that eternal object into a possible concrete actual entity, and the latter specifies all actual entities which in themselves would only constitute a multiplicity, but which are, in virtue of the possible ingression of that single eternal object into them, transmuted into a nexus of actual entities, in case this proposition constitutes an objective datum of the concrescence. An n-fold alternative would then be an n-fold multiplicity of process philosophical propositions. There is however a problem that troubles me. This concerns the fact that for Whitehead propositions primarily envisage actual entities that have already become facts, whereas Weizsäcker's main concern is making predictions, i.e. with associating such formally possible answers with events that have not yet been objectified. I would appreciate discussing this point after my presentation.

Let me now simply state the three postulates of this second procedure and briefly indicate how they are used to reconstruct the four hypotheses of abstract quantum theory.

"(Postulate 1) Separability: Two alternatives are called separable, if the result of the decision of one of them does not depend on the result of the decision the other. There are separable alternatives.

"(Postulate 2) Expansion: To each pair x and y of mutually excluding states of an alternative there is (at least) one state z which cannot be separated from them and which excludes none of the two, but which determines conditioned probabilities p(z,x) and p(z,y) different from zero or one. (Remark): This is the central realistic postulate of QT. The state z is not an element of the alternative but is said to belong to the alternative.

"(Postulate 3) Kinematics: States change with time. In this the probability relations belonging to the same alternative do not change" (AP 345-347).

On the background of these three postulates Weizsäcker then constructs three hypotheses of abstract QT in connection with three deductions from these postulates:

"(Deduction 1) State-Space (*Zustandsraum*): We define the state-space S(n) as the set of all states belonging (highlighted by me) to a given n-fold alternative. In the abstract theory we ascribe isomorphic state-spaces to all alternatives of the same (order) n" (AP 346). Remark: the set of states constituting S(n) does not only include the elements of the alternative but in addition all other states that are not separable from some element of the alternative. As such it is a deduction from the postulate of expansion.

"(Deduction 2) Symmetry: All states of S(n) are equivalent, i.e. they allow no distinctions" (AP 348). It can be shown that this is a deduction from the postulate of separability. Given this (symmetric) equivalence, one can represent this state-space S(n) using an n-dimensional vector space R^n whose metric is the conditioned probability p(x,y). It can be shown that the probability metric will be an orthogonal and invariant bilinear form in R". This constitutes the first hypothesis of abstract quantum theory.

"(Deduction 3) Dynamics: The development of all states in time must be describable using a one-parameter subgroup of the symmetry-group whose parameter is time. This leads to complex vector space" (AP 350). This is a deduction from the postulates of kinematics and the symmetry of state-space. It allows the formulation of the law governing the dynamics of the state vectors and in addition the construction of Hubert space. This is too complicated to unfold in the present context. It should however be noted that the impossibility to observe the phase of a state in quantum theory is not introduced as a presupposition but follows as a deduction from this approach. We thus already have reconstructed three of the hypotheses of abstract quantum theory, namely the probability metric, Hubert space and dynamics. The only remaining hypothesis, that of the composition rule, follows directly from the postulate of kinematics.

Weizsäcker summarizes this procedure in the following manner: "We thus have reconstructed the four hypotheses (of abstract QT): Hilbert space from dynamics, dynamics from the probability metric, the latter from the definition of states in the postulate of expansion. The composition rule of the state-spaces follows from the cartesian multiplication of alternatives. Nevertheless, our Hilbert space up till now is only finite dimensional. The complete concept of an object (which implies an infinite dimensional Hilbert space) will be derived using procedure 4" (AP 352).

WH1TEHEADIAN REMARK: We have to keep in mind that the elements of an alternative and the states/statements that belong to an alternative each denote one specific characteristic in its capacity of potential realization in an empirical test. This is why I think that these characteristics implied in the elements of an alternative come very close to the nature of an eternal object. And since Hilbert space, which is the fundamental structure in QT, is directly associated to these alternatives in a one-to-one relationship, one can say that to each complete dimension of Hilbert space corresponds one individual eternal object. The manner of their being together in one space then reminds us of how eternal objects in Whitehead's view form an ordered realm. (The coordinates along each dimension representing an eternal object is related to the probability with which this specific eternal object finds ingression into a concrete act of measurement.) But, here again, we have to keep in mind that Weizsäcker does not clearly distinguish between the characteristic of an event and the event itself, as does Whitehead in his distinction between an eternal object (= characteristic of an actual entity) and the actual entity in which that eternal object can find ingression. The elements of an alternative are potential events, not characteristics of events with the potentiality of realization in an event.

(v) PROCEDURE THREE: Reconstruction via amplitudes to vector space. Having given you a general idea as to how Weizsäcker reconstructs the hypotheses of abstract QT from specific postulates we can now shortly summarize procedure three in Weizsäcker's own words: "The third route does not start with countable states and in its intention not even with countable objects but with currents. In accordance with this fact it does not start with probabilities, i.e. with relative frequencies, but with futural modalities. These have an additive group, which is due to the additivity of temporal durations. In this way Hilbert space is first defined as a linear space, in which only afterwards countability and thus also a metric is introduced on the basis of stationary states. This route up till now is only a program" (AP 36).

e) The Reconstruction of Concrete Quantum Theory (Procedure 4)

We can now turn our attention to the last procedure, which constitutes a reconstruction of concrete QT. In many of the more complex details it can be based on one of the three previous procedures. But since it neither presupposes the concept of an object nor time as a parameter, but only the concept of a question, it is important to notice the changes in the preliminary definitions regarding alternatives. It is here that Weizsäcker in many points begins to coincide with the conceptuality of PR. Unfortunately I again have to limit myself to some hints that should be understood as directions and motivations for future inquiry. With respect to procedure 2, this procedure also redefines kinematics and dynamics. The other postulates and deductions are the same as in procedure 2.

Procedure four introduces two new fundamental concepts derived from the original idea of an alternative, namely the concept of a variable alternative and that of a primordial alternative.

(i) Variable Alternatives. This concept is developed in three postulates and in three deductions.

"(Postulate 1) Foundation of possibilities: The actual possibilities are determined by the actual facts. ... (Weizsäcker remarks:) The word 'actual' refers to what is at hand (*was vorliegt*) in the respective present. An actual fact is that, which in the respective present can be stated using a presentual statement. ... An actual possibility then is that which just now becomes possible in the respective present, i.e. that which a futural statement asserts regarding the imminent future. ... The phenomenal present is neither an instant (temporal point) nor a duration, and cannot be measured on any scale at all. (The time axis will be viewed as a mathematical idealization). ...This postulate can be viewed as a present-day response of Kant to Hume, asserting that the principle of causality is a precondition of possible experience, only that in our version the actual facts only determine the possibilities and not the future facts" (AP 3850.

WHITEHEADIAN REMARK: I know of no other passage in AP where Weizsäcker comes closer to process philosophical categories such as prehension, the actual world, novelty, and the distinction between the morphological and genetic analysis of actual entities.

"(Postulate 2) Open Finitism: All alternatives decidable in reality are finite, but one cannot provide an upper limit on the number of its elements" (AP 386). Underlying this fundamental quantum theoretical postulate is the judgment that "in a finite area of space-time only a finite number of distinguishable irreversible processes can take place. …The whole philosophical quarrel over quantum theory, in the language here utilized, concerns the question whether there are, in principle, limits to the objectification of the concept of an event. The golden rule says that there will appear no contradiction in quantum theory if this limit is respected" (AP 372).

WHITEHEADIAN REMARK: This clearly is in consonance with Whitehead's concept of the atomicity of actual entities.

"(Postulate 3) Actual alternative: The actual possibilities in the approximation of the separability of alternatives, are given respectively by the state-space of one alternative" (AP 387). This postulate presupposes all of the reconstruction of abstract quantum theory (in procedure 2) with the exception of the time-dependent part. It is exactly this part, containing kinematics and dynamics that he develops differently in the present procedure. This is why he needs the concept of variable alternatives.

"(Deduction 1) The determinism of possibilities: The actual possibilities determine their own temporal change. …The actual possibilities are formally possible events with an actual probability not equal to zero. Our deduction then asserts that these events in their turn determine the subsequently relevant actual possibilities, and so on" (AP
388).

WH1TEHEADIAN REMARK: This is the closest Weizsäcker gets to the subjectivity of an actual occasion and to the category of conceptual valuation.

"(Deduction 2) Variable Alternatives: The temporal change of an actual possibility can involve the transition to another actual alternative (in accordance with postulate 3). …This is based on the experience of time, according to which actual possibilities can become and vanish. This will not only occur in the state-space of a fixed alternative. Larger and smaller alternatives will come into being" (AP 389).

WH1TEHEADIAN REMARK: This clearly implies the novelty of the process especially as secured by the category of conceptual reversion so important in Whitehead's theory of prehension.

"(Deduction 3) The Growth of Possibilities: In the statistical mean the quantity of actual possibilities grows. (Weizsäcker associates this deduction with the following statement by Picht:) 'That which has passed by does not perish. The quantity of possibilities grows.' (Weizsäcker then comments on this statement:) The sentence 'That which has passed by does not perish' asserts the facticity of the past. The sentence 'The quantity of possibilities grows' then can be interpreted in the following manner: If that which is past does not perish (*vergehen*), i.e. if everything that once is a fact, remains fact, then the quantity of facts will continuously grow, because permanently new facts come into being (which is what one calls events). Thus the quantity of the possibilities determined by these facts should also grow. Now of course only the quantity of perfectual facts grows, but not necessarily also the quantity of actual facts and with it the actual possibilities. Every actual event eliminates certain possibilities and creates new possibilities. But the (the postulate of) open finitism suggests that also the quantity of the actual possibilities grows at least in a statistical mean" (AP 389f).

WHITEHEADIAN REMARK: This passage furnishes what is still missing from Whitehead's category of the ultimate, namely that the process is not only a process of concretion in which the many become one, but also a process of augmentation in which the many are increased by one. Also the Whiteheadian concept of negative prehension and again the category of conceptual reversion are used here.

(ii) Primordial Alternatives. In this section I will only briefly mention the definitions, theorems and postulates involved and indicate where possible the points which are consonant with Whitehead.

"Theorem of the Logical Decomposition of Alternatives: An n-fold alternative can be mapped onto the cartesian product of k binary alternatives with 2^k GE n (GE here means: greater than or equal to" (AP 390).

"Theorem of the Mathematical Decomposition of the State-Spaces: An n-dimensional complex vector space can be mapped onto the tensor product of k two-dimensional vector spaces with 2^k GE n in such a way that its linear and metric structure remains conserved" (AP 391).

WH1TEHEADIAN REMARK: These two theorems were the first points that I clearly recognized as consonant with PR. For Whitehead also uses this decomposition of multifold entities into binary entities, e.g. in the chapter on "The Theory of Feelings" Whitehead distinguishes between "multiple contrasts" and "dual contrasts" and he says: "A multiple contrast is analyzable into component dual contrast" (PRc 229). In addition, since we have already observed above that the elements of an alternative as well as each individual dimension of Hilbert space, i.e. of a complex vector space with a certain physical semantic, each correspond to a certain eternal object, we must assess that such a binary alternative, or the equivalent two-dimensional vector space, is the closest that Weizsäcker gets to a single eternal object.

"Definition of a Primordial Alternative: The binary alternatives, out of which the state-spaces of quantum theory can be constructed, we call primordial alternatives (*Uralternativen*). The subobject associated with such a primordial alternative will be called a prime (*Ur*)" (AP 392).

"Postulate of Interaction: All dynamics is Interaction" (AP 392).

"Postulate of the Indiscriminability of the primes: Primes are momentarily indiscriminable" (AP 393).

f) The Unfinished Program of the Reconstruction of Physics from a Universe of Primordial Alternatives

Weizsäcker then goes on to discuss some of the mathematical properties of the tensor space associated with these primes. On the basis of these properties he shows how it is possible to construct special relativity out of this tensor space. Since this treatment is very mathematical in nature I cannot here go beyond this simple indication. Weizsäcker in addition purports that it should be possible to develop the content of other important physical theories from his conception of a universe of primes. In chapter 10 of AP he, for example, gives hints as to how free particles, interaction and its separability from particles, quantum electrodynamics and even the sharply defined masses of particles could be derived from the fundamental definitions and postulates regarding variable alternatives and primordial alternatives. But unfortunately most of this part of the reconstruction of modern physics is still an unrealized project. And it is one of the greatest disappointments of Weizsäcker that, in spite of the fact that he has traveled widely to get physicists interested in his approach, hardly anybody followed him in this project. This is why Weizsäcker's grand vision of the reconstruction of the unity of physics still waits to be achieved. (NOTE: The main reason why Weizsäcker and his colleagues have failed to achieve their aim lies in the insurmountable mathematical problems that they encountered in this project. This problem is similar to the mathematical difficulties Einstein encountered in his unified field theory.)

6. CONCLUDING REMARK

The parallel between this inacceptance of Weizsäcker's approach by physicists and the inacceptance of process philosophy in the circles of accredited scientists is very striking. I have no explanation to offer for either fate. I can only deplore the loss of depth and insight that accompanies this decision to ignore philosophical reconstructions of physics such as were proposed by Whitehead and Weizsäcker. That there is an increase in the depth of insight, Weizsäcker has demonstrated in the third part of AP, which treats the interpretation of physics. I cannot present this very extended discussion here, but anticipate, just as with other sections of AP that I have not yet thoroughly analyzed, further fruitful dialogue with Whitehead's philosophy of organism. (NOTE: This open ended conclusion well reflects the essence of my presentation: not to summarize sure results, but to report on the advance of an enquiry that is still in process of realization.)

[Note: Weizsäcker's *Zeit und Wissen* (*Time and Knowledge*) is now published by Hanser of München, 1992.]

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Note on the Physical Meaning of Impetus

The following insight into the physical meaning of impetus in Whitehead's theory of relativity is based on an argument that to my knowledge was first proposed in C.B.Rayner, *Foundations and Applications of Whitehead's Theory of Relativity* [Ph.D. Dissertation, University of London, 1953, p.13]. The basic strategy is to compare the Lagrange function of a particle moving in a gravitational field with Whitehead's formula for the potential mass impetus.

The Lagrange function is the basis in classical mechanics for formulating the problem of the dynamics and motion of a particle utilizing a mathematical formalism alternative to Newton's laws of motion. Thus, instead of starting out with velocities and forces in order to set up the equation used in Newton's second law of motion, you start out with a general function, called the Lagrange function of the mechanical system under study. This general function only depends on the positions and velocities of the particles involved. The demand that this function have a minimal value for actual paths of the particles involved leads to a general equation involving only this Lagrange function. This partial differential equation is the equation of motion of the system involved.

Now in classical mechanics the Lagrange function L for a particle in a gravitational field has the following form

$$L = mv^2/2 + m\phi$$

The first term ($mv^2/2$) gives the kinetic energy of the particle and the second term (m) its potential energy in the gravitational field. The Lagrange function per unit mass has the following form

$$L = v^2/2 + \phi$$

Multiplying throughout with $2dt^2$ we obtain

$$2Ldt^2 = v^2dt^2 + 2\phi dt^2$$

Now to obtain Whitehead's relativistic law of gravitation you simply replace v by v^2-c^2 and 2ϕ by $2\phi(v^2/c^2 - 1)$. Thus we obtain an expression utilizing the Lagrange function per unit mass for the relativistic motion of a particle in the gravitational field

$$2Ldt^2 = (v^2 - c^2)dt^2 + [2\phi/c^2]\,(v^2 - c^2)dt^2$$

Noticing that $(v^2 - c^2)dt^2$ is equivalent to Whitehead's dG^2, we obtain Whitehead's law

$$2Ldt^2 = dG^2 + [2\phi/c^2]dG^2$$

Thus the potential mass impetus dJ of Whitehead is identical with $\sqrt{2Ldt^2}$. The interesting thing is that this physical quantity impetus has the dimension of length only in a derivative sense for it involves the product of an energy per unit mass with the square of the time. This then is the physical meaning of the square of impetus: energy per unit mass multiplied with the square of time or equivalently action per unit mass multiplied with time. Both have the dimension of length squared.

C. Wassermann Tübingen, January 1986.

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Appendix E. A Generalized Whitehead Theory of Gravity: the Kerr Solution

By Robert J. Russell and Christoph Wassermann, including notes on converting Whitehead's Theory of Relativity into modern notation.

A Generalized Whiteheadian Theory of Gravity: the Kerr Solution

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1. Introduction: Has Whitehead's Theory of Gravity been 'Disconfirmed'?.

a. Background.

In 1922, Alfred North Whitehead published *The Principle of Relativity* (referred to as*R*) where he proposed a theory of gravity which differed significantly, both in its philosophy of nature and in its mathematical construction, from the <u>general</u> theory of relativity given by Albert Einstein in 1915. Still Whitehead's theory is fully consistent with <u>special relativity</u>, using the spacetime (or "Galilean") metric in its tensor algebra. Whitehead's strongest criticism of general relativity involved its interpretation of gravity in terms of the non-uniformity of spacetime. This criticism was the fruit of his detailed analysis of perception as he endeavored to uncover the essential concepts in the foundations of physical theory. In particular he distinguished between the uniform significance of events, which according to his analysis is reflected in the stratification of nature into time systems and their relation to each other by a flat Galilean metric tensor, and contingent objects which go to make up the basis for masses, forces and fields in nature.

Whitehead's theory of gravity (specifically his fourth law in *R* p. 87) is a relativistic extension of the Lagrangian formalism incorporating a gravitational function which satisfies the four-dimensional Laplace equation. This led him to search for an appropriate gravitational metric from which to obtain the equations of motion. (We discuss the significance of Whitehead's term "impetus" for the line element in a separate paper (see Wassermann, Appendix D). As a result, and contrary to Einstein's analysis, Whitehead's metric contains both a nondynamical flat background metric by which measurement is interpreted unambiguously and a physical term in which the gravitational action is evaluated along the null cone. Whitehead believed that the ability to interpret local measurement without appeal to a global result was a major advantage of his theory over Einstein's theory. In addition, since his theory is essentially a Lorentz-invariant quasilinear action-at-a-distance theory, it is in principle easier to solve.

Given the difference in these two theories, it was of considerable surprise when, in 1924, Eddington pointed out a remarkable formal equivalence between Whitehead's theory and Einstein's general relativity: for the simple case of the gravitational field due to a single particle at rest Whitehead's theory leads to a metric which is algebraically equivalent to the Schwarzschild solution of Einstein's field equations (Eddington, 1924). The Schwarzschild solution applies to planetary astronomy, where the gravitational fields are small ($m/r << 1$, where m is the sun and r the average distance to the planets). Hence the implication of this equivalence was that the predictive power of Einstein's and Whitehead's theories would be identical with regard to standard tests of Einstein's theory: the perihelion precession of Mercury. Since then, Whitehead's theory was shown to be consistent with the other three standard tests of all gravitational theories: deflection of star light by the sun, time delays in radar ranging, and the gravitational red-shift, when electromagnetism was included in the theory in a natural way (see, for example, Synge, 1951). Most other theories of gravity except Einstein's general theory of relativity fail these standards tests.

However in 1971, Clifford Will argued that Whitehead's theory predicts an anisotropy in the locally measured gravitational constant, G, due to the influence of other masses in the universe (Will, 1971). If the predictions were significantly greater than the upper bound resulting from measurements of variations in G, Whitehead's theory would be disconfirmed. (Alternatively, a positive measurement of an anisotropy in G would disconfirm Einstein's theory, since the latter presupposes that G is constant and isotropic.) Based on measurements of the principal frequencies of the semidiurnal earth tides, Will concluded that "*Whitehead's theory cannot be the correct theory of gravity*, because it predicts an effect 200 times larger than the experimentally measured value. Since Whitehead's theory agrees with general relativity in its predictions for the tests (redshift, light deflection, time delay, and perihelion shift), this is the first accurate experimental evidence ruling out this theory.' (Will, 1971, p. 144-145, Will's italics)

The claim that Whitehead's theory had been ruled out spread through the literature in physics without, to our knowledge, any challenge. For example, in their immensely influential text on general relativity, Misner, Thorne and Wheeler echoed the 'disproof' of Whitehead's theory; Will's calculation was cited without qualification (MTW, p. 1124). In his recent book *Theory and Experiment in Gravitational Physics*, Will dismisses Whitehead's theory in a single sentence which cites the "violation of Earth-tide measurements" without reference to the original papers! (Will 1981, 1985, p. 139).

Nevertheless, interest in Whitehead's theory of gravity continued among those scholars who found Whitehead's general system of thought attractive. Recently Dean R. Fowler challenged the disconfirmation of Synge/Whitehead's theory in a brief paper based on his doctoral research (Fowler, 1974; note, however, Ariel, 1974). Fowler argued that Will had used an oversimplified model of the galactic hub by (apparently) assigning it a mass roughly equivalent to the entire galaxy. "However, with a more realistic model in which the mass is smeared throughout the galaxy, Whitehead's prediction is altered by a factor of 100 greatly diminishing the divergence between his prediction and Will's experimental limit" (Fowler, 1974, p. 288). Fowler also pointed out that other large-scale masses in the universe, such as Andromeda, would affect the calculation. "To settle the issue between the two formulae (Einstein's and Whitehead's) would require far more detailed work than has yet been done."

Since Will's calculation appears to be the single instance of a published calculation purporting to falsify Whitehead's theory of gravity, and since it seems to be the sole citation by others who accept this result, Fowler' claim deserves careful attention. Two questions arise immediately of Will's calculation: 1) Given a more realistic model of the galaxy, including its disk and halo, what would be the prediction for the anisotropy of G? 2) Similarly, what are the effects due to the local cluster of galaxies and of other galactic clusters? In addition, in light of current astrophysics, there are many other factors, such as dark matter, the possibility of a large black hole at the center of the galaxy, the contribution of neutrino mass, which would radically affect the question of anisotropy in G. Since these issues are currently being studied in astrophysics and particle physics, their effects on the anisotropy of G cannot be determined at present. However, the presence of so many unknown conditions makes Will's argument seem highly inconclusive. We do not believe that Whitehead's theory should be abandoned on these grounds alone, and we therefore hope to re-open the theory for serious study.

Other theoretical arguments against Whitehead's theory have been advanced: that it predicts an anomalous secular acceleration in the two-body problem and anomalous amounts of gravitational radiation from a binary star system. These problems must be dealt with at some point, hopefully in the near future. Nevertheless, the fruitfullness of Whitehead's approach can be explored along somewhat independent lines.

b. The present paper.

Meanwhile we believe that an important step in the renewal of research in Whitehead's theory of gravity will be to generalize Whitehead's theory to include the gravitational effects of rotation. In 1963, R. P. Kerr found a new solution to Einstein's free-space equations which, unlike the Schwarzschild solution, takes rotation into account and which therefore has been widely used in studying the stars (Kerr, 1963). It would be very interesting if the Kerr solution could be interpreted as a valid extension of Whitehead's gravitational theory.

To warrant such an interpretation we must ask what would constitute general criteria for identifying a Whiteheadian solution. We approach this by first summarizing Whitehead's four laws given in *R*. To facilitate the discussion we have transcribed these laws, along with several of his more important tensor formulae, into current tensor notation, following the notation of Misner, Thorne and Wheeler. Though Synge had done something similar for the fourth law, we believe that presenting all four in this fashion will simplify the discussion of Whitehead's work as a whole. We then give our arguments for regarding the Kerr solution as Whiteheadian.

2. Whitehead's Four Laws.

3. Generalization to the Kerr Solution.

4. Conclusions.

Is the Kerr solution Whiteheadian? One can argue affirmatively in two ways: 1) By placing the complexities of the Kerr algebra into the definition of the null coordinates we can retain the Laplacian form of the argument for a gravitational law as Whitehead gives it.
2) The Kerr solution, like Whitehead's explicit law (#23), is consistent with the two criteria given above, which emphasize linearity in the flat-space metric [symbol] and its use in constructing the gravitational metric.

If however we make an additional requirement that the null vectors be "displacement vectors" then the Kerr solution is not Whiteheadian, and only the Schwarzschild qualifies. However in this case we can still claim that the Kerr solution, being a solution of Einstein's equation which Whitehead also gives as his first law, can be interpreted within the framework of Whitehead's relativity theory.

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Appendix F. Electromagnetism, Time, and Immanence in Whitehead's Metaphysics

By Lawrence W. Fagg, The Catholic University of America (emeritus)

Abstract

The electromagnetic interaction is the physical mechanism that underlies the existence and/or functioning of virtually all of the nature on this earth from rocks to plants and animals, including humans and their brains. Furthermore, it is electromagnetic radiation, light, that has served as symbol or metaphor of divine presence in the spiritual life of men and women for millennia. Given these facts it is suggested that it is primarily the electromagnetic interaction that is the essential physical agent in effecting the concrescence of microscopic events interpreted by Whitehead as "actual occasions." Moreover, it will be argued that it is the electrodynamic phenomena involved in atomic and molecular radiative emissions and in interparticle collisions at the microscopic level that underlies the irreversible temporal nature of an actual occasion in its prehension process. Finally, it will be suggested that in the context of Whitehead's metaphysics the electromagnetic interaction and light, its radiation, are meaningful physical correlates for the immanence of God, the same immanence that influences the maturation of an actual occasion. These hypotheses are offered with the purpose of stimulating further study in this area.

Introduction

While Alfred North Whitehead was a student at Cambridge he became interested in the lectures on electricity and magnetism by W.D. Niven, a former pupil of James Clark Maxwell. It was Niven who later edited the second edition of Maxwell's monumental "Treatise on Electricity and Magnetism." Whitehead decided to develop his own thought concerning the "Treatise" by choosing it as a subject for his research dissertation at Trinity College in 1884 (MHW 95). His research and his study under Niven served as a basis for his first course of lectures at Harvard in 1924 in which he attempted a nontechnical presentation of Maxwell's equations. More importantly, however, this thorough foundation in the principles of electromagnetism was a vital influence in the development of his philosophy of physics (MHW 96).

However, Whitehead's insightful understanding of physics was balanced by his conviction that mathematical physics should not be considered the sole means of describing nature. Direct experience and perception were of equal and complementary importance in any description of natural phenomena: "For us the glow of the sunset is as much a part of nature as are the molecules and electric waves by which the man of science would explain the phenomena" (CN 29). Undoubtedly the subjective sensitivity apparent in this viewpoint helped inform the religious aspects of his metaphysics, involving for example his conception that God influences (but not determines) the concrescence of actual occasions.

With the foregoing aspects of Whitehead's thought in mind, I wish in this paper to present the case for electromagnetic interactions being primarily the underlying physical agents in effecting the becoming of an actual occasion. Moreover, given the fact that actual occasions are unique and irreproducible clearly implies the irreversible advance of time as expressed for example by the so-called thermodynamic arrow of time, I will suggest that it is quantum electromagnetic phenomena at the microscopic level (i.e. radiations from atomic and molecular emissions along with that from collisional interactions) that is primarily responsible for this irreversibility. As such, these phenomena are a part of the characterization of an actual occasion in its process of prehension and consequent manifestation of temporal irreversibility.

Finally, after outlining the premise that Whitehead's conception of God influencing the maturation of an actual occasion can be considered a central feature of God's immanence, I will maintain that the physical correlate for that immanence, in particular as it impacts on actual occasions, is the electromagnetic interaction (EMI).

Accordingly in the next section, after a brief review of the role that each of the four forces of nature in general plays in the existence of us and the universe, I will show that when we focus our attention on this earth it is primarily the electromagnetic interaction (EMI) that underlies properties and operation of virtually all of nature. With this as a background in the third section I will discuss how the EMI acts as a physical agent in the prehension process of an actual occasion. This is prefatory and relevant to exploring the consequent suggestion that quantum electrodynamic processes play a significant role in effecting time's irreversibility and in characterizing an actual occasion. In the concluding section arguments are forwarded in support of the contention that in the context of Whiteheadian thought the EMI is a physical correlate for the immanence of God.

Electromagnetism's Role as a Force of Nature on Earth

As far as we know today there are four different physical forces in nature. The strongest of these is the nuclear force, which, for example, keeps quarks together to form protons and neutrons and in turn keeps protons and neutrons together in a nucleus. Next in order of strength is the electromagnetic force which, as discussed in this paper, is the fundamental mechanism that makes possible the operation of us and most of the world to which we usually relate. The third is known as the weak force, which comes into play in the radioactive decay of a nucleus and many other elementary particle phenomena. By far the weakest of the four is gravity.

Despite the difference in their relative strengths, the electromagnetic and gravitational forces are both distinguished by the fact that they are long range forces, in contrast to the other two which have very short ranges. More specifically the electromagnetic force between two electrically charged bodies and the gravitational force between any two bodies with mass are both proportional to the inverse square of the distance between the two bodies. Although this means that these two forces become weaker the larger the distance between the bodies, it also means that however weak they become, in principle they never die out to exactly zero.

Therefore by their natures the electromagnetic and gravitational forces can lay claim to some kind of spatial universality, if only because their range can be so extensive. Indeed in the case of gravity it is its great range that renders it the dominant force cosmologically. Einstein has shown us that mass and space-time are intimately interdependent, so that it is the distribution of gravitationally interacting masses in the universe that defines the limits of the universe's space. It is also the mutual gravitational attraction that slows the universe's expansion and controls the interaction of planets, stars, and galaxies.

It is also true that the other two forces (weak and nuclear), although very short range, play a very vital role in sustaining the balance in cosmic nature that makes possible our existence. For example, if the nuclear force were roughly one percent weaker, deuterium (heavy hydrogen) could not form to go on to make helium and the result would be a universe made up of hydrogen only and we would not be here. If it were about one percent stronger, there would be too much helium, and we would not be here either. The nuclear and weak forces drive the processes that form the heavier nuclei in supernova explosions which later lead to the formation of second and third generation stars, such as our sun. It is such heavier nuclei that are at the core of the atoms and molecules making up our bodies.

So while the gravitational, nuclear, and weak forces are unquestionably vital, in this paper I will focus attention solely on characteristics of the electromagnetic force because, as will be seen, this force and electromagnetic radiation (or light), its carrier, are by comparison with the other forces so much more intimately dominant and omnipresent in all aspects of our lives and the way we sense and relate to the world.

This omnipresence became more apparent with the development of quantum electrodynamics (QED) which showed that the electromagnetic force between electrically charged particles is carried by unobservable photons, called virtual photons. Though they cannot be directly observed, their existence is certified by the fact that without including them QED calculations could not yield the results, which are in such incredibly accurate agreement with experiments.

In part because of the accuracy of QED but also because of the wide technological application of electromagnetic theory, the electromagnetic force is known far better than the other three forces. Its effect and presence in all aspects of our life and relation to the world is ubiquitous. At the microscopic level electrons are constrained to orbit around the nucleus of an atom by the electromagnetic force via its virtual photons. It is the same interactive "glue" that keeps atoms together in a molecule so that all of chemistry and biology at root operate via the electromagnetic force. For example, this force makes it possible for bacteria, the smallest living cells, to exhibit the purposeful mobility, coherent collective action, and remarkable sophistication they do in their growth and survival (SC). Bacteria as well as all other biological organisms are, from a thermodynamic viewpoint, far from equilibrium systems which exchange matter and energy with their environment for their sustenance and growth, but they do this via the electromagnetic interaction.

Humans are the farthest-from-equilibrium system of all, but as with less complex organisms the coherent action making possible this dynamic balance again depends on the electromagnetic interaction. So that we ourselves, and all our organs, are run by this mechanism, from the interactions of blood cells to the activity of neurons in the brain. The electronic imaging techniques currently being used to locate the regions of the brain activated by thoughts or emotions are based entirely on electromagnetic phenomena.

Light from a fire, gasoline consumption, and explosives (except for the nuclear bomb) all proceed via this interaction. It is the same force with its photonic "glue" that governs the incessant interplay of the molecules in air and water that collectively unite their motion to give us sound and ocean surf. While it is gravity that keeps us, all earthly objects, and the atmosphere attached to the Earth, it is the electromagnetic force with its mediating photons binding the atoms and molecules tightly together in solid objects that is a prime factor along with certain quantum effects in keeping the table lamp from falling through the table, and the table from falling through the floor. It is this force that makes possible all modern communication: telephone, radio, TV, satellite, etc. The wonders of laser technology, including the ease of delicate eye surgery, are based on this force.

Virtually all experimental studies of the other three forces, whether in the microscopic realm using particle accelerators or the cosmologic realm using telescopes, are conducted through an electromagnetic "filter." This, of course, includes the operation of all the computers and complex electronic instruments that store and analyze the data, and that make calculations based on the data. The now-famous cesium atomic clock is based on the fact that the cesium atom in one of its transitions between energy states emits photons, which oscillate at a precise frequency somewhat greater than 9 billion Hertz.

However, in this paper perhaps the most relevant property of the electromagnetism and its mediating photons are a host of very low energy, subtle, electromagnetic quantum events that make possible the life of humans and their consciousness (QES). The extreme subtlety of the events is quantified in recent experiments in microbiology which show that voltage gradients as low as 10^{-7} volts/cm and frequencies between 0 and 100 Hertz are involved in the interaction between cells in living creatures. All plant and animal life is bathed in, and interacts with, a sea of such very low frequency radiation that envelopes the earth. This is independent of radiation superimposed by technology (WC).

Obviously there are an indefinite number of examples of how universal the electromagnetism is in our internal and external experience. For no other phenomenon of physical nature so totally and intimately permeates and affects our lives and the nature on this planet.

Electromagnetism, Actual Occasions, and Time

With the EMI underlying virtually everything in our world from the dynamic stasis of rocks to the subtle operation of our own brains, it begs consideration as a primal factor in the full understanding of the nature of an actual occasion. An actual occasion acquisitionally "feels" or prehends data from previous occasions as well as the potentialities represented by eternal objects to realize its concrescence. But it is the subtle interaction of quantum electrodynamic events involving a multitude of mostly very low energy photons, real and virtual, that execute the "orders" in the prehension process (UEPI). Thus an actual occasion is a prehensive, processive unification of selected past data and a given pattern of eternal objects that is unique and peculiar to that occasion (WPR 23), but underlying this uniqueness is the action of an unique array of real and virtual photons. In the concrescence process delicate guidance is given an actual occasion by its subjective aim, which gives a value to it and is the "unifying factor governing the successive phases" of the process (PR 343). However, the elementary agent effecting the completion of these successive phases is again a host of real and virtual photons (UEPI).

Whitehead's concept of actual occasion involves some rather specific views about time and space. Indeed his treatment of space-time is at the core of his philosophical position (WPI 1). In particular time is regarded by him as an intrinsic expression of reality which for him is creative process in nature (BT 24). Whitehead notes that all knowledge is confined to observations which take time (PNK 6), which in turn implies temporal duration (RPT 23). For him "there is no nature apart from transition, and there is no transition apart from temporal observation" (MT 131).

Accordingly, actual occasions define a spatio-temporal domain and thus manifest a finite temporal duration and spatial extent in their becoming and the display of their uniqueness in maturation. It is this uniqueness that directly implies the irreversible nature of time. No two actual occasions are exactly the same; they are irreproducible and once having occurred are irrevocable, as is time.

However, there are a number of microscopic electrodynamic phenomena that may be of use in learning more about the structure of an actual occasion and its role in revealing the irreversible nature of time. Probably the best known of such phenomena is the emission and absorption of electromagnetic radiation by atoms and molecules [Higher energy electromagnetic radiation is also emitted and absorbed by nuclei, but here I am focusing on the lower energy phenomena that generally characterize most of the nature we ordinarily experience.] These particles can be excited to a higher energy state via a collision or the absorption of radiation, then in turn decay to their ground state with the emission of radiation. This kind of exchange of radiative energy is proceeding constantly all around us.

Another equally relevant phenomenon is known as *bremsstrahlung*, occurring in all electron, atomic, and molecule collision processes. Whenever an electrically charged particle is deflected in a collision it undergoes an acceleration and it emits photons whose energy varies depending on the kinetic energy of the particle and the angle of deflection.

Such emissions can also occur in collisions between neutral atoms and molecules among other things by virtue of what is known as van der Waals forces, which for example come into play in particular if the atoms or molecules have a non-spherical distribution of orbital electrons. But a lack of sphericity can also be induced in a collision between two neutral atoms which are ordinarily spherical (AB), resulting in what is called polarizational *bremsstrahlung*. In these cases very low energy bremsstrahlung photons can be emitted. Such photons, as well as higher energy photons from more energetic collisions, are lost in the medium; that is, the collision by the amount of this loss, however small or large is irreversible. This behavior of *bremsstrahlung* photons is in addition to that of photons ultimately lost to the medium, which, as noted above, are emitted and absorbed by atoms and molecules via transitions among their energy states.

In any case I suggest that this incessant electromagnetic energy exchange via photons, whether due to *bremsstrahlung* or to excitation and decay of atomic and molecular energy states, plays a fundamental role in the ultimate concrescence of an actual occasion. These photons are the physical agents executing the acts of prehension in the process leading to concrescence. In this process photons received from a previous microscopic actual occasion constitute data prehended in a present actual occasion, which occasion in turn furnishes data in the prehension involved in a subsequent occasion.

The integrated effect of this interrelation of the progressive, irreversible realizations of a host of microscopic actual occasions, each of which is unique and unrepeatable, gives support to the view that time can be seen as a holistic becoming. That is, each microscopic actual occasion can be regarded as a becoming, the aggregate effect of which at the macroscopic level yields the perception that time itself can be described as becoming. Indeed all three temporal modes, the past, present, and future, can be seen as becoming. The past is becoming because it is continually being added to. The present is becoming because it is always new. The future is becoming because the configuration of its potentialities is constantly being rearranged through the loss of those potentialities made real by the present. Accordingly, time is best identified with becoming and cannot be fairly or accurately described by such popular spatial metaphors as "arrow, linear, or direction" (BT 1567). In what "direction" does the "arrow" point? Although such metaphors are convenient and admittedly it is virtually impossible to describe the irreversible character of time without using words with some spatial connotation, the habitual use of such patently spatial terms tends to obfuscate the true nature of time as becoming.

Light and Divine Immanence in Whitehead's Metaphysics

Just as cognizance of the pervasiveness of electromagnetism here on earth can inform us concerning the temporal aspect of actual occasions, so also such cognizance may be useful in realizing a fuller understanding of the religious dimension of Whitehead's metaphysics. One salient feature of this dimension is his contention that an actual occasion is influenced but not determined by God in its process of concrescence. This omnipresent influence on all, even microscopic, actual occasions clearly suggests a perception of divine indwelling or immanence. But it is a myriad of electrodynamic events in the form of real and virtual photons that "execute the spiritual orders" in the exercise of that immanence and that underlie our ability to be aware of that immanence.

Since it is virtual photons, unobservable quanta of light, that carry the electromagnetic force, then they along with real photons can be said to constitute the realm of electromagnetism. So that in a sense all electromagnetic interactions can be seen as "light." This electromagnetic "light" is the physical agent of the divine immanence Whitehead sees as affecting actual occasions.

In order to appreciate more fully the importance of light as a physical agent in the realization of divine immanence it is worthwhile to give a brief distilled review of its place in the world's religious and spiritual life. Indeed light has served as a primary symbol for the spirituality of men and women since the dawn of human consciousness. Moreover, in mystical experiences it has actually served as a medium for relating to God. Scriptures of religions worldwide are replete with the use of light to symbolize God's provident and salvational relation to men and women. In the Old Testament, to cite a very few examples, God dwells in light in Exod. 24:10, is the light of Israel in Isa. 10:17, and is a light to the Gentiles in Isa. 42:6 and 49:6. And in the New Testament, Jesus is the light of the world in John 5:19, 8:12, 9:5, and 12:35. He is the light for revelation to the Gentiles in Luke 2:32.

In the Quran, light goes ahead for believers in Sura 62:12-15 and is provided by God so that believers may walk straight in Sura 62:28. The Svetasvatara Upanishad, often called Hinduism's theistic Upanishad, since it synthesized traditional meditation with worship of a personal god, speaks of "the great Purusha, who is luminous like the sun, and beyond darkness" (chap. 3,v. 8); "He is the Ruler and the Light that is imperishable" (chap. 3, v.12).

In many of the spiritual paths traveled by the Christian mystics, light has been a major feature in the visions they have experienced. For example, Saint Theresa of Avila speaks of a "light which knows no night" and Mechchild of Magdeburg: "The flowing light of the Godhead" (M 248). Christian saints are pictured with a halo of light surrounding their heads. When Yahweh spoke to Moses, it was by means of the burning bush. Paul's conversion on the road to Damascus was accompanied by blinding light. Many of those who have had near-death experiences report finding themselves at the final stage of the episode in the presence of a "Being of Light," which exudes unquestioning warmth and love and requires an unequivocally honest response (LL 58-64).

The quiet, calm glow of a small candle has been a spiritual symbol and aid that has engendered a sense of divine indwelling for men and women for millennia. Such use of candles to symbolize the spirituality expressed in rituals is found in religions throughout the world.

All of the foregoing are examples of the intimate relation of electromagnetic radiation, light, to a sense of divine indwelling experienced by men and women of virtually all religious traditions. A comparable apprehension of immanence is apparent in the thought of Whitehead not only because of the abundant subjective metaphors he uses in delineating his philosophy, but again because of the interactive influence he maintains that God has on the becoming of an actual occasion, luring it but not determining it.

The fact that light plays such an intimate role in catalyzing, if not conveying, God's immanence along with the universal role played by the EMI in all of earthly nature prompts me to maintain that the EMI is a meaningful physical analogue for the immanence of God. I base this contention on the logical assumption that at least some of the characteristics of God as Creator are transmitted to the created, i.e. us and the world. A total disconnect between Creator and creation, between Cause and effect, would be difficult to accept (PoR 26). One of the methods used by natural theologian is to seek patterns and characteristics in the properties and operation of the natural world that might reasonably be analogous to at least some attributes of God (PoR 15ff). In essence this is the approach followed here by selecting one part of nature, electromagnetism, and arguing that its omnipresence in our world constitutes a compelling physical analogue to the immanence of God.

However, in the context of Whitehead's religious philosophy I suggest a stronger claim may be made: that the EMI is a viable physical correlate to God's immanence. That is, more than simply a paralleling analogue, the EMI plays some interactive role in the relation between God and actual occasions.

The world is acted upon via Whitehead's perception that every actual occasion derives the initial stage of its subjective aim from God. To the extent then that every actual occasion draws its nature from this aim, God is objectified by each actual occasion (WPR 83). It is therefore in this way that God provides an antecedent influence on the behavior and future of an actual occasion. However, God by this influence on the subjective aim can only provide attraction for the actual occasion to its most fulfilling realization. It is in this way that:

He adds Himself to the actual ground from which every creative act takes its rise. The world lives by its incarnation of God in itself. (RM 56)

Thus it is the provision of the initial datum of the subjective aim that constitutes God's unique role in the creation of the world (WPR 76). Furthermore it is through this mediative interaction and the resultant objectification of God by actual occasions that God can be said to be processive. God uses and needs actual occasions "as an intermediate step towards the fulfillment of His own being" (PR 61).

It is Whitehead's conception of God being interactive with actual occasions and consequently in this sense also being processive that I suggest that the EMI may be a physical correlate for God's immanence. Given that it is the EMI that is the "workhorse" that provides the underlying physical operations that help bring about the fruition of an actual occasion, I suggest it also plays some role as the physical conveyer of the interaction between God and the actual occasion, an interaction that influences both the occasion and God. The EMI is the physical component of this reciprocal interaction and in this sense then may be said to be a physical correlate for the immanence of God.

In conclusion it must be understood that this paper has been presented in the context of classical Whiteheadian philosophy and does not deal with any subsequent related work in process philosophy or theology. Also I wish to emphasize that what is described in this paper I consider to be only reasonable suggestions for further explorative thought. I make no claims of exhaustive philosophical or theological rigor. Accordingly, the ideas expressed here are intended to stimulate continued research in this area.

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Fagg, Lawrence. "Electromagnetism, Time, and Immanence in Whitehead's Metaphysics." *Process Studies* 26 (1997): 308-317.

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