QUANTUM PHYSICS AND FREEDOM IN A WHITEHEADIAN PERSPECTIVE

by George Arkell Riggan

Abstract. This paper attempts to demonstrate the critical significance of early advances in quantum physics for Alfred North Whitehead's development of the categories of his metaphysics and to illustrate the capacity of his system to serve as a bridge between the sciences and the humanities by relating specific Whiteheadian categories to concrete microphysical behavior with special reference to the notion of freedom.

One of the ways to relate knowledge from the contemporary sciences and insights from religion is to place science and religion together into a system of philosophical categories, technically a metaphysics—categories that are general enough to be useful in analyzing all aspects of human experience as well as conceptualizations of human experiencing itself. While this is not the only way of yoking science and religion, many scholars argue that philosophy can provide one of the most substantial bridges between what Alfred North Whitehead judged to be "the two strongest general forces . . . which influence men . . . —the force of our religious intuitions, and the force of our impulse to accurate observation and logical deduction."[1]

It is especially noteworthy that advances in quantum mechanics in the first quarter of the present century were critically significant in Whitehead's development of the revolutionary metaphysical categories that he employed in his process philosophy—categories expressed of necessity as neologisms. His metaphysics has been employed by a small but distinguished group of theologians in what is called "process theology."[2] Theologians deeply influenced by Whitehead generally employ his categories responsibly and with creative insight; yet typically they fail to make explicit Whitehead's grounding

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of those categories in the phenomena of quantum physics. Scientists, therefore, who are interested in theology and religion are not infrequently bewildered by neologisms characteristic of Whiteheadian theological discussion. It is the purpose of this paper to illustrate the capacity of the Whiteheadian system to serve as a bridge between the sciences and the humanities by relating Whiteheadian categories to concrete microphysical behavior.

My focus will be on the notion of freedom, in particular on the physical processes prerequisite to the origin and maintenance of specifically human freedom. Of course, human freedom—the capacity to shape intentionally to some extent the environment in which one is involved and to direct to some extent one's own becoming toward self-selected goals—is not reducible to what we shall see as the spontaneity of physical processes. Further, one could also explore the biological, social, and spiritual processes prequisite to human freedom—a project beyond the scope of this particular paper. My purpose here is to indicate the physical substructure that, when interpreted in terms of Whiteheadian metaphysical concepts, helps to set human freedom in the context of the workings of the physical world, so that, although distinctive, human freedom is not viewed as anomalous in the evolutionary history of the universe. In doing this I also will be providing concrete illustration from physics of some of Whitehead's metaphysical ideas.

Whitehead himself was among the first to perceive that our understanding of human subjectivity and freedom can be illumined by models in quantum physics descriptive of the behavior of microphysical particles. An account by Richard Schlegel of the behavior of a quantum of light in an interferometer has greatly enhanced my long admiration of Whitehead's originality by helping me more clearly to perceive certain analogies between the behavior of microparticles and that of human beings in regard to freedom.[3] In just a moment I shall review Schlegel's account, but first I should like to recall the conceptions of light and microparticles that prevailed before the advent of quantum physics.

From the Nineteenth Century to the Quantum View of Light

Physicists of the nineteenth century assumed that light has no mass, and to account for its wave characteristics they postulated a universal space-filling medium, called ether, in which light is simply a wave phenomenon. They conceived the atom to be the smallest of microparticles, indivisible, and as moving from one point to another along a single path after the fashion of macrophysical objects—a bullet or a baseball for example. Hence it could be inferred that, if one

could but know at a point in time the location, mass, velocity, and trajectory of every single atom in the universe, theoretically one then could predict the course of all future events in the physical world. In this persistent and thoroughly deterministic world view the physical and the mental were perceived as disjoined and the latter was viewed as purely epiphenomenal.

Now let us turn to the behavior of light in an interferometer. Already in the nineteenth century, physicists knew that a beam of light directed toward a point midway between the two parallel slits of a simple interferometer will split and recombine on the screen of the instrument in alternate bands of light and dark, with diminishing intensity of light in bands increasingly distant from the center of the screen. Bands of light appear in areas of reinforcement where the wave crests of the split beam coincide, and dark bands in areas of interference, where crest and trough coincide (see figure 1).

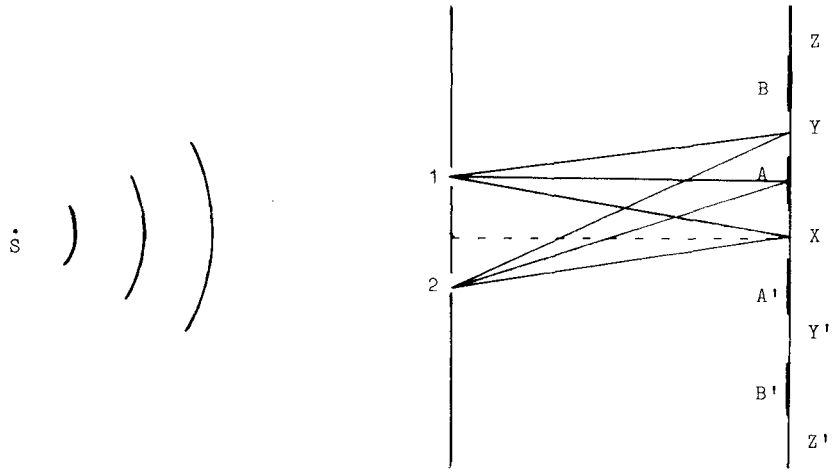

FIG. 1.—Light from the source "S" passes through the slits 1 and 2. Alternating bands of light and dark are formed on the screen by the light coming from the slits, with a maximum of light when the path lengths from the slits to the screen differ by an integral number of wavelengths (zones x, y and y', z and z'), and zero light when the path-length difference is (n + 1/2) where "n" is an integral number of wavelengths (zones a and a', b and b').

Schlegel reminds us, however, that two characteristics of light and of other forms of radiant energy were unknown in the nineteenth century. The first is that the transfer of radiant energy to the screen of the interferometer is by discrete units, or quanta. Thus in its interaction with the screen each quantum of light (a photon) delivers all of its energy to a single atom rather than being spread out wavelike

over many atoms. If the screen of the interferometer is a photographic plate and if the light source is extremely weak so that generally only one photon enters the apparatus at a time, each photon will make a tiny dark spot where it interacts with an atom in the light-sensitive emulsion. The precise spot at which a given photon will strike cannot be predicted. Therefore, light enters the two-slit apparatus as a wavelike phenomenon, as indicated by the alternate zones of light and dark, but it interacts with the screen as corpuscular photoms—the well-known wave-particle dualism. Incidentally, the corpuscular behavior of light obviates the need to postulate a universal space-filling ether, for the existence of which there is no evidence.

The second characteristic is that the observed interference pattern of alternate light and dark zones is, surprisingly, a consequence of interference *within* each individual photon. This conclusion is inevitable in view of the fact that photons admitted singly through the two slits over a long period of time distribute themselves over alternate zones of light and dark in exactly the same way as if all came through in a single burst. (If on the other hand one slit of the interferometer is closed and photos are admitted through the other slit, either singly over a long period of time, or in a short burst, they will distribute themselves in a single band upon the screen.) With both slits open, the probability for a given photon's making its dark spot in zone x, y, y′, z, or z′ can be calculated.

As of now the only way of bringing these newly discovered characteristics of light into a coherent theory is to assert that each photon exists in a set of substates superimposed one upon another in such way that one substate corresponds to a path that brings the photon to a point in zone x, another substate to a path that brings it to a point in zone y, and so on. In other words, the wave-interference effects require that the photon entering the interferometer be regarded as distributed over all its possible trajectories until, in the course of an observation-interaction, it moves along a single trajectory to a single molecule in the screen as its "wave function collapses"—to use a picturesque metaphor for describing the transition from its superposition of states to its observed single substate. Thus the appearance of any particular substate as an observed event can be calculated only as a statistical probability, despite the fact that quantum theory provides mathematical models exactly predicting and describing how the specific superposition of the photon, electron, neutron, or other microsystem will behave through time.[4] It is noteworthy that the superposition of a microsystem can never be observed as such but can only be inferred from observation-interactions of numerous particles of the same kind.

Whitehead and Quantum Physics

The behavior of the photon as a quantum of energy (its wave-corpuscular dualism) is the critically significant empirical model upon which Whitehead based his construction of the concept of the "actual entity"—a concept central to his philosophy of organism.[5] We live in a special cosmic epoch, he warned, an era we have later come to know as the atomic or nuclear age. "This epoch is characterized by electronic and protonic actual entities, and by yet more ultimate actual entities which can be *dimly discerned in the quanta of energy*" (italics added).[6] A quantum of energy, therefore, is for Whitehead not itself an actual entity in the most precise meaning of that technical term, but in the behavior of such a quantum an actual entity can be dimly discerned.

Actual entities are "the final real things of which the world is made up. There is no going behind actual entities to find anything more real. "They differ among themselves: God [surprisingly] is an actual entity, and so is the most trivial puff of existence in far-off empty space. But, though there are gradations of importance, and diversities of function, yet in the principles which actuality exemplifies all are on the same level. The final facts are, all alike, actual entities; and these actual entities are drops of experience, complex and interdependent."[7]

Whitehead distinguishes between a single actual entity ("actual occasion") and societies of actual occasions.[8] He restricts the term "society," in this technical usage, to mean a nexus of organically interrelated and systemically unified actual entities.[9] A living cell is such a society. So also is a worm, a jellyfish, an insect, a human, by way of example.[10] But so too every electron, every proton is to be regarded as a society of actual occasions.[11] Whitehead himself observes that in the interest of brevity of statement he sometimes refers to societies of actual occasions as themselves actual occasions.[12] However, when he is speaking quite precisely, he clearly means by "actual entity" that which can be *discerned* in a quantum of energy. The behavior of the photon in an interferometer comes at once to mind as the event from which an actual entity, in Whitehead's meaning, can be inferred.

Whitehead perceived, in the behavior of the quantum of energy, empirical evidence for a monistic ontology that allegedly overcomes the mind-body dualism so widely prevalent in Western philosophy. He notes that both René Descartes and John Locke maintained a two-substance ontology—the former explicitly, the latter implicitly. Descartes, though methodologically starting with thinking substance ("I think, therefore I am"), placed emphasis upon his account of corporeal substance. However, Locke achieved, within the strictures of his special perspective, a description of mental substance more

philosophically penetrating than Descartes' account of corporeal substance. By radically transforming the notion of substance into the concept of actual entity, Whitehead intentionally sought to preserve Locke's insights while giving balanced attention to the corpuscular characteristics of actuality. The philosophy of organism (or process philosophy) is the elaboration of this monadic "scheme for a single type of actual entity."[13]

It must be remembered, however, that Whitehead developed his philosophy while quantum physics was still in its infancy. Furthre, it can be argued that his bias towards Lockian idealism prejudices his interpretation of the evidence available from quantum mechanics in his own day. He assumes, for example, that an actual occasion or actual entity never moves through space.[14] The particles of microphysics, by contrast, do move through space and some have extended duration in time. Whitehead perceives a molecule, therefore, (and presumably a photon), not as an actual occasion but rather as a determinate nexus of actual occasions. More specifically, he sees it as "an historic route of temporal succession of inter-related occasions," propagated through successively overlapping spaces.[15]

Whitehead's notion of an unmoving actual occasion, inferred from the behavior of a quantum of energy, exhibits what he himself called the fallacy of misplaced concreteness, that is, the reification of a conceptual abstraction. *If, however, we grant the theory that a photon, proton, electron, or similar microphysical particle exists in a superposition of states, then the moving microparticle itself can be shown, both at its origin and at the collapse of its superposition in an observation-interaction, to exhibit the characteristics that Whitehead ascribed in philosophic and poetic metaphor to one of his actual occasions, with the important exception that an actual occasion moves.*

The Becoming of an Actual Occasion Illustrated by a Photon

Consider the behavior of a photon—not just any old photon but a particular one originating in the sun and moving along a path intercepted on earth by a particular green leaf. According to Whitehead, every actual entity (in this instance the photon) is at once a "superject" and a "subject"[16] As superject the photon emerges into concrete existence from the world, specifically in this case from interactions within the sun. Furthermore, as the fundamental unit of "concrete reality" every actual occasion (in our example the photon) exhibits both physical and at least rudimentary mental characteristics. In other words, every actual entity is a dipolar phenomenon, having both a "physical pole" and a "mental pole." For Whitehead, therefore, it can be said of

every actual entity (the photon) that at once it is a process and it is atomic, so that in no sense is it the mere sum of its parts.[17] "The philosophy of organism is a cell-theory of actuality. Each ultimate unit of fact is a cell-complex, not analysable into components with equivalent completeness of actuality."[18]

Therefore, Whitehead completely abandons the notion of an actual entity as the unchanging subject of change. (As the subject of change the photon itself, in its observation interaction, becomes what it was not.) "The ancient doctrine that 'no one crosses the same river twice' is extended. No thinker thinks twice; and to put the matter more generally, no subject experiences twice. This," said Whitehead, "is what Locke ought to have meant by his doctrine of time as a 'perpetual perishing.' "[19]

As subject, the photon approaching the living leaf "prehends" the molecules within the field of its superposition as "physical data"; it also prehends the novel possibility entailed in uniting in the leaf with this or with that different kind of molecule as a "conceptual datum" for its own becoming and perishing. Prehensions are of two kinds: "positive prehensions" ("feelings")[20] hold their data as operative in the becoming of the subject (photon); "negative prehensions" hold data as inoperative.

The modes in which subjects prehend their data, that is, the possible "subjective forms" of prehension, are numerous, including: adversions, aversions, emotions, valuations, purposes, and consciousness.[21] Consciousness is not necessarily involved in the prehension of either physical or conceptual data.[22] In reference to our reconstructed example of an actual entity, the photon's exhibition of rudimentary mental activity presumably does not involve consciousness; rather its prehensions involve internal electro-magnetic modifications responsive to its particular microphysical environment. The non-conscious "mentation" of the photon is thus distantly analogous to the human experience of mentally registering the presence of myriad objects or activities beyond later recall except under the influence of hypnosis or special drugs. Subjective form is determined by the "subjective aim," at further integration.[23] This in turn depends upon the constitution of the particular actual entity. "An actual entity [the photon of our reconstructed illustration] is a process in the course of which many operations with incomplete subjective unity terminate in a completed unity of operation termed the '*satisfaction*' " (italics added).[24]

Let us suppose that the superposition of our illustrative photon actually collapses in an interaction with a molecule of amine—itself a complex society of actual occasions—in the green leaf. The photon and the amine cease to exist as photon and amine. Each "perishes" and in perishing, together they become a molecule of thiamine—a

new creation, an instance of photosynthesis, the general process that provides the several kinds of building blocks for almost all living organisms. As I understand Whitehead, the *pure potential* of photon and amine for becoming thiamine is an "eternal object." The *actualization* of thiamine consequent upon the union of this particular photon with that particular molecule of amine is a novel actual occasion or system of occasions. Again applying Whiteheadian categories in our reconstructed case of the photon: "The terminal unity of operation, here called the 'satisfaction,' embodies what the actual entity is beyond itself. . . . Its own process, which is its own internal existence [*i.e.*, its subjectivity], has evaporated, worn out and satisfied; but its effects are all to be described in terms of its 'satisfaction.' The 'effects' of an actual entity are its interventions in concrescent processes other than its own. Any entity, thus intervening in processes transcending itself, is said to be functioning as an '*object*'" (italics added).[25] Subjectively the photon has perished, but by its concrescent transformation with amine into thiamine it has achieved objective immortality in the solidarity of the universe. As a result, the world will never again be exactly the same.

The growing together (concrescence) of the photon with the amine molecule to form a novel actual entity (thiamine) could not occur if the leaf and the particular molecule of amine were not where and as they were in the moment of the photon's transformation. Indeed, if we allow for degrees of relevance, and for negligible relevance, we must say that the concrescence exhibited as thiamine required for its creation that every constituent in the whole flux of the universe be where and as it was at the moment of the photon's and amine's "objectification."[26] Yet no reason internal to history can be assigned as to why the flux of the universe at that moment should have been in just that state rather than some other alternative state internally determined by the multiplicity of antecedent actual occasions.[27]

Thus the Whiteheadian process philosophy holds that "organism" has two meanings, intellectually distinguishable but inseparable in their actual referent: a microscopic meaning and a macroscopic meaning. The former is "concerned with the formal constitution of an actual entity, considered as a process of realizing a particular unity of experience." The latter, macroscopic meaning is "concerned with the giveness of the actual world, considered as the stubborn fact which at once limits and provides opportunity for the particular actual occasion."[28] Viewed microscopically therefore, the thiamine molecule itself is immediately a concrescence of photon and amine molecule; viewed macroscopically it is a particular concrescence of the whole internally self-creative universe.

The Microphysical Matrix of Human Freedom

Freedom seems intuitively to be a metaphor appropriately applicable to the behavior exhibited by the superposition of a microphysical particle at both its origin and collapse. Of course, this is a rudimentary freedom—even a negligible freedom for most practical purposes. Qualitatively it does not approximate human freedom. For one thing, there is no evidence of intentionality, that is, of conscious purpose, in the self-creation of microphysical entities nor in their contributions to the transformations of their particular environments.[29] Yet this is, I would argue, a freedom singularly significant for the understanding of the expansion of freedoms in successive phases of the evolutionary process.

The attribution of "mental" states and of freedom to microphysical quanta obviously does not advance the science of quantum physics. Viewed externally, objectively, and scientifically, what we are here discussing is simply the fact of microphysical indeterminancy. It is just Whitehead's signal contribution, however, to remind us from another viewpoint that at least a meager internality, an incipient subjectivity, a rudimentary self-determination or freedom constitute a polar aspect of minute entities we too commonly regard as exclusively physical. The problem is to focus upon this dipolarity of the actual without being seduced by our metaphors into the pathetic fallacy.

The concrescence of every individual actual entity, according to Whitehead, is internally determined and externally free. By way of further elaboration, he adds that "in each concrescence whatever is determinable is determined, but that there is always a remainder for the decision of the *subject-superject of that concrescence*" (italics added).[30] This subject-superject (in the reconstructed case of the photon, for example) may be viewed ultimately and macroscopically as the universe functioning self-creatively in the synthesis of the particular concrescence.[31] Or this subject-superject may also be viewed immediately and microscopically as the particular actual entity (in our reconstruction, the photon itself) functioning at once in its own self-determination and in the initiation of another actual entity (the thiamine molecule.[32] ". . . each concrescence is to be referred to a definite free initiation and a definite free conclusion."[33] In macroscopic perspective, the universe "decided" on the spur of that moment to provide for our photon a number of options for its becoming, among which was the possibility of concrescent participation with that particular molecule of amine in creating a particular molecule of thiamine. In microscopic perspective, the photon itself "decided," though without consciousness, to actualize that one possibility out of all the options provided. Its "decision" could have been predicted only

in terms of statistical probability even under conditions of objective experimental control.

Whitehead observes that "each actual entity exhibits its measure of creative emphasis in proportion to its measure of subjective intensity." He adds that some actual entities (again I suggest our photon, not as a Whiteheadian, but as a reconstructed illustration) are of such slight subjective intensity that their decisions are individually negligible compared to the determined components which they receive and transmit.[34]

The individual human being, in contrast to a microparticle, is an actual entity, or a society of actual entities, of exceedingly rich subjective intensity, whose final decision among alternative courses of action in a situation of multiple possibilities is the foundation of the human experience of responsibility, of approbation or disapprobation, of self-approval or self-reproach, and of specifically human freedom and creativity. I concur with Whitehead that this element in human experience is too large to be put aside merely as misconstruction.[35] Furthermore, human freedom and its correlative functions should not be treated as anomalies that alienate us from the world out of which we originate and within which alone we continue to live. The advantage of a metaphysical framework, such as that of Whitehead, is that it allows us to perceive the microphysical universe as the indispensable matrix out of which the most cherished characteristics of human life have emerged and enlarged through successive stages of an evolutionary process that embraces the physical, biophysical, and socio-cultural dimensions of our existence.

NOTES

1. Alfred North Whitehead, *Science and the Modern World* (1925; New York: Mentor Books, 1964), p. 162.

2. Any comprehensive list of process theologians would inevitably include, among others, the names of John B. Cobb, Jr., David Griffin, Charles Hartshorne, Schubert M. Ogden, Daniel Day Williams, and of course Alfred North Whitehead. For excerpts from major works in process theology see Delwin Brown, Ralph E. James, Jr., and Gene Reeves, eds., *Process Philosophy and Christian Thought* (Indianapolis and New York: Bobbs-Merrill Co., 1971). See also articles in the journal *Process Studies*, ed. Lewis S. Ford (Claremont, Calif.: Process Studies, 1971-).

3. Richard Schlegel, "Quantum Physics and Human Purpose," *Zygon* 8 (September-December 1973): 200-20. Compare my own remarks in George Arkell Riggan, "Epilogue to the Symposium on Science and Human Purpose," *Zygon* 8 (September-December 1973): 448-51.

4. Roberto Colella, A. W. Overhauser, and S. A. Werner have used a nuclear reactor and a neutron interferometer at the University of Michigan to demonstrate in a single experiment both the gravitational and the wave-interference effects of neutrons. For reference to the experiment see "Falling Quanta," *Scientific American* 234 (January 1976): 61-62.

5. Compare Alfred North Whitehead, *Process and Reality* (New York: Macmillan, 1929), pp. 141, 53-54, 121-22.

6. Ibid., p. 139.
7. Ibid., pp. 27-28.
8. Whitehead uses "actual occasion" as a synonym for "actual entity" chiefly when its extensiveness has some direct relevance to the discussion—either temporal extension (i.e., duration), spatial extension, or both. Ibid., p. 119.
9. Ibid., pp. 136-41.
10. Ibid., pp. 165-67.
11. Ibid., pp. 139-40.
12. Ibid., p. 141.
13. Ibid., pp. 28, 29.
14. Ibid., pp. 113, 119, 124.
15. Ibid., pp. 113-14, 124. Cf. also pp. 127-67. 431-508.
16. Ibid., p. 136. Cf. also p. 234.
17. Ibid., p. 213.
18. Ibid., p. 334.
19. Ibid., p. 43.
20. Ibid., p. 337. Cf. also p. 35.
21. Ibid., p. 35.
22. Ibid., p. 35, 246, 262.
23. Ibid., p. 29.
24. Ibid., p. 335. Cf. "category of explanation" xxii, p. 33.
25. Ibid., pp. 335-36.
26. Ibid., pp. 29-80.
27. Ibid., p. 74.
28. Ibid., pp. 196-97.
29. On the self-creation of actual entities, cf. "category of explanation" xxii, ibid., p. 39, *passim*.
30. Ibid., p. 41. Cf. also p. 74.
31. Cf. ibid., pp. 41, 75.
32. Cf. "category of explanation" xxiii, ibid., p. 38. Cf. also p. 43.
33. Ibid., p. 75.
34. Ibid.
35. Ibid., p. 74.