Articles

QUANTUM MECHANICS AND "SONG OF MYSELF": GETTING A GRIP ON REALITY

by Robert M. Schaible

Abstract. Most recent writing linking science and literature has concerned itself with challenges to the epistemological status of scientific knowledge in an attempt to demonstrate its contingency, arguing in the more radical efforts that the structures of science are no more than useful fictions. This essay also includes an epistemological comparison between science and literature, but instead of making grand or meta-statements about the nature of knowing generally in the two fields, mine is a much narrower aim. My exploration entails two tasks. First, I provide a close-up look at a particular type of experiment, called the delayed-choice experiment, which clearly reveals the strangeness of the quantum world. In connection with this experiment, I discuss wave functions—mathematical expressions used by physicists to describe quantum behavior and predict the outcome of experiments involving quanta. Second, I look at Walt Whitman's "Song of Myself" focusing on the meaning of the "self" in the poem. My aim is to treat the object of study in each field as a "text" and to assert and demonstrate a parallel in the strategies of thought and response between physicists ("readers") pondering the meaning and status of a wave function and poem readers pondering the meaning and status of the poem's self. In Whitman's "Song" we find an attempt to understand complex aspects of human experience that are said to transcend ordinary reality, an effort for which I believe there are parallels in the attempts of modern physicists to understand complex, nonintuitive aspects of the subatomic world. While not making the kind of broad claims eschewed above, I do suggest that this focused study has interesting implications since both the wave function and the poem's self force their respective sets of "readers" to confront

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questions of ultimacy—to consider, that is, epistemological and ontological issues of more than passing interest to students of science as well as those of metaphysics and theology.

Keywords: Copenhagen Interpretation; correspondential and instrumental notions of truth; delayed-choice experiment; mathematical formalism; metaphysics; mysticism; potentia; quantum facts; quantum reality; quantum wave function; sign; signified; signifier; thematic formalism; transcendent Self.

Someone once quipped, as Wendell Harris has reminded us, that "one ill afflicting the humanities, and especially English departments, is 'physics envy.' Like Ogden Nash's sea-gull who will never become an eagle, the study of literature will never operate like the study of physics" (Harris 2000, 222). This is no doubt true. The obvious differences between the ways these two fields, separated into what C. P. Snow (1959) famously called the "two cultures," operate in their respective realms of experience should not, however, keep us from exploring possibly legitimate parallels and similarities between them. To do this, moreover, certainly need not mean to indulge in any of the extremes justly lamented by Harris whereby literary types attempt to show "that science is a fiction in the same sense that a novel is a fiction" (2000, 213). Instead of making such antagonistic metastatements about the nature of knowing across the two fields, I profess a narrower, more tentative, friendlier aim.

My exploration entails two tasks initially. First, I provide a close-up look at a particular type of experiment, called the delayed-choice experiment, which clearly reveals the strangeness of the quantum world. In connection with this experiment, I discuss wave functions, the mathematical expressions used by physicists to describe quantum behavior and predict the outcome of experiments involving quanta—those minute entities, like photons and electrons, that make up the special province of quantum physicists. The second part of the essay entails a look at Walt Whitman's "Song of Myself" (1855) with a focus on the meaning of the "self" in the poem. While not making the kind of broad claims eschewed above, I think it reasonable to suggest that this study has interesting implications for students of the two fields. Both the wave function and the poem's self push their respective sets of "readers" into a consideration of epistemological and ontological issues—and do so in a way that demonstrates a surprising commonality, at this level, in strategies of thought and response between physicists, on the one hand, and poets and readers of poems, on the other.[1]

I chose the delayed-choice experiment because it has been widely discussed and exemplifies quantum experiments that force us to go beyond the framework of classical explanations, specifically explanations that rely on simple causal determinism (i.e., a belief that a given "cause" is a sufficient condition for its "effect" 100 percent of the time). I chose the wave function because it appears to play, in the physicist's exploration of a quantum reality that lies beyond quantum theory, a role analogous to that of Whitman's "self" whenever the poem's readers contemplate the possibility of a transcendent Self as a reality that lies beyond the poem's abstract notion of such a Self. One may not agree with Roger Asselineau when he says, "All poetry, in order to be valid, must be the expression of a Weltanschauung" (1962, 21), but many great poems do indeed present something approaching an encompassing philosophical scheme, and Whitman's "Song" is clearly such a poem, one that elicits the kinds of response that concern us here. The poem forces readers to grapple, as the poet has done, with complex aspects of human experience that are said to transcend ordinary reality, an effort for which I believe there are parallels in the attempts of modern physicists to understand complex, nonintuitive aspects of the subatomic world.

The Physics

Figure 1 (see next page) is a description of the delayed-choice experiment. In an attempt to explain these results by ordinary cause and effect (what physicists call local causality), we might say that the photon "decides" at the first beam splitter whether to travel both paths, and thus to produce interference and reveal its wavelike nature, or to pick one path and reveal its particlelike nature. The outcome of this experiment implies that the photon would have to "know" (that is, feel some effect of) the position of the switch in order to "make the decisions" that give the observed results. But the switch lies in a part of the path the photon has not yet traveled. Perhaps information about the switch position is somehow transmitted to the photon. If so, because the photon travels at the speed of light, the information would necessarily travel at a speed greater than that of light, which physicists believe to be impossible. (Causal effects that would have to move faster than light are called nonlocal causes.)

The last sentence of the figure caption shows the deep strangeness of the quantum world as revealed by this experiment. Even if we wait until the photon—considered as a deterministic object traveling at the speed of light—has had time to pass the first beam splitter, we still observe particle behavior if, prior to detection, we set the switch to deflect photons toward the photodetector. Correspondingly, we observe wave behavior if, prior to detection, we set the switch to transmit the photon so that interference occurs in the second beam splitter as the photon in path A somehow interacts with itself or with another photon presumably traveling path A'. Results depend on the switch's position at the time of measurement, not its position when the photon passes the first beam splitter, when, common sense tells us, it must "decide" which of its two behaviors—wave or particle—to adopt.

Stranger still, even if we wait until the photon has had time to travel beyond the second beam splitter and then change the position of the switch before the photon is detected, the result will reflect that final position of the switch, as if the switch affects the photon even after it has passed. Physicists have no satisfactory classical explanation for these results, which defy common sense but which are in perfect agreement with the laws of quantum physics—that is, the results are perfectly predicted by sets of mathematical expressions known to physicists as wave functions. Because wave functions are central to the theme of this essay, a brief explanation, along with an illustration of their use, is in order.

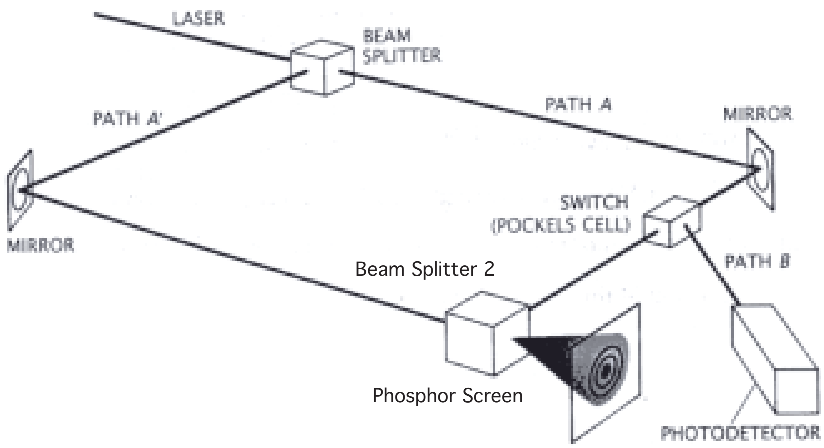


Fig. 1. DELAYED-CHOICE EXPERIMENT is another test that reveals the strangeness of the quantum world. A photon impinges on a beam splitter. Two questions about the photon can be asked. Does the photon take a definite route so that it is either transmitted or reflected by the beam splitter, thereby exhibiting a particlelike property? Or is the photon in some sense both transmitted and reflected so that it interferes with itself, exhibiting a wavelike property? To find out, a switch is positioned in one of the two paths the photon can take after interacting with the beam splitter *(here, path* A). If the switch is on, the light is deflected into a photodetector (*path* B), thereby answering the question of which route and confirming the photon's particlelike properties. If the switch is off, the photon is free to interfere with itself *(paths* A *and* A') and produce an interference pattern, demonstrating the photon's wavelike properties. Results from the experiment show that a photon behaves like a wave when wavelike properties are measured and behaves like a particle when particlelike properties are measured. Remarkably, the switch was triggered after the photon had interacted with the beam splitter, so that the photon could not have been "informed" whether to behave like a particle and take a definite route or to behave like a wave and propagate simultaneously along two routes. (Reprinted with permission from Shimony 1988, 52. The labels "Beam Splitter 2" and "Phosphor Screen" were added by author.)

The results of the delayed-choice experiment imply that photons are quite unlike objects in our everyday world. Their behaviors and certain properties seem to depend upon how the physicist decides to detect them, and the assumption that they, in any ordinary sense, exist and travel definite paths independently of and prior to our efforts to detect them is in conflict with the experimental results. This central insight of quantum mechanics runs directly contrary to the assumption in classical physics that particles exist and behave in ways that are completely independent of the observer—an assumption enshrined in the common epistemology that presumes knowledge is either objective (i.e., a fully accurate picture of an objective reality that is utterly independent of the knower and his or her instruments) or subjective (i.e., the result of individual ideology, mood, and so on). Rather, the assumption that particles exist and travel in predictable paths whether we detect them or not—an assumption also denoted as the assumption of local reality—is in direct conflict with the experimental results. In the words of physicist David Lindley, "quantum mechanics denies the existence of any absolute reality, denies that there is a mechanical world of particles and forces existing independently of us. The [subatomic] world is what we measure it to be, and no more than what we measure it to be" (1993, 76).

In addition, there is a random element in the behavior of quanta, revealed most obviously in the observation that when the delayed-choice apparatus is set to reveal particle behavior, roughly half the photons appear at the photodetector, but no one can predict whether a particular photon will appear there or not; we can know only what the probability is of detecting a particular photon. This random element in photon behavior is further exposed when the apparatus is set up to reveal wave behavior. Under these conditions, the physicist still detects individual photons as if they were particles but finds that a collection of many such photons sent through the apparatus over a period of time produces a pattern that suggests wave interference has occurred. Mathematical descriptions of such patterns can be derived from functions identical to those used to describe classical waves, such as water waves or sound waves. These expressions, which apply to all quanta, are the wave functions mentioned earlier and are referred to by the symbol Ψ (psi, the twenty-third letter in the Greek alphabet).

The symbol Ψ represents the quanta being measured and can be thought of as the quanta's "proxy" wave, "one way in which Ψ differs from ordinary waves," explains physicist Nick Herbert (1985, 85). Working with Ψ^2, obtained directly from the wave function, physicists can obtain a description of the pattern of behavior that a collection of photons (or other quanta) will exhibit. The new expression $|\Psi^2|$ can be interpreted in two equivalent ways: (1) it gives the probability that an individual quantum will contribute in a specific way to the overall pattern produced by many quanta, or

(2) it gives the percentage of quanta in a collection that will contribute in a specific way to the overall pattern.

As an example of this collective, patterned behavior of quanta and of the way this behavior is described with a wave function, let us consider the diffraction of electrons. We see diffraction when a beam of electrons is aimed at a barrier in which there is a small hole beyond which is a phosphor screen covered with a film that develops a small black spot wherever an electron strikes. The beam of electrons produces black spots in an array called an Airy pattern, after Sir George Airy, whose early work on interference and diffraction of light waves first provided a classical mathematical description of the pattern. The Airy pattern produced by several thousand electrons looks like the image in Figure 2.

Physicists have never achieved the ability to predict where an individual electron will land on the film during this kind of experiment. Indeed, the wave function means in part that no one will ever be able to predict where an individual particle may land. We can only know that, if many electrons pass through the hole, this pattern will result. Each electron has, as it were, a will of its own, but the collective will of a large number of electrons always is to form this ringlike pattern of spots, which is dense at the center and becomes less dense at greater distances from the center. This limitation to statistical predictivity of the results is typical of all experiments involving quanta.[2]

How does the physicist describe such results and formulate the patterns into stated laws of quantum behavior? Whereas the path of an everyday object like a baseball can be described by a deterministic equation giving the position of the baseball at any time and point along its trajectory, physi-

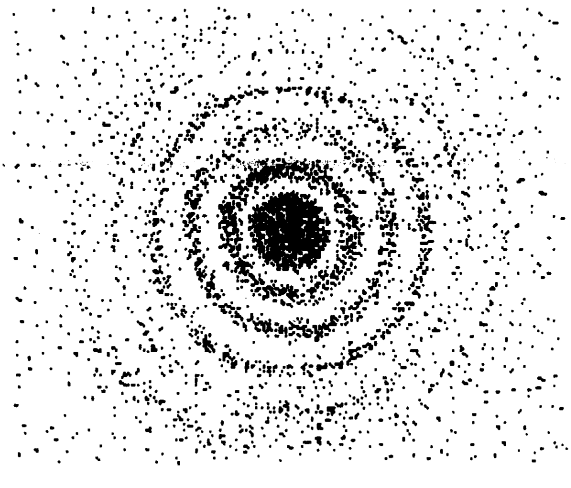
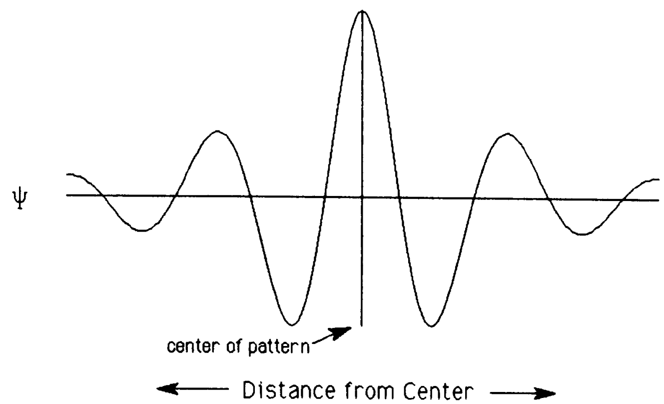


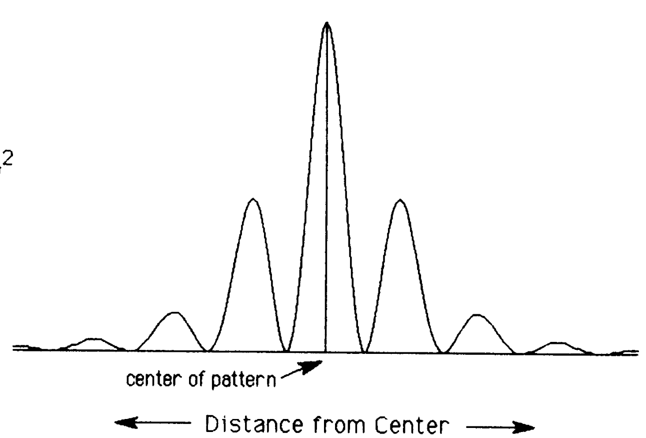
Fig. 2. The Airy Pattern. (Reprinted with permission from Herbert 1985, 62.)

cists have discovered no way to describe the motions of these electrons at all. Instead, they derive a description, in probabilistic terms, of the final pattern of spots, the *result* of the electrons' motion. This description is derived from a wave function that, when squared, allows physicists (1) to calculate the probability that an electron will land within a given distance of the center or, equivalently, (2) to calculate, for a collection of electrons produced by the electron gun over a period of time, the percentage of electrons that will land within a given distance of the center.

A graph of the wave function for electron diffraction is shown here:[3]



This graph gives a numerical value (on the vertical axis) of Ψ for every value of the distance from the center of the pattern (on the horizontal axis). To obtain Ψ^2, we multiply each value of Ψ by itself (that is, we square each value), and then we can draw a graph that displays the numerical value of Ψ^2 at each distance from the center, giving this result:



The height of the curve at a given distance represents the probability that one electron will land at that distance from the center of the screen (or the percentage of the electrons in a collection that will land there). Notice that the probability that an electron will land at the center of the pattern is high, as indicated by the largest peak in the center of the graph, and that the probability rises and falls as we go out from the center, just as the observed pattern of spots is darkest at the center and exhibits alternating rings of dense and sparse spots.

This wave function allows the physicist to calculate the probability of all possible outcomes of the diffraction experiment, with a specific size hole, a specific distance from hole to screen, and electrons of specific energy. The wave function would be different for some other type of experiment—for instance, if there were two holes in the screen instead of one. Each quantum-mechanical system, which includes quanta—in this case electrons—and some measuring device—in this case the film—has a characteristic wave function. All wave functions have in common that they allow us to see what experimental outcomes are possible and how often each possible outcome is expected to occur. However, what physicists do not have is a physical description of an electron itself or of its actual path from source to film. One means of approaching the problem is to use the wave function as a guide and to ask, in effect, What is a quantum, that it should behave as its wave function predicts? and, Does the wave function itself, which provides the most complete descriptions and predictions available of the behaviors of quanta, reveal anything about some presumably physical reality behind the mathematics?

Before addressing these questions, we must first note a couple of significant distinctions and briefly consider the role of language itself in this discussion. In his book *Quantum Reality: Beyond the New Physics* (1985) Herbert examines the distinction between two realms, that of quantum facts and that of quantum reality. The realm of facts is the laboratory, where experimental apparatus (such as the photon source, mirrors, beam splitters, and electronic counters of the delayed-choice experiment) are used to produce the results of measurements that can be classified as concrete data. A result is said to be measured (or a fact recorded) whenever the physicist observes such phenomena as an electric discharge in a particle detector, a flash on a phosphor screen, darkened areas on a photographic plate, or tracks in a bubble chamber. We enter the realm of quantum reality when we seek "the *reality* behind the mathematics" (1985, xii) or, as Bernard d'Espagnat puts it, "the physical events that are presumed to underlie the observed results" (1979, 158)—that is, when we speak of the entity that presumably exists prior to measurement and that is responsible for the strange results obtained in experiments involving quanta. Most physicists operate within the realm of quantum facts and leave speculation about quantum reality to philosophers, but a few physicists tackle this additional challenge. (Herbert, in fact, provides eight distinct explanations by a variety of theoretical physicists of the nature of quantum physics' most fundamental reality [1985, chaps. 9 and 10].) A consideration of both realms together suggests that the task facing philosophically minded physicists is similar in its structure and impetus, as we shall see, to that facing the readers of Whitman's poem. In other words, when physicists study the data produced by a photon gun, beam splitter, photographic plate, and so on, we can think of them as "reading" the "text" of physical nature as it presents itself in the alphabet or language of the lab. And because this text presents strange happenings that for some physicists/readers suggest the need for a (meta)physical interpretation, such physicists are impelled to construct such a reading of the textual data. Similarly, the readers of Whitman's poem confront a vast array of such data as individual words, statements, images, and complex metaphors, all constituting a text that features claims and happenings transcending the world of ordinary experience and demanding of its readers some sort of stance on the experience thus presented.[4]

At the level of quantum fact, language can be used as securely as it is by any classical physicist plotting the path of baseballs, missiles, and moons. We speak of particulars—of spark chambers, flashes on phosphor screens, and needles or digital devices that register electric discharges—and we speak with sufficient finger-pointing clarity to satisfy the most hard-edged of logical positivists. In popular parlance, such terms as *atom*, *particle*, *electron*, *photon*, and *wave* also suggest the level of real facts or objects. And, as Max Jammer informs us in his book surveying the history of philosophical perspectives on quantum mechanics, "It has been claimed that even the most 'progressive' theoretician believes at the bottom of his heart in a strictly deterministic, objective world even if his teachings categorically deny such a view" (1974, 253). A careful consideration of the meaning of terms like *atom* and *photon*, however, plops us uncomfortably into the sea of quantum reality, where the linguistic and philosophic waters begin to roil. Referring to electrons, for example, physicist John Bell once declared in an interview for a popular science magazine, "these you are not allowed to speak about. You . . . can't talk of them" (1988, 86). Speaking of waves, he later puzzled, "What is it that 'waves' in wave mechanics? In the case of water waves it is the surface of the water that waves. With sound waves the pressure of the air oscillates. . . . In the case of the waves of wave mechanics we have no idea what is waving . . . and do not ask the question." In a similar vein, he went on to confess, "We have no right whatever to a clear picture of what goes on at the atomic level" (1993, 187, 188). And Nobel laureate chemist Roald Hoffmann has written that thinking of atoms "as if they were normal objects [is] a little naive, unavoidable, and endearing—not unlike a belief in angels in past centuries" (Hoffman and Laszlo 1989, 35).

Using the vocabulary of semiotics, we might say that these terms (atom, electron, and so on) are ambiguous signs, for they are signifiers with disputable signifieds.[5] In philosophical terms, at stake here is a contrast between instrumental and correspondence notions of truth. Instrumental notions of truth, applied to science, accept our accounts, claims, and theories as simply instruments or models for thinking about physical reality and attempting to predict how the world will behave as it appears to us. By contrast, correspondence notions—in some ways, the most commonsense notions of truth—presume an external, "objective" reality; this reality, in turn, is known when our claims about it correspond as perfectly as possible to that reality. To say it another way, truth in this view is *literal* truth—a rendering of reality in words and mental pictures that re-present reality as it really is. Classical physics, for example, would say that notions of gravity, cause and effect, and so on are true because they correspond to the way the world in fact is.

Now to return to our central concern. As noted earlier, I wish to focus my investigation by exploring the possibility that the expressions "wave function" in physics and "self" in Whitman's poem occupy parallel kinds of mental space for their different users. First, "wave function" can be understood as a stand-in, or proxy, for quanta apparently existing prior to observation and exhibiting "both wave and particle aspects in the peculiar quantum manner" (Herbert 1985, 64). We are dealing here, as Herbert informs us, with what is called the quantum interpretation question, which asks: "what does the quon's proxy wave tell us about the factual situation of an unmeasured quon?" (p. 114; "quon" is Herbert's expression for any unmeasured quantum) Physicists, for our purposes, can be placed into two camps according to their response to the term *wave function*: (1) those following an instrumental notion of truth who accept it as signifying nothing more than a useful mathematical formalism and (2) those following a correspondence notion who believe it reflects some sort of deep reality that constitutes, or converts into, the substance of our ordinary world.

That the wave function is only a mathematical formalism is, as Herbert points out, "the prevailing doctrine of establishment physics" (p. 15). Developed at Niels Bohr's Copenhagen Institute, it is called the Copenhagen Interpretation. As the chief architect of this view, Bohr declared, "The entire formalism [that is, the wave function] is to be considered *as a tool* for deriving predictions, of definite or statistical character, as regards information obtained under experimental conditions described in classical terms" (quoted in Jammer 1974, 204; emphasis added). In the terms used here, the wave function offers an instrumental truth: it allows physicists to successfully predict and describe how particles will behave but does not directly "picture" or describe an independent, "objective" reality.[6]

It is just this instrumental character of quantum mechanics that forces what Bohr called for—a "radical revision of our attitude towards the problem of physical reality" (1958, 60). Just how radical the revision must be is made clear by Bohr's response when asked whether the wave function mirrors some deeper reality: "There is no quantum world. There is only an abstract quantum physical description" (quoted in Petersen 1963, 12). Jammer sums up the Copenhagen view of experimentation in this way: It "maintains . . . that only the macroscopic apparatus is something real and that the atom is merely an illusion" (1974, 205). And Bell explains that with the Copenhagen interpretation "I am entitled to assume that you are out there: but I'm not entitled to assume that you are made up of electrons that are out there" (1988, 86). Accordingly, while we may wish or feel compelled to assume that there is "something" "out there" (i.e., underlying the world as it appears to us), we cannot assume that there are any quanta with specific properties traveling down specific paths prior to their measurements. Or, as David Mermin in his recent Ithaca interpretation of quantum mechanics quite simply puts it, "Correlations have physical reality; that which they correlate does not" (1998, 753).[7]

In this interpretation of the wave function as a mathematical formalism, language remains firmly affixed to fact. We can say that the signifier *wave function* signifies the following: a mathematical expression or set of expressions and their attendant graphs that correlate observations and allow predictions. In this case, the sign (that is, the signifier combined with a signified) points to no deep physical reality, though it is impressively useful in working within the closed system of the experiment itself as well as in applying the results to practical problems such as those of electronic technology.

The other approach to the wave function is, for our purposes, most interestingly represented by Werner Heisenberg. It is necessary here to draw a subtle contrast between the views of Heisenberg and of Bohr. In doing so we use the distinction Max Black (1962) makes between what he calls *as if* and *as being* kinds of thought or statement. In an *as if* statement, one speaks of a condition, event, or thing in a manner the speaker considers contrary to reality or in a manner simply noncommittal about reality. In an *as being* statement, the speaker presumes to talk about the reality of interest "as it is." Bohr once said, "It is wrong to think that the task of physics is to find out how nature *is*. Physics concerns what we can say about nature" (quoted in Petersen 1963, 12). And when he spoke of the wave function in connection with what nature *is* (that is, when he spoke of the unmeasured quanta), he consistently used the *as if* way of speaking.[8] "In *as if* thinking," Black wrote, "there is a willing suspension of ontological disbelief, and the price paid . . . is absence of explanatory power" (1962, 228). When he spoke of atoms, electrons, particles, and waves, Bohr would suspend his disbelief in their reality, but he regarded himself as speaking in *as if* fashion. He theorized a model of the atom that would account for its behavior but did not presume to explain what the atom actually *is*.

Heisenberg, on the other hand, was willing to go beyond *as if* formulations and to speak in an *as being* manner about quantum reality. In doing so, he was well aware of the difficulties inherent in the language. In *Physics and Philosophy* (1958) he wrote,

> If . . . the atomic physicist is asked to give a description of what really happens in his experiments, the words "description" and "really" and "happens" can only refer to concepts of daily life or of classical physics. . . . Therefore, any statement about what "actually happened" is . . . by its very nature incomplete with respect to the details of the atomic events involved . . . these concepts cannot be applied in the space between the observations; they can only be applied at the points of observation. (pp. 144–45)

It would appear, on the surface, that Heisenberg has here denied the possibility of any *as being* formulation about the unmeasured quantum, but he was rejecting a physical, not a philosophical, interpretation.

"The first language that emerges from the process of scientific clarification," Heisenberg wrote, "is in theoretical physics usually a mathematical language; the mathematical scheme, which allows one to predict the results of experiments" (1958, 168). The need to communicate scientific knowledge to the nonphysicist, however, calls for ordinary language, and yet Heisenberg saw this language not as ornament or fiction used only in *as if* fashion. "Even for the physicist," he claimed, "the description in plain language will be a criterion of the degree of understanding that has been reached" (1958, 168). He believed, in other words, in the value of providing a theory of reality (a philosophical as opposed to a purely physical description) that would account for the patterns (or laws) discovered in the experimental facts. [9]

Willing, therefore, to employ the language of the philosopher in order to make statements about the quantum that lies behind the mathematical formalism, Heisenberg proposed what Herbert calls a "duplex world" that is "twofold, consisting of potentials and actualities" (Herbert 1985, 26). The wave function is, according to Heisenberg, a "quantitative version of the old concept of 'potentia' in Aristotelian philosophy. It introduced something standing in the middle between the idea of an event and the actual event, a *strange* kind of *physical reality*, just in the middle between possibility and reality" (1958, 41; emphasis added). He called the matter of Aristotle "a kind of indefinite corporeal substratum, embodying the possibility of passing over into actuality" whenever it takes on a form (p. 148). He then drew a parallel between Aristotle's idea of matter and "our concept of energy, which gets into 'actuality' by means of the form, when the elementary particle is created" (p. 160). For Heisenberg, the creation occurs at the moment of measurement.

According to Heisenberg, then, the unmeasured quantum is, as he variously called it, "a tendency for something," "a possibility for being," "a tendency for being," "an objective tendency or possibility," or "a potentiality" (1958, 41, 70, 180, 185). He also apparently viewed the quantum in its state of potentiality as energy. "All the elementary particles," he wrote, "are made of the same substance, which we may call energy or universal matter; they are just different forms in which matter can appear" (p. 160). We can say, then, that the signifier "wave function," as Heisenberg used it, signifies the following: one or more mathematical expressions and their attendant graphs that correlate observations and allow predictions *and* that point to an underlying quasi- or prephysical reality existing as energy in a state of potentiality. In this formulation, the sign points both to a tool or formalism and to some sort of substrate fundamental reality.

The Poem

Let me state at the outset that I do not propose to offer a new reading of Whitman's poem or even to suggest that any particular reading should be privileged over others. That "Song of Myself" has elicited from readers over the nearly one and a half centuries of its existence a wide range of interpretations—political, psychological, prosodic, structural, and religio-philosophical, among others—is compelling evidence of the richness and depth of the poem. As James E. Miller has observed of Whitman, "He has been called the poet of the family, and he has been called the poet of free love. He has been labeled poet of democracy, and he has been claimed by socialists and communists. He has been proclaimed poet of science, and he has been hailed as the poet of mysticism. He has been criticized as provincially patriotic, and he has been censured for indiscriminately embracing the world's masses" (1990, 128).

Clearly, however, one type of reading is particularly relevant to our present purposes—a reading that entails an exploration of the ultimate nature of being or reality—and it also happens to be an interpretation that, in its broad outlines, virtually all readers acknowledge as a viable response to the poem. This reading finds in the poem a celebration of some form of mysticism that merges the individual self (the persona speaking in the poem) with other selves and all that makes up the natural world into a larger Self that is in some sense cosmic, universal, transcendent.[10]

Turning now to the comparison I am attempting to establish, I propose that the poem's central concept of a "transcendent Self" occupies essentially the same kinds of mental space for the poem's different readers as the idea of wave function does for the various "readers" of the world of quantum physics. Poem readers and physicists, that is, employ ontological and epistemological strategies that are similar, in kind albeit not in substance, as they attempt to come to terms with the more profound questions raised by their respective "texts." Like quantum physicists in their response to wave function, readers of the poem can be placed into two groups according to their general response to Whitman's "self-as-Self": (1) those who accept it only instrumentally as signifying a key, or thematic formalism, for understanding the poem and (2) those who see it as pointing correspondentially to some kind of transcendent reality. Before considering each of these views, let us first look more closely at the self as Whitman appears to have understood it.

At least eight years before he published "Song of Myself" in *Leaves of Grass* (1855), Whitman was already moving toward the notion of a transcendent spiritual unity that lies behind all material reality. In his 1847 notebook, for example, he wrote, "The soul or spirit transmits itself into all matter—into rocks, and can live the life of a rock—into the sea and can feel itself the sea—into oak, or other tree—into an animal and feel itself a horse, a fish, or bird—into the earth—into the motions of the sun and stars. . . ." Later in the same passage, he mused: "I guess the soul itself can never be anything but great and pure and immortal; but it makes itself visible only through matter" (Whitman 1921, 2:64–65). These thoughts are quite similar to those of Ralph Waldo Emerson, whose 1847 edition of *Essays: First Series* Whitman had very likely read the year of their publication (Stovall 1974, 290–91). Scholars frequently note the remark Whitman made in an 1854 conversation with his friend John Trowbridge—"I was simmering, simmering, simmering. Emerson brought me to a boil" (quoted in Loving 1982, 168)—and few would deny that, as David Kuebrich has put it, "when Whitman began to elaborate the religious vision of the *Leaves*, Emerson's essays undoubtedly served him well" (1989, 1).

Whitman began his poem by declaring, "I celebrate myself and sing myself,/ And what I assume you shall assume,/ For every atom belonging to me as good belongs to you" (Whitman 1959, sec. 1; all subsequent references to the poem are to this edition). The notion of self/Self introduced here and developed throughout the poem bears a marked resemblance to the one articulated by Emerson as "that great nature in which we rest, as the earth lies in the soft arms of the atmosphere; that Unity, that Over-Soul, within which every man's particular self is contained and made one with all other" (1979, 2:160). Still, other influences were also present. Whitman's father was a good friend of Elias Hicks, the radical Quaker minister, and on at least one occasion took his son Walt to hear Hicks preach (Allen 1985, 7–8, 11–12). Whitman's free-thinking father would have been naturally drawn to a religion that allowed each individual to rely upon a personal, inward, divinely inspired intuition to guide his or her way. And although Whitman denied to Henry David Thoreau in 1856 that he had ever read "the Orientals" (Thoreau 1958, 445), some twenty years later, in a consideration of how great literature of the past had helped form his mind and imagination, he included "the ancient Hindoo poems" among those works he labeled the "embryonic facts of 'Leaves of Grass'" (Whitman 1948, 1:476–77).

Absorbing these various influences, then, along with others, Whitman created in his poem a persona that is an ordinary, separate self but one that also assumes a broader identity and transcends, at least potentially, the categories that constrain and limit the self of ordinary being. Almost thirty years later, Whitman continued to regard this particular philosophical issue—that is, the relation between the "Me, the human identity of understanding, emotions, spirit" and the "Not-Me, the whole of the material objective universe and law, with what is behind them in time and space, on the other side"—as "the most profound theme that can occupy the mind of man" (Whitman 1948, 2:175).

Many Whitman scholars have written on the central importance of mysticism in the poem.[11] Noting and interpreting the mysticism in the poem is not, of course, the same as embracing it. Poet David Ignatow, recognizing a tension within his "son to father" relationship to Whitman, captures quite well the difficulty that modern readers have with Whitman's transcendent vision:

> He demands, as he does of himself, total allegiance to a transcendental version of existence. I can't see it, especially not on or in his terms. Quite possibly, if he had lived long enough to see the technological advances in space exploration, he would have begun to sense our isolation in the universe which would have given him an altogether different and desolating view of man's relationship to the universe and to himself. . . ." (1981, 178)

Few scholars go as far as Ignatow to confess one way or the other their own convictions. They seldom offer any clear indication that they see the mysticism as other than a formal key for explicating the poem's structure and meaning. This is hardly surprising, since scholars are not known collectively as an expressive culture, especially as regards religious-belief commitments. What historian Elizabeth Fox-Genovese says, in summing up church history professor D. G. Hart's argument on this matter vis-à-vis historians, is equally true of literary academics: "contemporary academic historical culture has made room for, and frequently embraced, an extensive company of ideologies and allegiances, but has resolutely placed religious conviction, especially on the part of historians themselves, beyond the pale" (Fox-Genovese 2000, ix). The vast majority of historical and literary scholars are as reluctant to enter the realm of religious-belief commitments as most quantum physicists are to engage in speculative philosophy, even when laboratory results point them in that direction. The self-as-Self, then, operates essentially the same way for our first group of Whitman readers, which includes virtually all Whitman scholars, as the wave function operates for those physicists who view it as only a useful mathematical formalism. Whatever the critical or theoretical leanings of contemporary scholars, they generally have little patience for personal talk about soul, spirit, and transcendence, and yet these readers will nonetheless find, if they attempt a religious interpretation of the poem, the self-as-Self to be a useful tool for approaching the data of the poem and finding in them a coherent pattern.

For these readers, the signifier "myself" signifies, in my argument, a complex idea (or set of ideas) that identifies the "self" as personal *and* cosmic and functions within the closed system of the poem as a tool to unify and interpret its numerous and disparate elements.[12] Though the sign "myself" points for these readers to no metaphysical reality beyond the confines of the poem, it does help them handle the welter of images ranging from armpits to asteroids, from grass blades to gods. It helps to make sense of such seemingly contradictory statements by the poem's speaking self as, on the one hand, "Divine am I inside and out" (sec. 24) or "Nor do I understand who there can be more wonderful than myself" (sec. 48) and, on the other hand, "I project my hat, sit shame-faced, and beg" (sec. 37) or "If you want me again look for me under your boot soles" (sec. 52). The usefulness of the self-as-Self thematic is made abundantly clear by the misreading of no less a reader than the dean of late nineteenth-century American letters, William Dean Howells, who associated the poet/speaker of his poetry with "the devil of reasonless, hopeless, all-defying egotism" (quoted in Miller 1969, 7). A firm grasp of the thematic key of self-as-Self, along with an appreciation, which Howells sorely lacked, of Whitman's innovative poetic line, would have saved Howells from this sort of inept reading of the poem's persona.

Like the mathematical formalism of the wave function, the thematic formalism of the ordinary self that is simultaneously a transcendent Self also has predictive power. The reader can approach an obscure or difficult passage reasonably confident that it will fit into the pattern already developing around the notion of a transcendent Self. If the wave function is more precise in its predictions, it is perhaps due to the differing materials on which the two formalisms operate. One deals only with the results of experiments involving submicroscopic entities, the other with a poem that purports to treat nothing less than the myriad realities of the entire cosmos.

Readers in the second group likewise find Whitman's self/Self notion a useful thematic tool for interpreting the poem, but they go further and view it as pointing to some actual transcendent reality beyond the confines of the poem. For reasons already noted, few Whitman scholars fall into this group, at least professionally. Among them, one appearing to come closest to the second group of readers is David Kuebrich (1989), who approaches Whitman from a religious-studies perspective. He observes that Whitman requires "spiritually active readers" and "makes a series of claims upon [them] which, taken together, constitute a program to develop their souls and convince them that this world is immanent with spirit" (p. 1). Kuebrich rejects earlier readings that have treated Whitman's spirituality only in terms of psychological and intellectual frames of reference (pp. 2–

3). Noting that Whitman feared his work "would be taken hold of by the 'literary, professional fellows,'" Kuebrich wishes to rescue the poet and take him seriously as a minor prophet whose "goal was to descend anew into the sources of idealism in raw or preconceptualized religious experience; and then . . . express these experiences in a new religious vision that would incorporate the other forms of modern culture" (pp. 176, 175). Like many others, Kuebrich knows that "we live in the interstice of two epochs: the old vision [that] no longer suffices and the new [that] is not yet" and suggests that we approach the poet "as the prophet of the political and spiritual possibilities of our national community" (p. 177). He argues that Whitman, for all his deficiencies as a religious thinker and prophet (pp. 177–81), might still offer some insight and inspiration to a nation struggling to overcome its cultural and political malaise. As Kuebrich puts it,

> Whitman is not a new Christ or even a lesser but major prophet of a new religion. Yet the fact remains that his vision of American possibility continues to have an inspirational effect upon many readers that is unique in our literature. The political nature of this influence in combination with the pervasively religious character of Whitman's undertaking suggests that he should be viewed as an early minor prophet of a needed but largely inchoate civil faith—a faith that would not replace Judeo-Christianity, as Whitman anticipated, but rather coexist with it. (p. 191)

Although Kuebrich's reading treats the spiritual in Whitman as part of the political, it is nonetheless clear that his approach to the poet and the poem are markedly different from the more academic, literary studies that are the norm. And thus, I think it is not unreasonable to place him within, albeit on the margins of, the second group of readers.

Whitman's great poem, however, is not restricted to the narrow subset of scholarly readers, and many lay readers embrace or are at least willing to accept the possibility of a transcendent Reality. To do so is to accept the poem's Self as one might accept Plato's Forms, the Hindu's Atman/Brahman, the Buddhist's Dharmakaya, the Taoist's Tao, Martin Buber's Eternal Thou, Paul Tillich's ground of being, Pierre Teilhard de Chardin's Omega Point, and Alfred North Whitehead's antecedent ground or primordial nature of God. More broadly, such readers would subscribe to what Aldous Huxley has called the Perennial Philosophy, which includes the notion of "that eternal Self in the depth of particular, individualized selves, and identical with, or at least akin to, the divine Ground" (Huxley [1944] 1990, 1). Viewed thusly, to return to our comparison, Whitman's Self stands to some postulated metaphysical reality in virtually the same fashion as wave function stands to Heisenberg's prephysical reality, the *potentia*, or potential-for-being. In each case, the reality of interest is regarded as knowable only indirectly—that is, can only be inferred through what is perceived as its interaction with the ordinary world.[13] Thus it is that Whitman and like-minded readers believe they see in the world around them evidence of some transcendent unity. The poet declares, "a mouse is miracle enough to stagger sextillions of infidels" (sec. 31), "The nearest gnat is an explanation" (sec. 47), and "I hear and behold God in every object" (sec. 48). It is the claim of mystics in every epoch.

One need not ferry physics over into mysticism to see that here, too, an undergirding reality must be inferred rather than known directly and proven. Whatever may be presumed to exist "out there" can be known only through measurements—measurements that then force "particles" to "choose" between their various probable outcomes. Whatever we may presume about physical reality, nothing may be known about this reality, at least from the perspective of quantum mechanics, except indirectly as it is related to the knower through the act of measurement. Just as the Self is grasped only through its relation to the ordinary self, the fundamental physical "reality" of quantum mechanics can be known only as it is related to the physicist/knower through the act of measurement. Indeed, the results of Bell's theorem and the Aspect experiment[14] strongly reinforce the emphasis on the essentially relational quality of reality and knowledge at the quantum level—so much so that they call into question especially the atomistic assumptions of classical physics and the associated notions of "local reality," "objective reality," and correspondential truth. Theories about quantum reality (such as Heisenberg's theory of *potentia*) need to be consistent with the results of experiment, but the results never prove or directly reveal the nature, or even the prior existence, of a quantum. Calling the supposed reality reflected or represented by the wave function a "possibility wave," Herbert writes,

> It would be tempting to dismiss the possibility wave of a single atom as an airy statistical fiction with no more reality than the dice odds for a single roll, but these waves of possibility have more tangible consequences than dice odds. Try, for instance, to push your hand through the nearest wall. Since atoms are mostly empty space, their electrons are too small to stop you. Only each atom's possibility wave pushes back at you. Pretty substantial, aren't they? (Herbert 1985, 124)

This may convince us of the unmeasured quantum's existence as, to quote Heisenberg again, "a certain intermediate layer of reality, halfway between the massive reality of matter and the intellectual reality of the idea or the image" (quoted in Jammer 1974, 44), but we are still in the realm not of proof or empirical verification but of indirect evidence and reasoned inference and speculation.

Discussing his conception of God, Whitehead once wrote, "To be an actual thing is to be limited" (1960, 143). This statement points to another sense in which Whitman's Self as a transcendent reality and Heisenberg's wave function as *potentia* occupy similar mental terrain. Though it is not within the scope of this essay to explore this issue in depth, I should note briefly that both the physicist's act of measurement and the poet's act of naming can be said to enhance as well as reduce, in our knowing, the reality of the two entities under consideration. Prior to the act of measurement a Heisenberg potential-for-being "takes all paths open to it" (Herbert 1985, 119), just as Richard Feynman's quanta take all possible paths.[15] Also, the potential occupies its state of tentative reality as both particle and wave. Encompassing "a wealth of coexistent possibilities, most of which are contradictory," the potential, with its multiplicity, seems more vibrantly real than a physical object, datum, or mathematical equation in its state of reduced ordinary reality. On the other hand, it seems "less real" in its vague, "ghostly" state of quasi-reality (Herbert 1985, 27) and becomes palpably real, in the sense that we ordinarily experience reality, only when it gains representation by a mathematical formalism or manifests itself indirectly in a counter or bubble chamber or on a phosphor screen. Likewise, the unnamed metaphysical reality that some readers speak of as prior to or reflected in Whitman's transcendent Self can be thought of as existing on some spiritlike plane where it is everything in general and nothing in particular. Were it able to speak, it would say, as Whitman gives it voice, "Do I contradict myself?/ Very well then I contradict myself,/ (I am large, I contain multitudes)" (sec. 51).

It can be viewed as a kind of potential for being, waiting to become known to us in the concept we construct of a transcendent Self and palpable to us through all the named, limited particulars of the poem and the world. The poet tries to leap the gulf between the constricted but actual particulars and the unbounded but nebulous Self by way of the catalogues, as if he could reach a critical mass of particulars-brought-together whereby the unity of particulars-and-whole could be experienced. His frustration over his inability to name the reality he intuits without reducing that reality is felt in several statements found near the end of the poem: "There is that in me—I do not know what it is—but I know it is in me" (sec. 50); "I do not know it—lt is without name—it is a word unsaid, it is not in any dictionary, utterance, symbol" (sec. 50); "I too am not a bit tamed, I too am untranslatable" (sec. 52).

The French expression for the wave function, *densité de présence* (Herbert 1985, 96), provocatively suggests some kind of omnipresent reality underlying the wave function. For those who view the wave function as a mathematical formalism only, the expression simply refers to the probability (density) of a measurable result (presence) at a particular location. (This is the predictive power of the tool discussed earlier.) With Heisenberg's approach, however, "presence density" also suggests a reality characterized by different intensities of being or presence at different locations. The *potentia* gain a certain presence for us simply by being represented with a wave function. This presence becomes more palpable and exact in Ψ^2. Thus, a quantum may be revealed to have a 50 percent presence as potential in one location and only 25 percent presence in another. Correspondingly, the very concept of a transcendent Self provides, for some readers, a measure of presence for the "untranslatable" reality it purports to reflect, although no numerical calculations exist whereby we can state an exact intensity of presence. Perhaps the only roughly analogous operation within the poem would be the subjective judging of the varying power of particular images, metaphors, or other tropes to evoke in the reader some sense of transcendence. Among a community of readers, one might expect that over time some approximation of agreement would arise as to a ranking of these choices, but we cannot expect that an exactness will ever be reached.

It is important to emphasize that, in drawing the foregoing parallels, I do not suggest that modern physics confirms or bolsters the notion of a transcendent spiritual reality or that subatomic entities are in any way sentient or personal. Heisenberg's concept of *potentia* falls, strictly speaking, in the realm neither of religion nor of empirical science. Whenever Heisenberg did speak of religion, for him it clearly involved such concepts as a central order of the universe, ethics, community, and values (Heisenberg 1971, chaps. 7, 17). These concepts do not appear in connection with his various discussions of *potentia*. On the other hand, the concept of *potentia* is not empirical science either, because it is subject neither to verification nor to falsification. Neither religious nor scientific, Heisenberg's thought on the deep reality underlying or preceding the results of quantum experiment can be classified as metaphysical, as Bohr once defined the term. Refusing to view *metaphysics* as a "synonym for 'loose thinking', and hence a term of abuse," Bohr argued that the prefix *meta* should not be "anathema in physics." He then added, "The prefix, after all, merely suggests that we are asking further questions; i. e., questions bearing on the fundamental concepts of a particular discipline, and why ever should we not be able to ask such questions in physics?" (quoted in Heisenberg 1971, 210)

It is generally agreed that poetry delights in the proliferation and play of ambiguities, while science is determined to sort them out into as few clarities and definites as possible. This is true enough and helps one understand the gulf between Snow's two cultures. And yet, Heisenberg and Bohr were willing to ask questions where clarities and finalities are hard to come by. Heisenberg liked the old wisdom that the one who insists on "never uttering an error must remain silent" (1958, 86). Both he and Bohr were willing to risk error and ask metaphysical questions about the deeper reality of the physical world. Bohr concluded one thing, Heisenberg another, and in so doing both engaged in thought processes very similar to those in operation by readers responding to Whitman's poem. The parallel suggests that even in areas of investigation as different as quantum physics and a mid-nineteenth-century poem about the self, the further those investigations move in the direction of asking questions at the outer boundaries of possible knowledge, the more their participants will engage in similar patterns of thought and response as they take on the challenge of getting a grip on their perceived ultimate reality. This parallel does not allow us, in my view, to draw ontological conclusions about any possible similarities linking the self and that enigmatic reality of wave/particle/energy that so puzzles physicists. Epistemologically, however, we are on firmer ground. That is, the parallel I have articulated does seem to warrant the suggestion that the nature or status of the knowing itself, at this level of exploration, remains essentially the same as one moves from one field to the other.

In his classic work *Science and Human Values*, Jacob Bronowski maintains that "the progress of science is the discovery at each step of a new order which gives unity to what had long seemed unlike" (1965, 15). It is surely not my claim to have produced a unity between physics and poetry. I do hope, however, to have taken a transdisciplinary step that not only constrains those inclined to make invidious epistemological claims either privileging one way of knowing or denigrating another but also encourages others disposed to celebrate both physics and poetry as offspring of the same human brain—a brain that seems compelled, using multiple means, to measure, to name, to make sense of the world.

NOTES

I am grateful to Gale Rhodes, professor of biochemistry at the University of Southern Maine, and Charles Ess, professor of philosophy and religion at Drury University, for their careful readings and very helpful suggestions and contributions to this essay.

1. Because of the issues pursued, furthermore, the study might well also be of more than passing interest to students of metaphysics and theology. Indeed, the coherency I am suggesting here between procedures and findings in quantum mechanics and Whitman's poetry is consistent with the larger rapprochement between the natural sciences and the humanities, including precisely the disciplines of theology and philosophy (metaphysics). While the literature is already too extensive for us to do justice to it here, it has been amply represented in the pages of *Zygon* with numerous articles by (and about) such scholars as Ralph Burhoe, Arthur Peacocke, John Polkinghorne, and Ian Barbour, among many others.
2. I am well aware that my language here and in other parts of the essay implies that "particles" are real things, in the way golf balls and moons are in the realm of classical physics, and that they have motion in the ways balls and moons do. This unintended implication, however, is largely a limitation of our language, which was created to help our ancestors negotiate the macroworld tens of thousands of years before our minds conceived notions of an atomic and subatomic world. Here, as elsewhere in the field of quantum physics, we are forced to recognize the metaphoric nature of our descriptions in which we talk about the strange in terms of the familiar, the unknown in terms of the known.
3. For the figures on this page I am indebted to my colleague, Professor of Chemistry Gale Rhodes.
4. A further, quite interesting aspect of this analogy is that like the poet the physicist is also a creator of the text being read and like the physicist the poet is also a theorizer and experimenter as well as, no doubt, a reader of his or her own text. Each is presented with a vast chaos of data, known respectively as the universe of physical matter and that of human experience. Each would-be knower constructs a text by using the concepts and tools of his or her trade to reduce the chaos into structured form. Theoretical and experimental physicists, for example, produce, respectively, the initial ideas on how fundamental physical matter is made up and behaves and the instrumentation to explore and test the ideas. The quantum physicist is thus no mere recorder or discoverer of facts. Indeed, he or she might more aptly be compared with Theseus' description in *A Midsummer Night's Dream* of the poet whose "imagination bodies forth/ The forms of things unknown" and who then "Turns them to shapes, and gives to airy nothing/ A local habitation and a name" (Shakespeare 1963, V, 1, 14–17). In this extension or refinement of the analogy, the "readers" of the physicists' "text" would come from that group of physicists who create the text and are also inclined to ask probing questions that take them beyond the realm of quantum facts

and into Herbert's realm of quantum reality. The readers of the poem include its author along with other poets and that subgroup of literate readers composed of literary scholars and lay readers interested in grappling with questions of transcendence.

5. According to Saussurean linguistics, a *signifier* is a unit of sound or writing (such as the word *electron*), and its *signified* is the idea or mental concept it calls forth. Taken together, signifier and signified are the two components of what Swiss professor of linguistics Ferdinand de Saussure called a *sign*. Central to Saussure's thought is the assertion that the relationship between a signifier and its signified are purely arbitrary and contextual.

6. The resistance that many physicists of the day felt toward accepting Bohr's conception is manifest in the vigor with which they jumped on Schrödinger's bandwagon once he produced his wave equation in 1926. Not only did Schrödinger's math work quite well in explaining most aspects of the new physics, it also allowed physicists to visualize quantum reality as small waves in a way that seemed to bring quantum physics closer to the correspondence reality of classical physics. Max Born, who had helped Heisenberg develop his matrix mechanics, which allowed no visualizing of the quantum world, represents the excitement others felt over Schrödinger's achievement: "I want to defect—or, better, return—with flying colors to the camp of continuum physics," he wrote to Schrödinger. "I feel myself drawn to the place from where I set out, namely, the crisp, clear conceptual formulations of classical physics" (quoted in Crease and Mann 1986, 56). Born's enthusiasm waned somewhat after he realized that Schrödinger's waves were more likely probability than literal waves.

7. It is interesting to note that with quantum physics as discussed here, the "substance" metaphysics begun in ancient Greece—the quest for the underlying reality defining the beginnings of Greek philosophy and science in Thales—is now replaced by a metaphysics that is intrinsically relational. Quantum mechanics can be said, that is, to emphasize a reality of interconnections (which can be measured) but not one of any underlying "stuff" or substance existing objectively apart from those interconnections.

8. Black suggests that when Bohr offered his model of the atom he conceived himself to be describing the atom *as it is*. That may have been the case in 1913 when he announced his model, but as early as 1922 he stated, "there can be no descriptive account of the structure of the atom; all such accounts must necessarily be based on classical concepts which . . . no longer apply" (quoted in Heisenberg 1971, 40). He apparently held this position for the rest of his life, since the statement on the task of physics was quoted by his longtime assistant Aage Petersen the year following Bohr's death as representing his unwavering position on this issue.

9. By *facts*, we mean the results of reproducible measurements or observation; by *laws*, we mean the descriptions of patterns in the facts; by *theories*, we mean attempts to explain why the laws hold. For a fuller discussion of these terms, see Rhodes and Schaible 1989, 228–32, 288.

10. *Transcendent* is a notoriously ambiguous term in philosophy and theology, and I need to be clear as to what I mean and do not mean by it. The prevailing sense of "transcendent" in the West suggests a state of being or reality that is the opposite of immanence or presence. That is, the transcendent—especially under the influence of more dualistically inclined thinkers such as Descartes—usually means not simply "above and beyond" but also "radically separated from," perhaps even "opposed to," the transcended. By contrast, its meaning for other philosophers and theologians—e.g., in Plato's conception of the psyche or self, Whitehead's "antecedent ground conditioning every creative act," and Tillich's "ground of being"—point to a use of "transcendent" that entails an inextricable connection with the transcended. This more complementary relationship between the transcendent and the transcended, in contrast to dualistic opposition, is clearly more compatible with Whitman's presentation of the self-as-Self as well as with the various expressions of complementarity and connectedness at work in quantum mechanics.

11. A representative list would surely include Bucke [1901] 1964; Allen 1946; Miller 1957; Cowley 1959; Asselineau 1962; Chari 1964; Hutchinson 1986; Kuebrich 1989.

12. Note one important difference between this view of the self and the view of the wave function with which I am drawing a parallel. For these readers of the poem, the notion of a deeper reality (a transcendent Self) is of necessity included in their understanding of self but is regarded only as part of a tool useful for interpreting the poem. Among their physicist counterparts, the notion of the deeper reality is not necessary to make the formalism of the wave function useful.

13. The obvious exception would be the case of a person's having a mystical experience, in which the ultimate reality is said to be apprehended directly. Even here, however, that reality can

then be articulated to others only indirectly through language derived from experiences in the ordinary world.

14. "Bell's theorem reads: The quantum facts plus a bit of arithmetic require that reality be non-local. In a local reality, influences cannot travel faster than light. Bell's theorem says that in any reality of this sort, information does not get around fast enough to explain the quantum facts: reality must be non-local" (Herbert 1985, 51). Alain Aspect's 1982 experiment validated Bell's theorem and supported his "contention that our phenomenally local world is in actuality supported by an invisible reality which is . . . faster than light" (1985, 227).

15. Feynman noted that wave functions equivalent to those derived from Schrödinger's fundamental equation could be obtained by assuming that quanta take all possible paths through an experimental apparatus and that the effects of some paths cancel out the effects of others, leaving only the effects predicted by Schrödinger's wave mechanics. This method is called the sum-over-histories approach.

References

Allen, Gay Wilson. 1946. *Walt Whitman Handbook*. Chicago: Packard.

———. [1955] 1985. *The Solitary Singer: A Critical Biography of Walt Whitman.* Chicago: Univ. of Chicago Press.

Asselineau, Roger. 1962. *The Evolution of Walt Whitman: The Creation of a Book*. Vol. 2. Cambridge: Harvard Univ. Press, Belknap.

Bell, John. 1988. "Interview." *Omni* 10 (May): 85–92, 121.

———. 1993. *Speaker and Unspeakable in Quantum Physics.* Cambridge: Cambridge Univ. Press.

Black, Max. 1962. *Models and Metaphors: Studies in Language and Philosophy.* Ithaca, N.Y.: Cornell Univ. Press.

Bohr, Niels. 1958. *Atomic Physics and Human Knowledge*. New York: John Wiley.

Bronowski, Jacob. 1965. *Science and Human Values*. Rev. ed. New York: Harper and Row.

Bucke, Richard Maurice. [1901] 1964. *Cosmic Consciousness.* New York: E. P. Dutton.

Chari, V. Krishna. 1964. *Whitman in the Light of Vedantic Mysticism.* Lincoln: Univ. of Nebraska Press.

Cowley, Malcolm. 1959. "Introduction." In *Leaves of Grass—The First (1855) Edition*. New York: Viking.

Crease, Robert P., and Charles C. Mann. 1986. *The Second Creation: Makers of the Revolution in 20th Century Physics.* New York: MacMillan.

D'Espagnat, Bernard. 1979. "The Quantum Theory and Reality." *Scientific American* 241 (November): 158–67, 171–81.

Emerson, Ralph Waldo. 1979. *The Collected Works of Ralph Waldo Emerson*. Ed. Alfred Riggs Ferguson and Jean Ferguson Carr. Cambridge: Harvard Univ. Press, Belknap.

Fox-Genovese, Evelyn. 2000. "Introduction." *Journal of the Historical Society* 1 (1): v–xv.

Harris, Wendell V. 2000. "Physics Is Physics, Literature Is Literature, and Criticism Is Something Else Again." *Philosophy and Literature* 24:210–22.

Heisenberg, Werner. 1958. *Physics and Philosophy.* New York: Harper and Row.

———. 1971. *Physics and Beyond*. New York: Harper and Row.

Herbert, Nick. 1985. *Quantum Reality: Beyond the New Physics*. Garden City, N.J.: Anchor Press, Doubleday.

Hoffmann, Roald, and Pierre Laszlo. 1989. "Representation in Chemistry." *Diogenes* 147 (Fall): 23–51.

Hutchinson, George B. 1986. *The Ecstatic Whitman: Literary Shamanism and the Crisis of the Union.* Columbus: Ohio State Univ. Press.

Huxley, Aldous. [1944] 1990. *The Perennial Philosophy.* New York: Harper and Row, Perennial Library Ed.

Ignatow, David. 1981. "Son to Father." In *Walt Whitman: The Measure of His Song,* ed. Jim Perlman, Ed Folsom, and Dan Campion, 178. Minneapolis: Holy Cow! Press.

Jammer, Max. 1974. *The Philosophy of Quantum Mechanics: The Interpretations of Quantum Mechanics in Historical Perspective.* New York: John Wiley.

Kuebrich, David. 1989. *Minor Prophecy: Walt Whitman's New American Religion*. Bloomington: Indiana Univ. Press.

Lindley, David. 1993. *The End of Physics: The Myth of a Unified Theory.* New York: HarperCollins, Basic Books.
Loving, Jerome. 1982. *Emerson, Whitman, and the American Muse.* Chapel Hill: Univ. of North Carolina Press.
Mermin, David N. 1998. "What Is Quantum Mechanics Trying to Tell Us?" *American Journal of Physics* 66:753–67.
Miller, Edwin Haviland, ed. 1969. *Walt Whitman: A Century of Criticism*. Bloomington: Univ. of Indiana Press.
Miller, James E. 1957. *A Critical Guide to* Leaves of Grass. Chicago: Univ. of Chicago Press.
———. 1990. *Walt Whitman*. Updated ed. Boston: Twayne.
Petersen, Aage. 1963. "The Philosophy of Niels Bohr." *Bulletin of the Atomic Scientists* 19 (September): 6–14.
Rhodes, Gayle, and Robert M. Schaible. 1989. "Fact, Law, and Theory: Ways of Thinking in Science and Literature." *Journal of College Science Teaching* XVIII (February): 228–32, 288).
Shakespeare, William. 1963. *A Midsummer Night's Dream*. Ed. Wolfgang Clemen. New York: New American Library.
Shimony, Abner. 1988. "The Reality of the Quantum World." *Scientific American* 258 (January): 46–53.
Snow, C. P. 1959. *The Two Cultures and the Scientific Revolution*. New York: Cambridge Univ. Press.
Stovall, Floyd. 1974. *The Foreground of "Leaves of Grass."* Charlottesville: Univ. of Virginia Press.
Thoreau, Henry David. 1958. *The Correspondence of Henry David Thoreau*. Ed. Walter Harding and Carol Bode. New York: New York Univ. Press.
Whitehead, Alfred North. 1960. *Religion in the Making.* Cleveland, Ohio: World Publishing.
———. 1921. *Uncollected Poetry and Prose of Walt Whitman*. 2 vols. Ed. Emory Holloway. New York: Doubleday, Page and Company.
———. 1948. *The Complete Poetry and Prose of Walt Whitman*. 2 vols. Ed. Malcolm Cowley. New York: Pellegrini and Cudahy.
———. 1959. *Walt Whitman: Complete Poetry and Selected Prose.* Ed. James E. Miller. Boston: Houghton Mifflin.