4. The Gifts of Louis de Broglie To Science

by Robert J. Moon

A review of Quantum, Space and Time—The Quest Continues,[1] *Part I, 14 essays prepared in honor of de Broglie's 90th birthday anniversary (Aug. 15, 1982) by 18 well-known scientists. This review first appeared in the* International Journal of Fusion Energy, *Vol. 3, No. 2 (April 1985).*

Louis de Broglie (1892-1987)

These studies and essays yield a wealth of insight, not only into the way scientists think, and much of the historical aspect of the development of scientific thought, but more important, into the conception of ideas from the spirit within a scientist. This always takes poetic form, with many facets that yield entrées into a more perfect description of God's creation. Indeed de Broglie described his discovery of wave mechanics in this *way:* "A great light suddenly appeared in my mind."

Ideas are buried within the individual's spirit and burst forth when the individual's freedom is not sup-pressed by worldly materialism and dogmatism. Ideas do not come from conscious mentation or reading, since ideas are part of the individual's spiritual makeup and must be searched for from within in order to be discovered. Ideas may flow contrary to the prevailing stream of human thought. The individual will most likely have to navigate upstream and avoid aimless drift, in order to find fertile soil in which to plant an idea for the benefit of mankind.

Such a navigator was de Broglie. Kind and gentle to all, but firm with his concepts, he "attempted to develop the most promising alternative to the orthodox version of quantum mechanics." He started with a model that involved a pilot wave or guiding wave vibrating within a particle, much like a radar on an airplane sees the entire topology ahead, and this in turn guides the plane by means of actions by the pilot. This pilot wave calls for a double solution to the equations of quantum mechanics.

De Broglie was pounced upon by members of the Fifth Solvay Physics Conference in 1927. The Congress did not like his concept of the pilot wave associated with a particle and the consequent double solution. Wolfgang Pauli made important objections to de Broglie's concept and felt that it did not provide a consistent account of the many-body system or, in particular, a two-body scattering process. De Broglie felt that his idea had at least a germ of an answer. This was not appreciated by those present at the Solvay Conference, and de Broglie's friend Einstein did not speak up for the theory. These two rejections led to rejection by the Congress, which in turn caused de Broglie to close his books on this theory, giving up further work on it.

Einstein had in fact written to H.A. Lorentz on Dec. 16, 1924:

> A younger brother of de Broglie (the one we know) has undertaken a very interesting investigation (Paris Dissertation, 1924) to interpret Bohr-Sommerfeld quantum rules. I believe this is a first weak ray to illuminate this most serious of our physical riddles. I have also found something that speaks for his construction. (p. 41)

De Broglie learned of the letter only after Einstein's death in 1955.

In the introductory paper titled "Louis de Broglie—Physicist and Thinker," Jean-Pierre Vigier opens with a statement very characteristic of de Broglie, "Great physicists fight great battles." These essays, Vigier says, underline "his present position as forerunner, inspirer, and leader of a trend of research which is rooted in his dissent with the overwhelming majority of theoretical physicists—and his solidarity with Einstein in the famous Bohr-Einstein controversy." His scientific observations and interpretations opened new areas particularly on the "meaning and value of scientific knowledge itself."

There are four essential groups of problems with which these essays are concerned and in which de Broglie fought great battles.

(1) The first set is concerned with Heisenberg's dictum that microphenomena exist if and only if they are observable. De Broglie, on the contrary, held to his concept of the pilot wave, Ψ—a real microphenomenon wave that guided particles.

(2) The second set of problems has to do with Bohr's concept that quantum probabilities represent an ultimate limit to human knowledge. Contrary to this, de Broglie conceived of a random set of subquantal hidden variables in a real vacuum with which particles interact and exchange energy; that is, a vacuum alive with subquantal distributions of violent motions,

so that particle energy changes when moving from one point to another, in accordance with the principle of least action. These new quantum forces reflect the "wholeness" of the surrounding universe. This concept is that of a new ether model. The vacuum state is the state of "empty space," vibrant with a covariant distribution of covariant spinning oscillators and with random jumps in the velocity of light. This ether is not the old ether-at-rest model, but is a "new description of nature's 'vacuum' that implies a Copernican revolution against the world vision of Newton and Laplace, since it organically combines causal motions with permanent randomness. It interprets quantum mechanics as a Markov process at the velocity of light," Vigier writes.

(3) The third set concerns "the physical origin of the laws of nature themselves." The Copenhagen School, according to Vigier, "regards Quantum Theory as a general form of knowledge that is final in its essence. If this is true, knowledge of nature will never change again but only eventually develop through the introduction of new elementary particles, new Lagrangians, new quantum numbers, and new forms of interaction."

De Broglie and Einstein's approach to theory is basically different, Vigier says. Reality is immense, and no description of the universe by means of a theory and experimental proof will ever be a total and final one. Rather, each new theory proved by experiment is just another thin layer of insight into the nature of the real world.

(4) The fourth set of problems deals with "the existence of causality in nature and covers the present controversy raised by the, now very probable, confirmation of the nonlocal character of quantum mechanical predictions, discovered by John Bell in the Einstein-Podolsky-Rosen type of experiment."

Bohm Rediscovers the Pilot Wave

John S. Bell's contribution, "On the Impossible Pilot Wave," attempts to present the essential idea "so compactly, so lucidly, that even some of those who know they will dislike it may go on reading...." Referring to the von Neumann impossibility proof, Bell "saw the impossible done" in David Bohm's papers (1952, 1952a) demonstrating "how parameters could indeed be introduced into nonrelativistic wave mechanics, with the help of which the indeterministic description could be transformed into a deterministic one." The pilot wave, ignored by Born and von Neumann, was not impossible. David Bohm had rediscovered the pilot wave!

Bell sets up a simple model of a system whose wave function is $\Psi(a, x, t)$ with one discrete argument, $a = 1, 2 \ldots N$, one continuous argument, x, of position, where $-\infty < x < +\infty$ as well as a continuous argument of time, t.

He then considers a particle with an "intrinsic spin" free to move in one dimension, and finds a solution of the Schrödinger equation that yields various wave packets Φ that "move apart from one another, and after a sufficiently long time,. . . overlap very little." This model is similar to that of a Stern-Gerlach experiment.

Then, by means of the ideas of de Broglie and Bohm, Bell adds to the wave function, Ψ a particle position, $X(t)$. A particle always has a definite position, and the time evolution of the particle position after many repetitions of the experiment yields a probability distribution of $\rho(X(t),t)\ dX(t)$, which is the conventional quantum distribution for position. Thus the conventional predictions for the result of the Stern-Gerlach experiment obtain. The result is a position observation. Bell writes, "probability enters once only, in connection with initial conditions. . . . Thereafter the joint evolution of Ψ and X is perfectly deterministic." Thus in accordance with Bohr, the results are products of the complete experimental set-up, "system" plus experimental "apparatus" and are not to be regarded as "measurements" of preexisting properties of the "system" alone.

Bell concludes with these precepts so clearly emphasized in the de Broglie-Bohm picture:

(1) "Always test your reasoning against simple models."

(2) The only observations that must be considered in physics are position observations.

(3) In using the word "measurement" it is easy to expect that "'the results of measurement' should obey some simple logic in which the apparatus is not mentioned." "System and apparatus" are inseparable in probing the nature of God's creation. Bell favors banning the word "measurement" in favor of "experiment."

In order to best understand how an idea of de Broglie's had been shelved in 1927, forgotten, and then rediscovered by David Bohm in 1951, Bohm's own testimony of the sequence of events is most apropos. It is reproduced here in full, for it has many facets that should help any physicist to go forward in spite of the many vicissitudes that may intervene.

David Bohm is quoted (pp. 90-91) as follows:

> I wrote a book from Bohr's point of view, mainly in order to understand the quantum theory. But after I had written the book, I felt that I still didn't really understand the quantum theory, and so I began to look for new approaches. Meanwhile, I had sent copies of the book to Bohr, Pauli, Einstein, and other scientists. Bohr did not respond, but Pauli sent an enthusiastic reply, saying he liked the book very much. Einstein also got in touch with me, saying that though the book explained the quantum theory about as well as would ever be possible, he still was not convinced but wanted to discuss the subject with me.
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> We had several discussions, the net result of which was that I was considerably strengthened in my feeling that there was something fundamental that was missing in quantum theory. This may perhaps have made me work with greater energy, but Y. Ne'eman's statement that I was "shaken" by my conversation with Einstein and "had not recovered to this day" is entirely false. In any case, what actually happened was that I soon came upon the trajectories-interpretation, and prepared a preprint, copies of which were sent to many physicists including de Broglie, Pauli, and Einstein. I learnt shortly thereafter from de Broglie that he had developed this idea much earlier and so, in later versions of the paper, I acknowledged this fact. Pauli was very negative in reply, saying also that de Broglie had developed the same model many years earlier, and that it had been shown by him to be wrong at the Solvay Congress.

> As a result of Pauli's letter, I developed a theory of the many-body problem answering his objections, which was incorporated in a second paper [(1952) *Phys. Rev.* **85:** 180]. I had several further discussions with Einstein, but he was not at all enthusiastic about the idea, probably mainly because of the feature of nonlocality of the quantum potential, which conflicted with his basic notion that connections had to be universally in the fundamental laws of physics.
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> While I can understand Einstein's objections fully, I feel that it may have been a tactical error on his part to dismiss such ideas because they conflicted with his own notions as to the nature of reality. For though perhaps unsatisfactory in many respects, they made possible, as explained in the present paper [by Bohm and B.J. Hiley, pp. 77-92 of the work reviewed here; see below] certain important insights into the meaning of the quantum theory. I feel that a correct approach might have been to encourage such work as a purely provisional approach, but recognizing that it was not likely in itself to be a fundamental theory, without further radically new ideas. The result of not doing this sort of thing was that, for the most part, fundamental physics was reduced to its present state of relying almost exclusively on formulae and recipes constituting algorithms for the prediction of experimental results, with only the vaguest notions of what these algorithms might mean physically.

Bohm and B.J. Hiley ("The de Broglie Pilot Wave Theory and the Further Development of New Insights Arising Out of It") discuss de Broglie's approach in which he assumed a double-solution model to quantum mechanics. That is, (1) a real physical wave which satisfied Schrödinger's equation, (2) a particle following a well-defined trajectory, (3) the momentum, **p**, of this particle was related to the wave through the equation:

$$\mathbf{p} = \hbar\nabla\phi \tag{1}$$

where ϕ is the phase of the wave function. The particle is being guided by the wave ("pilot wave"). (4) Inside the particle there is a periodic process (a "clock") which, when at rest has a frequency $\omega_0 = m_0c^2/\hbar$, and the condition for the clock to stay in phase with the pilot wave was derived to be

$$\oint \mathbf{p}\cdot d x = nh.$$

(5) The locking in phase, he suggested, is a nonlinear interaction, which is crucial in order to obey Schrödinger's equation, and this double solution described the guidance condition. De Broglie's model "provides at least a conceptual connection between quantum mechanics and Einstein's attempt at a unified field theory, in which the particle is also treated as a nonlinear singularity that merges with the background field."

Members of the Fifth Solvay Congress in 1927 objected to this idea, in particular Pauli, and not even Einstein spoke up for the theory. Twenty-five years after de Broglie cast the idea aside, David Bohm rediscovered the "double solution" with its pilot wave and showed it to be a consistent account of a one-body system. In a second paper he extended it to a many-body system in answer to Pauli's objection and this led to new insights as to the meaning of quantum mechanics. Bohm's exchange of ideas with de Broglie led the latter—then 60 years of age—to again take up his old ideas after 25 years, although his approach is not accepted by most physicists.

The Trajectory Interpretation

Bohm and Hiley develop the trajectory interpretation for a many-body system as an extension of de Broglie's ideas. Their contribution here (pp. 80-87) is so significant that it merits a detailed account. They start with the *N*-body wave function as

$$\Psi(\mathbf{x}_1 \ldots \mathbf{x}_n) = R(\mathbf{x}_1 \ldots \mathbf{x}_n) \exp[iS(\mathbf{s}_1 \ldots \mathbf{s}_n)/\hbar]$$

and define the momentum of the *n*th particle (as did de Broglie) as:

$$\mathbf{p}_n = \nabla_n S \tag{2}$$

Equation (2) is substituted into the many-body Schrödinger equation which yields the conservation equation in configuration space:

$$\partial P/\partial t + \sum_n \nabla_n \cdot (P\nabla_n S)/m = 0 \tag{3}$$

(where $P = \Psi^*\Psi$, the probability density in this space), and the modified Hamilton-Jacobi equation

$$\begin{aligned}\partial S/\partial t + \sum_n(\nabla_n S)^2/2m + V(\mathbf{x}_1 \ldots \mathbf{x}_n) \\ + Q(\mathbf{x}_1 \ldots \mathbf{x}_N) = 0.\end{aligned} \tag{4}$$

They conclude from this that "each particle will be acted on, not only by the classical potential, *V*, but also by the *additional quantum potential Q*" (emphasis added):

$$Q = (-\hbar^2/2m) \sum_n [(\nabla_n^2)R/R]. \tag{5}$$

This interpretation shows that new features of quantum mechanics arise basically from the quantum potential *Q*.

As an illustrative example they consider the case of a two-body system with a product wave function:

$$\Psi(\mathbf{x}_1,\mathbf{x}_2) = \phi_A(\mathbf{x}_1)\phi_B(\mathbf{x}_2) \tag{6}$$

where

$$\phi_A(\mathbf{x}) = R_A(\mathbf{x})e^{iS_A(\mathbf{x})/\hbar} \text{ and } \phi_B(\mathbf{x}) = R_B(\mathbf{x})e^{iS_B(\mathbf{x})/\hbar}$$

Thus:

$$Q = \frac{-\hbar^2}{2m}\frac{\nabla_1^2 R_A(\mathbf{x}_1)}{R_A(\mathbf{x}_1)} - \frac{\hbar^2}{2m}\frac{\nabla_2^2 R_B(\mathbf{x}_2)}{R_B(\mathbf{x}_2)} \tag{7}$$

The quantum potential, *Q*, is the sum of two independent functions. If the classical potential, *V*, is likewise a sum, $V_A(\mathbf{x}_1) + V_B(\mathbf{x}_2)$ then the Hamilton-Jacobi equation reduces to two separate parts:

$$\frac{\partial S_A}{\partial t} + \frac{(\nabla_1 S_A)^2}{2m} + V_A(\mathbf{x}_1) - \frac{\hbar^2}{2}\frac{\nabla_1^2 R_A(\mathbf{x}_1)}{R_A(\mathbf{x}_1)} = 0 \tag{8}$$

$$\frac{\partial S_B}{\partial t} + \frac{(\nabla_2 S_B)^2}{2m} + V_B(\mathbf{x}_2) - \frac{\hbar^2}{2m}\frac{\nabla_2^2 R_B(\mathbf{x}_1)}{R_B(\mathbf{x}_2)} = 0 \tag{9}$$

The conservation equation also apparently splits into two

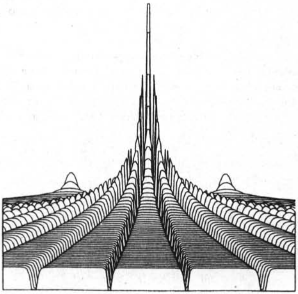

Figure 1
QUANTUM POTENTIAL FOR A PAIR OF GAUSSIAN SLITS
The slits can be seen in the background. The fringes are formed in the foreground, the dark bands coinciding with the valleys of the quantum potential.

independent parts.

Bohm and Hiley note that "the one-body equation (as treated by de Broglie) arises as an abstraction and a simplification of that of the two-body system, and eventually of the *N*-body system. (It is clear moreover that ultimately these *N*-bodies must be extended to include the whole universe.)"

Note that quantum mechanics and classical mechanics are expressed in terms of the same language.

> [T]he quantum potential, *Q*, is not altered when the wave function is multiplied by a constant, so that it does not fall to zero at long distances, where the wave intensity becomes negligible. However, the classical notion of analyzability of a system into independent parts depends critically on the assumption that whenever the parts are sufficiently far removed from each other, they do not significantly interact. This means that the quantum theory implies a new kind of wholeness, in which the behavior of a particle may depend significantly on distant features of the over-all environment. This dependence produces consequences similar to those implied by Bohr's notion of unanalyzable wholeness, but different in that the universe can be understood as a unique and in principle well defined reality.
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> To illustrate in more detail what is meant here. . . consider an interference experiment, in which a beam of electrons of definite momentum is sent through a two slit system. In Figure 1, we show the results of a computation of the quantum potential [C. Philippidis, C. Dewdney, and B.J. Hiley (1979) *Nuovo Cimento* **52B:** 15]; and in Figure 2, we show the trajectories resulting from the potential.
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> What is especially significant in Figure 1 is that the quantum potential remains large at long distances from the slits, taking the form of a set of valleys and high ridges, which latter gradually flatten out into broad plateaux. In Figure 2, one sees how the trajectories are ultimately bunched into these plateaux by the overall effect of the potential, and that this brings about the interference pattern. (So that, for example, if one of the slits had been closed, the quantum potential would have been a smooth parabolic function, which would produce no pattern of fringes.) The fact that the quantum potential does not in general fall off with the distance is thus what explains interference and diffraction patterns, and this is clearly also what implies the kind of wholeness of particle and environment to which we have referred above.
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> One may return here to the analogy of the airplane guided by radar waves. Evidently, it is not a case of

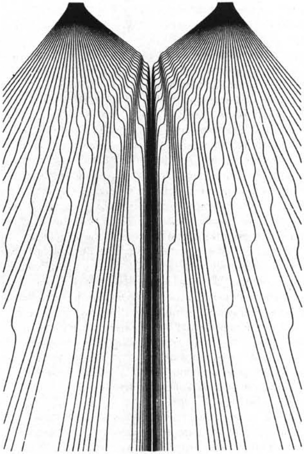
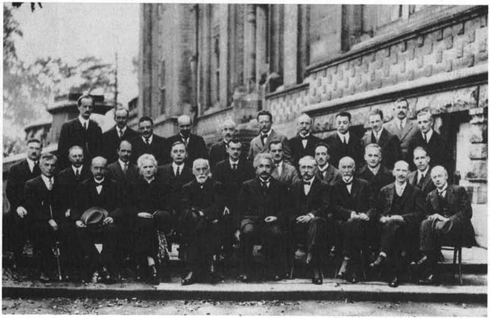


Figure 2
The particle trajectories emanating from the Gaussian slits at the bottom of the figure. The fringes at the top result from the bunching of the trajectories.

mechanical pressure of these waves on the airplane, but rather, the information concerning the whole environment is enfolded by the waves, and carried into each region of space. The airplane thus responds actively to the *form* of the waves, and this *form* is not altered as the intensity falls off with distance. A similar response to the *form* of the quantum potential is seen to be characteristic of the behavior of the electron. This means that in the microworld the concept of active information is relevant (see Bohm and Hiley [(1975) *Found. Phys.* **5:** 93] for more detail).



Courtesy AIP Emilio Segré Visual Archives

The Fifth Solvay Physics Conference, held in Brussels, Oct. 23-29, 1927, sponsored by the Solvay International Institute of Physics. Among the 30 scientists who attended the conference were E. Schrödinger, W. Pauli, W. Heisenberg, W.L. Bragg, P.A.M. Dirac, A.H. Compton, L. de Broglie (middle row, third from right), M. Born, N. Bohr (middle row, far right), I. Langmuir, M. Planck, M. Curie, H.A. Lorentz, and A. Einstein.

What has been said thus far about the new kind of wholeness implied by the quantum theory for the one-body system is further strengthened by a consideration of the many-body system. For here one finds that when the wave function is no longer separable as a product of functions of the coordinates of each particle, the quantum potential leads to a strong interaction between all particles of the system, that does not in general fall off to zero when the particles are distant from each other. This is evidently an extension of the dependence of the particle on its overall environment that characterizes the one-body system. But in addition, there is a yet more thoroughgoing breakdown of the possibility of analysis, because the force acting on each particle is no longer expressible as a predetermined function of the position of the other particles. Rather, the functional form of the force depends on the whole set of conditions in which the wave function is defined and determined (so that, for example, the form changes whenever this quantum state of the whole changes).

Let us take, as an example, the hypothetical experiment of Einstein, Podolsky, and Rosen [A. Einstein, B. Podolsky, and N. Rosen (1935) *Phys. Rev.* **47:** 777]. We consider there the original form of the experiment, in which we start with a quantum state of a two-particle system in which $(x_1 - x_2)$ and $(p_1 + p_2)$ are both determined. This is given by

$$\begin{aligned}\Psi(x_1 x_2) &= f(x_1 - x_2 - a) \\ &= \sum_k C_k \exp[ik(x_1 - x_2 - a)] \qquad (10)\end{aligned}$$

where $f(x_1 - x_2 - a)$ is a packet function sharply peaked at $x_1 - x_2 = a$, while C_k is its Fourier coefficient. Evidently, in this state $p_1 + p_2 = 0$ while $x_1 - x_2$ can be made as well defined as we please.

In this experiment, one can measure x_1 and immediately know that $x_1 - x_2 + a$ (to an arbitrarily high degree of accuracy). Alternatively, we can measure p_1 and immediately know that $p_2 = -p_1$. In both cases, the first particle is disturbed in the process of measurement and, of course, the disturbances can account for the Heisenberg uncertainty relations as applied to the particle $\Delta p_1 \Delta x_1 \geq h$. But since the second particle is assumed not to interact with the first in any way at all, it follows that we are able to find its properties without its having undergone any disturbance whatsoever. Nevertheless, according to the quantum theory, the uncertainty principle, $\Delta p_2 \Delta x_2 \geq h$, must still apply. So Heisenberg's explanation of this uncertainty as due to a disturbance resulting from measurement can no longer be used. It was this which indeed led Einstein, Podolsky, and Rosen [1935] to argue that since both x_2 and p_2 were in principle measurable to arbitrary accuracy without a disturbance, they must have already existed independently in particle 2 as "elements" of reality with well-defined values before the measurement took place. And so, they concluded that quantum mechanics is an abstraction giving only an incomplete and fragmentary description of the underlying reality (as insurance statistics are abstractions that similarly yield an incomplete and fragmentary description of the people to whom they are applied).

As is well known, Bohr [N. Bohr (1935) *Phys. Rev.* **48:** 696] answered this argument by means of a further development of his notion that the measurement process is an unanalyzable whole, which led in this case to the conclusion that there is no meaning to the attempt to give a detailed description of how correlations of position and momentum are carried along by the movements of the parts of a many-body system. It is interesting, however, to go carefully into how the trajectory interpretation differs from that of Bohr, and yet comes to a similar notion of unanalyzable wholeness, though, of course, in another way. For this case, writing $f = Re^{iS/\hbar}$, we obtain for the quantum potential

$$
\begin{aligned}
Q &= \frac{-\hbar^2}{2m}\left(\frac{\partial^2 R}{\partial x_1^2}+\frac{\partial^2 R}{\partial x_2^2}\right) \Big/ R \\
&= \frac{-\hbar^2}{m}\,\frac{\partial^2 R}{\partial \Delta x^2}\,(\Delta x - a) \Big/ R(\Delta x - a) \qquad (11)
\end{aligned}
$$

with $\Delta x = x_1 - x_2$. This function evidently remains large, even when the distance, *a,* separating the particles is not small. Therefore, when the properties of the first particle are measured, the quantum potential brings about a corresponding disturbance of the second particle. And from this, it can be shown [D. Bohm (1952) *Phys. Rev.* **85:** 180] that in a statistical ensemble of similar measurements, Heisenberg's uncertainty solutions, $\Delta p_2 \Delta x_2 \geq h$ will still be obtained.

Karl Popper on Bohr and de Broglie

"The new gospel of irrationality," Karl Popper writes, "was first publicly preached by Bohr in Como at the International Congress of Physics 1927; and a few weeks later, in Brussels, at the [Fifth] Solvay Congress." Popper's contribution is "A Critical Note on the Greatest Days of Quantum Theory." He reports young physicists thinking Einstein had become prematurely old at the age of 48! Bohr became the favorite of the young brilliant physicists led by Heisenberg, Pauli, and Max Born into what the young considered a greater revolution than Relativity. Some thought Einstein an antediluvian. Popper thinks "the real break was . . . between a radical and dogmatic empiricism . . . and a critical realism." This empiricism was hidden under the "general usage of the almost incredible term 'observable.' . . . *There are, in fact, no observables in atomic physics."* There are only indirect observations, that is, traces of the effects of particles on the environment through which the particles pass.

The de Broglie waves made Bohr's atom understandable. The advent of recording Geiger counters and photographic Wilson cloud chambers began the death of the "observer."

A new term, "hidden variable," arose to offset "observable," Popper writes. "In fact . . . *all* physical 'variables' are hidden." Hidden variables are a consequence of Heisenberg's interpretation of his indeterminacy formulae.

The Copenhagen school interprets Heisenberg's indeterminacy principle as *excluding:*

(a) all measurements which would be better than the product of the change of momentum with the change of position, $\Delta p_x \Delta x \geq h$;

(b) as well as all subjective knowledge better than this; and

(c) the existence of all particles that possess position and momentum to a greater precision than (a).

On the other hand, "a realist interpretation of quantum mechanics would interpret" (a) above "neither speaking about measurements nor about our knowledge," but rather "as speaking about the preparation of particles, and their position and momenta," independent of whether they are being observed or measured, though the realists recognize that the particles of course will respond to fluctuation in the environment mostly in a partially unpredictable fashion.

Einstein, Podolsky, and Rosen published their famous paper, "Can Quantum Mechanical Description of Physical Reality Be Considered Complete?" in 1935 "to show that a particle possesses both a precise position and a precise momentum." Popper considers the argument valid.

De Broglie on the Poetry of Creativity

Georges Lochak of the Fondation Louis de Broglie ("The Evolution of the Ideas of Louis de Broglie on the Interpretation of Wave Mechanics") writes that de Broglie "always experiences creation as a dazzling poetic vision, and he cannot help feeling sad when he sees it weaken and fade as it is translated by himself or by others into a necessarily mathematical language."

O. Costa de Beauregard ("Reminiscences on My Early Association with Louis de Broglie") tells this related story of de Broglie's appreciation of Paul Valéry: "One spring afternoon, in those days bygone, I went to his [de Broglie's] home in the Paris suburb of Neuilly, with a work on physics I wanted to discuss with him. The weather was beautiful, and the chestnut trees in blossom. I don't remember how it happened that Louis de Broglie came to ask me which was, in my opinion, France's greatest poet. Somewhat hesitatingly, I answered that this was a question of personal taste, and that he might not agree with my choice of Paul Valéry. Well, this choice was also his. His following question was, among Valéry's masterpieces, which one would I select? Again with hesitation, I said that my selection was not the (very rightly) celebrated *Cimetière Marin* but rather the long, superb, philosophical poem with the understated title *Ebauche d'un Serpent* (Sketch on the Theme of a Snake). It is a sparkling theological address of Lucifer to God, starring the Garden, the Snake, Eve, the Tree—and what followed therefrom. Well, again de Broglie agreed. And we spent the rest of the evening reading and commenting on the wonderful poem, which finally has to do with the irresistible growth of knowledge from roots in the darkness beneath, to leaves in the brilliance above.... So it seems to me that there is some Leibnizian preharmony between Valéry and scientists."

As John Bell proclaims, "Long may Louis de Broglie continue to inspire those who suspect that what is proved by impossibility proofs is lack of imagination."

Notes

1. *Quantum, Space and Time—The Quest Continues,* Asim O. Barut et al., eds. (Cambridge: Cambridge University Press, 1984, 680 pp., $49.50, paperbound). The 14 essays in Part I, covering 245 pages, are by the following authors: Jean-Pierre Vigier, Georges Lochak, Alwyn van der Merwe, O. Costa de Beauregard, Karl Popper, J. Andrade e Silva, J.S. Bell, D.J. Bohm and B.J. Hiley, L. de la Peña and A.M. Cetto, Stanley P. Gudder, Ph. Guéret and J.-P. Vigier, Mioara Mugur-Schächter, F. Selleri, and H.-H. v. Borzeszkowski and H.-J. Treder.

   Part II is a collection of essays dedicated to Eugene Paul Wigner on the occasion of his 80th birthday, Nov. 17, 1982. Part III, in like manner, is dedicated to Paul Adrien Maurice Dirac on the occasion of his 80th birthday, Aug. 8, 1982.

References

Bohm, D. (1952, 1952a) *Phys. Rev.* **85:** 166 and 180.