LBL-32761
UC-414

# Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

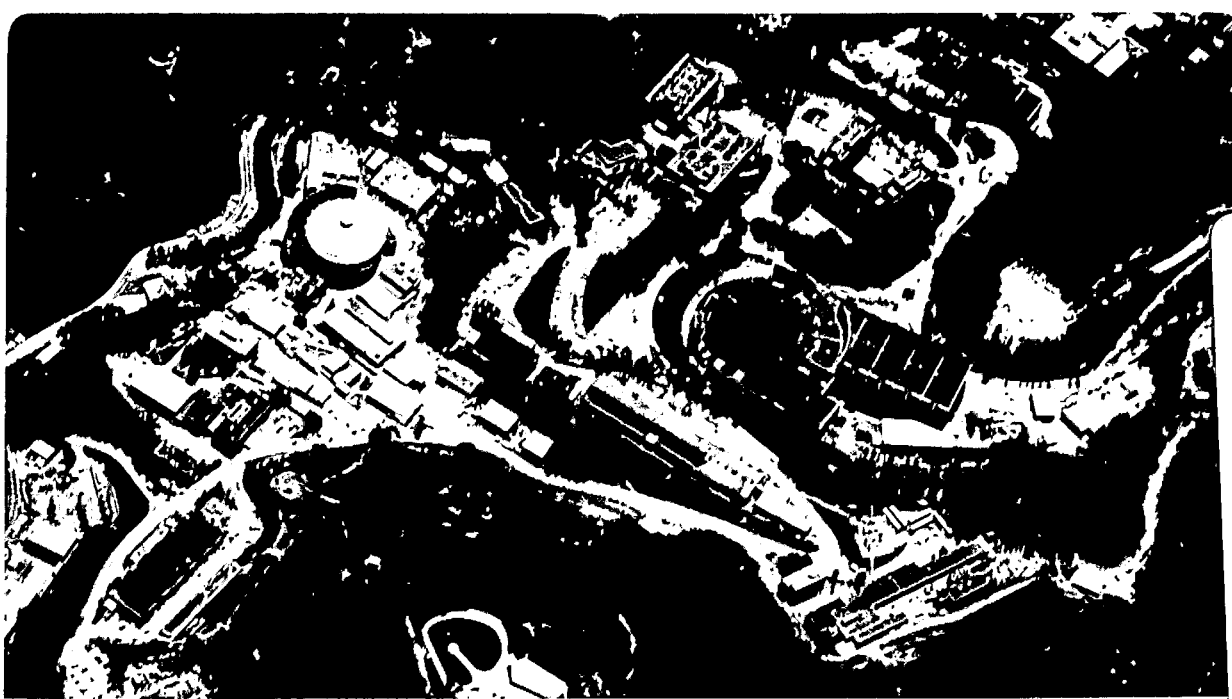
## Physics Division

Invited lecture at the Symposium on the Foundations of Modern Physics 1992: The Philosophic Thought of Wolfgang Pauli, Helsinki, August 10–12, 1992, and to be published in the Proceedings

# Mind, Matter, and Pauli

H.P. Stapp

September 1992



LOAN COPY
Circulates
for 4 weeks
Bldg. 50 Library.
LBL-32761
Copy 2

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

## DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

September 10, 1992 LBL-32761

# Mind, Matter, and Pauli *

Henry P. Stapp

*Theoretical Physics Group*
*Physics Division*
*Lawrence Berkeley Laboratory*
*1 Cyclotron Road*
*Berkeley, California 94720*

**Abstract**

The role of subjective experience in physical theory is discussed, with particular attention to the later ideas of Wolfgang Pauli. These ideas appear to open the door to a unified framework for the development of science.

Invited Lecture at the Symposium on the Foundations of Modern Physics 1992: The Philosophic Thought of Wolfgang Pauli. Helsinki, Aug. 10 - 12, 1992.

*This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

## I. Introduction

Wolfgang Pauli was called by Einstein his 'spiritual heir,' and his unrelenting demand for precision and clarity earned him the title of 'the conscience of physics'. A godson of the great philosopher of science Ernst Mach, he was philosophically astute and, with Niels Bohr and Werner Heisenberg, a principal architect of the orthodox Copenhagen interpretation of quantum theory. This approach to the theory allowed physicists avoid assigning paradoxical properties to nature. It did so by adopting a philosophically radical stance: regard atomic theory not as a description of atomic processes themselves, but rather as a description of connections between human observations. This renunciation of the traditional scientific ideal of erecting a coherent idea of physical reality was the chief objection against the Copenhagen view raised by Einstein. Though Einstein admitted that it was still unexplained why science had succeeded even as far as it had in creating a mathematical understanding of nature, he held that we must nonetheless persist in the endeavor: otherwise even the possible would not be achieved.

In a 1948 letter to his friend Marcus Fierz, Pauli writes[1]: "When he speaks of 'reality' the layman usually means something well-known, where as I think that the important and extremely difficult task of our time is to build up a fresh idea of reality". This idea was meant to encompass not only the material side of nature, but also its psychic or spiritual side: "It seems to me — however it is thought, whether we speak of 'the participation of things in ideas' or of 'inherently real things' — that we must postulate a cosmic order of nature beyond our control to which *both* the outward material objects *and* the inward images are subject... *The ordering and regulating must be placed beyond the difference between 'physical' and 'psychical'* — as Plato's 'Ideas' have something of the concepts and also something of the 'natural forces' ... ". In a later letter (October 13, 1951) Pauli goes on to say, in regard to the significance of the entry of a basic element of chance into physics, "Something that previously appeared closed has remained open here, and I hope that *new concepts* will penetrate through this gap in the place of [psycho-physical] parallelism, and that they should be uniformly *both* physical *and* psychological. May more fortunate offspring achieve this".[2]

These ideas of Pauli appear to represent a fascinating reversal of his earlier position; the quantum element of chance is viewed no longer as a *veil* that must obscure forever our complete understanding of reality, but rather as an *opening* to a still deeper understanding. Yet Pauli's view is no mere a conversion to the Einsteinian view that science should strive to represent physical reality. Einstein accepted the traditional scientific separation of mind from matter, whereas Pauli is suggesting that the element of chance in quantum theory provides an opening not to a traditional physical reality but rather to a reality lying beyond the mind-matter distinction.

My intention here is to explore this idea, which, if correct, would open up a whole new chapter in science. But before venturing beyond the confines of mind and matter it will be useful to review briefly the role of mind in modern science.

## II. Mind in Classical Physics.

The conceptual separation of mind from matter initiated by Descartes—and completed by other philosophers and physicists—rendered classical physics both reductionistic and local. It was reductionistic because the full description of the material world was reduced to a *collection of numbers,* and it was local because these numbers described *local* properties, such as 1), where particles are positioned at various times, and 2), the strengths of the electric, magnetic, and gravitational fields at various points in space and time. This local-reductionistic aspect allowed the material world, *as it was conceived of in classical physics*, to be brought, at least in principle, under full mathematical control. The thought-like aspects of nature, which Descartes placed in a separate realm called *res cogitans*, were eventually detached from the material world in a way that rendered them irrelevant to the course of material events.

Science, as conceived by Newton, was not a closed book: it was expected to grow and develop. Consequently, a scientific theory did not need to be *complete* in order to be useful and acceptable. For example, Newton did not explain the cause of gravity. He admitted to having tried and failed to find such a cause, yet affirmed his conviction that such a cause must nonetheless exist.[3] He left the unsolved problem to the consideration of his readers. Two centuries passed before a reader, Albert Einstein, found a satisfactory solution. Similarly, the omission

of human experience from Newton's laws does not mean that the relationship of thought to matter must remain forever beyond the reach of science.

## III. Heisenberg's 'Ontologicalization' of the Copenhagen Interpretation

The Copenhagen interpretation of quantum theory is fundamentally epistemological: it is concerned with our knowledge. The quantum-mechanical formulas "merely offers rules of calculation for the deduction of expectations about observations obtained under well-defined experimental conditions specified by classical physical concepts."[4] Within this mathematical framework, devised by quantum physicists, the central object is the so-called 'wave function.' It is considered to represent *our knowledge* of the physical situation, and it therefore changes suddenly when we receive new information and our knowledge therefore suddenly changes.

Heisenberg helped to create this orthodox interpretation of the quantum formalism, and accepted it. But he was eventually willing to discussed *also* the problem of "what happens 'really' "[5]. According to his later idea , a wave function represents real 'objective tendencies' for the occurrence of a "transition from the 'possible' to the 'actual.' " He further asserts—and this is crucial—that these transitions, which I call Heisenberg events, occur at the level of the macroscopic measuring device, which is part of the external world, *"it is not connected with the act of registration of the result in the mind of the observer."* Since he also affirms that the wave function of *orthodox* quantum theory *does* change with the registration of the result in the mind of the observer, it follows that there is, in Heisenberg's later view, not only the *subjective wave function* of the orthodox interpretation, but also an *objective wave function*, which exists outside the minds of men. It represents objective tendencies, and 'collapses' with the occurrence of Heisenberg event. Thus there is, in this view, a close parallel between the representation of 'our knowledge' provided by the orthodox theory and the form of external reality itself.

## IV. The Mind-Matter Problem

Perhaps the central thesis of James's monumental text, the Principles of

Psychology,[6] was that each conscious thought is essentially a complex whole: each thought has components, which can be examined by subsequent analysis, but, *as given*, is a unified whole that cannot be reduced to a collection of parts without destroying its essence. On the other hand, matter, according to the science of James's day, was reducible to a collection of simple local parts. Consequently, there was no possibility of finding within matter, as classically conceived, any faithful image of a human thought. James himself drew from this structural mismatch the conclusion that the classical conception of nature was essentially deficient: he apparently anticipated important developments in the natural sciences that would bring our conception of matter into better alignment with the characteristics of thoughts. However, this prescient idea, that classical physics was fundamentally flawed, was not shared by the psychologists of the early twentieth century, who, instead, recoiled from the entire approach based on introspective analysis of thoughts, and the problem of mind and brain , and embraced the opposed ideology of behaviorism.

True to James's expectation there have been fundamental conceptual changes in physics. Heisenberg's picture of nature envisages events that actualize, as units, entire patterns of action in the material world. This physical process permits the emergence, in human brains, of holistic structures that can mirror, simultaneously, both the *structural forms* and *functional effects* of conscious human thoughts.

## V. Mental Events as Heisenberg Events.

According to William James our conscious thoughts have an event-like quality: they appear as "buds" of reality — either all or nothing at all. This holistic "all or nothing at all" property is precisely the characteristic feature of quantum phenomena that distinguishes it from classical phenomena: either the entire mark appears on the photographic plate, or no mark appears at all; either the entire Geiger-counter suddenly discharges, or there is no discharge at all; either the pointer on the measuring device swings suddenly to the right or it swings suddenly to the left — there is no intermediate possibility. In Heisenberg's picture of nature these discrete events occur in 'measuring' devices, which amplify small-scale changes into large-scale signals.

Brains are similar in this respect to measuring devices. At the synaptic

events, and also at neuron firings, there are large amplification effects. Moreover, and this is the crucial point, an analysis by John von Neumann[7] shows that the quantum events in the brain need not occur either at the level of the individual synaptic discharge or at the level of the individual neuron-firing: they can occur, instead, at the level of the entire brain, in conjunction with the event-like occurrence of a conscious thought. Such a quantum event in the brain would actualize, or be the actualization of, an entire complex, quasi-stable, large-scale pattern of neural firings. An actualized pattern of this kind can have the complexity and causal efficacy needed to represent both the structural form and functional effect of a conscious thought.

The basic postulate of this understanding of the mind-brain connection, as developed by the present author in reference 8, is that conscious thoughts are represented within the physicist's description of nature by Heisenberg events that actualize entire complex patterns of neurological activity. It is shown how, at least in principle, this postulate can lead to a relatively simple, but scientifically adequate, conceptualization of the mind-matter connection. Some chief features of the theory are that it provides for:

(1) An isomorphic connection (i.e., a one-to-one mapping that preserves certain structural relationships) between the structural forms of conscious thoughts, as described by psychologists, and corresponding actualized structural forms in the neurological patterns of brain activity, as suggested by brain scientists.

(2) A correspondence at the functional level between the experiential event and the corresponding Heisenberg event in the brain.

(3) An explanation of puzzling temporal anomalies observed in mind/brain research. (e.g., in the Libet experiments)

(4) An explanation of puzzling temporal anomalies observed in psycho-physical experiments. (e.g., in the Kolors-Gruenau experiment)

(5) A mechanical explanation of the efficacy of conscious thoughts.

(6) An explanation of the event-like and holistic natures of conscious thoughts.

This psycho-physical theory, as presently conceived, does not seek to go beyond the Heisenberg picture of nature: it merely extends that idea from external measuring devices to human brains. At this level, the theory is apparently compatible with the Churchland[9] thesis that 'mind is brain,' or at least an *aspect*

of brain. For, according to the theory, every structural and functional aspect of each conscious thought is completely represented within the physicist's representation of the host brain. Even the special 'feel' of a conscious thought, the feel that the thought is somehow *bringing itself into being,* is captured by the actualizing quality of Heisenberg's quantum transition. It is hard to see how a theory could do any better job of representing a conscious thought, and the theory that does it is precisely a quantum theoretical picture of what is happening to the *brain.* Psycho-dynamics has become an aspect of brain dynamics.

This unification of our understanding of the physical and psychological aspects of nature resolves a long-standing problem. However, it does not address the question of *agency*: it does not say what *causes* the quantum transition to occur? Are these happenings indeed purely random, or are they controlled by some still-hidden level of reality?

## VI. Comparisons to the Ideas of Pauli

Pauli's idea of a regulative principle lying beyond the mind-matter distinction is intertwined with the Jungian concepts of archetype and synchronicity. Synchronicity refers to the occurrence of representations of archetypes *in meaningful coincidences that defy causal explanation.* Pauli apparently believed, perhaps on the basis of his own experience, that the synchronistic aspects of nature identified by Jung were sufficiently striking to place them beyond the bounds of explanation in terms of pure chance. This judgement, if correct, would mean that behind the processes of nature that we already know and understand there lies another, which *acausally* weaves *meaning* into the fabric of nature.

In classical physics the course of events is determined in a local-mechanical way: the change of each local part is fixed by its immediate environment. Thus nature is 'myopic': every aspect of the orderly evolution is governed by 'perceptions' that have no breadth of vision at all; only infinitesimally nearby things can have any influence. But 'meaning' has to do with a grasping of wholes, and this demands expanded vision. Consequently, there is no way for nature's process, as it is understood in classical physics, to incorporate or embody meaning.

In quantum physics the situation seems even worse. The basic process first generates probabilities, or tendencies, by a similar sort of senseless local process.

Any residual hope for meaningfulness is then dashed by the entry of pure chance: the actually occurring course of events is fixed by the blind rolls of cosmic dice.

Yet it is an absurdity to believe that the quantum choices can appear simply randomly 'out of the blue,' on the basis of absolutely nothing at all. *Something* must select which of the possible events actually occur. If this something is a local-mechanical process then we are back again at square one. However, the quantum selection process, if it exists at all, *cannot be local:* it must, at least in certain circumstances, allow happenings one region to be influenced by human choices made in a distant regions at essentially the same time.[10] Moreover, according to the psycho-physical theory described above, this process actualizes *intrinsic wholes* that are simultaneously thought and matter. These two features make the underlying quantum process strikingly similar to Jung's synchronistic process: both are *acausal*, i.e., violate the principle of local causation, and both manifest holistic structures in a realm that lies, in the words of Pauli, "beyond the difference between the 'physical' and the 'psychical.' "

Logical arguments imply, as just mentioned, that the underlying quantum process must involve instantaneous influences. These would be expected to produce *causal anomalies*, i.e., observed coincidences that cannot be explained in terms of normal ideas of causality. However, the structure of quantum theory guarentees that all traces of these peculiar influences must disappear from the *statistical averages* that occur in the empirical scientific tests: all acausal aspects are completely masked by the effects of chance. This masking depends crucially, however, upon the exact validity of the quantum statistical rules: if the probabilities specified by quantum theory were to disagree with those defined by nature herself then the way would be opened for the appearance of causal anomalies.

This interlocking of causality and chance has important consequences. It means that the play of quantum chance acts both to veil the form of fundamental reality and to unveil the form of empirical reality. However, if causal anomalies actually do appear then the veil has apparently been pushed aside: we have been offered a glimpse of the deeper reality.

My interpretation of Pauli's interest in Jungian ideas, in connection with development of science, is precisely that he saw in the acausal character of the phenomena studied by Jung some evidence of a breakdown in the quantum laws

of chance, and, hence, a possible opening to the deep question that quantum theory fails to address—and that Bohr's philosophy encourages us to ignore—namely the question of what decides what actually happens.

What is salient here is that Jung purports to construct, *on the basis of empirical data*, an idea of the form of the synchronistic process. If he has indeed arrived in this way at some knowledge of nature's process itself, not merely an illusion based on improperly evaluated data, and if the quantum and the synchronistic processes are indeed essentially the same process, then an empirical window may have been opened on the process that had been thought by quantum theorists to lie beyond the ken of empirical knowledge.

Of course, the data involved here are not data of the kind that most physicists are comfortable with. Yet there is no reason why the critical scientific tenor of mind cannot be exercised in domains lying far from physics. (Indeed, Pauli must have done this.) Thus we are led to conceive of science as a large array of scientifically conducted endeavors that covers a very wide range of subjects. The problem then arises of choosing the theoretical foundations for each of these separate parts. If this problem is addressed from within the confines of the individual field then the number of possibilities is great, and ambiguities and divergences of opinion generally emerge.

Traditionally, scientists cope with such conflicts by insisting on the unity of science: they require the theoretical foundations of the various parts to fit into a single unified framework. This effectively adds to each isolated discipline the extra condition that it fit smoothly onto its neighbors.

The ideal of the unity of science might seem so secure and reasonable as to need no mention. However, if 'science' is supposed to cover all of the physical, biological, and psychological sciences then the demand for unity creates a problem. It can be imposed only if there is a single unified framework into which the foundations of each of these diverse components fit. Our historical inability to find such a framework is the cause the present fragmentation of science. Yet the conception of nature described above, which is based upon my interpretations of the ideas of James, Heisenberg, and Pauli, does appear to accommodate in a coherent and unified way the bodies of knowledge arising from the fields of classical physics, quantum physics and chemistry, the brain sciences, psychophysical experimentation, introspective psychology, and Jungian psychology. It

appears, therefore, to be a viable candidate for the framework that is needed if we are to achieve the ideal of the unity of science.

REFERENCES


1. W. Pauli, in K. V. Laurikainen, Gesnerus **41**, 213 (1984)

2. ibid.

3. I. Newton, Principia Mathematica, General Scholium (See Introduction to Newton's 'Principia,' I. Bernard Cohen, Harvard University Press, Cambridge, 1978); Letter to Bentley (1691)

4. N. Bohr, Essays 1958/1962 on Atomic Physics and Human Knowledge, Wiley, New York, 1963, p. 60.

5. W. Heisenberg, Physics and Philosophy, Harper and Rowe, New York, 1958. Ch.III

6. J. von Neumann, Mathematical Foundations of Quantum Theory, Princeton Univ. Press, Princeton NJ.

7. W. James, The Principles of Psychology, (Reprint of 1890 text) Dover, New York, 1950.

8. H. P. Stapp, A Quantum Theory of the Mind–Brain Interface, in Mind, Matter, and Quantum Mechanics, Springer-Verlag, Heidelberg, 1992.

9. P. S. Churchland, Neurophilosophy: Toward a Unified Theory of The Mind/Brain, MIT Press/A Bradford Book, Cambridge MA.

10. J. S. Bell, Physics,**1**,195 (1964); H. P. Stapp, Noise-Induced Reduction of Wave Packets and Faster-Than-Light Influences, to be published in Physical Review A; Significance of an Experiment of the Greenberger-Horne-Zeilinger Kind, Submitted to Physical Review A; EPR and Bell's Theorem: A Critical Review, Foundation of Physics **21**,1 (1991).

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
TECHNICAL INFORMATION DEPARTMENT
BERKELEY, CALIFORNIA 94720