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The mind of Wigner's friend

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1. INTRODUCTION

The course and outcome of interactions between science and philosophy depend on the length and depth of the preceding preparation. An example of adequate preparation is furnished by events leading up to the interaction between Einstein's theory of gravitation and Kant's philosophy of space and time. The ground for the effect of Einstein's theory was prepared first by the discovery of non-Euclidean geometries, still within pure mathematics, and later by Helmholtz' analysis of physical geometry. Although the latter was at first known only to a small group of experts,[1] it furnished all but a theory actually asserting the need for a non-Euclidean physical geometry. When Einstein constructed such a theory, it was Kantian philosophy which yielded ground at the controversial points.

It is only in hindsight that the early events can be interpreted as a preparation for the later events; the preparation was not conscious. When science in its development knocks against one of its own basic presuppositions (not expressed, until then, within the science), this comes as a surprise; what may then be eventually seen as a preparation is to some extent fortuitous because science develops unpredictably.

The philosophical effects of quantum mechanics have been less clear-cut. Several profound epistemological results are widely accepted—e.g., the non-existence of a normal description of interphenomena,[2] and the possibility of interpretation by three-valued logic.[2] The deepest philosophical implications of quantum mechanics are connected with the need for the explicit introduction of events occurring in the consciousness of an observer, into the description of the quantum mechanical measuring process.[3] Here the ground happens to be prepared so little that the most important results

are misnamed 'paradoxes' and are considered to indicate either an intrinsic weakness of quantum mechanics,[4] or the inapplicability of quantum mechanics to consciousness,[5] or to living systems in general.[6] I propose to show, on the contrary, that these aspects of quantum mechanics may be viewed as straightforward rather than paradoxical, and that they had been long foreshadowed in Vedantic thought. They appear paradoxical to our thought merely because, despite Schrödinger,[7,8,9] the conceptual preparation has in this case been inadequate.

2. CORRELATED SYSTEMS

A very brief summary of the quantum mechanical ideas[4,5,6,10,11] used below will be given in this section. Consider a system consisting of two subsystems, S_1 and S_2. The fullest possible description of each subsystem is given by its wave-function, which may be viewed as a state-vector in a Hilbert space. We choose some representation in which the physically possible states (called eigenstates) of each sub-system are eigenfunctions of an operator with discrete eigenvalues, the eigenvalues giving all possible results of measurement of an observable O associated with the operator. Let O_1 pertain to S_1, O_2 to S_2.

It will suffice to suppose that subsystem S_1 is capable of only two eigenstates, ϕ_+ and ϕ_- say, with two corresponding eigenvalues; and that subsystem S_2 is capable of only three eigenstates, say χ_0, χ_+, χ_-, with three corresponding eigenvalues. The subsystems may be made to interact; the interaction, represented by a linear (unitary) operator U, may be removed at will. Before the interaction, S_2 is in the eigenstate χ_0. The eigenstates of the joint system $S_1 + S_2$ are products of the eigenstates of the subsystems.

Now, the subsystems and their interaction can be arranged so that if S_1 is in the eigenstate ϕ_+ then S_2 is in the eigenstate χ_+ after the interaction, and similarly for ϕ_-, χ_-:

$$\left.\begin{aligned} U(\chi_0\phi_+) &= \chi_+\phi_+ \\ U(\chi_0\phi_-) &= \chi_-\phi_- \end{aligned}\right\} \qquad (1).$$

Next, suppose that the initial state vector of S_1 is some linear superposition

$$\alpha_+\phi_+ + \alpha_-\phi_-$$

of the eigenstates of S_1, with complex coefficients α_+, α_-, so that the joint system $S_1 + S_2$ is initially in the state

$$\psi_0 = \chi_0(\alpha_+\phi_+ + \alpha_-\phi_-) \tag{2}$$

Then the interaction U transforms (2) according to (1) into

$$\psi = U\psi_0 = \alpha_+\chi_+\phi_+ + \alpha_+\chi_-\phi_- \tag{3}$$

According to the postulates of quantum mechanics, suitable experiments will detect the joint state $\chi_+\phi_+$ with the probability $|\alpha_+|^2$, or the state $\chi_-\phi_-$ with the probability $|\alpha_-|^2$, and no other state ($|\alpha_+|^2 + |\alpha_-|^2 = 1$). The state ψ in (3) is a *pure state* of the joint system $S_1 + S_2$, that is to say, we may *not* assert that before the measurement the joint state is actually $\chi_+\phi_+$ *or* $\chi_-\phi_-$, but that we do not yet know which: for experiments may be performed which exclude such an interpretation (showing that the joint system described by (3) is in some sense in both the states $\chi_+\phi_+$ *and* $\chi_-\phi_-$).

On the other hand, a joint system $S_1 + S_2$ *may* be actually put into *one* of the states $\chi_+\phi_+$, $\chi_-\phi_-$, in such a way that we know only probabilities $|\alpha_+|^2$, $|\alpha_-|^2$ of finding the one state or the other. The joint system $S_1 + S_2$ is then said to be in a *mixture of states* which I shall denote by

$$\alpha_+\chi_+\phi_+ V \alpha_-\chi_-\phi_- \tag{4}$$

using the logical V ('or') to denote that the system really is in one *or* the other of the two eigenstates, only we do not know which. I shall not use here the more usual and more complicated formalism of the density matrix,[3,5] which includes both (3) and (4). The distinction between the pure state and the mixture (even with the same probability distribution $|\alpha_+|^2$, $|\alpha_-|^2$ of the results of the requisite measurement) is one of the most radical features of quantum mechanics. The experimental distinction between (3) and (4) is made by a measurement *other* than that which establishes one of the states $\chi_+\phi_+$, $\chi_-\phi_-$ as the state of the joint system.

Suppose that the interaction is now removed, leaving the joint system in the pure state (3). The states of the subsystems S_1 and S_2 are left *correlated*, as a result of the interaction, in the following sense: if we measure the observable O_2 on S_2 and find the state χ_+, then we can infer with certainty that S_1 is in the eigenstate ϕ_+, and we may confirm this inference by a measurement of O_1 on S_1. If χ_- is found for S_2, ϕ_- can be similarly inferred for S_1.

3. CONSCIOUSNESS

The quantum mechanical equation of motion (Schrödinger's equation) allows a more detailed description of the interaction process which was represented here briefly by the effect of the symbolic operator U. In fact, U can be written down as a time-dependent expression in terms of the interaction Hamiltonian and Planck's constant. Furthermore, subsystem S_2 may be viewed as a model of a measuring apparatus designed to ascertain the state of an object S_1, and χ_0, χ_+ and χ_- may then describe three possible positions of a pointer. The correlation between the states of the apparatus and of the object has been brought about in accord with the equation of motion, and the resulting joint state ψ is given by (3). However, this does not complete the process of measurement because we still know only the probabilities $|\alpha_+|^2$, $|\alpha_-|^2$ of eigenstates $\chi_+\phi_+$, $\chi_-\phi_-$, neither of which can as yet be said to be realised: the pointer position is yet to be read. It is not difficult to see that the introduction of further pieces of apparatus does not lead to a completion of the measurement, either, since these would merely introduce further correlations.

On the other hand, it follows from the postulates of quantum mechanics that when observation is completed, the observer knows that the joint state *is* $\chi_+\phi_+$, or $\chi_-\phi_-$, as the case may be. Thus the conditional knowledge expressed by (3)—if χ_+, then ϕ_+, etc.—is converted into the unconditional knowledge of the joint state: $\chi_+\phi_+$ (or $\chi_-\phi_-$), when the knowledge of a state of the apparatus (χ_+ or χ_-) has entered the consciousness of the observer. This event of the conversion of ψ in and by a consciousness (sometimes called 'reduction of wave packets') follows no known equation of physics; it is instantaneous, or else it occurs at a rate not determined by the physical system and its law of motion (Schrödinger's equation). It is a step admittedly 'shrouded in mystery',[12] yet one without which no measurement is completed. This event in consciousness separates the physical state (3) of the joint system, from the physical state $\chi_+\phi_+$ (or $\chi_-\phi_-$); certain experiments on the joint system[6] would yield undoubtedly different results before and after it. This experimentally observable effect of the event in an observer's consciousness is a feature of quantum mechanics. Classical physicists would, of course, concede that 'someone must get to know the result of the interaction with apparatus', but the same physical situation would be postulated to hold for $S_1 + S_2$ before and after someone 'getting

to know'. The classical joint state after interaction always corresponds to the mixture (4); experiments distinguishing between (4) and (3) are characteristically quantum mechanical.

It is interesting to note that the need for such explicit introduction of events in consciousness, and of their physical (experimental) effects, has not been part of the aims or hopes of the original founders of quantum mechanics.[11] It is as if the subject itself, through its internal coherence, had made its demands—an impression which is typical of great advances of science. The absence of any known law of physics describing the conversion of the joint state (3) into the mixture (4), indeed the *suspension* of the known physical law during the conversion, may be viewed in the light of Russell's definition[13] of matter as 'that which satisfies equations of physics'. Thus the internal coherence of quantum mechanics demands explicit note to be taken of non-matter.

4. WIGNER'S FRIEND[6]

Consider the following two premisses, adapted from Schrödinger[7] for my present purpose.

A. My body with its central nervous system (explored to any future degree of physiological completeness) functions as a pure mechanism according to the laws of nature. Furthermore, quantum mechanics is the ultimate basis of the mechanism.

B. I am aware, by incontrovertible direct evidence, of knowledge (information) entering my consciousness.

We shall call the observer of §3 (above), whose consciousness is involved in the conversion of the joint state (3), the *ultimate* observer. Wigner[6] has discussed the consequences of replacing the measuring apparatus S_2 by a second conscious observer (Wigner's friend), whom we shall call the *intermediate* observer. The functions χ_+, χ_-, χ_0 then correspond to the possible contents of the consciousness of the intermediate observer with respect to the object S_1, and U represents symbolically his interaction with S_1. Wigner[6] adds a schematic example in which the interaction consists of S_1 emitting and S_2 detecting flashes of light according to a simple probabilistic rule connecting the occurrence of successive flashes. While this example illustrates the eigenstates $\chi_+\phi_+$ and $\chi_-\phi_-$, it must be admitted that the preparation of the states (3) and (4), and their essential properties, are not elucidated by the example. Indeed, a plausible illustration for the

general reader, which would contain everything essential while avoiding the rigours of serious quantum mechanics, is not available. This is an aspect of the departure of quantum mechanics from common sense.

Now assume that the premiss A holds for the intermediate observer. Then the considerations of §§2 and 3 are unchanged from the point of view of the ultimate observer, for whom the intermediate observer functions as the measuring apparatus S_2. After the interaction U between S_1 and S_2, the ultimate observer may ask the intermediate observer about the state of S_1 (this corresponds to the reading of a pointer); he will receive the answer ϕ_+ (with probability $|\alpha_+|^2$) or the answer ϕ_- (with probability $|\alpha_-|^2$). The answer may be subsequently checked by a further measurement on S_1, which had ceased to interact with S_2.

On the other hand, assume that the premiss B holds for the intermediate observer. Wigner expresses this assumption by the revealing question from the ultimate observer to the intermediate observer: 'What did you know about S_1 before I asked you?' The reply will be: 'I told you already, ϕ_+ (or ϕ_-).' The state of S_1 had entered the consciousness of the intermediate observer independently of the ultimate observer, and the conversion of (3) was an event in the consciousness of the *intermediate* observer. That event converted (3) into one of the joint states $\chi_+\phi_+$, $\chi_-\phi_-$ for the intermediate observer, but into the mixture (4) for the ultimate observer: the latter knew that one and only one of the two states $\chi_+\phi_+$, $\chi_-\phi_-$, was the case after the interaction of the former with S_1; then the conversation tells him, which.

These consequences of the premisses A and B are usually considered to be paradoxical (Wigner's paradox), since two accounts of one process lead to two different, experimentally distinguishable states, i.e., the pure state (3) and the mixture (4). Various interpretations have been proposed. Wigner[6] considers that his train of thought indicates a specific influence of consciousness on physical phenomena, and that the resulting paradox shows the inadequacy of quantum mechanics (in its present linear form) for the description of that influence. Jauch[5] considers present-day physics incapable of incorporating adequately effects of consciousness. Thus both authors resolve the paradox by denying the second part of premiss A, whereby the opportunity of confronting premisses A and B in a specific process is abandoned for the present time.

The force of Wigner's paradox would be reduced if the validity of quantum mechanics were confined to microscopic phenomena, as had been suggested,[14] and if the conscious observer were fully explicable in macroscopic terms in the sense of the first part of premiss *A*. Here I accept Wigner's view[6] that evidence for such confinement of the validity of quantum mechanics is lacking experimentally, while theory suggests no basic line of division between macroscopic and microscopic domains of physics. Furthermore, as few as three light quanta are perceived by man[6] and probably a single quantum can be perceived by the crab Limulus.[15]

In particular, there is no known physical objection to the application of the quantum theory of measurement to macroscopic phenomena—a point emphasized both by leading opponents and supporters of the possibility of the universal validity of quantum mechanics.[16,17] It has been shown in detail[10] that if S_2 admits many eigenstates (and thereby becomes a more realistic model of a measuring apparatus), the correlating interaction with S_1 must result in a pure state for the joint system, though that joint state becomes more difficult to distinguish from a mixture by means of experiments; this practical difficulty will be recalled in §9.

5. ONENESS OF MIND

Like Schrödinger in a somewhat different context[7] I propose to retain both premisses *A* and *B* in full and to seek a way of drawing a non-contradictory conclusion.

It is apparent from the above exposition that the paradox hinges on the introduction of a second conscious observer, such that an event in his consciousness is independent of the consciousness of the first observer. A third, hitherto tacit premiss of Wigner's paradox is, therefore:

C. There exist at least two independent conscious minds.

I now propose to resolve the paradox by denying premiss *C* (thus adopting a Vedantic view) while retaining premisses *A* and *B*. In this interpretation the apparent paradox becomes a *reductio ad absurdum* of the hypothesis of the plurality of conscious minds; there is thus only one consciousness, namely that postulated in premiss *B*. That is the conscious mind of Wigner's friend, and 'all conscious minds' are identical with it. In Schrödinger's formulation,[7] consciousness is a singular of which the plural is *unknown*. I assert here, furthermore, that the plural is *inadmissible*.

It is now clear that a genuine paradox would arise from the retention of all three premisses *A*, *B* and *C*. The plausibility of my resolution of the paradox depends on the demonstration that *C* is relatively the weakest premiss and that it should be abandoned.

I maintain, following Descartes, that premiss *B* is the strongest of the three: I have no knowledge more direct and less uncertain than that. Next, the first part of premiss *A* incorporates and extrapolates the marvellous and continuing advances of the physiology of the nervous system, to which no limit or check has yet been encountered. There is nothing known to indicate that brain physiology, pursued with maximum subtlety to maximum depth, will fail to keep extending our knowledge of the brain as a network of finely interconnected electrochemical operating units (cells, axons, synapses).

The second part of *A*, being more specific, is open to more doubt: quantum mechanics may yet be modified on the level relevant to the present discussion of the nervous system. Paraphrasing Wigner,[6] the weakness of the second part of premiss *A* is in the total reliance on the tenets of orthodox quantum mechanics 'in all their consequences—a reliance which would be, on the basis of our experience with the ephemeral nature of physical theories, difficult to justify fully'.

Such caution is fitting. But we may ask what knowledge of the external world is less ephemeral than physical theories supported by as great a mass of experimental facts as quantum mechanics. Such a physical theory, if we are not to be confined to the introspectible, must be taken as a reasonable basis for philosophical considerations. (Einstein's theory, commonly accepted as a corrective to the Kantian views mentioned in the Introduction, has far less evidence in favour of its salient features than quantum mechanics.) It remains remarkable that the discoverer of wave mechanics, and a modern advocate of the Vedantic view, did not choose to use quantum mechanics in any philosophical context;[9] but the ephemeral character of physical theories did not keep him from using Boltzmann's theory of the arrow of time as a basis for far-reaching philosophical speculations.[8]

Turning finally to the examination of premiss *C*, I stress the fact that it is supported by no direct empirical evidence whatever:[7] 'Consciousness is never experienced in the plural, only in the singular. Even in the pathological cases of split consciousness or double personality the two persons alternate, they are never manifest

simultaneously.' The origins of the conjecture of the plurality of conscious minds will be discussed further in the next two sections; but it should be now apparent that, from the *empirical* point of view, premiss *C* is the weakest of the three.

The argument of the present section (which is the central point of the present paper) may be re-cast in somewhat different terms. Introspection (in premiss *B*) can involve only one consciousness. The external world (in premiss *A*) is introduced and confronted with introspection in such a way that a hypothesis about plurality of conscious minds (premiss *C*) is denied as a result. Just how has introspection been brought into interaction with the external world to engender that result? I accept Wigner's view[6] that the conversion of the pure state (3) of the joint system into the mixture (4) by an event in consciousness represents a specific effect of consciousness upon the physical world; he views such an effect as a plausible reaction corresponding to the commonly recognized action of the physical world upon consciousness. I recall that[18] 'it is contrary to the mode of thinking in science to conceive of a thing which acts itself but cannot be acted upon'. Einstein referred to the action of space-time upon matter in this quotation, but the action of the physical world on consciousness may be substituted.

Now it is this specific effect of consciousness on the physical world which may be taken to couple introspection to physics so as to generate the paradox. If premiss *C* is acepted, then in the course of the process of measurement (described above) the specific effect takes place according to premiss *B* with the result (4); and it does not take place according to premiss *A*, the result being (3). From here my argument proceeds as before.

I now revert briefly to my introductory remarks about the degree of historical preparation for the present train of thought. The initial step of the paradox may be viewed as a confrontation of introspected consciousness (ultimate observer) with a hypothetical entity claiming symmetry (the consciousness of the intermediate observer). Wigner comments[6]: 'The theory of measurement, direct or indirect, is logically consistent so long as I maintain my privileged position as ultimate observer.' (Here 'ultimate' is used in a non-technical sense not identical with mine.)

An interesting counterpart to this remark is reported by Schrödinger[9] as having been recognized in Indian Samkhya philosophy: 'Assume two human bodies, *X* and *Y*. Put *X* in some particular

external situation so that some particular image is seen, let us say the view of a garden. At the same time Y is placed in a dark room. If X is now put into the dark room and Y in the situation in which X was before, there is then no view of the garden: it is completely dark (because X is *my* body, Y someone else's).'

6. THE NATURAL HISTORY OF MAJA

If premiss C is abandoned and the plurality of conscious minds is an illusion, it becomes surprising that the ultimate observer had to address questions to the intermediate observer in order to discover the contents of their one consciousness. One would rather expect a direct knowledge which, in our accustomed pluralistic language, would be described as telepathy between any two such observers. Yet we know that if telepathy exists at all, it is a weak and uncontrollably erratic phenomenon. In Indian terms, the veil of Maja must be very effective. Can its effectiveness be accounted for in scientific rather than mythical terms?

The essential scientific insight has been pointed out by J. B. S. Haldane:[19] 'We should expect such phenomena [leakage from one mind to another] to be unusual as, from the standpoint of natural selection, a person who habitually experienced other people's sensations would probably be less fit than a normal person. I should not be surprised if our mental insulation turned out to be a special adaptation.' An adaptation, we add, which would yield a favourable coupling of one mind with the many bodies involved in the evolution of species.

From the Vedantic point of view Haldane's remark is the most important of all insights furnished by the theory of evolution. The genetic fixation of the proposed insulating adaptation would be one amongst the many recognized constraints exerted by the body on mind. But we know that such genetic fixations are subject to variations. Surprising results of future mutations, or even of combinations of existing recessive mutations, would have to be admitted as possible. Some existing species might be shown to be deficient in the insulating adaptation between members of that species.

A complementary problem may also be elucidated from the evolutionary point of view. Sherrington[20] discussed in detail the plurality of entities in any one living body which all seem physiologically as capable of having separate minds as different bodies

themselves: 'How far is the [individual] mind a collection of quasi-independent perceptual minds integrated physically in large measure by temporal concurrence of experience?'

Such integration may be viewed as a complementary adaptation of the individual vehicle of natural selection: that is, Haldane's insulating adaptation may be complemented by a total lack of insulations within the selected domain of physico-chemical processes called 'the individual body'. The veil of Maja is absent so completely between Sherrington's quasi-independent perceptual minds that not even a suspicion of plurality within the human individual comes about until the onset of abstract speculation; no one speaks of this integration as perfect telepathy. The presence and absence of the veil, respectively, are so perfect in the two contrasting aspects that Schrödinger[7] could advance his empirical argument quoted above: consciousness is never experienced in the plural. Maja too is tied to the wheel of evolution.

7. THE INTELLECTUAL HISTORY OF MAJA

'How does the idea of plurality arise at all?' asks Schrödinger.[7] 'Consciousness finds itself intimately connected with, and dependent on, the physical state of a limited region of matter, the body. Now, there is a great plurality of similar bodies. Hence the pluralization of consciousnesses or minds is a very suggestive hypothesis.'

It is clear that in order to suggest a plurality of independent minds, the similar bodies must themselves be independent of each other in the sense that their interactions must be mediated by physical agents which may be arbitrarily reduced, for example, by sufficiently increasing the distance between the bodies. It is remarkable that such independence is severely restricted, for an important class of cases, by the quantum theory of correlated systems summarized in §2, that is, by the very source of my argument against the plurality of conscious minds. The restriction follows from the argument of Einstein, Podolsky and Rosen[4] (EPR for short) by means of the interpretation (unintended by these authors) which would maintain the completeness of quantum mechanics.[21]

Suppose again, as in §2, that subsystems S_1 and S_2 have become correlated by an interaction U which then ceased, leaving them in the joint state (3). We now measure the observable O_2 on subsystem S_2 alone (by inspection, or by means of some further apparatus).

If we find the state χ_+, we infer that S_1 is in the state ϕ_+ (and similarly for χ_-, ϕ_-). But S_1 could be arbitrarily far separated from S_2 so that the measurement on S_2 could involve no physical disturbance of S_1. If the subsystems S_1 and S_2 are independent bodies in the above sense, then S_1 must have been in the state ϕ_+ (or ϕ_-) even before χ_+ (or χ_-) was found in S_2 by observation. But this would mean that before the measurement the joint state was the mixture (4), which is detectably different from the pure state (3) supposed at the outset.

This contradiction is the version of the EPR argument that will suffice here, though several other deep conclusions follow.[2,4,5,11] The EPR argument has led to discussions with Bohr[21] and others; the conclusions have been summarized by Einstein[22] in a concise form, fully understandable from our brief account, as follows:

'The EPR paradox forces us to relinquish one of the following two assertions:

(i) The description by means of the ψ-function is complete.

(ii) The real states of spatially separated objects are independent of each other.'

If we follow Bohr in relinquishing (ii), the suggestive force of a plurality of bodies, leading to the hypothesis of plurality of conscious minds, is greatly weakened. It is to be noted that this loss of independence occurs only for pairs of bodies which had previously interacted closely enough to establish a correlation of the kind discussed in §2. This seems usually possible for pairs of subjects suspected of being in telepathic communication.

In this context Einstein[22] reports 'a conversation which I had with an important theoretical physicist. He: "I am inclined to believe in telepathy." I: "This has probably more to do with physics than with psychology." He: "Yes."' In the present context there is a connection also with the discussion of §6: while the possibility of telepathy may be a matter of physics, the non-existence or weakness of telepathy may be a matter of natural selection.

8. THE SCOPE OF *reductio*

After some thought, the premisses *A*, *B*, *C* and the reasoning connected with them should be fully understandable to anyone. Now suppose that my conclusion holds: I am led to the Vedantic view that denies the plurality of conscious minds. That view I do not

understand *per se*, in terms of my world and my personality, but rather as an abstract attachment to intelligible premisses, which is connected to my thought by a chain of logical steps. Schrödinger[7] comments: 'The striving of all scholars of Vedanta was, after having learnt to pronounce with their lips, really to assimilate in their minds this grandest of all thoughts.' If the argument of §6 is sound, we may be congenitally handicapped in such assimilation. (It is possible to see a motivation of asceticism from this point of view.)

In this situation it is profoundly significant that the argument has the form of a *reductio ad absurdum* of understandable premisses. Only such an argument allows my thinking to grope towards a conclusion which is in itself utterly alien to my intuition, concept-formation and even, except in a superficial sense, to linguistic expression. In that psychological sense *reductio* can be said to have a scope far beyond any constructive proof which might be equivalent to it from the purely logical point of view.

This methodical insight has a long history. Thus Jaspers[23] writes: 'Cusanus had but one goal: in his thinking to attain to the One, in which all things are and whence they spring, in which I too have my source. What must a man think in order to come into contact with the incomprehensible? What can he say in order to express the ineffable, to make it communicable? What methods must be devised? . . . Our non-comprehension is manifested in conceptions that are absurd from the point of view of discursive reason. But by apprehending these absurdities, reason prepares a springboard from which we are enabled to attain the other kind of comprehension.' Indeed, what other kind? We do not expect a ready convergence of linguistic expressions concerning the ineffable. In the present context I mean understanding from which we are separated by biological factors such as Haldane's insulating adaptation (§6).

The special position of the *reductio ad absurdum* can be elucidated from the point of view of brain physiology. Griffith[24] has recently discussed the question of the neural mechanism underlying 'certainty' or, we might add, the neural counterpart of Descartes' 'clear and distinct ideas': 'How do I know that, when I have performed a mathematical proof, it is correct? How do I know that the number which comes to mind when I try to recall a telephone number is the right one? Subjectively, of course, one has a direct

intuitive feeling. It seems to me possible that this may be correlated with a *lack of conflict* [italics mine] in the production of the corresponding mode ['mode' is used here in a technical neural sense]. For example, if one remembers the number 7 as the number of a house, one might be sure of it, if the mode for 7 gets established straight away. If, however, the modes for 5 and 7 get established simultaneously, mutually inhibit and then 7 gets established, one might not feel so sure. At the neural level, there is a clear difference between these two situations, in the number of inhibitory neurons which get excited. This difference could be utilized by the brain. Subjectively, then, we might not be aware of the brief establishment as '5' or '7', but merely have a feeling of doubt which gets attached to the following proper establishment. Note the slightly unpleasant feature of this interpretation. Things seem correct or not, not according to whether they are correct in any absolute sense, but merely according to whether or not they satisfy certain criteria'.

As noted, I put Griffith's 'lack of conflict' in italics. On the basis of his account, the *reductio* has a radically distinct structure at the neural level, even though it is deemed logically equivalent to other arguments in mathematics: it consists of a persisting conflict between modes corresponding to *premisses*. Equivalence to other forms of argument may be expected when the reasoning does not run counter to the sets of modes rendered possible by the evolved structure of the neuronal network; but persisting conflict is just what we would expect when a biological adaptation is to be transcended in thought. Whether such a persisting conflict of neural modes might itself exert an evolutionary pressure, and whether it may be actually modified by mystics, is a question which I shall not discuss here.

Assuming plurality, I have deduced a contradiction. It would be desirable to complement this result by assuming oneness and deducing a specific consequence which might be observable at least in principle. This would ensure that the distinction between plurality and oneness is meaningful even in the sense of natural science. But the customary notion of an act of observation involves a subject and an object, and these do not fit in with the hypothesis of oneness when both subject and object involve consciousness. The recognition of this difficulty is over two and a half thousand years old:[25]

'For where there seems to be a duality, there one sees another, one hears another, one feels another's perfume, one thinks of another, one knows another. But when all has become spirit, one's own self,

how and whom could one see? How and whom could one hear? How and of whom could one feel the perfume? How and to whom could one speak? How and whom could one know? How can one know him who knows all? How can the knower be known?'

9. REICHENBACH'S CHOICE

In §5 I argued that laws of physics need not be considered too ephemeral to be brought to bear on philosophical questions. I now turn to a contrasting view: 'Quantum mechanics should not be misused for attempts to revive philosophical speculations which are not on a level with the clarity and precision of language of physics.'[2] We see an interaction of physics with philosophy discouraged on one side by the physicist Wigner, concerned about the relatively ephemeral character of physics; and on the other side by the philosopher Reichenbach, concerned about the relatively imprecise language of speculative philosophy.

Now, the remarkable fact that aspects of the world can be grasped with the clarity and precision of the language of physics, is itself a most powerful source of philosophical speculation. For many thinkers, it is just this aspect of physics that makes physics interesting enough to justify the choice of emphasis which permits such precision.[26] Others prefer to leave philosophical impulses implicit in a statement such as: 'I find physics interesting', which they do not analyse further. I shall not pursue here such matters of subjective motivation, except to suggest a counterpart to Reichenbach's admonition: the danger of confusion should not be misused to sever philosophical roots which ultimately sustain the interest of science.

There are two less subjective points associated with these programmatic remarks. Firstly, how extensive a domain of discourse can be fruitfully chosen, and how disparate are the elements it should contain? Newton was justified in considering together the then separate disciplines of Galileo's dynamics and Kepler's astronomy. The metaphysical faith in the coherence of the world was tested much further in our time by combining[7] into one discourse the quantum mechanics of molecules, and the transitions and replication of the then hypothetical units of heredity (genes). It is true that in each pair the disciplines were on roughly similar levels of clarity and precision of language. On the other hand, an argument of the kind used in §5 (related to an argument of Schrödinger[7]) confronts

a premiss taken from immediate introspection, with a premiss which is the result of a long chain of scientific inference. (The earliest confrontation of this kind is probably due to Demokritus[27] (fragment 125), who had also suggested that 'dark' knowledge would be replaced by genuine knowledge when our investigations reach the domain of atoms (fragment 11)). Pursuing philosophical considerations, I ventured to follow Schrödinger in combining such disparate premisses (A and B) while Reichenbach, pursuing precision and clarity of language, would not have chosen to do so.

Secondly, can Reichenbach consistently isolate the domain of precisely expressible physics from the less precise concept of an event in introspected consciousness? That is: can my premiss B be consistently ignored in a suitably defined physics? It is interesting that such a programme can be carried through[2,11] by always interposing a *macroscopic* apparatus between the object and the conscious observer. Such an apparatus is accurately describable in classical terms; it may be automated, leaving irreversible paper-marks which may be inspected at any later time.

Such a choice does not change any of the principles discussed above, but it offers a consistent *practical* demarcation of Reichenbach's physics. As pointed out at the end of §4, according to quantum mechanics even a large (classically describable) apparatus does not convert a pure state of an object into a mixture of states of the system object-plus-apparatus; but it renders the actually resulting pure state *practically* indistinguishable from a mixture (distinguishing experiments become utterly impracticable). The knowledge that such a restrictive definition of physics is possible without inconsistency is valuable, even when it is not adopted.

SUMMARY

The quantum mechanical paradox of 'Wigner's friend' is interpreted as a *reductio ad absurdum* of the hypothesis of the plurality of conscious minds. Some presuppositions and some consequences of this interpretation are examined.

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