11. Agents and Evolution.

Human beings play a singular role in Copenhagen quantum theory: within that scheme science is viewed as a human endeavor, performed by human beings for human beings. Still, most scientists believe that *something* was going on before homo sapiens arrived on the scene, and many hold that the task of science will not be finished until we have a science-based idea of what that something was, and how our species emerged from it.

My intention here is to find the place of human beings in a broader non-anthropocentric setting, and I believe that this can be done by building upon the foundation laid by the creators of quantum theory, rather than by retreating to a mechanistic conception of man that ignores consciousness, or tries to replace it by something else, such as classically describable brain processes. Indeed, the approach of scientists and philosophers who base their thinking on the classical conceptualization of human brains depends on a promissory note that can never be redeemed. That promise, or completely unsupported hope, is that *someday* we shall be able to understand how a conscious experience---a feeling or knowing---can either ***be***, or *be a necessary consequence of*, a structure built exclusively out of the elements allowed by classical mechanics. Those ingredients are the (unphysical) notions of tiny invisible atomic particles with no properties other than exact location, velocity, electric charge, and mass, evolving in accordance with some simple force laws. Certainly one can build out of these conceptual elements many intricate structures with all sorts of complex behaviors, and such a structure can be "emergent" in the sense that its coming into being could never be deduced by examining the laws of classical physics. For example, one could never deduce from Newton's and Maxwell's equations that a "wheel" or a "locomotive" would ever come into existence. But given the structure of such an object, and the assumption that it is built out of nothing but the elements specified by classical physical theory behaving in accordance with the laws of that theory, then every theoretically entailed property of that "wheel" or "locomotive" is a consequence of those laws and the geometric arrangement of its component parts. Occasionally a physicist might say that one particle "feels" the force exerted on it by a neighboring particle, but he understands that this is just a picturesque way of

referring to some geometrically describable property such as acceleration, and that the specified rules of classical physics can never entail the existence of anything like, say, a feeling of pain. The key point here, understood by all mathematicians and logicians, is that in a proof, or deduction, one can never get out more than what is put into the assumptions and the rules of proof. And in the case of classical physical theory no definition or characterization of a "conscious feeling or knowing" is put in, and hence no conclusion pertaining to these qualities can be deduced: the ingredients of the dynamically complete classical physical theory simply do not possess the capacity to entail anything beyond evolution of the geometric structure. Nothing in those principles can *ensure* or *dictate* that some such changing configuration of points, and of numbers assigned to space-time points, will *necessarily* be accompanied by, say, a "painful feeling".

Feelings can be only gratuitous---not rationally entailed---add-ons to any structure built solely from entities possessing only the properties specified by the classical concepts. Such supernumeraries, being logically unnecessary, would be dynamically superfluous and without causative power, hence devoid of survival value. Nor can it be argued that feelings *must* emerge from such systems because we ourselves are the living proof. For we ourselves are certainly not built out of elements that conform to the idealized unphysical concepts that are the basis of classical physics. We, insofar as contemporary science has correctly informed us, are built out a very different kind of stuff that is qualitatively more like information or knowledge or tendency for an experiential happening to occur, than like classically conceived matter or substance.

In short: in order to get something like consciousness out of a theory one must put something like consciousness in. Consequently, it is logically impossible to deduce the existence of consciousness, or of feelings, from classical physical theory. On the other hand, quantum theory already requires for its logical completeness the dynamically efficacious Process I, which must be linked to our conscious experiences in order to tie the theory to empirical data.

So far I have restricted myself to the orthodox framework created by the founders of quantum theory, and developed by John von

Neumann. But the focus of those works was on *human* agents. To proceed to a more general theory that accommodates evolution I shall need to build upon the essential core of that orthodox approach.

The first needed clarification concerns the infamous "collapse". Copenhagen endorses it, but only as a feature of the subjective calculations of a human scientist who is making a computation pertaining to his future experiences. Von Neumann moves from this subjective Copenhagen position in the direction of an objective conception of nature herself. But he never introduces "collapse." He brings in his Process I, which can be construed as a physically objective action on the part of some agent. This Process I act is considered to be a real aspect of nature also in the Copenhagen approach. So I shall accept Process I events as real elements of nature. Collapses, on the other hand, have a different status. I shall call them Process III events. Eugene Wigner's exposition of von Neumann's theory seems to introduce them as real features of nature, but von Neumann himself makes no such commitment. I believe this to be a deliberate and profound move on von Neumann's part, about which I shall have a great deal to say.

The distinction between Processes I and III is technical, but vitally important. So I must make it clear.

A "state vector", as explained in earlier chapters, is represented in the theory by a (generally infinite) sequence of numbers, which can be thought of as a long row or column of numbers. The "State" of a physical system can, under certain very severe conditions, be specified by a State Vector. However, these conditions are rarely met in practice. In general, the state of a physical system is, according to quantum theory, specified by a *square array* of numbers with (generally) an infinite number of rows and an infinite number of columns. A Process I 'Yes-or-No' event associated with that physical system has the following effect: it divides this square array, or matrix, into four parts: two non-overlapping squares located on the diagonal, and two rectangles that lie symmetrically on opposite sides of the diagonal. The Process I event abruptly sets to zero all of the numbers in the two off-diagonal rectangles, but leaves untouched the numbers in the two diagonal squares. This action effectively separates the original physical system into two independent parts, or branches,

specified by the two untouched square matricies. The numbers in the two off-diagonal rectangles *would* represent, had they not been set to zero, the possibility that some future Process I event in some (possibly other) system could detect the simultaneous presence in nature of the two parts specified by the two retained squares. But the Process I event, by setting the numbers in these two off-diagonal rectangles to zero, appears to eliminate, forevermore, the possibility of any observation ever occurring that could detect the simultaneous existence in nature of both of the two retained parts. The Process I event ensures that, according to the orthodox von Neumann rules, no memory structure, or any other physical trace, will ever exist that could reveal an interference between the two now-separated branches.

If some other subsystem comes into physical contact with this now two-branched system then, as von Neumann explained, this other system will itself divide into two branches, with one branch arising from the interaction with one of the two branches of the original two-branched system and the other branch arising from the interaction with the other branch of the original two-branched system. Thus the combined system of the two subsystems will separate into just two branches, one corresponding to the original 'Yes' branch, the other corresponding to the original 'No' branch. The whole future of the world, or at least those parts that are *physically affected* by the originally split system, will split into one part manifesting consequences of the original 'Yes' choice and a second part manifesting consequences of the original 'No' choice. A future experience may feel the properties of the original 'Yes' branch or the properties of the original 'No' branch, but will never reveal any hint of the simultaneous existence of both branches. Thus the prior objective physical state has been converted by the Process I event to one that is, as far as can ever be known by any agent, identical to one in which only one branch or the other exists: any future knowing will correspond to one branch or the other, not both. A similar bifurcation of the entire realm of future experiences is induced by each Process I event. This effect of the Process I event is not some wild science-fiction invention, but what the mathematics of quantum physics, as spelled out by von Neumann, dictates.

One clarification must be made: it is obvious that this separation of the original array into the two squares and two rectangles would be disrupted if one rearranged the rows and columns of the array. In quantum theory there are always many superficially different-looking ways of arranging the same physical information. The transformations that achieve such rearrangements are “unitary transformations.” The picture that I gave of Process I is how it would look in *some* way of arranging the physical information into a matrix form. The effect of the Process I could *look* very different if some other way of arranging the information were used.

Now comes the crucial question! What does nature do with these two branches? The mathematics of quantum theory assigns a well defined “statistical weight” to each of the two branches. These two weights add up to unity, as the probabilities of two *alternative possible branches* should. But what actually happens next? Does nature completely eradicate one branch and leave only the other, or do both continue to exist.

The first possibility is this: Nature, governed by the “quantum statistical weights,” chooses one branch or the other. That option is called “Reduction of the State Vector” or “Collapse of the Wave Function.” It is Process III. In our matrix picture it would be represented by following up on the Process I action of setting to zero the numbers in both of the two off-diagonal rectangles *by now setting to zero all of the elements in one or the other of the two squares on the diagonal,* with the choice of which of the two diagonal squares survives being a random choice governed by the quantum statistical weights of the two possibilities.

The second possibility is that there is no Process III: that both branches continue to exist!

The Process I choice is associated in orthodox quantum theory with the participant/observer, or agent. It represents within the mathematical structure his choice of which aspect of nature his observation is going to probe. It is the Process I choices on the part of the agent that allows the agent to influence, via the Quantum Zeno Effect, the probabilities of the different possible courses of action between which he is free to choose. This Process I should therefore

be associated with the evaluations, and hence with the *feelings,* of the agent. On the other hand, a process III choice between the 'Yes' and "No' branches, being pure chance, would be in Pauli's word "irrational." It seems to be a choice that "comes from out of the blue" with no sufficient reason to be what it is, say a 'Yes' rather than a 'No.'

Von Neumann never mentions this further collapse process.

In what follows I shall accept the reality of a Process I event as the action of some embodied agent, which, however, may not be human, or even highly developed. But, following von Neumann, I shall avoid referring to an ensuing Process III collapse. Feelings and conscious experiences will be associated with Process I, not with a possibly nonexistent Process III.

It might seem at first that if the 'Yes' and 'No' branches are both saved then nothing is accomplished by Process I. That is incorrect. Process I can, via the Quantum Zeno Effect, channel probability into configurations of greater order and stability, while nonetheless conforming to the second law of thermodynamics, which asserts that the overall orderliness of the universe can never increase. I shall describe in the next chapter von Neumann's development of this key point.

So how does the evolutionary scenario work?

According to this theory, the universe initially evolves under the governance of Process II (the Schroedinger equation) alone. All possibilities are mechanically generated by this evolving wavelike state. Given the nature of the laws implemented by the Schroedinger equation---which support, among other things, the possibility of the formation of organic molecules---the set of all possibilities will eventually lead to the formation of potential agents, which are simply mechanical subsystems that exist for a time in equilibrium with their environment, as (perhaps rudimentary) stimulus-response (input-output) system. These systems are essentially collections of quasi-classical states that tend to endure for intervals of time in communication with their environments.

Each of these subsystems has, due to its wave-like nature, or the effects of the uncertainty principle, a tendency to degenerate into less cohesive states. However, nature has armed all potential agents with a counter-weapon: access to Process I.

We have as our building blocks the assumed existence of Processes I and II, and the known existence of feelings. This brings us to the critical questions: (1) What determines when a Process I event occurs? (2) What determines the specific form of that event? And (3) How is that event related to the experiential aspect of nature?

To describe my proposed answers let me first bring into clear focus the situation that I have described in the preceding ten chapters. The founders of quantum theory, having discovered how to generalize the laws of classical mechanics to a form that allowed them to correctly calculate the probabilities of the various possible observable outcomes of various experiments that they might perform, were first at a loss to explain how to incorporate these beautiful laws into some rationally coherent understanding. Finally, they recognized that the mathematical laws were fundamentally incomplete, and had to be placed in a larger framework. This larger framework involved bringing "the observer" into the overall picture: the gap in the mathematical equations fit perfectly with the idea that there were participant/observers who were free to choose to probe nature in any one of many possible ways, and that nature would then deliver to them, in accordance to specified statistical laws, an answer, 'Yes' or 'No' to the chosen question. Thus the participant/observers had two separate functions: first to choose a specific question put to nature, and then to experience the answer returned by nature. Attempts by curious scientists to go beyond this pragmatic approach were discouraged, although each of the founders had some ideas about how these practical rules fit into a bigger picture. Heisenberg suggested that an *actualization of a potentiality* occurred at the measuring device, but adhered to the official line that the detailed mathematical theory was about "our knowledge." Von Neumann effectively made our human brains the important measuring devices, and formalized the agent's act of selecting which aspect of nature was to be probed as his famous Process I. But the details of its operation were not specified. That is the problem that we now address.

Here is how I think it works. Due to the inherently wave-like quality of physical systems the quantum state of the agent will tend to evolve into a collection of alternative possible courses of development. Within that collection there may be a large-scale state of high organization (low entropy) in which various modules---partially autonomous subsystems---within the agent act together in mutual support to create a state of harmonious equilibrium. This state extends over a large region in the agent, and hence cannot be grasped as a whole by the dynamically local Process II acting within the agent. But it can be singled out and specified by a projection operator P acting on the degrees of freedom of the agent. My postulate is that there is non-local real process that is a feel that grasps this state of harmonious organization and separates it from its complement, and that this grasping action is represented physically by the von Neumann Process I event specified by P.

One might immediately object that this “feel”, if precisely definable in physical or mathematical terms, could be eliminated from the dynamics, which would render the feel superfluous and without causal efficacy. But the situation in this regard is very different from the classical one. In the classical case an ontology (i.e., reality) is specified that has no hint of the existence of anything like a “feeling.” But in the quantum case the mathematically defined quantum state specifies in practice a potentiality, or probability, for an experiential event to occur. That event is the occurrence of a “feeling,” if, following William James, we recognize all experiential events as feelings of one kind or another. The entire thrust of quantum theory is that the physical state, represented mathematically in Hilbert space, is, ontologically, a tendency for an experience to occur. Conscious experiences are, after all, real aspects of nature, so it is illogical to argue against a theory that naturally accommodates them by claiming that there might be some way to eliminate them, whereas it is completely reasonable to criticize as incomplete a conception of nature that has no logical place for them.

My postulate, then, is that a “feel” is a grasping of a state of low entropy (high organization) in which various modules (individual computational elements devoted to specific tasks) in the brain act cooperatively together in a state of harmonious equilibrium. This state is extracted from the prior state by an associated projection operator

P. This grasping is represented in Hilbert space by a von Neumann Process I event. That event separates the prior physical reality into two independent branches, ‘Yes’ and ‘No’. The ‘Yes’ branch contains the organized state of equilibrium, which persists long enough for its physical traces to be etched into the physical structure of the agent. The left-over remainder persists, and subsequent Process I events can occur in either one of the two branches.

If the rapidity of nearly identical Process I events in a chain of ‘Yes’ choices is sufficiently great then, by a straightforward application of the dynamical laws specified by von Neumann, the probability associated with this evolving ‘Yes’ state will not decrease as quickly as it otherwise would: thus this state of organization can sustain itself by means of the Quantum Zeno Effect in the face of mechanical processes that tend to destroy it.

But what is the empirical significance of the “probability associated with this evolving ‘Yes’ state” if there is no collapse; i.e., if *both* the ‘Yes’ and the ‘No’ branches created at each event continue to exist in parallel?

What must be appreciated is that the meaning of ‘probability’ is a matter of dispute among the experts. We all have a pretty clear intuitive idea of what it means for some possible future event to be ‘highly probable’ or ‘highly improbable’, and we are all familiar with the definition of probability in terms of the fraction of outcomes ‘Yes’ in a long sequence of trials. But how long should this sequence be? “Infinitely Long” is the only precise answer. But no such series exists!

Consider the following conundrum. Suppose the predicted probability for ‘Yes’ is one, but in a series of a million trials the outcome is ‘No’ every time. Is the prediction proved false by this empirical evidence? No! For in all the millions and millions of future trials on the way to infinity the outcome might always be ‘Yes’, so that the limiting fraction of ‘Yes’ outcomes would be one, in agreement with the prediction.

The origin of this problem (and of other deep problems with “probability”) is that in classical physical theory the notion of probability is not intrinsic: probability is a human addition connected to our human lack of knowledge. But probability is intrinsic to quantum ontology. All that is needed is to specify its meaning there.

The meaning is this: If in a Process I event the mathematically defined quantum probability of the outcome 'Yes' is *p*, then the experiences of all agents will be *as if* the actual state prior to the event were one of an infinity of equivalent states, and the fraction of them that moves to the 'Yes' state is *p*. A sufficiently rapid sequence of nearly identical Process I actions will then have the effect of keeping both the subjectively and objectively defined probability of the evolving 'Yes' branch larger than it would be without the effects of Process I.

According to this conception, probabilities are subjective in the sense that they influence the structure of the experiences of agents. But this influence is rooted in the laws of nature, not in ignorance, and it affects equally the experiences of all agents. The probabilities in the separated branches are carried forward objectively by Process II. I shall go into these important matters in more detail in Chapter 12.

This extension of von Neumann's ontology removes the anthropocentric bias: human beings no longer occupy a favored status. Low entropy is not an anthropocentric idea. These ideas appear to mesh well with von Neumann's opinions about the nature of probability and of mathematics, and of entropy and knowledge, as we shall see in Chapter 12.

The removal of the anthropocentric bias coupled with the dynamicalization of "feels" provides the means by which experiential-type elements of nature can influence not only the probabilities of alternative possible courses of our individual streams of consciousness, but also the probabilities for the evolution of species of agents that develop in ways that increasingly exploit Process I as contrasted to those that do not. Since Process I is available, according to the laws of quantum theory, one would expect existing life forms to use it.