10. Double Slits, Nerve Terminals, Brains, and Agents.

Neuroscientists and philosophers probing the relationship of consciousness to brain process believe, almost unanimously, that classical physics provides the appropriate description of the brain. That belief would have been reasonable during the nineteenth century, but now, in the twenty-first, it is rationally untenable, The reason why quantum theory *must be used* in this endeavor originates in the dynamics of the nerve terminals.

Nerve terminals lie at the junctions between two nerves, and mediate the connection between them. The way they work is this. Each "firing" of a nerve sends an electrical signal along that fiber. When this signal reaches the nerve terminal it opens up tiny holes in the terminal membrane, through which calcium ions flow into the interior of the terminal. Within the terminal are "vesicles", which are small sacks containing chemicals called neurotransmitters. The calcium ions migrate from their entry holes to special sites, where they trigger the release of the contents of a vesicle into a gap between the terminal and a neighboring nerve. The released chemicals influence the tendency of the neighboring nerve to fire. Thus the nerve terminals, as connecting links between nerves, are basic elements in brain dynamics.

The holes through which the calcium ions enter the nerve terminal are called "ion channels." At their narrowest points they are not much larger than the calcium ions themselves. This extreme smallness of the opening in the ion channels has profound quantum mechanical import. The consequence is essentially the same as the consequence of the narrowness of the slits in the famous double-slit experiments, which prove the wave nature of photons, electrons, and ions.

In all these cases the smallness of the hole or slit restricts the lateral dimension of the beam. Consequently, the lateral velocity is forced by the *quantum uncertainty principle* to become large. This causes the wave packet associated with the particle to balloons out over an increasing area as it moves from the tiny hole or slit to the target where it will be absorbed on some small site.

This spreading of the ion wave packet means that the ion may or may not be absorbed on the triggering site. Accordingly, the vesicle may or may not release its contents. Consequently, the quantum state of the vesicle becomes a quantum superposition consisting of a state where the neurotransmitter is released and a state where the neurotransmitter is not released. This quantum splitting occurs at every one of the trillions of nerve terminals.

What is the effect of this *necessary* incursion of the wave nature of matter into the evolving state of the brain?

The principal function of the brain is to receive clues from the environment, form an appropriate plan of action, and direct the bodily or mental action specified by the selected plan of action. The exact details of the plan will, for a classical model, obviously depend upon the exact values of many noisy and uncontrolled variables. In cases close to a bifurcation point of the dynamics the effects of noise might even tip the balance between two very different responses to the given clues: e.g., tip the balance between the 'fight' or 'flight' response to some shadowy form.

The effect of the independent superpositions of the "release" or "don't release" options at each of the trillions of nerve terminals will be to cause the quantum mechanical state of the brain to become a collection of different states representing different alternative possible plans of action. As long as the brain dynamics is controlled wholly by the deterministic Schroedinger equation of motion---which is the quantum generalization of the Newtonian laws of motion in classical physics---all of the various alternative possible plans of action exist in parallel, with no singled plan of action singled out as the one that will actually occur. Some other process, beyond the deterministic Schroedinger equation, is required to select some particular real course of events from the smeared out mass of possibilities generated by all of the alternative possible combinations of vesicle releases at all of the billions of nerve terminals.

But what can intervene?

According to quantum theory only one thing can intervene. Orthodox Copenhagen quantum theory says that the dynamics must be completed by the intervention of an observation. Without an observation quantum theory merely generates an undifferentiated mass of possibilities, with no particular actualities.

Curiously, almost all physicists who attempt to "understand" quantum theory, or improve upon it, see the problem with the orthodox view as this intrusion of the observer: their aim is to try to rid quantum theory of "the observer", who by virtue of his subjective nature, is not, in their opinion, a suitable element in science. Thus most neuroscientists, philosophers, and physicists stand firmly united in the contemporary determined attempt to rid science of ourselves, considered as anything beyond the mechanical notion of human beings inherited from pre-twentieth century science. This stance is maintained in direct opposition to the greatest finding of twentieth century physics, which is that the failure of classical concepts entailed by the non-zero value of Planck's constant both opens the door to---and seemingly demands the presence of---agents that intervene in the otherwise inconclusive mechanical workings of nature: it is the intervention of participant/observers that brings particularity, or particular outcomes, into being. The crucial point is that the mathematics of quantum theory has a dynamical gap that provides both a natural place for, and apparently an absolute need for, interventions by efficacious **agents**. That was the conclusion reached already in 1926, and clarified by von Neumann in 1932. But in the latter part of the twentieth centuries, with the founding giants gone, the revisionists have been busy in a vain attempt to evade that profound discovery of the founders, and return to the naïve simplicity of the nineteenth century mechanical conception of man.