4. Double Slits, Nerve Terminals, and the Necessity to Use Quantum Brain Dynamics.

Neuroscientists and philosophers probing the relationship of consciousness to brain process appear to believe, almost unanimously, that classical physics provides the relevant description of the conscious brain. That belief would have been reasonable during the nineteenth century, but now, in the twenty-first, it is rationally untenable. The general dynamical reason why quantum theory must be used when the effects of consciousness are involved was described in the preceding chapter. But the further question is a quantitative one: How important are the quantum wave-like (i.e., cloudlike) properties of, say, ions in brain dynamics? That they are very important is made particularly evident by an examination of the dynamics of 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 balloon 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?

A principal function of the brain is to receive clues from the environment, form an appropriate plan of action, and direct the body/brain 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 ProcessII---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 one plan of action singled out as the one that will actually occur. Some other process, beyond the local deterministic Process II, 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 trillions of nerve terminals.

But what is this other process that selects distinct alternatives with well defined probabilities from the amorphous conglomeration of overlapping possibilities. According to both the Copenhagen and von Neumann formulations of quantum theory it is Process I.

Curiously, almost all physicists who attempt to improve upon these orthodox formulations of quantum theory see the problem with these mainline views as this intrusion of the observer into physics: their aim is to try to rid quantum theory of “the observer”, who by virtue of his subjective nature, must, in their opinion, be excluded from 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 what would seem to be the most profound advance in physics in three hundred years, namely the overcoming of the most glaring failure of classical physics, its inability to accommodate us, its creators. The most remarkable and salient feature of quantum theory is that the mathematics has a dynamical gap that, by virtue of its intrinsic form, provides a perfect place for Homo sapiens as we know and experience ourselves. That was the conclusion reluctantly recognized by the founders of quantum theory already in 1926, and clarified by von Neumann in 1932. In view of the profound philosophical difficulties attendant upon the classical mechanical conception of man it is odd that any thinking person would want to revert to it.