**Memory as a Property of Nature**

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**Abstract**

Prerequisite to memory is a past distinct from present. Because wave evolution is both continuous and time-reversible, the undisturbed quantum system lacks a distinct past and therefore the possibility of memory. With the quantum transition, a reversibly evolving superposition of values yields to an irreversible emergence of definite values in a distinct and transient moment of time. The succession of such moments generates an irretrievable past and thus the possibility of memory. Bohm's notion of implicate and explicate order provides a conceptual basis for memory as a general feature of nature akin to gravity and electromagnetism. I propose that natural memory is an outcome of the continuity of implicate time in the context of discontinuous explicate time. Among the ramifications of natural memory are that laws of nature can propagate through time much like habits and that personal memory does not require neural information storage.

Keywords: time; wave function; decoherence; implicate order; laws of nature; mind and brain

**1 Introduction**

Memory is typically regarded as stored information about the past. For Plato, human memory was akin to inscriptions on a wax tablet. Hooke's belief in a neural equivalent of phosphorus, which continues emitting light long after absorbing it, gave way in the 19th century to the photographic plate as a metaphor of memory. Where Spencer saw the brain as a mechanical piano and Taine compared it to a printing works that retains clichés, Guyau invoked the phonograph, which not only stores but reproduces memories on command (Draaisma 2002: 52, 91).

All these metaphors have since been displaced by the computer. Babbage's design for an analytical engine included a mill for processing numbers that went to a storehouse. In the landmark essay, "Computing machinery and intelligence," Turing initially placed quotation marks around memory in reference to Babbage's storehouse but dropped the quotes later in the article, implicitly equating memory with stored information (Draaisma 2002: 146, 151). Yet computer memory, like that of a photographic plate, is too accurate to serve as a model of human memory. Whereas our memories are vague and often wrong in detail even if correct in outline, computer memory is precise and reliable. On the flipside, whereas we instantly know if we lack memory of a given event, a computer must search its storehouse to the end before determining that it lacks the requested information.

Perhaps the organic nature of the brain accounts for the messiness of human memory, while our ability to know immediately when we do not remember something might result from distributed storage of information much like a hologram (Draaisma 2002: 170). But the idea of the brain as a kind of organic computer opens up a much deeper problem, namely that the brain offers no equivalent to the user of a computer. Is a "little man" tucked away somewhere in those cerebral folds? And if a homunculus is required to operate the brain, is the brain of the homunculus operated by a still smaller homunculus? Despite the paradox, most theorists assume the outstanding issues of neural information storage and retrieval will be cleared up. Where else but the brain can our memories be located?

We might take to heart St Augustine's observation that memory occupies "an inner place -- though it is wrong to speak of it as a place" (Draaisma 2002: 57). Memory is a function of time, not space. Yes, my brain is inside my head, but my memories are inside *me*. Memory invokes a kind of interiority unknown to tablets, whether wax or silicon. The interiority of one's private past simply does not compute.

The homunculus fallacy arises from the misconception of a human being as a collection of parts. The solution is that each of us is whole. What operates the brain is not a little man inside it but the whole person. From the spatial perspective, this notion has no meaning. In space we are infinitely divisible, composed of parts that exist outside each other. The meaning of memory is that the brain's current state *enfolds* the moments that came before. Our wholeness is derived from deep temporal continuity and has nothing to do with moment-to-moment operations of the brain, the final metaphor of memory.

In this paper I explore the possibility that the storage of information *about* the past is merely artificial memory and that natural memory depends on the endurance of the past itself. To reconstruct the world in terms of time instead of space requires returning to the beginning, to the quantum foundation of existence. Of the many concepts to emerge from quantum inquiry, David Bohm's implicate order is best suited to the task of establishing memory as a property of nature.

Natural memory resolves a perennial problem: how do timeless laws of physics relate to temporal existence? Rather than express a transcendent realm of pure mathematics, physical law represents a set of habits dependent on the conveyance of the past, in outline form, into the present.

**2 Temporal Complementarity**

Overlooked among the lessons of the two-slit experiment is that the unmeasured quantum system occupies a ceaseless present devoid of history. So long as it remains undetected, the electron has no definite location but consists of a probability wave encompassing numerous locations. As such, it can pass through both slits and leave a wave-interference pattern on the screen beyond the slits. Only if the electron is detected does it take a definite path through one slit or the other on its way to the screen (Whitaker 2006: 287). Implicit in Bohr's concept of particle-wave complementarity is that the electron is a wave in its unmeasured state but comes across as a particle with a definite position upon detection. Einstein was dissatisfied by this explanation. Whether or not the electron is detected, he wanted to know which slit it went through (Whitaker 2006: 314). Yet a history implies a sequence of definite states prior to the present, and this is precisely what the undetected electron lacks. Unmeasured, the electron has only a superposition of *possible* histories and therefore no past defined apart from its present.

Rather than try to nail down a hypothetical quantum reality, Bohr simply observed that small-scale and large-scale phenomena require very different descriptions. In contrast to classical systems, which can be analyzed according to the local interactions of distinct parts, a quantum system is fundamentally holistic and must be treated according to a unifying principle, namely the wave function, which combines states of a system in a non-classical way (Whitaker 2006: 307).

The Schrödinger equation, the bulwark of quantum theory, allows for retrodicting the devolution of the wave function as readily as predicting its evolution. Since every set of superposed values seamlessly evolves into the subsequent set, nothing serves to delineate a present moment from either past or future moments. Rather than a sequence of discrete moments, each bearing a definite state of matter, the undisturbed quantum system occupies unbroken presence. Quantum theory can violate Newton's principle that every particle has a fixed trajectory and velocity *at any given instant* for the simple reason that time is not limited to a succession of instants.

Particle-wave complementarity stems from the dual aspects of time. Depending on the context, time is either continuous presence or a sequence of distinct moments. Whereas subatomic matter is perfectly content to ride the ongoing present in a state of superposition, macroscopic existence generally takes the form of definite values, and definite values require definite moments, not indefinite presence.

This is why the choice of whether or not to detect a photon, for instance, can be delayed until after the photon has passed the two slits (Wheeler and Zurek 1984: 182-213). Because the photon occupies ongoing presence, it has no history distinct from its present. Thus its passage through the slits is still present when the decision is later made to detect which slit it went through. The photon can be retraced to the time it arrived at the slits because its entire path remains present. On the other hand, once an interference pattern appears on a screen, it cannot later disappear. Only indefinite presence, as described by the continuously evolving wave function, is time-reversible. A sequence of moments, including the moment an interference pattern becomes visible, is set in stone.

The wave function enables calculation of the probability that a quantum system will resolve into a particular state upon being measured. Left unexplained is why the act of measuring a system triggers its transition from potential values of the properties of the system to definite values. Does measurement entail a natural process which, on its own, translates a system from wave to classical? Reconfiguring the quantum transition in terms of continuous presence and discrete moments suggests an answer: the passage of time implicit in the act of measuring a system momentarily dislodges it from its default state of continuous presence in conformance to the wave function. As a large-scale process, measurement cannot help but translate the system from continuously evolving wave to classical time, along the way chopping up the innate holism of the quantum into the distinct properties characteristic of successive moments.

In contrast to Bohr, who saw a fundamental divide between microphysical and macrophysical, von Neumann assigned a wave function to classical systems and placed the divide between the subjective observer and the entire experimental set-up from particle to measuring device. The observer, he declared, causes the wave function to collapse, resolving a superposition of potential values into a set of determinate values (Whitaker 2006: 173, 237). According to Zeh, since the Schrödinger equation makes no allowance for a break in the evolution of the wave function, von Neumann's proposal amounted to the introduction of an extra-physical dimension into quantum theory. The transition from quantum ambiguity in continuous and reversible wave evolution to the discontinuous and irreversible time of classical definitude is restricted to the mind of the observer. As Everett noted, however, the introduction of a role for mentality negates the need for wave function collapse in the first place, as every possible quantum outcome can be housed in a different mind operating in parallel to physical existence (Zeh 2010: 130-32).

Zeh approaches quantum theory from the standpoint of decoherence. Quantum systems, by this view, shed their superpositions of values as a result of local interaction. Decoherence marks the transition from probabilistic to determinate values -- that is, from indefinite presence to a definite moment. In effect the environment of a quantum system continually "measures" it, causing it to *momentarily* take on a set of definite values rather than a cloud of potential values. Does this mean the wave function collapses in defiance of the Schrödinger equation? Or does decoherence cause an Everett-style subjective impression of a classical outcome?

Zeh's resistance to wave function collapse stems from his adherence to the doctrine that the Schrödinger equation is a complete description of reality (2010: 132). Yet the Schrödinger equation -- and the wave function that solves it for any given circumstance -- cannot be a complete description since it accounts for only one aspect of time, the time of continuous presence, and leaves out the discontinuous time of moment-to-moment existence. The fact that classical existence has no reality apart from its quantum foundation in no way denies the world of the senses an emergent, subsidiary reality, much as momentary presence emerges from continuous presence.

**3 The Implicate Order**

Bohm formulated his ontological interpretation of quantum theory so as to eliminate the need for wave function collapse. To get around the problem of how distinct particles emerge from wave evolution, Bohm postulated particles with definite positions prior to measurement and reinterpreted the wave function as an actual wave in addition to the unobserved particle.

Like the Copenhagen interpretation, the ontological interpretation accounts for all experimental evidence, but Bohm took it a step further by attempting to account for what exists at the subatomic level even without measurement. Rather than merely a mathematical device for computing probabilistic outcomes, the wave function is conceived as a "pilot wave" directing particles, though not in the mechanical sense suggested by Bohm's predecessor, de Broglie. Instead the wave function is the means by which particles are *informed* of the whole system to which they belong (Bohm and Hiley 1993: 32, 39). Rather than wave and particle as complementary descriptions of matter, particle is guided by wave (Nichol 2003: 188).

Key to Bohm's model is the idea that information can be either passive or active, only the latter of which affects the properties of particles. The tendency of the wave function to "spread out" across all possible pathways is countered by the tendency to narrow the portion that has the potential to influence the system of particles (1993: 82). The meaning of wave function collapse -- far from implying a break in the flow -- is simply that local interaction restricts its active portion, the quantum potential or *Q*, to a single "channel" (1993: 95, 100). Thus "the universe can be in a fairly well-defined state at any given moment in spite of… the general 'spreading of' wave functions" (1993: 73).

The chief lesson of decoherence is that Schrödinger's isolated quantum system is an idealization, much like the frictionless pendulum. In reality local interaction continually eliminates quantum coherence, whether in the form of a superposition of potential states or nonlocal entanglement as an expression of quantum wholeness (Zeh 2010: 86). For molecules, recurrent loss of coherence is inescapable under ordinary conditions. This is suggested in Zurek's concept of decoherence time, during which potentialities become irreversible actualities, i.e. moments in classical time. Sugar molecules, for instance, typically decohere on a scale of 10-9 seconds (Zeh 2010: 106). One-billionth of a second evidently suffices for the components of a sugar molecule to interact, at which point they resolve as definite entities for a limited "instantaneous" duration before returning to their natural state of superposition, and the wave function begins spreading once more into multiple channels. Thus the decoherence clock is reset and the process begins anew.

As revealed in Heisenberg's "microscope" thought experiment, the indivisible wholeness of a quantum system constrains its measurability insofar as the intrusion of a measuring device causes it to be woven into the system it ostensibly measures (Nichol 2003: 135). Nonlocal entanglement is merely a dramatic illustration of the holism inherent in all quantum activity. Fundamental to quantum theory, including conventional interpretations, is the recognition of "indivisible quantum processes that link different systems in an unanalysable way" (Bohm and Hiley 1993: 352).

In contrast to the autonomous objects depicted in a photograph, quantum systems exhibit the logic of a hologram, which contains everywhere within it the entirety of a given image. Illuminating the hologram explicates for local viewing what is distributed in it globally (1993: 354). Now suppose that each time the hologram is illuminated, the image it encodes is slightly altered in the act of explicating, and this alteration is fed back into the hologram. When the revised hologram is illuminated, the image alters again as it unfolds, and once more the alteration folds back into the hologram. Instead of constant illumination of the same image, an evolving hologram repeatedly explicates as an evolving image.

This, according to Bohm and Hiley, is how nature makes the world. Though information represented by the active portion of the wave function manifests or unfolds as a tangible system, any alteration introduced during explication is enfolded into the holistic state of the system, which unfolds again into a classical state, and so on. "Whatever persists with a constant form is sustained as the unfoldment of a recurrent and stable pattern..." The apparently enduring object is an approximation of repeated folding and unfolding (1993: 357).

Once the possibilities enfolded in the implicate order have explicated (i.e. decohered), the resulting determinate state or event cannot be undone. Only probabilistic information evolving in ceaseless implicate presence can be reversed. The arrow of time emerges in the sequence of explications. Natural memory is the endurance of implicate order across this sequence.

Explication signifies completion of a moment, the fleeting "presentation" of the informational background, the very act of which alters that background and thereby causes the subsequent explication to differ slightly, and so on. Not only a minimal amount of duration but the gradual emergence of locality -- and therefore the opportunity for local interaction -- generates a distinct moment out of ceaseless presence. A world of defined values, so different from that of their subjective apprehension, is built atop a sequence of snapshots. Under ordinary conditions, beyond the classical limit matter is exclusively explicate. Only particle and atom -- lodged in the spatio-temporally infinitesimal -- combine implicate and explicate, operating by default as evolving probabilistic information and periodically punctuated as tangible structure with definite properties.

Despite the compatibility of the ontological interpretation with a fundamentally temporal outlook, Bohm followed Einstein by rejecting the reality of time, calling it "an abstraction from movement, becoming and process" (Griffin 1986, 177). At best time is a secondary property that unfolds from implicate order (Bohm 1980: 211). Yet the continuous presence exhibited by the wave function, from which the implicate order is woven, is nothing if not temporal. The division between past, present and future is an accidental attribute of time subsidiary to its essential nature.

Bohm's adherence to timelessness comes with a cost. Whereas causation takes place from implicate to explicate and back again, his model makes no room for simple causation from one event to the next (Griffin 1986, 129). If, however, implicate order entails continuous presence, the problem disappears. The discontinuity of wave evolution at the completion of a moment signifies only that the flow of information is restricted to one channel, not that it momentarily stops. To put it another way, though disturbing a quantum system decouples it from its wave function, the underlying presence is unbroken. Continuous presence is the means by which each moment causally connects to its successor. What defines time is not a sequence of instants but the continuous flow that connects them.

Bohm's rejection of particle-wave complementarity is ironic given that the principle of complementarity perfectly captures the relation of implicate and explicate order, not to mention continuous and moment-to-moment presence. Rather than postulate pre-existent particles in the unmeasured quantum system and thus eliminate the need for wave function collapse, we simply recognize that the continuous time of the wave function is *complemented* by the discontinuous time of determinate states. Matter is probabilistic information in the context of ongoing presence and explicate structure in the context of the discrete moment. Memory is the informing of current explications on the basis of prior explications preserved in ongoing presence.

We cannot directly detect the probabilistic nature of matter in unbroken presence because something always gets in the way, something we cannot get around because we require it for our very existence as large-scale systems, namely a sequence of completed moments bearing definite states of matter.

**4 The Habits of Nature**

In the context of ongoing presence, matter is information, periodic explications of which influence but in no way interrupt its "computation." As a property of nature, memory is the unbroken flow of information across a sequence of irreversible momentary materializations.

Prigogine's transition "from being to becoming" is explained by the explication of quantum information. Time involves not only a fleeting but a permanent aspect. The permanent aspect means that whatever the clock says, the time is *now*. Presence is ongoing. According to Bergson, no eternal ground of being is to be found outside time (1946: 166-67). Instead the ceaseless presence of the wave function is the ground of becoming.

Davies points out that no experiment has ever proved the existence of time in terms of flow or passage (Griffin 1986: 34). I would add that none ever will. Given that "fluidity," as Bergson observed, "is the only immediate datum of experience," the default or *natural* view is that existence is fundamentally temporal (Pearson and Mullarkey 2002: 217).

This means not only matter but the laws by which it behaves are time-bound, originating in time and propagating through it on the basis of the unbroken presence from which every distinct moment emerges. Rather than manifest eternal mathematical principles, the laws and constants of nature developed in tandem with enduring forms of matter in the very early universe. Since nothing prior to nucleosynthesis can be inferred from current laws, we have no reason to believe they existed in the immediate wake of the big bang (Unger and Smolin 2015: 171). Instead, whatever form randomly emerged at that time increased the probability, via natural memory, that it would repeat. With the emergence of the first electron, the probability of a second electron increased. With two electrons, a third was even more likely, and so on, until the electron as a set of properties was ingrained in the implicate order. The same process of cosmic habituation brought on photons, protons, neutrons and the entire quantum menagerie.

Given that current physical law is based on interactions of known particles and fields, how can it account for their emergence in the first place? A more reasonable alternative is to apply the implicate-explicate model to the formation of nature's regularities. Just as information explicates as definite matter, so explicate outcomes are incorporated into the background memory, generating co-evolution of explicate forms and cosmic regularities. Over time, properties of particles are imprinted onto implicate order, lending the impression that they reflect timeless law. The improbability of the early universe in the context of current laws makes perfect sense when we realize they did not yet exist (2015: 129).

Whereas causation itself is perennial, lawlike causality applies only in the consolidated universe of today (2015: 164). As Peirce put it, the "pure arbitrariness" of the very early universe "would have started the germ of a generalizing tendency… and from this, with the other principles of evolution, all the regularities of the universe would be evolved" (Hartshorne and Weiss 1960: 26).

However, given the peculiar suitability of universal constants to the emergence of life, the initial universe may not have been completely random after all. The standard approach to the problem of why the constants are so finely tuned for fruitful development is the multiverse, the idea that if the likelihood of our universe is a trillion to one, there presumably exist another trillion universes in which the constants were not formed so as to allow for life and consciousness. The trouble with the multiverse is that it only multiplies the mystery of the mechanism by which cosmic regularities and enduring structures originate (Unger and Smolin 2015: 135). The model of natural memory suggests a deeper explanation: this universe was *preceded* by many others, each in turn impacting the implicate order and influencing the development of subsequent universes. Over many cosmic iterations, a fruitful set of constants gradually evolved and became ingrained, informing each universe at its initiation.

Unger makes an exception for any principle without which existence is inconceivable. Even in the relatively lawless initial universe, cause preceded effect, an inescapable consequence of the reality of time. Unger also suggests that the principles of least action and relativity, the conservation of energy and momentum and the degradation of energy are embedded features of nature which, like time itself, could not have emerged in time. By contrast, the strengths of the various forces, the cosmological constant and the masses of elementary particles are all likely vestiges of long-established habits (2015: 278-85).

Smolin notes that the influence of the deep past over the present, which he calls the principle of precedence, can be put to the test. Because it is without precedent, a novel state is inherently unpredictable. "The first several iterations of a novel state are not determined by any law. Only after sufficient precedent has been established does a law take hold…" (2015: 467). According to the principle of precedence, the outcome of a measurement of a quantum system is determined by the ensemble of previous measurements of identical systems (2015: 470). Generating novel entangled systems might allow researchers to demonstrate the evolution of lawlike behavior from scratch (2015: 490).

**5 Models of the Mind**

Like the wave function in the standard account of quantum mathematics, Bohm's quantum potential, *Q*, is a device for calculating likelihoods of where a particle will be when measured. Bohm and Hiley illustrate the role of *Q* with a ship steered by radar reflecting off the ship's surroundings (1993: 31-32). The fact that wave evolution concerns not just the particle in question but its environment is made explicit in Bohm's model. Since *Q*, unlike Newton's classical potential *V*, influences particles solely according to its form and not its intensity, the informational nature of the wave function is also made explicit (1993: 35).

For Bohm nothing fundamental separates atom and organism (1980: 194). Whether physical or biological, a system perpetuates forms and behaviors already established for its type -- its species -- in typical environmental contexts. Far from a throw of the dice, any given explication can reflect prior explications preserved in implicate order. In the context of an organism, implicate order is mind.

As unlikely as the emergence of life on Earth surely was, it might have been impossible without the assistance of implicate order. Like the very first quarks and electrons, pre-biotic chemical feedback loops presumably appeared many times in many different combinations before the original microbes coalesced. Without the continued influence of past explications, key autocatalytic loops might never have reappeared after initially running their course.

The complexity of a microbe and its environmental interaction reflects a set of implicate "instructions" vastly more refined than those associated with quantum systems. This applies even more so for eukaryotes and the multicellular creatures made from them. With complex animal morphology and instinct comes a nested hierarchy of living structure, every explicate order -- be it protein, organelle, neuron, brain region, nervous system or body -- unfolding from an implicate order built up from past explications. Only at the highest level of structure, the organism as a whole, do we find the distant descendent of the wave function known as consciousness.

The primacy of implicate order, as Bohm and Hiley suggest, applies to mind as much as matter. Consciousness is the implicate ground from which distinct perceptions and thoughts are abstracted like well-defined particles from wave evolution. The wave function as the active information of a particle recapitulates with mind as the active information of a body (1993: 383-84).

Whether a quantum system determined by a wave function or an organism under conscious direction, the whole is the primary reality to which the parts are subservient. Every organism, as embryologist Paul Weiss observed, emerges in outline form and is literally fleshed out at each developmental stage (1973: 26). Bohm and Hiley reference Mozart's claim that every new composition came to him whole, and all he had to do was play out the parts (1993: 383).

Rather than containing or possessing mental features, the brain merely explicates them. This idea is wholly foreign to a biological community long committed to understanding the organism within the confines of a classical framework.

According to Damasio (2012, 146), the traditional view among neuroscientists is that perception begins in the cortical pathways associated with sense organs and culminates in higher processing regions in the frontal or temporal lobes. Somewhere in these regions a so-called grandmother cell not only activates at the moment the subject perceives his grandmother but re-activates when he remembers her. If this is the case, notes Damasio, damage to higher processing regions ought to prevent recall. Yet patients with such damage "display only selective deficits in the recall and recognition of unique objects and events" (2012: 147). Whereas damage to sensory cortical pathways blocks the recall of images, damage to higher regions merely compromises the patient's ability to categorize an image or recognize its uniqueness, for instance that an elderly woman is the patient's grandmother (Damasio and Damasio 1994: 67).

Though improving on the standard view, Damasio retains the belief that memories must be locatable in brains, if not in the higher regions than in the sensory cortices. "Beyond perceptual images in varied sensory domains, the brain must have a way of storing the respective patterns, somehow, somewhere, and must retain a path to retrieve the patterns, somehow, somewhere, for the attempted reproduction to work, somehow, somewhere" (2012: 140). Damasio conjectures that memory depends on "convergence-divergence zones" that receive input from sensory cortices and can subsequently direct those cortices to reconstruct an image on the basis of the original stimulus. In contrast to sensory cortices, which contain the actual images, the convergence-divergence zones contain only dispositions for how to reconstruct an image when necessary (2012: 150-51).

"The contents exhibited in image space are *explicit*," writes Damasio, "while the contents in the dispositional space are *implicit*" (2012: 153). Lacking a concept of implicate order, Damasio has no choice but to assume that explicit images are housed in the brain. Bohm's model, on the other hand, suggests that both the convergence-divergence zone and the sensory cortices are explicate structures informed by implicate order. We have no need for images to be stored anywhere in the brain, whether in higher processing zones or sensory cortices, because each brain region merely explicates underlying information. Whereas convergence-divergence zones explicate instructions regarding which sensory cortices to activate, the relevant cortices explicate the images themselves. Either way mental contents are merely *implicit* in brain activity.

We have no need to make the mind tangible "somehow, somewhere" any more than we need to capture the wave function and measure that instead of the quantum system under investigation. The brain itself is a continual measure of the mind.

Key to Damasio's view of mentality is the idea that brain regions map body regions. Since a map refers to something other than itself, Damasio thus places not only images but representation and intentionality in the brain (2012: 95-96). He goes so far as to claim that body mapping in the brain is the basis of the self (2012: 98). Though the upper brainstem receives signals from every part of the body (2012: 260), Damasio offers no reason why this bundle of nerves or its associated cortical processing regions should be regarded as maps. The fact that a circuit board correlates with the positions of electrical outlets in a house does not make it a map of the house. That a breaker trips when an outlet short circuits does not mean the circuit board "knows" there has been a short. The connection is purely mechanical, having no representational or mental content. Nor does the vastly greater complexity of the neural system somehow render it into a mind. The conviction that the circuitry of a body differs fundamentally from that of a house follows solely from the assumption that mentality must be localized to the brain.

From "small neural circuits" to networks and systems in the cerebral cortex, Damasio discloses the basic constituents of consciousness. "The conscious mind," he writes, "is built from the brain's nested, hierarchical componentiality" (2012: 267-68). If indeed brains build minds, it ought to be possible at least in theory to engineer a conscious technology. Indeed, mechanized algorithmic operations are symbolic insofar as computations are meant to be interpreted by human users. Because brains *explicate* mental content rather than housing it, computers and even words on a page have a claim to symbolic or representational status that the brain completely lacks. Unlike ink on paper, no symbolic intent lies behind synaptic patterns in neural tissue. To recapitulate prior activity -- to unfold once more what has already unfolded countless times in countless systems of the same type -- is a purely natural process without symbolic intent or meaning.

Aside from neural hierarchy and the interactions of brainstem, thalamus and cerebrum, Damasio attributes the mind-building power of the brain to its astonishing capacity for synchrony of the activities of distant cortices (2012: 93, 268). Needless to say, if a brain is the unfolding of implicate information into localized structure in the context of a completed moment, its operations are by necessity synched. Like the wave function, consciousness is rooted in the *never*-completed moment, the ongoing present in the immediate wake of which is the synchronized explication of matter.

The necessity of brain activity for mental properties in no way equates to its sufficiency. Instead of reducing mind to brain, we may treat them as complementary aspects of a single reality, much like the local particle and the nonlocal wave function. Given the viability of a neurologically irreducible mind, the central assumption of Damasio and his colleagues can no longer be taken for granted.

**6 Conclusion**

The great question of memory is not how such a thing is constructed but its relative absence. Ongoing presence of past explication makes memory nature's default, not something that must be cobbled together from neural tissue. Prior moments are implicit in the present. The task is to narrow down from the flood of enfolded formations a usable source of knowledge for navigating a life. Enduring implicate order in the face of repeated explication is general to nature, not specific to brains. Every intrinsically formed system from electron to human exhibits a kind of interiority inaccessible to externally formed systems, whether mineral dust or microchip.

Instead of connecting across neurons, memory connects us to our past, infusing the sensorial present with a different kind of presence, non-spatial and therefore "within." Even the brain, though physiologically internal, is fundamentally external, a function of moment-to-moment spatialized presence as opposed to the continuous presence that cannot help but convey prior actions into current states. Though the brain, like every organically generated explicate system, is informed by past actions relevant to current circumstances, what actually remembers is not the brain itself but ongoing *conscious* presence periodically explicating as brain states correlated with thoughts.

Depending on temporal context -- whether fleeting or perennial presence -- a microphysical system is particle or wave. In Bohr's original formulation of complementarity in conjunction with Heisenberg's uncertainty principle, the quantum system emerges as a particle when measured for position or as a wave when measured for momentum (Whitaker 2006: 177). Likewise, the explication of consciousness is dual aspect, yielding both a pattern of neurotransmission and a distinct perception. As with the quantum system, the underlying complementarity is temporal: the living system is a brain in the context of time-receding and a mind in the context of time-renewing.

The quantum quandary -- a classical world adrift on a sea of wave functions -- is resolved according to the principle that particle is to wave as instant is to flux. Information unfolding into particles is a function of presence shedding completed moments. The resolution of the quantum measurement problem is ultimately temporal insofar as time needs no further explanation. Time is the ontological foundation, the primary meaning of *is*. To question the reality of time is to question the existence of existence.

How did time originate? Since origination is a temporal property, the question has no meaning. By contrast, laws of nature cry out for explanation. What is the origin of the laws that regulate the cosmos?

Peirce's conjecture, echoed by Wheeler, of physical laws as habits propagating down the ages can be expressed in terms of the conservation of information (Elsasser 1998: 118). Because every explication feeds back into the implicate order, the entirety of the past is available to every new moment. With a model of memory in the form of a conservation principle, we may admit to the possibility of not only human memory without neural information storage but laws of nature without inexplicable transcendent origin.

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