THE TWO-BRAINS HYPOTHESIS: IMPLICATIONS FOR CONSCIOUSNESS: A Foundational Approach

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Biophysics of Consciousness: A Foundational Approach
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THE TWO-BRAINS HYPOTHESIS: IMPLICATIONS FOR CONSCIOUSNESS

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Abstract

The human brain is a product of gravitation, quantum biophysics and evolution by survival; a 'universe', with 85 billion neurons and a hundred trillion synapses; more than stars in our galaxy. In the context of the unresolved, unpredictability of modern physical theory and as a stimulus and guide for research, we postulate the novel Two-Brains Hypothesis (TBH). The animal 'brain' evolved in parallel as two fundamentally different, interdependent organs, complementary in the Bohr sense: one, electro-ionic, tangible, known and accessible, the other electro-magnetic, intangible, difficult to access, but a relatively stable, structurally and functionally integrated 3D compendium of differently induced fields arising from and interacting closely with specific counterpart regions of the electro-ionic brain. Natural selection ensured normally efficient, anatomic, metabolic and functional integration of the two brains. Understanding aspects of them such as mind, consciousness, aging and pathologies is a major human challenge and it is suggested that research be undertaken on the possible nature, workings and potential of the two interdependent entities by which *Homo sapiens* may have risen and may yet fall.

Keywords:

7.1. Introduction

7.1.1 *Unpredictable and problematic: The quantum in biology*

Alongside conjectures on the Universe, fundamental problems in physics of immediate practical importance to humans remain unresolved. Quantum and gravitational theory are still not united, or particle-wave duality explained. Following Einstein's confirmation of the particulate nature of energy and Rutherford's of the existence of atoms, Bohr proposed that electrons occupy closed, fixed orbits around the nuclei of atoms while gaining or losing energy by instantaneous 'jumps' to a higher or lower orbit. These findings and those such as Schrodinger's representation of those electrons as a wave-like, 3D "cloud" of charge density and other phenomena of quantum mechanics, less or more weird and based on probabilities, mystify and made difficult accessibility of quantum physics to non-physicists.

Fortunately, wave mechanics enabled intuitive understanding of molecular bonding as overlap of smeared-out electron clouds and soon became a standard tool in biochemistry. However, though life science research also came to enjoy technological fruits of the new physics e.g., in electron microscopy, X-ray crystallography, chemical spectroscopy, fMRI and electro-encephalography, wariness of quantum denial of the objectivity of natural physical laws has persisted. Thus, though quantum theory has advanced understanding, for example of biological light gathering (in photosynthesis and bacteria) (Engel *et al*., 2007; Prokhorenko *et al*., 2006) and of bird navigation (photon induced reading of earth's magnetic field) (Gauger *et al*., 2011), understanding of complex biological systems such as conduction of action potentials along axons, intertwined nucleic acid chains, gene function, whole cells and whole organs such as the brain, remains mainly in the realms of classical physics and chemistry. The problems for quantum analysis in biology were already recognized in the 1930's and especially defined by Bohr (1933).

7.1.2. *Complementarity and biology*

Bohr proposed that though particles and waves are mutually exclusive in the means of their measurement, both are essential and complementary for understanding their interdependence and suggested that the principle may also assist in describing complex biological phenomena. However, traditionally, biological study has been reductionist: breaking down systems such as chromosomes, cells and even the brain, to the simplest molecular level. So as biological complexity was not experimentally accessible to quantum analysis, Bohr (1933) considered life "un-derivable from physics and chemistry". Denying this was mysticism, when considering higher levels of biological organization and behavior he and his supporters nevertheless regarded 'purpose' as necessary and convenient in the thought process (Stent, 1989; McKaughan, 2005). A century later, the philosophy and other problems associated with quantum complementarity as being possibly applicable to biology in which Mazzocchi (2010) has done nothing for understanding of the brain, particularly consciousness, a major key in human behavior. Here, we will propose a new direction of thought.

7.2. Consciousness

7.2.1 *The 'hard problem'*

In recent decades, progress has been made in understanding the mind, a controversial term but convenient here to describe the functional totality of memory storage and recall, cognition and perception. Consciousness remains a conundrum. Attempts to explain it have been highly controversial. Thus, according to Chalmers (1995) awareness, often equated with consciousness, is only a functional aspect of it, not consciousness itself. Termed by him the 'hard problem', he asks why and how widely distributed detectors in the awake brain, constantly sense different features such as size, color, tone, shape, sound and motion and bind them together with associated thoughts and memories into innumerable private conscious experiences "qualia" (Chalmers, 1995). These merge and emerge in a stream of thought and awareness that can be shared in conversation with others, though they remain uniquely personal to the individual.

Other explanations of the nature of qualia differ widely. Crick & Koch (1990) suggested 35–75 Hz neural oscillations in the cerebral cortex are the basis of consciousness, Edelman (2007) linked it to the self-concept and

Jackendoff (1987) described underlying computational processes as a basis for consciousness. Chalmers himself, roots conscious experience in information, notes consciousness has quantum characteristics for some, while also implying that it is beyond derivation from physical theory.

7.2.2. *Quantum-gravity to the rescue?*

Avoiding Kantian 'purpose', the Penrose and Hameroff (1996) model of consciousness posits closely spaced, quantum mechanical, coherent molecular condensations in the long microtubule structures based on tubulin and well known to extend within neuronal dendrite and axons. The condensations are considered stable for a microperiod long enough for physiological information transfer over distance to synapses which are crossed by quantum tunnelling (for which there is still no evidence), thus supposedly influencing brain activity regionally or as a whole. Slight deviation in superposition of the tubulin moieties is said to be caused by a quantum-gravity-induced, minute change in the geometry of space-time which, on becoming critical causes collapse (reduction) of the wave function by objective reduction, i.e., not by the orthodox 'subjective reduction by observation'. The collapse is said to be an event irreversible in time and constantly occurring in a sequence of such events flowing in time. Thus, a unified quantum-gravity principle novel to biology was proposed to underlie consciousness (Hameroff & Penrose, 1996). Was this the fundamental, non-reductionist principle that Bohr sought over 60 years before?

The possible de-coherence of condensation caused by random, room-level thermal influences, is indeed claimed to be prevented by organisation of the aqueous environment around and within the microtubule framework (Hagan *et al*., 2002). However, microtubules unqualified of that function are widespread, and intra-axon sheathing of microtubules by the water molecules which is said to be preventing thermal decoherence, would restrict other functions, such as in intra-axonal transport. The model remains much argued and very controversial (Tegmark, 2000). Also, still controversial, there have been proposals concerning electromagnetic (EM) fields in the brain.

7.2.3. *Electromagnetism to the rescue?*

Among theories of consciousness developed in the last two decades involving EM fields in the brain is, for example, findings that synchronized firing in large groups of neurons create fields strong enough to feed back to the neuron groups which are their source (Smith, 2009). There is evidence that such synchronization is strongly correlated with attention, awareness and conscious perception. This has suggested to McFadden that oscillations at certain frequencies in the firing neurons, perturb a global EM field external to them, creating in it a pattern representing neuronal information. This is combined and fed back to the neurons as consciousness (McFadden, 2013).

Different EM field theories disagree as to how a conscious EM field actually effects brain function. For example, whereas in McFadden's theory the EM field in a feed-back loop deterministically modifies electric charges across neural membranes and thus the probability that specific neurons will fire, for Pockett (2000) a causal link between the EM field and willed actions is not necessary. Moreover, it is not actually clear how a 'patterned', overall EM field encompassing a concatenation of data, is sensed in a bound, intimate conscious experience. That drawback is not really answered by a claim that evolution eliminated the problem (McFadden, 2013). Nevertheless, evidence suggests that endogenous, extra-cellular electric fields in the brain feed back onto the electric potential across the neuronal membrane thus influencing action potentials, independently of synapses (Frohlich & McCormick, 2010). Moreover recently, experimentally applied external fields of physiological strength and frequency, changed firing characteristics of specific neurons in rat brain cortical slices (Anastassiou *et al.*, 2011). As Smith (2009) concludes, the neural correlates of consciousness are unresolved.

7.2.4. *Natural selection of induction*

Nature has from archaic times relied on ion flow to create a charge differential across membranes which run in sequences, can initiate action at a distance; and electrostatics for example, has provided animals with electric darts for defence. However, when a varying flow of charge exists in whichever form, it is accompanied by a magnetic field, yet apart from what seem to be relatively special situations, such as the magnetism used in navigation by some animals, magnetic fields seem to have been mainly regarded as side products of chemical activity; perhaps because biological magnetic fields seem so small, inaccessible and masked by the earth's field. Yet humans have increasingly succeeded in their exploitation, for clinical imaging, whether, for example for 'reading' metabolic activity via local presence and flow of haem, or nervous activity via charge-derived magnetic fields (Goodman & Gershwin, 2011). However, it seems unlikely that natural selection did not precede man in a full exploitation of the physical laws of induction.

Recently, it has been proposed that fatty myelin-protein membranes wrapped by satellite Schwann cells in numerous turns almost totally ensheathing the axons of peripheral motor neurons in vertebrates and some invertebrates, are not, as has been thought for many decades, primarily or just insulation against charge leaking from the axons. Nor are they though, now just means for 'jumping' action potentials more rapidly along their membranes. Instead, it was argued that the axon's electric field threads the Schwann wrapping and induces in it a secondary, magnetic field influencing the axon membrane, its flow and complex content and its extra-cellular environment (Goodman & Bercovich, 2013). Though more obviously effective at the node of Ranvier and paranode, it was suggested that the secondary field is also induced in the very long, sub internode section of the axon and in the remarkably stable extra-cellular gap between axon and its internodal sheath. These peripheral secondary fields could be the first known example of such animal adaptation associated with induction. At the same time, it was also suggested that it was unlikely that such selection for induction was only peripheral and not central. This has now been formulated and is considered for further discussion (Goodman *et al.*, 2014).

7.3. The Two-Brains Hypothesis (TBH)

The animal 'brain' evolved as two fundamentally different, but complementary, interdependent organs: one, electro-ionic, tangible, known and accessible, the other electromagnetic, intangible, currently unidentified and difficult to access. Natural selection ensures normally efficient, anatomic, metabolic and functional integration of the two brains (Fig. 1).

7.3.1. *Axon-myelin EM induction in the CNS*

An obvious source of induction in the brain would be similar to that found peripherally. However, whereas wrapping in the periphery by a given Schwann cell is limited to a single axon, in the brain, axons are very much shorter and wrapping by an oligodendrocytic cell (CNS equivalent of the peripheral Schwann cells) can extend around a number of axons.

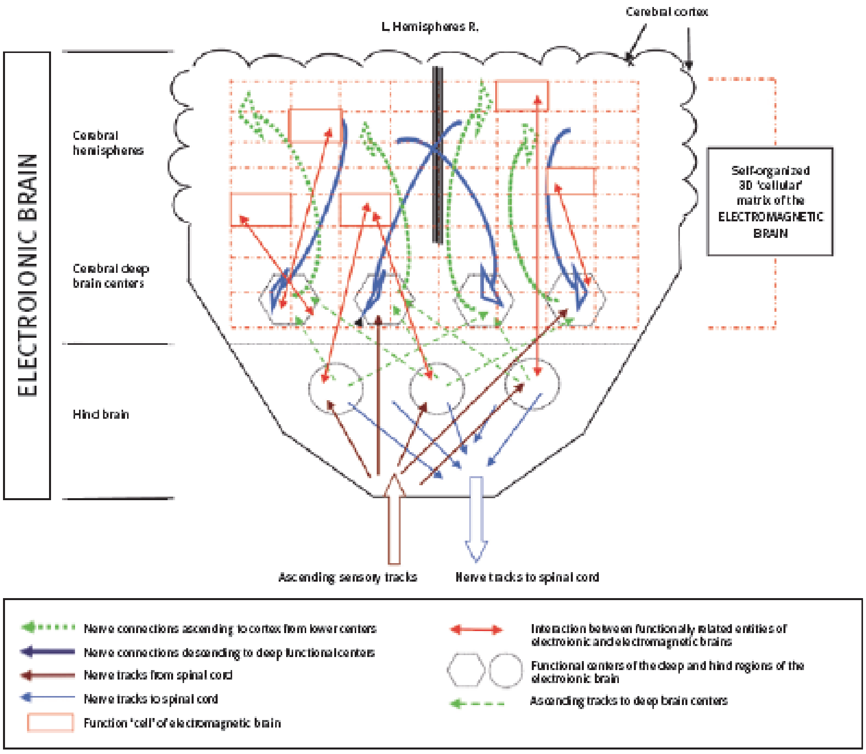

Fig. 1. A schematic expression of the Two-Brain Hypothesis according to which an electroionic and an EM brain interact together as independent but complementary organs, thereby enhancing higher processes of recall, perception, thought, judgment and decision in a process engendering a uniquely individual consciousness (Goodman *et al*., 2014).

This partly reflects the exceptional crowding in the brain resulting in a premium on space and energy and a need for dissipation of heat due to the intense metabolism. It is not clear that increased axonal signalling speed afforded by satellite-supported, 'jumping' of action potentials as in the periphery, is justified in the conditions of the brain. Indeed, it was reported recently that energy for sheath production, maintenance and operation in CNS white matter, costs more than the energy saved by 'jumping' of potential (Harris & Attwell, 2012). However, those costs may be warranted in the brain for a critical function quite different to any in the peripheral nervous system, viz. EM induction.

7.3.2. *EM brain: structure*

McFadden (2013) proposed here (unlike a generalized, patterned EM field in the brain) that the EM brain is a relatively stable, structured but flexible, integrated 3D grid of specialized regions of EM field arising from and interacting closely with specific counterpart regions of the electro-ionic brain. We suggest that the EM brain evolved as a self-organized, EM small-world networks were first modelled in 1998 by Watts and Strogatz as dynamic constructs, artificial and neural (in *C. elegans*, a nematode). Interesting here, is that the model exhibited enhanced signal-propagation speed, computational power and synchronizability. Even networks with no material topological structure can be of this type and their development is usually bottom up (Watts & Strogatz, 1998). Accordingly, it is proposed that the structure of the induced EM brain is based on evolution over aeons of an independent functional integration of magnetic fields separately and secondarily arising from dendrite and oligodendrocyte electro-ionic activity, according to the intensity and frequency characteristics of their electric fields. How the fields are integrated is unknown, though frequency and dynamic continuity rather than 'all-or-nothing' is an attractive conjecture.

Confirmation or denial will come as newer research provides methodology and anatomical detail different from that which over a century has described the more accessible electro-ionic brain. The magnetic fields of the neuronal dendrites massively present in the brain were once thought to be inconsequentially minute. Recent model simulation suggests otherwise. Development of direct, spatially and temporally accurate MRI measurement of brain magnetic neuronal activity now seems possible, independent of haem-indicated metabolism (Blagoev *et al*., 2007). This was demonstrated as 3D magnetic fields represented by vortex like clouds of vectors (Fig. 2) corresponding to the simulated electrical activity of the dendrites of a monkey brain pyramidal cell.

7.3.3. *Magnetic data storage?*

Remarkably too, the white matter of the cerebral hemispheres now studied by diffusion MRI in humans and four primate species, was shown to be not just a chaotic mass of brain axons as has been usually thought. Rather, it is an orderly, dense, criss-crossing at 90° to each other, of parallel layers of axons, held side by side with some intertwined bands. Thus, in

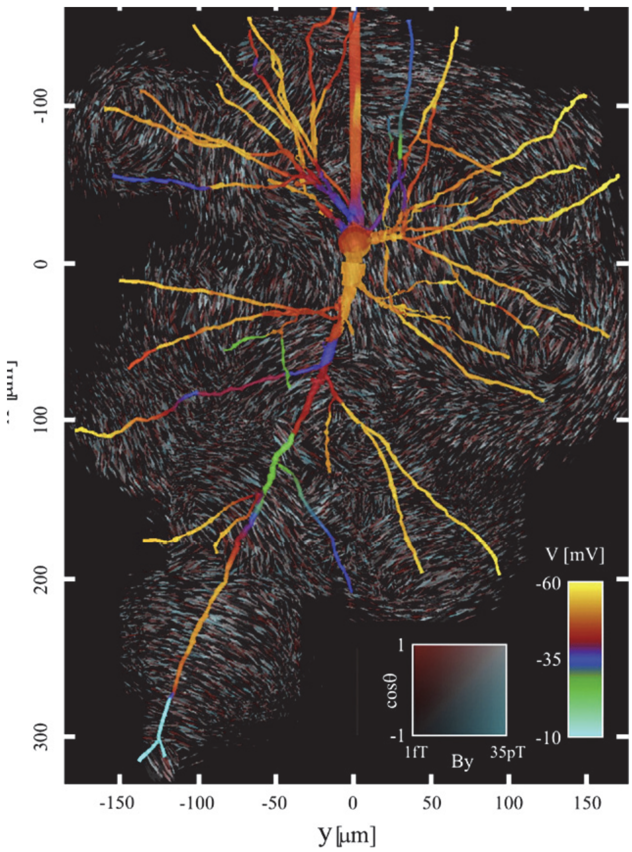

Fig. 2. Reconstructed pyramidal neuron from macaque monkey with the simulated electrical activity and corresponding magnetic field at 30 ms after start of the simulation. The neuron is viewed from a point in the +*z* direction looking down on an *x*–*y* plane. In the coordinate system, the soma is at (0, 0, 0). Dimensions of the box that contains the neuron are 480 ìm in *x* by 350 ìm in *y*, by 180 ìm in *z*. The potential in the dendrites is color coded. The two axes are labelled in microns (ìm), whereas the color scale represents millivolts (mV). The 3-D magnetic field is represented by vortexlike clouds of vectors whose colors represent direction and whose lengths represent relative magnitude (Blagoev *et al.*, 2007).

the deep white matter of the occipital lobe of the rhesus monkey, the parallel grid structure of pathways was not limited to particular 2D surfaces but extended throughout entire 3D volumes, no diagonal paths were observed and no brain pathways were observed without sheet structure.

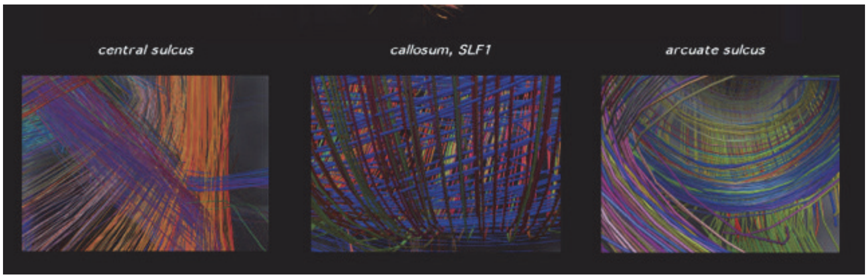

Fig. 3. Continuous grid structure of rhesus frontal lobes. All cortico-cortical pathways show highly curved elements in a continuous sheet of interwoven paths in two nearly perpendicular orientations aligned with gyral topography in the acuate sulcus and callosum, but oblique in central sulcus (Weeden *et al.*, 2012).

The grid structure was found in all orientations and anatomic curvatures and coherency and continuity with the three principal axes of development of the grid, was maintained at all scales from single small voxel to hemisphere: a telling ubiquity [Wedeen *et al.*, 2012; Fig. 3].

It is proposed that, depending on presence or absence and direction of flow in the axons at the points at which cerebral myelin-protein sheathed axons cross, EM vortices may be engendered. Lloyd *et al.* (2012) suggest two different characteristics present in EM vortices, spin direction and core polarity are well known, both switchable by the very low levels of field and frequency changes that have been associated naturally with, and by external application to the nervous system (Kammerer *et al.*, 2011). Appropriate to the CNS scale, the vortices involved in the latter work (experimental and simulated) ranged from 10 nm to 300 nm. A 3D EM matrix of such vortices in the brain may enable natural digital mechanisms analogous to magneto-electronic random access memories and processors. Evolution of such an induced field in the layered, wired architecture of the electro-ionic brain would have increased overall efficiency of brain exploitation and space use, without increasing demand on the local cardio-vascular system for gaseous exchange and heat removal.

Similarly, the brain dendritic masses mentioned above as having active magnetic fields were thought to be involved in data storage, because of their sub-unitary nature (Blagoev *et al.*, 2007). As part of a widely integrated induced process, this would be much more energy efficient than membrane-based nervous activity, and much faster. Indeed, speed would have been of the essence in an evolution of the EM brain, parallel to that of long term memory — a major advantage to the first creatures surviving long enough to benefit.

7.3.4. *Data recall*

Access to memory storage must be increasingly rapid as data quantity increases in line with evolution of capacity for perception, analysis, judgement, action and communication.

Moreover, accuracy of recall would have been increasingly vital for performance and preventing energy waste by mistakes. For this and structural stability, the relatively simple EM brain may have an advantage over one based directly on complex genetic, molecular pathway processes. Though originating in and interacting with the latter, the physical nature of the EM organ, once formed, may in general have been less prone to attrition by random problems, than the more archaic, labile, chemical-based processes on which short-term memory depends.

The speed adequate for motor reactions, is surely much less than in the conscious processes in which memories, mentality in its widest sense, individual psyche and reactions to changing dynamic internal and external environments, merge and emerge, seemingly in a stream. It is suggested that the electro-ionic nervous system including in the brain, rapid electric synapses through CNS gap junctions or tuned up speed as between neurons in the *C. elegans* hermaphrodite, could not provide the signal transmission speeds required for the advanced vertebrate CNS. EM brain recall, abstraction and permutation in complementarity with the slower electro-ionic brain, has resulted in an evolutionary peak, human consciousness: a candidate for satisfaction of Bohr's prediction for biology — without his concern for 'purpose'.

Differences in function between the two brains, does not necessarily exclude overlap or similar activity when advantageous: a short term memory mainly associated with the electro-ionic brain and long term memory with the EM brain, may not be absolute. However, the electromagnetic brain may be generally more sensitive to the extra-corporeal, the electro-ionic brain to the internal environment, while the electro-ionic brain evolved earlier, for action, the EM brain perhaps later for the recall, analysis and formulation now at the heart of human consciousness and creativity.

7.3.5. *'Consciousness' as a shared 'conversation'*

What and how animals other than man, experience in consciousness is likely very limited. Rooted in archaic selection, animal interaction usually entails relatively simple, conscious, vocal signalling and body language. In the case of man alone, thought processes of individuals and in communication between them, involves complex language and symbolism. In search of the reality that is consciousness, is it necessary to go beyond physical theory? It may be considered that interaction between the relatively slow sensory system which informs and is responded to by the electroionic brain for action, and the incomparable speed of the EM brain in recall, abstraction and permutation, is a process analogous to conversational intimacy between two individuals each of whom perceives the outlook of the other, allowing a synthesis objective to both. This 'conversation' is between the centers in the electroionic brain known to be involved in 'language' and emotion and the EM brain about which we know so little. When we know much more about both and their 'conversation' the immediacy of consciousness may be more understandable.

Speculatively, though evolution of language may have lessened development of direct inter-personal communication between human EM brains, this presumably would not be the case in other vertebrates; for example, in marine communication at a distance, or for advantage in swarming, particularly in situations where chemicals could be ineffective. Thus although Pocketts' view that EM-based animal consciousness extends across the universe is tenuous by Harris & Attwell (2012), it may yet be proved realistic on a modest scale. For example, extra-corporeal unification of EM brain fields due to synchronous firing in huge numbers of different avian brains, may extend across close-formation swarming of tens or hundreds of thousands of starlings and their EM brains. This may lead, for example to central tranquilizer release and calming during gathering and night roosting. Signs of such extra-corporeal EM fields may be seen in the effect of power pylons and radio masts as seemingly suggested by Fig. 4. Though magnetism is involved in navigation of many animals, the mechanism for this in many is unknown; a barely developed EM brain may be involved. The question arises: Has linguistic ability and modern means of communication at a distance actually deprived mankind of a potential for direct interpersonal contact via the EM Brain? We suggest that there is no reason why such a lack should be permanent. If not, its physical nature and possible relatively rapid openness to epigenesis, suggests its development as not inconceivable.

Fig. 4. Bird swarm close to high voltage electric pylon (Neels Castillon).

7.3.6. *Cosmos and consciousness*

The enigma of consciousness has encouraged flights into realms appropriate to mysticism and philosophy rather than science. Some of the theories go far into the universe. Seeking to find laws unique to biology, when realizing the problems associated with applying quantum physics to the complexity of living systems, Bohr may have been closer to rarefied regions than he cared to accept. There are more recent examples of such venturing. Chalmers was not prepared to equate awareness with consciousness and seems to have finished up with something not entirely distanced from mysticism. More adventurous are those who consider it a short step from consciousness to the universe.

Penrose and Hameroff as mentioned, regard consciousness as the result of coherent quantum processes in microtubules of brain neurons. However even they also consider that, as a form of their theory of the collapse ('objective reduction') of coherent biological quantum processes is related to the fundamentals of quantum mechanics and space-time geometry, so also consciousness is part of the basic structure of the universe (Hameroff & Penrose, 2014). This seems like one giant step for mankind, derived from exceedingly small evidence from man — especially as they grant that we do not know what consciousness is. It could be added we know increasingly less about space, theories about which expand as do(es) the universe(s) — so fast that we cannot know what is 'beyond': bubbling universes, with an arrow of time perhaps opposite to ours; or nothing, just in our minds — 'stringed' and many dimensioned, an infinitely studied *ad infinitum*. Naturally, questions of free will and choice must also find a place in their mix, though more as a side show. Those can be central, as for Pockett: an issue for philosophy and psychology rather than anatomy.

Defining EM theory in terms of 3D patterns of extracellular, local field potentials which necessarily feedback from whence they came, Pockett has concluded that behavior precedes consciousness of it and that our predisposition to see events as caused by what went before is why we tend to think our consciousness causes our actions; a reasonable thought. However, she too strays into a giant step for mankind, by declaring that there is something to be said for regarding the whole of the universe as pervaded by consciousness. What is meant by this is not clear. As we are part of the universe, then it must pervade all our brains. Though not rejecting this brave leap totally as a possibility, a smaller, more modest step seems appropriate. We suggest that the EM brain of the TBH provides a suitable medium for what may best be considered as potential ultra-–conscious, interpersonal human contact. However, Earthly phenomena of other kinds may be eventually clarified rather more quickly by the TBH, such as sudden recovery from long term, severe coma — currently controversial, some out-of-body experiences and not least, various pathologies.

7.4. Conclusion

Here we considered the TBH which predicates two interdependent, complementary organs, one electro-ionic, tangible, well known and accessible, the other electro-magnetic, intangible and difficult to access. The latter organ conceives integration in unknown fashion of EM fields combining glial secondary induction with vorticular electronics. Thus, fundamental rethinking and research on consciousness will be advanced with reconsideration of conflicting and debated concepts and data under a novel light. Fortunately, newer means for measuring and analysing endogenous, induced EM fields and their simulation, together with means for applying them in newer, experimental techniques (Frohlich & McCormick, 2010; Anastassiou *et al.*, 2011; Blagoev *et al.*, 2007; Lloyd *et al.*, 2012; Kammerer *et al.*, 2011; Gross *et al.*, 2013; Sudre *et al.*, 2011; Ozen *et al.*, 2010) are now available to the life sciences. Bohr may not have worried in vain.

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