# THE BRAIN AS AN INFORMATION PROCESSOR*

MIHAI DRĂGĂNESCU**

Member of the Romanian Academy

## 1. INTRODUCTION

The brain is a peculiar device:
– it has mind and consciousness;
– it is a computing, but also a non-computing information processor.

These two aspects are not well understood. The problem of mind and consciousness was, in the cultural history of mankind, primarily a philosophical problem. In the last few centuries, it was also a problem of psychology, and still is. But with the advent of computers, artificial intelligence, neural circuits, molecular biology, and quantum mechanics, the problem of brain with mind and consciousness became, in the last 15 years, a problem of science in general.

No doubt that the brain is an informational device. The forms of information in the brain/mind cannot, perhaps, be reduced only to the information carried by bits, even if their organization, like in artificial intelligence, may carry context and reference significance. There is also a kind of information that has a manifestation in feelings, meanings, in qualia. Both kinds of information, it seems, may also act together, constituting a mixed type of information.

The brain/mind is working like a computer with the first type of information, that I called *structural*, and which can always be reduced, in principle, to bits. With the other type of information, that I called *phenomenological*, the brain/mind is not working as a computer, but still it is processing this second type of information. And when the two kinds of information are working together, in structural-phenomenological conditions, the brain/mind is capable of quite genuine performances as are the processes of deep creation. Roger Penrose has proved that the brain has really non-computing ways of processing information (Penrose 1994), and also myself advanced the same idea in some works of philosophy of science (Drăgănescu 1979, 1985).

* The 12th International Conference on Control Systems and Computer Science, Bucharest, 26–29 May 1999.

** dragam@valhalla.racai.ro
http://www.racai.ro/~dragam

At this stage of knowledge, we do not know if information is a fundamental ingredient of nature. Of course, we cognize the shannonian information, the algorithmic Kolmogorov-Chaitin information, and the syntactic and semantic information represented by bits. The other kinds of information of the brain/mind, shortly presented above, are not yet explored by science. They are not even recognized by science, because the nature of the brain/mind was not elucidated, although there are already good reasons, as we shall see, to accept them. Due to this situation, information is not a fundamental notion of science. One cannot say exactly that if the brain/mind information is recognized, as comprehensively as above, then we shall reach the notion of fundamental information, but perhaps we will be nearer. John Archibald Wheeler, the well known physicist from Princeton, defined the next stage of physics as the era of information, in which information will be recognized as a primary phenomenon and a fundamental notion. But we are not there yet, physics is not treating information as one of the primary ingredients of nature.

It is not sufficient to say that the brain is an information processor. Sooner, it is a structural-phenomenological processor of information or a brain/mind information processor. All the electronic computers that we know today are structural processors of information. According to some authors it will be possible to build a specific type of quantum computer that will be a breed of hardware/mind information processor (Amoroso 1997 b)

## 2. LEVELS OF INFORMATION PROCESSING IN THE BRAIN

Biology, neuroscience (neurobiology and neural circuits), physics, molecular nanometric science, quantum mechanics, informatics, artificial intelligence, cognitive science, psychology, philosophy of science, complex adaptive systems and others are necessary for the study of the brain. The brain is a problem of interdisciplinary science (Drăgănescu 1999, from where many ideas were taken and adapted in this paper).

This is also due to the existence of many levels of information processing in the brain:

a) The highest level is the psychological level, which may be seen as a specific macroscopic level, which comprises behaviour, intellectual activities, thinking, sentiments, will, and others. Could these be explained only by reduction to the known structures of the brain, that is only to the elements of the following two levels (b and c)?

b) The neuronal level that comprises the networks of neurons, modules of neurons and the structural organisation of the brain.

c) The molecular level, that comprises the molecular activities inside the neurons and at the synapses between neurons.

At these levels it may be added:

d) The quantum level, which was proposed by a number of physicists in the last years, and

e) The experiential level (phenomenological level) which proved to be a fact of the brain and mind reality.

It may be seen that the brain/mind reality has to be studied in detail at many levels, and at the same time it is necessary to integrate the processes of all these levels into a unity for understanding the information processing of the brain. In the brain, there is a cohabitation of macroscopic and microscopic levels.

The main attention was given by science to levels a, b, and c. It was considered that these levels were sufficient for explaining the brain/mind and consciousness. The main stream of the scientific theories of the brain, based especially on today neurobiology, is in this class, but these theories cannot explain the so-called subjective phenomena analysed by philosophy and even by psychology.

The problem is that the science of today has an ontological model of reality and a methodology which do not include and do not allow recognising some peculiar phenomena and information processing of the brain. Because they are not fitting in the mentioned model and methodology, they are not recognised as objects of science, or worse, they are, strangely, considered as non-existent. There is today a strong objection towards a too structural science, which proves to be insufficient to explain the brain/mind, and through this, the nature of the entire reality. The study of the brain/mind is leading towards the most fundamental problems of science.

### 3. THE PHENOMENOLOGICAL LEVEL

Concerning the first three levels they are well recognised today, although there are still problems referring to their interconnection, especially of the first level (a) with the levels (b) and (c). Nevertheless the most troubling problems appear when one considers the interconnection with the last levels mentioned above, the phenomenological level and the quantum level. The arguments that follow in this paragraph and in the following will consider only these two levels.

The phenomenological level is that level of the brain/mind which displays the so called *experience*, named also *phenomenal experience* or *phenomenological sense*.

For Stapp, phenomenology is “the study of experience” (Stapp 1993, p.239) and, experience is “the collection of events, or happenings, that constitute our conscious mental life” (Stapp 1993, p.236). The *subjective experience,* is considered the best characteristic of the mind (Schaffer 1994), having also an objective side.

But what is important is the fact that experience (phenomenological sense) is considered and demonstrated as a fundamental reality of nature. The recognition of a "new" phenomenon of nature (new only because it was neglected and considered as purely subjective or as an epiphenomenon), namely the "phenomenological sense" (Drăgănescu 1985, 1979), or the experience (Chalmers 1996) may be considered as a step further for a future theory of brain/mind. For Chalmers the term experiential is equivalent with phenomenological (Chalmers 1996). Experience is a phenomenological sense at the mental level. Kodratoff was among the first to recognise the phenomenological sense as a general phenomenon of nature (Kodratoff 1997) as was proposed by Drăgănescu (1996, 1985, 1979). For many years, many scientists have recognised the mental experience as a scientific fact without going further.

The phenomenon of experience is a kind of information, namely phenomenological information, quite different from the structural information. By its nature, experience is always semantic, and a better name for it is phenomenological sense or phenomenological information. Experience is considered, in general, as a scientific fact, as a fundamental process of nature (Drăgănescu 1998 a). Experience is a phenomenological sense in an organism, but the phenomenological sense may be a general property of existence, having perhaps its place of manifestation in its deepest reality.

If the phenomenological sense is a reality, and is a kind of information, it must have a physical substrate. The recognition of the phenomenological sense implies the recognition of such a substrate, and this becomes another serious problem for science.

If the mental processes are based, on the one side, on physical structures, as neurobiology is showing, and, on the other side, on phenomenological senses, it follows that there is a way of coupling between structural processes and phenomenological processes. The way to recognize this necessary coupling still has to be established, but underlying the structural-phenomenological character of reality is another challenge for science. This implies the way in which information is processed at the phenomenological level, conditioned by the nature of this information, and the way in which the structural information interact with the phenomenological one. The processing of information by the brain/mind is very peculiar, and very different from the present technical computers.

For the brain there is an explanatory gap or a coupling problem between structural (neuronal processes mainly) and experience. This is perhaps one of the main problems for the science of the brain (Taylor 1998, Drăgănescu 1998 b).

There is something more, namely the justified inference of the existence of a deep underlying reality of the universe which might be the substratum of the phenomenological senses and a source of primary energy. The deep existence, which is out of space and time of a universe, is a fact of reality (Drăgănescu 1979,

1985; Kafatos, Nadeau 1990; Drăgănescu, Kafatos 1998). It is very difficult today to contradict this assertion. The problem is whether there is a participation of the deep underlying reality (deep existence, deep matter) in the mind and consciousness processes of the brain. This is also a challenge for science.

#### 4. THE QUANTUM LEVEL

A series of authors consider the brain as a specific type of quantum device, otherwise, according to them, its functioning could not be completely understood.

Perhaps, for the first time, physicist Fred Alan Wolf (Wolf 1984) applied the concepts of quantum physics to the study of mind and human consciousness. He observed that "thousands of years ago we probably felt just as helpless about the physical world as we feel today about the psychic world" (Wolf 1984, p. 324). Although there are a few advances in the last fifteen years, his remarks are still, unfortunately, desperately true.

His point of view is described in the following quotation:

> "Our brains follow the same basic laws of the whole universe. These laws are quantum mechanical. In our brain dance electrons and photons – the particles of light responsible for communication between electrons. The dance of electrons with light makes up our minds and provides the stability of our 85-percent water-filled brains. Thus it is that mind will not be found in any physical pattern of our brain material, but instead in quantum wave functions" (Wolf 1984, p. 134).

Therefore, he considered that the wave function is the mind and even the consciousness. In a chapter entitled Quantum psychodynamics (Ch. 11) he writes:

> "In this chapter I offer the theory that events taking place in the physical world are matched to events in an internal space called the *mental space*. The physical events are classified according to time, spatial location, energy, and momentum. In a similar manner the internal events can be classified as thoughts, sensations, feelings, and intuitions in the Jungian sense. Thus every physical event has a corresponding mental event" (Wolf 1984, p. 267).

For him,

> "…quantum mechanics is the mechanics of the human spirit" (Wolf 1984, p. 267/268).

The wave function, which only for the photon coincides with the physical electromagnetic field, is in quantum mechanics an abstract mathematical way to describe the properties of the elementary particles and of aggregate of them, without being considered in itself a physical reality. The mentioned physicist considers it to be a form of physical reality, much more, as one can say today, to be phenomenological, carrying feelings, meanings, qualia. Is this true? Is there some truth here? It is interesting that the same wave function that describes physical realities is involved in phenomenological events, after Fred Alan Wolf.

The quantum theories of brain/mind that followed based only on the structural vision of quantum mechanics, elaborated by important authors (Umezawa 1993; Stapp 1993; Penrose 1994; Jibu, Yassue 1995; Hameroff, Penrose 1996), proposed many interesting ideas, but all these are lacking an explanation of the manifestation of the phenomenological sense or experience.

David Chalmers observed this and I am of the same opinion, concerning the structural quantum theory:

> "Nevertheless, quantum theories of consciousness suffer from the same difficulties as neural or computational theories. Quantum phenomena have some remarkable functional properties, such as nondeterminism and nonlocality. It is natural to speculate that these properties may play some role in the explanation of cognitive functions, such as random choice and the integration of information, and this hypothesis cannot be ruled out a priori. But when it comes to the explanation of experience, quantum processes are in the same boat as any other. The question of why these processes should give rise to experience is entirely unanswered" (Chalmers 1996 b).

In principle, and this is my position, any theory of life, mind and consciousness based only on structural principles, classical or quantum, will not be able to explain completely these objects and processes (Drăgănescu 1995 a, 1995 b).

Ludwig has shown that the structural science, classical or quantum, can not explain mind with the ingredients of this science (Ludwig 1995). The propositions of Ludwig were extended (Drăgănescu 1998 b), to accommodate the phenomenological sense (experience), and this opens the possibility of a quantum-phenomenological theory.

Together with Menas Kafatos, an astrophysicist from George Mason University, we advanced a number of fundamental principles (Kafatos 1996, Drăgănescu, Kafatos 1998) for a new philosophy of science. All these are bringing in the conception of the universe, the participation and the role of the deep underlying reality, of the phenomenological reality, of quantum physics and the necessity of a quantum-phenomenological theory.

Concerning these principles it was observed (Drăgănescu, Kafatos 1998):

> "The Universe is quantum-phenomenological (P) […] In a first approximation the universe is structural, and the structural science worked with this approximation, which was otherwise very useful. [...] The principle (P) is confirmed by the overall phenomena of experience. The way in which the universe is quantum-phenomenological is open for research in the philosophy of science and in science. There is much work to be done to build quantum-phenomenological models of the universe. The continuous deepening of the structural quantum theory and the new efforts towards a quantum theory of the brain (Amoroso 1997 a) might offer insights for a quantum phenomenological theory of the universe.
>
> [...] The universe is structural-phenomenological because it is quantum-phenomenological, and also because its phenomena of life, mind, and consciousness

> are structural-phenomenological. Evolving or deepening existing quantum theory we believe will allow phenomenological and energy-containing sources to be explored.
>
> Concerning living objects, it happens that in these objects, from itself, by self-organisation, a coupling of the structural and phenomenological parts, emerges as a general property of nature. This coupling may be the basis for explaining the "explanatory gap" of the brain-mind problem (Drăgănescu 1998 b). This coupling is different from the coupling of energy and phenomenological information in the deep reality. It seems that there are many forms of coupling of objects and phenomena in existence."

There are strong opponents of a quantum theory of brain/mind (Mulhauser 1998, Chalmers 1996 and others) and I am also an opponent of a structural quantum theory of the brain/mind. But if the quantum might be mixed with the phenomenological, then the problem of a role of quantum phenomena in brain/mind can remain on the agenda. Here I see two problems:

– Is the quantum theory, of the most advanced form, the last and final theory in science, that is, will it describe reality from the deepest substratum of nature?

I do not believe so, because quantum phenomena are rather generated from a deep underlying reality, the last having its own rules, including those that generate a quantum world, with space, perhaps quanta of space, with time, perhaps quanta of time, that generate the most ultimate "elementary particles" and that allow a place for the phenomenological information to intervene.

– How can a quantum phenomenological theory be developed?

There are two possibilities, as far as we know them, for quantum-phenomenological theories:

A) based on the concept of intra-openness (or intro-openness);

B) based on an imbrication of structural and phenomenological properties manifested by some quantum fields and corresponding particles.

The concept of intra-openess was introduced in previous works (Drăgănescu 1979, 1985) both for the human mind and living bodies, down to the minimum living biological molecule. This openness is not towards the environmental medium, but in the deep underlying reality, that is an interior openness (intra or intro). The intra-openness brings the phenomenological parts (elements) into (among) some specific structures of atoms and molecules that, by this, become alive. The coupling of some specific structures with phenomenological elements (a fundamental coupling problem!) it was suggested to be possible only by quantum ways (Drăgănescu 1985) and therefore the quantum physics was considered to be essential for explaining life, not only through quantum chemistry.

The possibility B mentioned above was sustained by Stapp who in his book *Mind, Matter and Quantum Mechanics* writes:

> "...the first basic proposal of this work, which is to attach to each Heisenberg actual event an experiential aspect, ... is called the feel of this event, and it can be considered to be the aspect of the actual event that gives it its status as an intrinsic actuality. [...] The central question then becomes: What principle determines the structure of the feel of the actual event? More narrowly: How is the structure of human experience connected to the structure of human brain processes? The answer, according to the present theory, is this: Each human experience has a compositional structure that is isomorphic to the compositional structure of the actual brain event of which it is the feel. [...] According to the theory advanced here each actual event has two aspects: a feel, and a physical representation within the quantum formalism" (Stapp 1993).

There is no coupling between the two aspects, but only an association. In such a case an experience (feel) might be only an epiphenomenon. Stapp still considers the feel may play an active role, but this is not sustained by his theory.

Richard Amoroso made a step further on the B line. Dismissing the role of the wave function collapse (reduction) for producing experience, which was sustained by some known authors from those mentioned above, and I agree that the wave function collapse cannot produce a phenomenological sense, Amoroso, considers the coherent quantum waves to play an important role in mind and consciousness phenomena. Such waves were put into evidence by Fröhlich (1968, 1983) and they were used by Jibu and Yassue (1995), for the dynamics of the brain, by using the quantum field theory of Umezawa (1993), *but there is no connection, in all these works, with the phenomenon of "experience" (phenomenological senses).* Amoroso presents a reconciliation of the quantum coherent wave with the phenomenon of experience in his, under construction, Noetic Field Theory. To do this, he was obliged to reconsider completely the ontological model of the entire reality, and to propose new quantum physics, a type, one can say, of a quantum-phenomenological theory.

In a series of papers, Amoroso (1997 a, 1995, 1996, 1997 b, 1998 a, 1998b) presented his concepts concerning the Noetic Field Theory.

For Amoroso, "Fröhlich and Bose-Einstein coherence have become central to quantum theories of mind-body" (Amoroso 1996) and the Bose condensate is the basis for consciousness, natural or artificially created. Bose condensation was known at cryogenic temperatures, but in organisms at biological temperatures is still possible at Fröhlich frequencies, avoiding thermal effects. Amoroso shows the possibility of Bose condensation even for protein oligomers in vitro, and states that "Coherence in biology and mind seems to be the rule rather than the exception" (Amoroso 1996). Coherent quantum waves are possible in polypeptides, DNA, microtubules, implying water molecules, synaptic connections.

These coherent waves constitute macroscopic quantum systems characterised

> "by the microscopic effects of quantization of energy and momentum at the atomic level extending into the macroscopic domain, showing long range order effects

> outside classical physics, which are nonlinear, discontinuous, and describable in terms of a wave function or order parameter. They are strong effects, but they only weakly couple to electromagnetic fields and thus behave as if at a very low temperature" (Smith 1998).

What about the phenomenal experience in connection with quantum waves and Bose condensate in organisms and brains? The latter are certainly present and the experience, at least for the brain, is also present. Is the explanatory gap here? Is the explanatory gap reduced from the <neurostructure-experience> gap (Taylor 1998) to the <Bose condensate-experience> gap? Taylor has shown that some modules of neurons in the brain are in relation with some types of experiences. A quantum wave related initially with such a module could contribute to an integratory activity of the brain, because it has a macroscopic character, and this might be a very important phenomenon. ***Still remains the problem of the way in which experience is also present.***

Amoroso considers that the quantum wave under the Bose condensate form is at the same time the carrier of experience, that **it is** at the same time the experience. For him this is not a simple declaration, or postulate, because he tries to find the cause (origin) of experience, produced neither by the classical physics, nor by quantum standard structural physics processes. Amoroso tries to find the roots of phenomenological senses (experience) by a deeper ontology than that admitted by present science. The brain being a Fermi device in Minkowskian spacetime, under this spacetime he considers the multidimensional spacetime of the superstrings, then a pregeometry zone where

> "*elemental intelligence*" can be found, and deeper the *Unitary Domain of the Cosmological ordering principle…*"(Amoroso 1997 b).

All these are necessary to be taken into account, on the one side, because of the latest advances in structural quantum mechanics, and, on the other side, to assure the roots of phenomenological senses (experience) in the brain/mind.

The connection with brain processes is supposed to be realised with the Bose condensation: "Bose-Einstein condensation allows the process to go unlocal and couple the Noumenon state of elemental intelligence" (Amoroso 1997 b). To accept this, it means that something in the stuff of the Bose condensate has not only a structural character, but also a phenomenological character, therefore there is an imbrication of type B. This imbrication is superior to the stappian imbrication which is only declared, here having a physical-informational source for experience.

*The unitary domain* is a domain where "time becomes timeless, matter becomes energy, and space becomes unextended" (Amoroso 1997 b). And, of course, it is a domain where the phenomenological senses are manifesting to participate in building matter and mind. Amoroso sees the unity as a Universal Consciousness. *Under this formulation there is more than simple or complex imbrication. It is a type of intra-openess (nearer the model A).*

## 5. FINAL REMARKS

The subject of the brain as an information processing device is a part of a larger aim of science: exploration of information and of ways of processing it, no matter if by animal, in general by living organisms, human or machine. It seems that mind phenomena are the most important characteristics of life. All the other aspects of life are more machine-like. If some machines in the future have mind, they will be alive, even if they are not biological.

It is interesting that the idea of building a conscious machine haunted a lot of scientists. Gregory R. Mulhauser proposed a number of years ago to Scotland's Learned Society a project for building a conscious machine. One of the fellows of the evaluation team asked: *"But don't you think building a conscious machine is a bit like building an atom bomb?"* The answer, which I appreciate, as mentioned by the above author, was the following: "No, […], building a conscious machine is not like building an atomic bomb, at the very least because the process of building a conscious machine would teach us something about our innermost selves, something about those aspects of personal existence with which we are so intimately familiar yet which remain so deeply puzzling – something which making atomic bombs has not taught us" (Mulhauser, 1998, p. 236).

There are a few teams in the world which are trying to build electronic brains by using huge numbers of complex electronic chips and very advanced concepts, but these will remain brains without mind, processing only the structural information. The realization of these brains, perhaps in the first few years after the year 2000, will be not only a great technological performance in artificial intelligence, but also a very important experiment for the science of mind/brain and, for science in general.

Attempts will be made to build mixed brains, electronic and biological, hoping that as in the natural brain, a mind, with all what this implies, will be self-developed.

Also, attempts will be made to use possibilities offered by the quantum-phenomenological theories, if these prove to be true, to build machines with brain/mind properties, as proposed by Amoroso (Amoroso 1997 b).

The structural science, including the newest domains of this science that is a neo-structural science (complex adaptive systems, artificial life, fractals, deterministic chaos, and others), is insufficient to explain completely the natural brain, mind and consciousness. A new physics seems necessary which will also bring the recognition of the fundamental character of information and, of kinds of information not taken into account until now.

It seems that the ingredients of physics (both classical and quantum physics), biology, and of the present science of information are not sufficient for the study of the brain/mind. There is more in nature: the phenomenological sense (experience in

mind and perhaps in any organism) and the deep underlying reality, maybe, even, a fundamental consciousness. All these may lead us towards a renewed science. There are many authors that contributed to this new line of thinking. Some of them were mentioned in this paper. Various authors, from different parts of the world developed similar ideas, independently. It is perhaps the time for them.

What will happen with such ideas in the next century?

## REFERENCES


Amoroso 1995, Amoroso Richard, Barry Martin, *Modelling the Heisenberg Matrix: Quantum Coherence at the Holoscape manifold and Deeper Complementarity,* in the volume J.King and K. H. Pribram eds., *Scale in Conscious Experience: Is the Brain too Important to Be Left to Biologists to Study*?, Lawrence Erlbaum, Mahwah.

Amoroso Richard, 1996, *The production of Fröhlich and Bose-Einstein states in vitro paracrystalline oligomers using phase control laser interferometry*, Bioelectrochemistry and Bioenergetics, **41,** 39–42.

Amoroso 1997 a, Richard Amoroso, *Consciousness, A Radical Definition: The Hard Problem Made Easy*, The Noetic Journal, **1,** *1*, pp. 19–26.

Amoroso 1997 b, Richard Amoroso, *The Theoretical Foundations for Engineering a Conscious Quantum Computer,* in Eds. M. G. Harns *et al., Mind Versus Computer*, IOS Press, 141–155.

Amoroso 1998 a, Amoroso Richard and Cerebroscopic systems, *An Introduction to Noetic Field Theory: The Quantization of Mind,* preprint, for the volume eds. R. Amoroso & M. Farias, Science and the Primacy of Consciousness, Orinda, The Noetic Press, to be published.

Amoroso Richard, 1998 b, *The quantization of mind (noetic field theory),* communication at the Workshop on Convergent Ideas in the Philosophy of Science in USA and Europe, George Mason University, Fairfax, VA, USA, July 21, to be published by The Noetic Journal.

Chalmers 1996, David J. Chalmers, *The Conscious Mind***,** New York, Oxford, Oxford University Press, 1996.

Chalmers 1996 b, David Chalmers, *Facing Up to the Problem of Consciousness,* Tucson Conference I, 1996, by Internet, chalmers@ling.ucsc.edu.

Drăgănescu 1979, Mihai Drăgănescu, *Profunzimile lumii materiale* (The depths of the material world), Bucharest; edition in English, *The Depths of Existence,* 1997, on the Web: http://www.racai.ro/books/doe

Drăgănescu 1985, Mihai Drăgănescu, *Ortofizica* (Orthophysics), Bucharest, Editura Ştiinţifică şi Enciclopedică.

Drăgănescu 1995 a, Mihai Drăgănescu, *Cognition, Models of Mind, Models of Existence*, Conference, Krasnow Institute/George Mason University, Fairfax, Virginia, USA, April 3, 1995.

Drăgănescu 1995 b, Mihai Drăgănescu *Sur la notion et le domaine de la Vie Artificielle*, Bulletin de la Classe des Sciences, Académie Royale de Belgique, 6e série, Tome **VI,** *7–12*, 1995, 13 pages.

Drăgănescu 1996, Mihai Drăgănescu, *L'universalité ontologique de l'information*, préface et notes par Yves Kodratoff, prof., Université de Paris-Sud, Directeur de recherche au CNRS, Bucuresti, Editura Academiei, 1996 (with an Internet edition, http://www.racai.ro/books/draganescu).

Drăgănescu 1998 b, Mihai Drăgănescu, *Taylor's Bridge across the Explanatory Gap and its Extension,* Consciousness and Cognition, **7,** pp. 165–168.

Drăgănescu, Kafatos 1998, Mihai Drăgănescu, Menas Kafatos, *Generalised foundational principles in the philosophy of science,* Bucharest and Fairfax, paper presented at the Conference on "Consciousness in Science and Philosophy", Charleston, Illinois, 6–7 Nov. 1998. Published by The Noetic Journal, vol. 2, 1999, No. 4, pp. 341–350.

Drăgănescu Mihai, 1998 a, *Structural-Phenomenological Theories in Europe and USA*, communication at the Workshop on Convergent Ideas in the Philosophy of Science in USA and Europe, George Mason University, Fairfax, VA, USA, July 21, 1998. Published by The Noetic Journal, vol. 2, 1999, No. 1, pp. 4–8.

Drăgănescu 1999, Mihai Drăgănescu, *The Interdisciplinary Science of Consciousness,* Jan.1999, for the volume *Science and the Primacy of Consciousness*, ed. Richard Amoroso a.o., to be published.

Fröhlich 1968, Herbert Fröhlich, *Long-range coherence and energy storage in biological systems,* Int. J. Quantum Chem., **2**, 641–649.

Fröhlich 1983, Herbert Fröhlich, *Evidence for coherent excitation in biological systems,* Int. J. Quantum Chem., **23**, 1589–1595.

Hameroff, Penrose 1996, R. Stuart Hameroff, Roger Penrose, *Orchestrated Reduction of Quantum Coherence in Brain Microtubules: a Model for Consciousness,* pp. 507–540, in the volume ed. by Stuart R. Hameroff, Alfrea W. Kazniack, Alwyn C. Scott, *Toward a Science of Consciousness. The First Tucson Discussions and Debates,* The MIT Press, Cambridge, Mass., 1996.

Jibu, Yassue 1995, Mari Jibu, Kunio Yassue, *Quantum brain dynamics and consciousness,* John Benjamins Publ. Co., Amsterdam, Philadelphia.

Kafatos, Nadeau 1990, Menas Kafatos, Robert Nadeau, *The Conscious Universe – Part and Whole in Modern Physical Theory*, Springer-Verlag, New York, 1990.

Kafatos 1996, Menas Kafatos, *Foundational Principles and Consciousness*, Krasnow Institute for Advanced Studies, GMU, Fairfax, April 1, 1996 (exposition and discussions).

Kodratoff 1997, Yves Kodratoff, *L'écoulement de l'information dans l'anneau du monde matériel,* Revue Roumaine de Philosophie, Tome **41,** *1–2,* 11–22.

Ludwig 1995, Kirk Ludwig, *Why the difference between quantum and classical physics is irrelevant to the mind/body problem*, PSYCHE: An Interdisciplinary Journal of Research on Consciousness, **2,** *16,* September.

Mulhauser 1998, Gregory R. Mulhauser, *Mind Out of Matter. Topics in the Physical Foundations of Consciousness and Cognition,* Kluwer Academic Publishers, Dordrecht, The Netherlands.

Penrose 1994, Roger Penrose, *Shadows of the Mind***,** Oxford, Oxford University Press.

Schaffer A. Jerome, 1994, *The Philosophy of Mind,* The New Encyclopedia Britannica, Fifteenth Edition, 1994, vol. **24,** 152–161.

Stapp 1993, Henry P. Stapp, *Mind, Matter and Quantum Mechanics,* Springer Verlag, New York, Berlin, Heidelberg.

Taylor 1998, J.G. Taylor, *Cortical activity and the explanatory gap,* Consciousness and Cognition, **7**, *2*, 109–148.

Umezawa 1993, Hiroomi Umezawa, *Advanced Field Theory: Micro, Macro and Thermal Physics,* American Institute of Physics.

Smith 1998, Cyril W. Smith, *Is a Living System a Macroscopic Quantum System?* Frontier Perspectives, **7**,*1*, Fall/Winter, 9 – 15

Wolf 1984, Fred Alan Wolf, *Star Wave. Mind, Consciousness, And Quantum Physics,* Macmillan Publishing Company, New York, 1984.