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STAPP's QUANTUM DUALISM: the James/Heisenberg Model of Consciousness*

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Abstract

Henry Stapp attempts to resolve the Cartesian dilemma by introducing what I would characterize as an ontological dualism between mind and matter. His model for mind comes from William James' description of conscious events and for matter from Werner Heisenberg's ontological model for quantum events (wave function collapse). His demonstration of the isomorphism between the two types of events is successful, but in my opinion fails to establish a monistic, scientific theory. We trace Stapp's failure to his adamant rejection of arbitrariness, or "randomness". He says

"*... Some writers claim to be comfortable with the idea that there is in nature, at its most basic level, an irreducible element of chance. I, however, find unthinkable the idea that between two possibilities there can be a choice having no basis whatsoever...*"

This makes it impossible for him (or for Bohr and Pauli before him) to understand the power of Darwin's explanation of biology, let alone the triumphs of modern "neo-Darwinism". We note that the point at issue is a modern version of the unresolved opposition between Leucippus and Democritus on one side and Epicurus on the other. We contrast Stapp's views with recent discussions of consciousness by two eminent biologists: Crick and Edelman. They locate the problem firmly in the context of natural selection on the surface of the earth. Their approaches provide a sound basis for further scientific work. We briefly examine the connection between this scientific (rather than ontological) framework and our new fundamental theory based on bit-strings and the combinatorial hierarchy.

1. INTRODUCTION

Cartesian dualism, at least in the specific form that human mind and matter interact through the pineal gland, and that the rest of the material world is mindless, probably has no defenders left. Nevertheless, in practice, most scientists — even brain scientists — avoid the concept of "mind" altogether in their professional work, yet use it freely and traditionally in their everyday lives. Logical coherence is not a widespread human characteristic.

ANPA members cannot escape the issue because the first line in our statement of purpose commits us to considering "...coherent models based on a minimal number of assumptions..." Hence Henry Stapp's recently published collection of papers representing his coherent thinking about the mind-matter issue demands our serious attention.* His involvement with the problem has extended over several decades and forms a very impressive body of work.[1]

Like many contemporary thinkers, Stapp sees in quantum mechanics a new way to resolve the mind-matter dichotomy. Unlike most of them he has as thorough a technical grasp of the relativistic version of that theory as its unresolved ambiguities allows. He is thoroughly conversant with the orthodox Copenhagen interpretation and has succeeded in giving it canonical form thanks to several exchanges of correspondence with Heisenberg.[2] One of the important services this book renders is to make this crucial paper easily available; it includes the complete responses of Heisenberg to critical questions that distinguish his position from Bohr's. Stapp is also one of the acknowledged experts on the implications of Bell's Theorem, and draws on this expertise in his discussions.

It is important to emphasize that the Heisenberg theory of matter on which Stapp relies for the "matter" in his dichotomic theory is not the "orthodox" Heisenberg of the Copenhagen interpretation, but the "ontological" Heisenberg who re-

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* I had hoped Hank would be here for this meeting, but interactive discussion will have to await another occasion.

jects the positivistic (Copenhagen) point of view, giving quantum events "reality" in the philosophical sense.

As I read the book, Stapp gives primary status to the cognitive psychology of William James, and hence to "mind" rather than matter. I have emphasized this assessment by referring to the "James/Heisenberg model" in my title for this paper rather than following Stapp's H/J order. In fact, some would claim that Stapp's model *and* Heisenberg's ontology are *both* mentalist. Stapp doesn't quite say "No mind $\Rightarrow$ NEVER MATTER", but I fear he is perilously close to doing so. This would be, of course, a monistic position, but many of us would refuse to call it a *scientific* position. Stapp's contention that his *mathematical* isomorphism between mental and quantum events has empirical consequences for mind-brain research has, to my knowledge, yet to be tested by workers in the field. Until it is read up or out on the basis of laboratory evidence, the model will remain for me a dualism rather than a resolution of the presenting dichotomy between mind and matter.

My bias has always been toward the position of the "Never matter $\Rightarrow$ NO MIND" protagonists. So, after explaining my objections to Stapp's model in more detail, I turn to research programs which are firmly grounded in evolutionary biology. Here we find that the concepts of "awareness", "primary consciousness", and "self-consciousness" only scratch the surface of what we need to describe what is already known about what is loosely called "mind". Indeed, some workers in the field feel that terms which come from cognitive psychology get in the way of careful scientific investigation unless or until they can be related to specific neurological structures.

My concluding chapter outlines how this whole problem looks from the point of view of the new fundamental theory of physics and cosmology based on bit-strings and the combinatorial hierarchy which is part of the ANPA research program.

2. SOME OBJECTIONABLE PREMISES IN STAPP's MODEL

Fortunately, Henry Stapp is very clear and explicit about his basic assumptions. I presume that these have not changed since the paper[3], reprinted as Chapter 4 in MMQM, was published in 1982. I expect that they were already a major part of his thinking when he spoke about "Mind, Matter and Quantum Mechanics" at Zurich in 1959 and at the University of Nevada in 1968. From a philosophical perspective, some of his assumptions are very revealing. I do not mean to imply that his thinking has not broadened and deepened since he first started thinking about this subject. Stapp has been a major contributor to the discussions of non-locality arising out of Bell's Theorem, in a very positive sense. He has also, as evidenced in this book, made serious efforts to keep abreast of developments in neuro-psychology and cognitive psychology.

If Stapp were following a more diffuse line of argument, a more general discussion of his theory would be appropriate. But, from a false premise any conclusion whatsoever can be drawn. (Computer scientists have a rather vulgar way of stating this.) So I introduce my objections as they arise, rather than waiting to present a coherent alternative viewpoint.

I quote from and comment on MMQM, p. 91. et. seq.:

4.5 The Psychophysical Theory

"... the physical world described by the laws of physics is a structure of tendencies in the world of the mind. ..."

[Clearly, he accepts the presenting dualism between mind and matter as his starting point. I read his first premise has giving ontological priority to mind over physics. The questions I wish to keep in front of us are (a) whether he ends with a vicious dualism in which the interaction between mind and matter remains inexplicable or (b) establishes a monistic theory at the cost of making matter in some sense the product of mind or (c) provides the starting point for

a scientific research program which could eventually increase our understanding of the interaction between minds (in my language, evolved, conscious, indirectly interacting brains of terrestrial species, including us) and matter.]

4.5.1 **Mind: The Creative Process**

"Mind is identified with the process of creation. Everything that exists is created by this process,..."

[This gives mind a prior status to "existence". I find this as objectionable as any other form of "creationism". To my mind, all we need as a starting point for science is Parker-Rhodes' postulate:[4]

SOMETHING exists, but this statement conveys no information.]

4.5.2 **Necessity and Chance**

" 'Naught happens for nothing, but everything from a ground and of necessity' (Leucippus; see, e.g., Russell [*A History of Western Philosophy*].)" ...

"... Some writers claim to be comfortable with the idea that there is in nature, at its most basic level, an irreducible element of chance. I, however, find *unthinkable* the idea that between two possibilities there can be a choice having no basis whatsoever..." [Italics supplied]

[This is, for me, the crucial issue, as I have already indicated by including the quotation in my abstract. I find it bizarre to call the concept of chance "irrational", despite the fact that Bohr and Pauli, and following them Stapp and Laurikainen, do so. "Irrational", after all, originally referred to the tradition that Pythagoras discovered that the diagonal of a square is incommensurable with its sides. Aristotle moved against this "irrational" theory by assuming that there is a "least step". Epicurus developed Aristotle's idea by introducing a "least swerve" due to chance into the atomic model (atoms and the void) of Leucippus and Democritus. They *were* determinists, in contrast to Epicurus and his disciple Lucretius. The issue remains unresolved to this day. (See comment after 4.5.3) To find one side of a debate "unthinkable" is hardly a "rational" procedure in my view.]

4.5.3 Necessity and Free Will

"Man's free will is no illusion. It constitutes his essence. And it rests on the law of necessity. Any play of chance would falsify the idea that I, from the ground of my essential nature, make a true choice."

[Here Stapp makes "free will" a *consequence* of his law of necessity. But this works only in a mentalist theory for which some of the characteristics of "mind" are already assumed given. While I agree that free will is not necessarily an illusion, I would place the concept in a biological context by noting the obvious selective value in evolution for organisms that can consider many alternatives In my view the limited free will of organisms, like their minds, are emergent developments on this planet. Whether this biological development conceals an underlying determinism is unresolvable at this stage in the evolution of rational thought; I think it likely that this situation will persist. In computer science a pseudo-random number generator is only good up to the point when a sequence it generates is shown to have a non-random component which has significant effects in the problem at hand. Natural events can never be decisively tested in the same way. In contrast to Henry Stapp, many quantum mechanicians take the success of quantum mechanics as evidence *for* randomness at the elementary level. But this does not constitute the kind of logical proof Stapp requires. I remind you that Epicurus introduced the chance swerve into his atomism deliberately in order to make room for free will.]

4.5.4 Necessity and Predetermination

"The law of necessity entails that the process of creation is internally determined. But it is not externally predetermined.

.....

"..... Both in principle and in practice the only way to determine precisely how nature will unfold is to let it unfold."

[I agree with the last sentence, but not with the reasoning that leads to it. *Some* of the conclusions that follow from false premises can be correct. This *proves*

nothing. For what I consider to be a technical advance toward clarifying the vexed issues here, I refer the interested reader to my recent paper on "Decoherence, Determinism and Chaos".[5]]

4.5.5 **Tendency, Propensity and Probability**

[This section is mainly explanatory. In a finite and discrete theory which defines probability via case counts, and probability amplitudes using the possibility of negative case counts derived from conservation laws, the three terms discussed in this section are absent or have different meaning.]

4.5.6 **Emergent Qualities**

"Each creative act brings into existence something fundamentally new: it creates a novel 'emergent' quality."

[As discussed below, Darwinian evolution explains "emergence" given a material framework of unknown origin. This explanatory theory gains more power when based on the quantum mechanical properties of molecules and DNA, but does not require this underpinning. There is a high degree of decoupling between the physical basis for evolution and its actual "historical" course.]

4.5.7 **Consciousness**

"... : a record of its acts is stored in human memory; and it exercises a partial functional control over both its own development and that of other human biological processes. This sub-process is called human consciousness. It is part of a larger process called consciousness, which includes the conscious processes associated with other creatures.

"Consciousness is part of the full creative process..."

[For me, to abstract "consciousness" as a universal singular noun from our experience of human and animal minds is an obvious mistake in a scientific theory. While it is often hard to agree on what we mean by the question whether or not a particular organism is "conscious", this to my mind is an indication that we

need a diversity of terms to replace the grab-bag concept rather than an abstract definition or (worse) postulate.]

4.5.7 **Color**

"Everything that exists was created by the world-process called mind. ..."

[To explain "qualia" metaphysically in this way, rather than seeing why color sensitivity has the structure it does in some primates, differs significantly in other primates, and is more widely different in other animals, is again a scientific mistake. I agree that to go from what we know about the vision system from neurophysiology to a consensus theory of "qualia" has yet to be accomplished. New ideas are probably needed. But I gravely doubt that "the world-process called mind" will find its place among them.

4.5.8 **Spacetime**

"Spacetime, like color, is an emergent quality that plays a prominent role in human consciousness, and in a certain theoretical activity within consciousness called physics. The success of physics indicates that the concept of spacetime bears an important relationship to the structural properties of the creative process."

[While I agree that space-time is a concept that has emerged from the thinking of physicists, and physics itself is a concept that emerged from discussions between Greek philosophers, this misses the point. Such tested structures are abandoned at considerable risk, but this does not *necessarily* imply that they have a meaning outside of human history and experience. It is one thing to recognize that science contains many structures which are historically conditioned and quite another to leap from that recognition either into the frying pan of calling them the product of "mind" or the fire of assuming that they can be arbitrarily reconstructed without using all our laboratory skills. We must be humble in the face of experience. We sometimes forget that the dangers of *hubris* have increased rather than decreased as our scientific "power" grows.]

The remaining sub-sections of section 4.5 of Chapter 4 go on into more detailed,

technical discussions of Dynamics, Collapse of Wave Forms, Explanation of Bell's Nonlocality, Compatibility with Relativity, and other models of the mind-brain problem. These will be of considerable technical interest to specialists in this cross-disciplinary arena, as will practically all of the book. But I do not see that they lend support to the basic premises listed above.

3. BIOLOGICALLY MOTIVATED MODELS

3.1 GENERAL CONSIDERATIONS

Stapp's attempt to ground his theory of mind and matter on physical theory plus cognitive psychology comes at a time when the basic validity physical theory itself is being questioned in a new way. The "reductionist" assumption that we have to get an accurate understanding of particle physics down to the level of quantum gravity in order to understand consciousness, as contended by Penrose[6] is being called into question at a much more prosaic level. For example, in a very thoughtful and provocative article about priorities *within* physics by Schweber[7], he contends that most of the problems of current scientific interest almost *decouple* from basic physics, but require instead strong coupling with any number of other scientific disciplines for their solution. One of his conclusions is that "We need to reconceptualize the growth of scientific knowledge. The Kuhnian model will no longer do." Although Schweber does not specifically mention the problem of consciousness, it would, in my opinion, offer a good illustration of his thesis. In particular, ignoring evolutionary biology in the discussion of the subject of this paper amounts to a glaring error on Stapp's part.

One of the problems in bringing physics and biology together in the study of consciousness is the very different training practitioners of the two disciplines, and perhaps even more basic the deep differences in personality types and skills which the students tend to bring to these studies from the start. Physicists tend to value generality, powerful theories, and mathematical or experimental precision —

preferably both. Biologists tend to value the richness and diversity of their field, and even to revel in the fact that practically every biological rule has exceptions. They are so distrustful of theory that even after 40 years of molecular biology, there is as yet no corpus of thinking that deserves the name of "theoretical biology".

Of course, there is the grand *explanatory principle* due to Darwin that heritable characteristics which convey differential probabilities for survival will, in time, lead to both short-term stability and long term emergence of novelty in the presence of a "random" background. This is not "testable" in the sense that many physicists take to be "paradigmatic" for science as a whole. Illustrations are subject to the vagaries of the historical and paleontological record. In fact, until the "organ of heredity" (the DNA double helix, with variations, of course) was discovered the basic stability of the process was something of a mystery. Physicists often are so put off by the "messiness" of the details that they fail to see how grand and tough an explanatory fabric has been woven by evolutionary biologists and paleontologists. On the other hand, geneticists can be too little aware of how long and non-deterministic the route from genotype to phenotype, or even from health to sickness in the adult organism, can be.

In spite of these difficulties, much progress has been made toward "understanding consciousness", though consensus on where the continuing research should be directed, or what constitutes "understanding" could elude us for some time to come. I try to give a little of the flavor of the field by mentioning two recent "popular" books by two eminent biologists. Not surprisingly, both started as molecular biologists.

3.2 CRICK: THE ASTONISHING HYPOTHESIS

Francis Crick's recent book[8] starts with a very clear statement of his position:

"The Astonishing Hypothesis is that 'You', your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assemblage of nerve cells and their

associated molecules. As Lewis Carroll's Alice might have phrased it: 'You're nothing but a pack of neurons.' This hypothesis is so alien to the ideas of most people alive today that it can truly be called astonishing." TAH, p.3.

Crick makes it clear that this is a *hypothesis*, and that his hope is to see what type of continuing research might, eventually, lead to its acceptance. As Hopfield remarks[9] "The book is a heroic attempt to wrest consciousness from the minds of philosophers and place it in the hands of scientists."

This forthright statement of the hypothesis will automatically be characterized by many as "reductionist". For Crick, this is not a valid objection:

"... What is ignored is that reductionism is not the rigid process of explaining one fixed set of ideas in terms of another fixed set of ideas at a lower level, but a dynamic interactive process that modifies the concepts at both levels as knowledge develops. After all, 'reductionism' is the main theoretical method that has driven the development of physics, chemistry and molecular biology. It is largely responsible for the spectacular developments of modern science. ..." TAH, p.8.

Those of us who follow the type of recursive methodology discussed by Gefwert, McGoveran and myself in *Discrete and Combinatorial Physics*[10–13] should resonate to this defense of standard scientific practice.

Whether this heroic effort succeeds or fails will depend more on how competent and dedicated the scientists who rally to its clarion call prove to be than on the book itself. The strategy which Crick and his close collaborator Christoff Koch are vigorously pursuing is the detailed understanding of the visual system in humans where possible, in other primates when necessary, and in other mammals when it appears relevant. This is certainly one line of attack which deserves to be vigorously pursued. Hopfield questions its wisdom as a strategy even when directed primarily, as Crick and Koch do, at that aspect of consciousness which might be called visual awareness. I tend to differ, particularly when there is speculative evidence in the book that something that might be called an "awareness center"and another center that might even have something to do with "free will" or at least choice may have

been located. There are even PET SCANS that purport to show specialized areas in the human brain related to reading lists of verbs and nouns![14] I am a firm believer in the old dictum that truth arises more readily from error than from confusion.

3.3 EDELMAN: BRIGHT AIR, BRILLIANT FIRE

The second "popular" book I have decided to mention is by Gerald Edelman.[15] His work emphasizes the fact that in the development of the nervous system from embryo to adult about 30% of the nerve cells die. Thus there is a very rigorous selective process going on which he calls "neural darwinism", and has discussed in three earlier books as well as numerous research papers. This work led him to the conclusion that it is not so much individual neurons but fairly large groups of neurons which are selected, and that the re-entrant back connections between these groups play a critical role in the way the nervous system works.

His discussion of "consciousness" is broader and more theoretical than Crick's, and places more emphasis on evolutionary biology. He distinguishes three very significant levels that have to be understood. The most primitive is "awareness", which can apply to individual sensory modalities. Where along the evolutionary line this merges into "primary consciousness" in which the organism combines various sensory modalities to form an internal (distributed) representation of the external world on which it can act at both the "conscious" and the "unconscious" level to produce appropriate behaviors is obviously not well defined. But many higher organisms have "primary consciousness" in his sense.

"Self-consciousness" could be the exclusive prerogative of human beings, and in his view requires an inter-communicating social system in order to develop. When this arose in us is a vexed question, which Edelman does not enter into. Some would claim that it is clearly present when burial of our dead is attested at least 70,000 years ago, while Julian Janes makes a case (not convincing to most) that self-consciousness arose as a reaction to the disasters attendant on the explosion

of Thera (1628 BCE). Others assume it occurs with the invention of language, which could have happened at least 3 million years ago! That linguistic ability is potentially present in Chimps (and for some, *a fotiriori* self-consciousness) is controversial. But new evidence presented on NOVA this week, is beginning to look pretty convincing to me. I find it significant that progress has been made by a deliberate process of socializing very young Chimps in a rich environment including a great deal of both verbal and nonverbal, unplanned interactions with tender human beings. Returning to Edelman's work, while he pays due attention to neurophysiology, he also makes extensive use of computer modeling. His results in modeling the primate visual system, achieved since the publication of his book and called "Darwin IV" are particularly impressive.[16] They explicitly show that "optical illusions" such as "entrainment" — bright dots moving past a fixed figure in the visual field cause the figure to appear to move with them — occur in a system consisting ofa television camera input coupled to a computer simulation of part of the primate visual system. They also show that the re-entrant paths Edelman builds into the model are required for it to perform properly. This work, to my mind, clearly demonstrates the fact that neural groups and re-entrant pathways organized in appropriate ways suggested by the actual neural architecture of the primate visual system could take us a long way toward understanding one input needed for primary consciousness and awareness.

Edelman's model is articulated using computers, and hence bit-strings (ordered strings of the symbols 0, 1) whose changes can be expressed in terms of XOR (addition, modulo 2) and concatenation (adjoining one string to the end of another. There is a widespread prejudice that such a "classical" system cannot be used to model quantum mechanics, which we deny (see final chapter). We illustrate our contention in terms of Edelman's model for the neuron (Ref. 16, Figure 1). Each neuron has a single output axon and many input dendrites with five different types of synapses. The axon can carry an output pulse at most once in each cycle. The time within each cycle is quantized into 256 steps, which are grouped into 32 phase bins. The output axon emits a single pulse of uniform height in one of these 32

phase bins of uniform strength with a probability and phase determined by input synapses of five different types. In addition to the spike from another axon, these carry a gaussian voltage distribution. In three of the types the spike precedes the voltage pulse, and in two overlaps with it. These inputs are summed at each of the 256 time steps within a cycle with specified weights, and the probability of the axon firing and its phase specified by thresholds. Thus the neuron in this model can be thought of as a Feynman diagram for a multiparticle system, with a specified transition matrix. The general analysis used in our bit-string physics applies, and the system is "quantum mechanical" in a formal sense even though the components are "classical". It would be interesting to see if Edelman's computer articulation when replaced by a quantum mechanical wave function could be computed more efficiently than by the direct simulation he employs, but this would be a lot of work!

4. DISCUSSION

My own philosophical bias should be clear by now. I find what I call Stapp's "quantum dualism" just as objectionable as the "Cartesian dualism" which both Stapp and I would like to see relegated to the dustbin of history. Like Darwin, I believe that the rational principle of creation of novelty by selection of heritable characteristics in the presence of an arbitrary background can be used to understand biology. I find this dependence on "chance" at the basis of biology eminently "thinkable" — in fact inevitable in the modern scientific environment — for those who give due weight to the progress of both biological and historical knowledge. As is clear from what Stapp himself says, Bohr never understood biology, and I fear that — for all his erudition — Stapp's rejection of "randomness" has had the same result for him.

On the technical side, McGoveran, Manthey and I[17] have claimed that the characteristic "quantum nonlocality" which most people find so weird not only has a ready explanation in any finite and discrete theory of sufficient complexity,

but can be modeled with extant hardware. Stapp, Suppes, and Redhead — and even more significantly for me, Tom Etter — do not believe we have proved our case. Producing a working model is one of many items I hope to accomplish soon. This would cut the ground out from under many of Stapp's arguments, and support my contention above that Edelman's DARWIN IV need not be explicitly quantum mechanical in order to provide insight into the primate visual system, and eventually into visual awareness.

Lacking this demonstration, I would claim that my recent paper on decoherence, determinism and chaos (Ref. 5) already shows that finite measurement accuracy leads to non-commutativity in such a way that it both mimics quantum mechanics and provides a well defined "correspondence limit"[18] for relativistic quantum mechanics in the classical relativistic field theory of electromagnetism and gravitation — in so far as the fields act on or are radiated by a single particle with a specified piecewise continuous trajectory.

More generally, Program Universe (Cf. Ref. 13), explicitly generates the standard model of quarks and leptons as the stable response to an arbitrary background, and hence explains elementary particle physics and physical cosmology using the same explanatory principle that Darwin used for biology. Whether this "grand unified theory" of physics and biology holds up, or has to be discarded before the "explanation" of consciousness is achieved, only the uncertain future can decide.

REFERENCES

1. H.P.Stapp, *Mind, Matter and Quantum Mechanics*, Springer-Verlag, Berlin, 1993, hereinafter referred to as MMQM.
2. H.P.Stapp, *Amer. J. Phys.* **40**, 1098-1116 (1972).
3. H.P.Stapp, *Foundations of Physics*, **12**, 363-399 (1982)
4. A.F.Parker-Rhodes, *The Inevitable Universe* (unpublished); H.P.Noyes, "The Inevitable Universe — Parker-Rhodes' peculiar mixture of ontology and physics", SLAC-PUB-5161, December, 1989, and *Proc. ANPA 11.*
5. H.P.Noyes, "Decoherence, Determinism and Chaos", SLAC-PUB-6397, January, 1994 and *Proc. ANPA 15* (in press).
6. R.Penrose, *The Emperor's New Mind*, Oxford University Press, 1989.
7. S.S.Schweber, "Physics, Community and the Crisis in Physical Theory", *Physics Today*, November 1993, pp 34-40.
8. F.Crick, *THE ASTONISHING HYPOTHESIS: The Scientific Search for the soul*, Charles Scribner's Sons, New York, 1994; hereinafter referred to as TAH.
9. J.J.Hopfield, *Science* **263**,4 February 1994, p. 696.
10. C.Gefwert, D.McGoveran, and P.Noyes, "Prephysics" in *Discrete and Combinatorial Physics; Proc. ANPA 9*, H.P.Noyes, ed; published by ANPA WEST, 409 Leland Ave., Palo Alto, CA 94306, 1987, pp. 1-36.
11. D.McGoveran, and P.Noyes, "Foundations of a Discrete Physics", Ibid, pp 37-104 and SLAC-PUB-4526 (June, 1989).
12. H.P.Noyes, "DISCRETE PHYSICS: Practice, Representation and Rules of Correspondence, Ibid, pp 105-137.
13. H.P.Noyes and D.O.McGoveran, "An Essay on Discrete Foundations for Physics", *Physics Essays*, **2**, 77-100 (1989).
14. J.Horgan, "Fractured Functions: Does the brain have supreme integrator", *Scientific American*, December 1993, pp 36-37.
15. G.M.Edelman, *Bright Air, Brilliant Fire*, Basic Books, 1992.
16. G.Tononi, O.Sporns, and G.M.Edelman, "Reentry and the Problem of Integrating Multiple Cortical Areas: Simulation of Dynamic Integration in the Visual System", *Cerebral Cortex*, Vol **2**, No. 4, July/August 1992, pp 310-335.

17. D.O.McGoveran, H.P.Noyes and M.J.Manthey, "ON THE COMPUTER SIMULATION OF THE EPR BOHM EXPERIMENT", presented at Conf. on *Bell's Theorem, Quantum Theory and Conceptions of the Universe*, Fairfax, Va., Oct 21-22, 1988, and SLAC-PUB-4729, Dec 1988.

18. H.P.Noyes, "On the Correspondence Limit of Relativistic Quantum Mechanics", SLAC-PUB-6010, May, 1993(unpublished).