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Contemporary Models of Consciousness: Part II

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Recent models of consciousness are reviewed which explore the relationship of consciousness to physical laws; many of these also explore the relationship of consciousness to biological findings. Issues investigated by these models are discussed, with the issues framed in a general way in order to provide a comparison between the models. In Part II the issues discussed include: (1) Does all of the information content of consciousness correspond to neural coding in the brain? (2) Does consciousness follow the brain passively, or can it act independently? (3) Is independent processing by consciousness compatible with the second law of thermodynamics?

A number of models of consciousness have appeared in the last fifteen years which investigate the relationship of consciousness to the brain and the physical world. The models discussed here all have a physical orientation, in that they investigate the relationship of consciousness to physical laws, and many of them also address biologically oriented questions about consciousness. This paper reviews these models with respect to various physical and biological issues they have discussed, formulating the issues in somewhat general terms so we can compare what different models have said.

An overview of the issues is given in another work (Burns, 1991a). Because a multidisciplinary approach is helpful in the study of consciousness, it may be useful to the reader to know of other recent works which discuss the relationship of consciousness to the brain; some recent books which give interesting perspectives from the viewpoint of the biological sciences and philosophy are authored or edited by Blakemore and Greenfield (1987), Churchland (1986), Edelman (1989), and Gulyás (1987).

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In Part I (Burns, 1990) the issues discussed are the causal (ontological) relationship between consciousness and the physical world, and physical characteristics which may be associated with the mind-brain interface. In Part II the issues to be discussed are:

1. Does all of the information content of consciousness correspond to neural coding in the brain?
2. Does consciousness follow the brain passively, or can it act independently?
3. How are self and self awareness defined in the models, and how are these related to independent processing?
4. Is independent processing by consciousness compatible with the second law of thermodynamics?

Every model discussed here considers consciousness to have some properties, if only awareness or subjectivity, which are different from known properties of the physical world. In this sense we can describe consciousness as a realm different from the physical world, which may have some properties in common with the physical world, but not all. Properties unique to consciousness might be considered "emergent" or "independent," depending on one's view about the causal relationship between consciousness and the physical world, as discussed in Part I; the point is simply that consciousness is in some respects described differently than the physical world. For convenience we will call the physical world Realm 1, and the aggregate of all possible conscious experience Realm 2. Some models refer to a third realm, in addition to or instead of Realm 2, which is spaceless, timeless, and incapable of division; we will refer to this as Realm 3. A list of authors who refer to these realms, and the terms they use to refer to them, is given in Part I of this paper (Burns, 1990, Table 2).

Does All of the Information Content of Consciousness Correspond to Neural Coding in the Brain?

A great deal of empirical evidence shows that conscious experience can be affected through brain injury, electrical stimulation of the cortex, or other means of affecting the brain (Blakemore, 1977), and several models discuss the nature of this dependence. Burns (1986) describes the "content" of conscious experience as being defined in the brain, and Stapp (1982) speaks of the "significance of meaning" as having a necessary association with a code in the brain; Kroon (1989, 1991) speaks of mental activities as having a necessary correspondence with neural processes.

Let us use the term *information* somewhat informally, but nevertheless include the idea, essential to the formal definition of this term, that anything described as information must be capable of being expressed in a quantitative way. In this sense, we can speak of the information content of a conscious

experience, with this phrase meaning that the content of the experience is capable of being expressed quantitatively, even though it is experienced in qualities unique to consciousness. Thus a cognitive thought, such as "Today is Tuesday," can be described as having an information content because it is capable of being expressed quantitatively, for instance, in bits on a computer. We can now express the idea that the "content," "meaning," or "quantitative" aspect of a conscious experience has a necessary association with encoding in the brain by saying that the information content of the experience is defined in the brain.

It is not necessarily true that all aspects of conscious experience can be expressed quantitatively. Kroon (1989, 1991) holds that not all thoughts and emotions can be described in a quantitative way; in a similar vein, one might hold that the way that context and content differ is that the conscious experience of context cannot be described in a quantitative way. Nevertheless, given (by definition) that the information content of conscious experience can be expressed quantitatively and that this content is known to be, in general, dependent on the brain, we can ask whether *all* content is encoded in the brain or whether it is possible for some content to occur independently of the brain. The above models specify that all of the information content of conscious experience is defined in the brain. However, the following models appear to differ from this point of view, not through explicit statement, but implicitly through other ideas they present.

Culbertson (1963, 1976, 1979, 1982, 1991) proposes that consciousness of an object resides in its space-time location, and is an objective phenomenon, the same as any ordinary physical quantity. Culbertson considers that some attributes of an object, such as color, are experienced differently from observer to observer, and that these experiences are defined through a "picture-making" network in the brain. However, his treatment suggests that the conscious experience of some attributes, such as size and shape, derives from the external object, rather than from the brain.

Eccles and Sperry each propose that the presence of consciousness can be determined through certain behaviors which they claim cannot be performed unless consciousness is present. Thus, in seeking to know whether animals are conscious, Eccles asks if they have the ability to recognize themselves in a mirror, to show compassion, or to attend to their dead (Eccles, 1989; Popper and Eccles, 1977). Similarly, Sperry (1977), in seeking to know whether the right hemisphere of a split brain patient is conscious, contends that this can be determined on the basis of whether the right hemisphere can recognize photos of friends and self. However, behavior consists of specific physical actions, so the determinants of behavior must be capable of being expressed in a quantifiable manner. If a behavior, in and of itself, can demonstrate the presence of consciousness, then at least part of its determinants must be unique

to consciousness and not present in the brain or nervous system. Thus, the hypothesis that occurrence of a certain behavior demonstrates the presence of consciousness implicitly supposes that information can be held in consciousness without any corresponding encoding in the brain or nervous system.[1]

Burns (1986) and Kroon (1989, 1991) discuss the reason for proposing that all information in conscious experience has a necessary association with encoding in the brain; in each case the reason derives from the concept of differences in properties between consciousness and the physical world. Burns points out that the qualities of conscious experience are very different from those of the physical world (Realm 1); nevertheless, extensive data in brain research shows the content of such experience to be dependent upon processes in the brain. In order to account for this dependence, she proposes that conscious experience (in Realm 2) can follow or "identify with" processes in the brain, and that this ability of conscious experience to follow processes in the physical world is a property of consciousness. If information content could also be defined within consciousness, then an additional capability of Realm 2 would be involved, one that is seemingly little used. Burns makes no postulate of such an additional property in Realm 2; rather, she specifies that all of the content of conscious experience derives from information defined in the brain. In a similar vein, Kroon, who describes consciousness in terms of Realm 3 rather than Realm 2, holds that all quantifiable experience must be encoded in the brain because such experience cannot be defined in Realm 3.

Does Consciousness Follow the Brain Passively, or Can It Act Independently?

A number of models make the postulate that consciousness can do processing independently of the brain. Such processing can, of course, take place even if all information is defined in the brain – to select, modify, or correlate brain programs. It is of interest that the postulate of independent processing is not limited to any particular claim of causality between the realms, but encompasses physicalism and mentalism, as well as dualism and other models (Table 1). (For discussion of postulates regarding causality, see Burns, 1990.)

Burns, (1986), Culbertson (1963, 1982), Eccles (1989), and Sperry (1976) each

[1]If all encoding and processing done by the brain were well understood, the presence of consciousness could be demonstrated by showing that a behavior occurs without all of the encoding or processing necessary to that behavior taking place in the brain. However, such a test would rely upon an extensive understanding of brain processes, and would not be a demonstration of the presence of consciousness from behavior in and of itself (Burns, 1991a).

Table 1

Models Which Propose Independent Processing by Consciousness

Author	*Postulate Regarding Causality Between the Realms*	*Type of Independent Processing Proposed*
Consciousness Generated from Brain/Physical World		
Culbertson (1963, 1982)	Physicalism	Independent processing, type not specified
Sperry (1965, 1976, 1987, 1991)	Mentalism (mind arises from brain, but can act causally on it)	Free will, holistic information processing
Independence/Dependence of Consciousness on Physical World Not Specified in Model		
Bass (1975)	Not specified	Free will
Jahn and Dunne (1987)	Not specified (model pertains to interface only, not to relationship between consciousness and its environment	Holistic information processing
Stapp (1982, 1985, 1991)	Not specified	Free will
Consciousness and Physical World Are Independent Realms Which Interact		
Burns (1986)	Dualism	Free will, holistic information processing
Eccles (1986, 1987, 1989, 1990; Popper and Eccles, 1977)	Dualism	Free will, holistic information processing
Walker (1979, 1984, 1985; Mattuck and Walker, 1979)	Pragmatic dualism	Free will, holistic information processing
Other Relationships		
Bohm (1982)	Implicate Order (mind and brain have no interaction; they derive from the Implicate Order and act synchronistically)	Holistic information processing
Goswami (1986, 1989, 1990)	Monistic idealism, with immanent brain-mind having a relationship of causal circularity to the quantum mechanical domain	Free will

make the point that if consciousness does not act independently of the brain, it would have no function and there would be no reason for it to develop in evolution. For instance, if consciousness has no function, we could be conscious of autonomic processes but not of vision, and be able to carry out our daily activities; it would not matter what we were conscious of.

If consciousness does perform some function, then evolution could act in

two ways: to improve the action of the brain per se and to improve the mind-brain interface so as to increase the use of this independent action. In this view, consciousness might occur relatively early in evolution, with animals higher in the evolutionary line making increased and more complex use of this independent action (Burns, 1986). On the other hand, if consciousness performs no function, then its occurrence is accidental; in the latter case, it might occur only sporadically in the animal kingdom, perhaps only in humans.

Two types of independent action have been proposed: free will and holistic information processing. Free will could make selections among different available brain programs, and holistic processing could activate, modify and/or coordinate such programs.

Free Will

The term *free will*, as used herein, refers not to any brain action, probabilistic or otherwise, but to the ability to choose between alternatives; such a process has no place within present physical law. All the models which discuss free will (see Table 1) consider it to be an agency acting independently of the brain, which can choose the action to be taken by an individual through selection of an appropriate brain program.

Whether information can be *processed* independently of the brain and whether it can be *defined* independently of the brain are separate questions. However, models which differ on what is defined in the brain may also differ on how alternatives for choice are determined. Eccles (1987; Popper and Eccles, 1977) holds that mind can think independently of neural coding. On the other hand, if all thought is defined in the brain, there is no way to think about anything separately from the brain. Thus in Burns' (1986) model, choice acts merely as a switch to select among brain-presented alternatives. These models also differ in their interpretation of the fact that various characteristic electric potentials arise in the brain before voluntary action begins (Kornhuber, 1974). Burns (1986) attributes these potentials to necessary processing the brain must do in order to present alternatives to consciousness. Eccles considers that these reflect the molding and changing by mind of patterns in the brain (Popper and Eccles, 1977).

Holistic Information Processing

Holistic information processing could make use of information encoded in different parts of the brain, and could act on the brain to correlate, activate and/or modify programs in the brain. This processing would take place independently of any brain action.

A variety of proposals have been made about specific ways such processing could act on the brain. Popper and Eccles (1977, pp. 471–472) propose that neural programs in the brain are coordinated by such a process. It is of interest that Davidson (1980), in a biologically oriented model, also proposes that consciousness coordinates and transforms brain-defined information. Basic programs for motor actions such as locomotion are known to be stored in the brain (Shepherd, 1983); however, Burns (1986) suggests that independent holistic processing could provide the details for such actions and thereby help an organism respond to varying conditions in the environment.

The models of Burns (1986) and Eccles (1989; Popper and Eccles, 1977) propose that vision processing cannot be fully done by the brain and that a holistic process must contribute. Parallel distributed processing, now being studied in artificial intelligence, shows how neurons can act collectively, and such processing is likely to account for some integrative action of the brain that is not presently understood (Rumelhart, McClelland et al., 1986). But it may not account for all processing in the mind-brain system. Thus Burns (1986) compares the stages necessary for the full vision computation, as it is known in artificial intelligence (Marr, 1982), to the areas of the brain known to be involved with vision processing. One of the primary problems of the vision computation is the determination of individual objects from what is originally only a pattern of light and dark on the retina, and the stage of computation at which this is accomplished is called the stage of the "primal sketch" (Marr, 1982). Burns notes that much more space in the brain is given to vision processing up to the stage of "primal sketch" than beyond, even though later stages in the computation appear to be fairly extensive; she suggests that independent holistic processing may contribute to computational stages past that level.

Such processing might also contribute to the temporal coordination of activity in the brain. It is known that neuronal activation corresponding to a sensory event can reach primary sensory cortex rather quickly, often within 10–25 msec; on the other hand, we ordinarily experience sensory events along with their associated meanings, and brain processing corresponding to the latter takes place over a larger area of cortex and a longer period of time. Thus, experiments show that there is a substantial time lag, up to 0.5 second, between a sensory event, such as a tap on the finger, and the conscious experience of that event (Libet, 1982). Direct electrical stimulation of primary sensory cortex can also produce a conscious experience, and thus one can ask, if cortical stimulation and a finger tap are presented simultaneously, would these be experienced simultaneously? This question is complicated by the fact that low level cortical stimulation will not produce a conscious sensation at all unless it is sustained for a duration of up to 0.5 second; however, experiments show that if a finger tap is presented at any time during cortical

stimulation, the finger tap will be experienced *before* the sensation from direct cortical stimulation (Libet, 1982). Further experiments indicate that, for signals that arrive at sensory cortex from a subcortical path, the relative time at which these signals are experienced is the time of their initial arrival at primary cortex, even though the time for complete processing of the event – which is much longer than the initial arrival time – varies according to the type of event (Libet, 1982). So the question arises of how simultaneous sensory events can be experienced at the same relative time. It is not known whether the temporal correlation of such events can take place through parallel distributed processing, although ways in which a temporal code might be used in the brain are being explored (Sejnowski, 1986). However, Eccles (Popper and Eccles, 1977) suggests that independent holistic processing, rather than a brain process, provides this antedating and correlation in the mind-brain system.

It is also proposed that independent holistic processing is used in the experience of insight (Bohm, 1982, pp. 51–53; Burns, 1986), and in the general cognitive process of organizing information (Jahn and Dunne, 1987, p. 338).

Self, Self Awareness, and Their Relationship to Independent Processing

Burns (1981, 1986, 1991b), Eccles (1989, Popper and Eccles, 1977), Goswami (1990), and Kroon (1989) discuss the place of the self in their models. However, there is a distinction between the models which can be expressed in terms of two different meanings of the term "self." The "self" can be viewed as the expression of what you are – all traits and memories. On the other hand, "self" may be viewed as simple self awareness, "I." The "I" can become associated with various traits and memories, such that one can say, "I am that," or "I did that." However, the traits the "I" is associated with may vary from person to person or from time to time, and self awareness can be viewed as a fundamental entity which has no inherent association with any particular trait.

Each of the above models describes the self as extra-physical. Eccles frames his discussion in terms of the first definition and speaks of a self which may have traits or express thoughts that are not defined in the brain. Burns, Goswami, and Kroon use the concept of self awareness in their models, rather than the concept of an extended self; thus it is self awareness per se that is considered extra-physical. Each of the latter models refers to concepts in Western or Eastern philosophy (*pure ego* – Phenomenology; *atman* – Hinduism; the *anatta* doctrine of Buddhism, respectively) in framing their idea of the self.

Let us now inquire whether self consciousness is necessary for independent processing to be done by consciousness. Burns (1986, 1991b) and Eccles (Popper and Eccles, 1977) explore this question (with the concept of self differing

somewhat, as described above). Each model holds that when a choice is made self consciousness is always present.

On the other hand, each of the above models proposes that holistic information processing can be done without self consciousness. Eccles states that consciousness could not have evolved in the animal kingdom if it was non-causal. But he doubts that animals have self consciousness and, after some consideration, he concludes that holistic processing can take place without it (Popper and Eccles, 1977, pp. 498, 518, 535). Burns (1981) cites examples from everyday life to show that people frequently carry out actions spontaneously, without self awareness; she concludes (1986, 1991b) on this ground that self awareness is not necessary for such processing.

There is a debate as to whether the right hemisphere of the brain is conscious (Natsoulas, 1987) and, supposing it is conscious, as to whether it is self conscious (Sperry, 1977). If independent holistic processing acts to correlate programs in the brain, then we might expect that consciousness is associated with both hemispheres so that brain programs especially associated with each (speech in the left, spatial interpretation in the right) can be carried out in an integrated way. Two of the models propose that the later stages of vision are carried out by independent holistic processing, i.e., that the full use of visual input to the brain cannot be made without the presence of consciousness (see previous section). Both hemispheres of split-brain patients demonstrate the use of ordinary visual perception, so the above proposal implies that both hemispheres are conscious. However, if independent holistic processing can take place without the presence of self consciousness, the possibility remains that the right hemisphere is conscious, that consciousness is essential to its proper functioning, and yet that it is not self conscious.

Is Independent Processing Compatible with the Second Law of Thermodynamics?

If you shake a box which contains black marbles on one side and white marbles on the other side, the colors become mixed. This result illustrates the action of the second law of thermodynamics, which states that the total disorder of the universe always increases.[2] You can reach in the box and sort out the colors, thereby producing an increase in order. Nevertheless, any physical action you take to sort them will produce a corresponding increase in disorder, such that the total disorder in the universe increases. For instance, the metabolic processes which produce the energy to move your fingers are associated with the generation of heat and an increase in disorder of molecular

[2]In the case of reversible processes, the total entropy (disorder) remains the same. However, the concept of a reversible process is an idealization, in which the total entropy gain in the universe is negligible, not non-existent.

motions in the body. Thus Jahn and Dunne (1987, pp. 335–340), in making the proposal that independent holistic processing can organize information, without any physical action involved, point out that such processing would violate the second law.

Burns (1986) notes that the second law can also be expressed as specifying that under given conditions, a physical process will go in a certain direction (for instance, heat will flow from warm to cold, but not the reverse). She points out that independent processing by consciousness would cause physical processes in the brain to go in a different direction than the way they ordinarily would, and concludes that such processing would necessarily violate the second law. Walker (Mattuck and Walker, 1979) also points out that independent holistic processing, by producing order, violates the second law.

Goswami (1989) explores the relationship of independent processing to the second law from a different perspective. He describes the equations of quantum mechanics as time reversible and, because irreversible phenomena take place in the ordinary world, he suggests that the act of choice which collapses the wave function confers irreversibility to ordinary reality. Irreversibility is an essential aspect of the second law of thermodynamics, and this is equivalent to proposing that collapse of the wave function produces the second law of thermodynamics. Thus Goswami's suggestion is not compatible with the view that action on the physical world through extra-physical means is contradictory to the second law.

However, as Prigogine (1980) points out, most processes described in physics are time reversible; only special types of interactions, such as a three-body interaction or a mixing process, can be irreversible. These processes would lack time reversibility in both the ordinary and quantum mechanical descriptions, so there is no reason to say that collapse of the wave function must confer irreversibility.

Finally, we should discuss how energy involved with physical processes might be affected by any interaction across the interface between consciousness and the physical world, and how such an effect would be related to the second law. As Eccles (1986, 1987, 1990; Popper and Eccles, 1977) points out, for any interaction across the interface, the question arises as to whether energy might be transported into or out of the physical world, thereby violating the law of conservation of energy (the first law of thermodynamics). However, energy in the physical world is defined in terms of physical space and time; if consciousness does not have the property of physical space, then it cannot contain physical energy, and such energy cannot be transported there.

Nevertheless, if independent processing by consciousness causes electrochemical actions to take place in the brain, then a source of energy is needed for these physical processes. The second law of thermodynamics governs the direction in which energy flows in the physical world; it is because of the

second law that energy flows from hot to cold, for instance. If independent processing can violate the second law, then physical energy needed to drive electrochemical actions in the course of such processing can be taken from any local source, such as the thermal motion of molecules (Mattuck and Walker, 1979).

Summary and Discussion

The nature of consciousness is presently little understood. However, one can ask questions about the relationship of consciousness to biological data and/or physical laws, make hypotheses, and consider any insights or further questions which arise. The models disagree on many points; however, disagreements are helpful because they serve to illuminate the underlying issues.

The models do not agree on whether the content of conscious experience is completely defined in the brain, or whether any information is defined outside the brain. However, if a behavior can proceed without the determinants of that action being defined in the brain, then this behavior can be a test for the presence of consciousness in humans or animals. The possibility of such a test, and the fact that models differ about whether that test can be made, show the importance of the question of whether all information is defined in the brain.

Several authors point out that the experience of "I," also called "self awareness," is an extraphysical quality, i.e., it does not appear in any (presently known) laws of physics. However, the term "self" is used with a different meaning in different models. This difference shows the importance of developing a conceptual framework to describe the nature of self, and of making clear in any model which discusses it just how the term "self" is being used.

A number of models propose that consciousness is not merely passive to the brain, but performs a function. Free will and holistic information processing have been proposed as ways in which consciousness can act independently of the brain, with various specific suggestions made as to what holistic information processing would do in the mind/brain system. However, as several authors point out, independent processing by consciousness would violate the second law of thermodynamics.

A theme which appears in the issues discussed herein is that consciousness has properties which are different from those of the physical world (as it is presently known). The fact that the content of conscious experience is expressed in qualities which are different from those of the physical world demonstrates that these realms are not described in an identical way. If the realms differ only through these qualities, one may consider that the difference between the realms is not significant. However, the issues raised by the models

suggest that there are additional, substantial differences. Probably the reason the nature of consciousness has been such an enigma is that we have not sufficiently understood the differences between the realms.

However, if one is to make an hypothesis that consciousness is in some respect significantly different from the (known) physical world, it is important to relate that hypothesis to empirical data. In this way an objective means of examining the idea is provided.

Clearly, a multidisciplinary approach is important in which hypotheses can be viewed in the light of data and perspectives from different fields. To this end, it would be helpful to have more review papers available about work done on the subject of consciousness in various disciplines. Although this paper has touched on some issues related to biological findings, only models which included a discussion of the relationship of consciousness to physical laws were reviewed. Although partial summaries have been published of work done within the biological sciences, no recent or comprehensive summary exists. Other fields, such as psychophysics, psychophysiology and cognitive psychology, also provide relevant findings, and it would be helpful to have summaries of work in such fields which would acquaint workers outside the fields with relevant findings. By inquiring about the ways in which mind is similar to brain and the ways in which it is different, and relating these inquiries to empirical data, we can hope to progress in our understanding of the nature of consciousness.

References

Bass, L. (1975). A quantum mechanical mind-body interaction. *Foundations of Physics, 5*, 159–172.

Blakemore, C. (1977). *Mechanics of the mind.* New York: Cambridge University Press.

Blakemore, C., and Greenfield, S. (Eds.). (1987). *Mindwaves: Thoughts on intelligence, identity and consciousness.* Cambridge, Massachusetts: Basil Blackwell.

Bohm, D. (1982). *Wholeness and the implicate order.* London: Routledge and Kegan Paul.

Burns, J. (1981). *Your innate psychic powers.* London: Sphere.

Burns, J. (1986). Consciousness and psi. *Psi Research, 5*, 166–205.

Burns, J. (1990). Contemporary models of consciousness: Part I. *Journal of Mind and Behavior, 11*, 153–172.

Burns, J. (1991a). Four questions about the relationship between consciousness and the physical world. *Proceedings of the First International Conference on the Study of Consciousness Within Science.* (in press)

Burns, J. (1991b). *The nature of pure ego.* Unpublished manuscript.

Churchland, P.S. (1986). *Neurophilosophy: Toward a unified science of the mind brain.* Cambridge, Massachusetts: MIT Press.

Culbertson, J.T. (1963). *The minds of robots.* Urbana, Illinois: University of Illinois Press.

Culbertson, J.T. (1976). *Sensations, memories and the flow of time.* Santa Margarita, California: Cromwel Press.

Culbertson, J.T. (1979). The spacetime structure of mental images. In S. Krippner (Ed.), *Psychoenergetic systems* (pp. 51–114). New York: Gordon and Breach.

Culbertson, J.T. (1982). *Consciousness: Natural and artificial.* Roslyn Heights, New York: Libra.

Culbertson, J.T. (1991). *A physical theory of experience.* Unpublished manuscript.

Davidson, R.J. (1980). Consciousness and information processing: A biocognitive perspective. In J.M. Davidson and R.J. Davidson (Eds.), *Psychobiology of consciousness* (pp. 11–46). New York: Plenum.

Eccles, J.C. (1986). Do mental events cause neural events analogously to the probability fields of quantum mechanics? *Proceedings of the Royal Society of London B, 227,* 411–428.

Eccles, J.C. (1987). The effect of silent thinking on the cerebral cortex. In B. Gulyás (Ed.), *The brain-mind problem: Philosophical and neurophysiological approaches* (pp. 29–60). Leuven, Belgium: Leuven University Press.

Eccles, J.C. (1989). *Evolution of the brain: Creation of the self.* New York: Routledge.

Eccles, J.C. (1990). A unitary hypothesis of mind-brain integration in the cerebral cortex. *Proceedings of the Royal Society of London B, 240,* 433–451.

Edelman, G.M. (1989). *The remembered present: A biological theory of consciousness.* New York: Basic Books.

Goswami, A. (1986). The quantum theory of consciousness and psi. *Psi Research, 5,* 145–165.

Goswami, A. (1989). The idealistic interpretation of quantum mechanics. *Physics Essays, 2,* 385–400.

Goswami, A. (1990). Consciousness in quantum physics and the mind-body problem. *Journal of Mind and Behavior, 11,* 75–96.

Gulyás, B. (Ed.). (1987). *The brain-mind problem: Philosophical and neurophysiological approaches.* Leuven, Belgium: Leuven University Press.

Jahn, R.G., and Dunne, B.J. (1987). *Margins of reality.* New York: Harcourt Brace Jovanovich.

Kornhuber, H. (1974). Cerebral cortex, cerebellum and basal ganglia: An introduction to their motor functions. In F.O. Schmitt and F.G. Worden (Eds.), *The neurosciences: Third study program* (pp. 267–280). Cambridge, Massachusetts: MIT Press.

Kroon, R.P. (1989). A mind/matter axiom. *Journal of Religion and Psychical Research, 12,* 74–84.

Kroon, R.P. (1991). Mind, matter and psi. *Journal of Religion and Psychical Research, 14,* 61–74.

Libet, B. (1982). Brain stimulation in the study of neuronal functions for conscious sensory experience. *Human Neurobiology, 1,* 235–242.

Marr, D. (1982). *Vision.* New York: W.H. Freeman.

Mattuck, R.D., and Walker, E.H. (1979). The action of consciousness on matter. In A. Puharich (Ed.), *The Iceland papers* (pp. 112–159). Amherst, Wisconsin: Essentia Research Associates.

Natsoulas, T. (1987). Consciousness and comissurotomy: I. Spheres and streams of consciousness. *Journal of Mind and Behavior, 8,* 435–468.

Popper, K.R., and Eccles, J.C. (1977). *The self and its brain.* New York: Springer International.

Prigogine, I. (1980). *From being to becoming.* New York: W.H. Freeman.

Rumelhart, D.E., McClelland, J.L., and the PDP Research Group (1986). *Parallel distributed processing, Volumes 1 and 2.* Cambridge, Massachusetts: MIT Press.

Sejnowski, T.J. (1986). Open questions about computation in cerebral cortex. In J.L. McClelland, D.E. Rumelhart, and the PDP Research Group (Eds.), *Parallel distributed processing, Volume 2* (pp. 372–389). Cambridge, Massachusetts: MIT Press.

Shepherd, G.M. (1983). *Neurobiology.* New York: Oxford University Press.

Sperry, R.W. (1965). Mind, brain and humanist values. In J.R. Platt (Ed.), *New views of the nature of man* (pp. 71–92). Chicago: University of Chicago Press.

Sperry, R.W. (1976). A unifying approach to mind and brain: Ten year perspective. In M.A. Corner and D.F. Swaab (Eds.), *Perspectives in brain research, Volume 45* (pp. 463–469). New York: Elsevier.

Sperry, R.W. (1977). Forebrain commissurotomy and conscious awareness. *Journal of Medicine and Philosophy, 2,* 101–126.

Sperry, R.W. (1987). Structure and significance of the consciousness revolution. *Journal of Mind and Behavior, 8,* 37–65.

Sperry, R.W. (1991). *Turnabout on consciousness: Science changes its mind.* New York: Plenum. (in press)

Stapp, H.P. (1982). Mind, matter and quantum mechanics. *Foundations of Physics, 12,* 363–398.

Stapp, H.P. (1985). Consciousness and values in the quantum universe. *Foundations of Physics, 15,* 35–47.

Stapp, H.P. (1991). A quantum theory of the mind-brain interface. *Proceedings of the First International Conference on the Study of Consciousness Within Science.* (in press)

Walker, E.H. (1979). The quantum theory of psi phenomena. *Psychoenergetic Systems, 3,* 259–299.

Walker, E.H. (1984). Review of criticisms of the quantum mechanical theory of psi phenomena. *Journal of Parapsychology, 48,* 277–332.

Walker, E.H. (1985). Pragmatic dualism and bifurcated idealism. *Journal of Religion and Psychical Research, 8,* 36–44.