Fall 2001

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The Journal of Mind and Behavior
Autumn 2001, Volume 22, Number 4
Pages 365–388
ISSN 0271–0137

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It has been claimed that quantum mechanics, unlike classical mechanics, allows for free will. In this paper I articulate that claim and explain how a complex physical system possessing fractal-like self similarity could exhibit both self consciousness and self determination. I use complexity theory to show how quantum mechanical indeterminacies at the neural level (as postulated by Eccles and Penrose) could "percolate up" to the levels of scale within the brain at which sensory-motor information transformations occur. Finally, I explain how macro level indeterminacy could be coupled with self determination to provide a physical system with the capacity for radically free willing.

According to an important tradition of thought in the West, human beings determine their own actions in a "radically free" manner. The concept of a radically free will was understood as essentially an undetermined ability to choose between options. Such an idea, though intimated by Aristotle (*Eudemian Ethics* 1223a), was absent from typical ancient Greek attempts to explain the origination of human action (Dihle, 1982; MacIntyre, 1986). The position was fully developed during the middle ages within the world-view that centered on a creator God who causes the whole universe to exist and whose act of creating is self determined and utterly free. Secular thinkers of the enlightenment era re-interpreted the will's freedom to be much less radical than as in the older biblically-based view. In his discussion "Of Liberty and Necessity," Hume (1739/1964, Book II Part III Section II)

I am indebted to the Pew Charitable Trusts for funding the 1998 seminar in "Theology and the New Physics" conducted at Calvin College by John Polkinghorne. I originally developed this paper in that seminar and am especially grateful to Dr. Polkinghorne, Brant Hinrichs and a reviewer for this journal for their criticisms of my understanding and employment of quantum mechanics and non-linear dynamics. I am also thankful to Professor Raymond Russ for his critical assistance in preparing the paper for this journal. Requests for reprints should be sent to Mark Pestana, Ph.D., Department of Philosophy, Grand Valley State University, Allendale, Michigan 49401. Email: pestanam@gvsu.edu

referred to this newer notion of the will's freedom as "liberty of spontaneity" and to the older religiously motivated view as "liberty of indifference" (Kenny, 1973, esp. pp. 97–112). The problem with the biblical view which precipitated the emergence and eventual predomination of the new liberty of spontaneity interpretation was that the doctrine of radical freedom appeared to contradict the modern powerful mechanistic understanding of the physical universe. Whether or not there really is any deep contradiction between classical mechanics and the will's radical freedom, the thinkers of the enlightenment certainly believed there to be this antagonism. Moreover, the same idea is prevalent today in spite of twentieth century developments in our physical understanding of the universe that apparently obviate the conflict. Here I will show how the contradiction can be overcome by employing complexity theory and quantum mechanics to characterize a physical system that could exercise radically free will. Compton (1935) argued along these lines fairly early in the development of quantum mechanics. He did not attempt, as I do here, to articulate a specific mechanism through which quantum mechanical indeterminacies could emerge at macroscopic levels of scale. The resulting account is non-dualistic in the sense that no spiritual entity beyond the physical world needs to be posited in order to accommodate, within a thoroughly naturalistic science, both the experiential sense of radically free agency and the correlative concept of a radically free will.

I begin my efforts by clarifying this concept of radically free agency. Then I characterize the various mental capacities required for self determination. Using complexity theory and fractal geometry, I next show how the human system of nerve cells could possess these capacities. In the following part of the paper, I use quantum mechanics and complexity theory to describe how atomic/subatomic indeterminacies in nerve cell activity could "percolate up" to the level of scale at which radically free willing obtains. I follow this, again using basic ideas from fractal geometry, with an explanation of the sense in which an indeterministic nervous system could yet be *self determining*. I conclude the paper with remarks on the empirical verifiability of my interpretations.

The Traditional Doctrine of the Radically Free Will

Both the liberty of spontaneity and the liberty of indifference conceptions of the will's freedom presuppose that willing is self determination. This means that when a person wills a bodily action, the principle of the resulting action is within the agent instead of being external to the person. Actions like this are ascribable to the person as "doer" only in so far as three conditions are fulfilled. First, the agent must be aware of what he is doing. If this condition is not fulfilled then the behavior that ensues is not caused by the individual *as a conscious agent*. The principle of the activity would be external to the person. In addition to knowing how his body is moving, the agent must be the cause of that behavior. In other words, either *his* desires or *his* acts of will must bring about his bodily activity. If something else (for instance, someone else's desire or act of will) causes the behavior then it is not ascribable to that person as doer. Finally, for an action to be self determined it must be "self referentially caused" (Donagan, 1987, chapter five; and Searle, 1983, chapters three and four) or, in the language of psychoanalysis, must be "ego-syntonic." This means that when I determine my own act, I will (or want) the action to occur *as a result of* my willing (or wanting). Part of the content of an act of will (or desire) is that the willed action be caused by that act of will (that desire). For instance, if I will (or desire) to raise my arm in order to attract someone's attention then what I am choosing (or wanting) is that my arm rise *by* my willing (or desiring). If my arm goes up because of some other cause, for example, someone lifts my arm up at just the right moment, then even if I am aware of what I am doing and will (or want) to do it, my behavior does not occur *as* I will (or want) it to occur. Again, the principle of the action would be external to me.

Clear cut examples of actions brought about by external principles include being physically forced into action by other people or being moved to act by forces of nature acting on one's body. Less clear examples of external causes are "ego-alien" compulsions and "irresistible" impulses. Even less clear examples of actions that are not self determined are habitual actions, that is, ones that were initially deliberately determined by oneself, now occur automatically outside awareness and yet could readily be made objects of conscious choice. Though the distinction between internal and external sources of action is difficult to articulate in theory and difficult to discern in certain practical situations, it is based on a ready intuition: willed actions flow from myself.[1] In the language of phenomenology, willed actions exhibit "interiority." Behavior which is not willed is determined "from without," not by the agent, and may be "ego-dystonic." Two quite different interpretations of the *freedom* in this self determination have been developed. Moreover, these interpretations are concomitant with different conceptions of the measure of interiority (syntonicity?) of willed action.

According to Hume's liberty as spontaneity conception of freedom, a freely willed action occurs when the act is in accord with what a person *wants* to do. In effect, the action flows *spontaneously* from the agent's desires. A person acts unfreely, on this view, when in addition to her desire to do what she is doing, she also has a very strong desire to do something else. For example, if she dines with the Jones family on Thursday night, but also strongly

[1]For very illuminating discussions of these issues see Donagan (1982) and Kenny (1978). The relevant passages in Aristotle are at *Nicomachean Ethics* 1110a.

wants to remain at home to work on a project, then she will regard herself as acting unfreely, as under duress, as "torn." If it is not the case that she would rather be doing something else and just really wants to be dining with the Joneses then she will take herself to be acting freely. Hume argued that this way of conceiving of freedom is quite compatible with determinism (compatibilism) since the strongest desire *always causes* the agent to act (or at least try to act). And Hume (and Dennett, 1984; and Spinoza, 1677/1992) further claimed that if someone thinks his action is not determined to occur and is free in some radical way then that is simply due to his being unaware of the cause of his act (which is always the strongest desire in the case of a self determined action).

Action is self determined on this conception of human freedom because the desire which causes the action is the agent's own, the agent is aware of that desire and wants that desire to be the cause of the act. This admits of degrees to the extent that the agent's awareness of her own desire admits of degrees and to the extent that the agent *wants* to be moved by the desire that in fact motivates her. The less aware the agent is of her own desire that causes her to act, the less the action is her own — something unknown to her is causing her to act. The more conflicted is the agent about the desire that causes her to act, the less is the act her own. In this case she is torn between two desires — the desire that in fact motivates her and another desire that she not be so motivated. Often this conflict causes the self referential content of the original desire to act (i.e., that the action occur *by* that desire) to become explicit in consciousness. When a person is torn in this way only a part of her own self determines what she eventually does. The principle of the action resides within the agent in the fullest sense when the agent is fully aware of her desire that causes her to act and she fully wants that desire to cause her action (Frankfurt, 1981). It is important to note that on this view, self determination obtains even if the desires which cause the action are causally determined in their turn and no "break in the causal nexus" occurs. The simple fact that the person's desire intervenes between that which causes the desire and the person's action (which is proximately caused by the desire), suffices to render that action self determined.

This understanding of freedom accords well with a common intuition about our own actions — we *feel* most free when we are doing what we most want to do and have no strong desire to do something else. The view was adopted by Hume and the British associationists and utilitarians. As Goldman argues, it seems to be the understanding of human action presupposed by game theory, choice theory, economic science and most of twentieth century psychology (Goldman, 1970, chapter five; cf. Davidson, 1980b; and von Neumann and Morgenstern, 1944, chapter one, sections 2 and 4). This conception was originally developed in light of seventeenth/eighteenth century mechanistic theories of the natural world and ever since has been associated with deterministic metaphysics.

Champions of Hume's liberty as indifference conception of the will's freedom take at face value that we do not experience the reasons for our behavior as causally sufficient for our actions (Searle, 2000). Because of this causal insufficiency of reasons for action, there is a causal *indifference* (indeterminacy) between what the individual does and his doing something else. Accordingly, on this view, the action of a person is freely willed if it is within the agent's power (or ability or capacity) to act otherwise. If I freely dine with the Jones family then it is within my power to do something else, even if this other act is minimally understood as the act of omitting to dine with them. Action occurs only if a person wills it, but it is within the person's power to will the action *or not*. Hence, on this conception, there are not necessary and sufficient conditions for willing a specific action to the exclusion of others since if there were, then I could not really do anything else. This led Hume to claim that such an understanding of freedom is incompatible with determinism (incompatibilism). Any deterministic network of causes would be sundered by the freely willed actions of human agents.

Within this view of volition the person's desires (wants, needs, drives, impulses, appetites, etc.) are taken to incline a person to will an action (inclinations), but not so much as to determine the action to occur. In a sense, the individual's desires and his beliefs about how to satisfy those desires form a set of motives of conduct from among which the person selects by a free act of will. This entails that the strongest desire or the most powerful motive never of itself issues into freely willed action (Descartes, 1649/1989, articles 41–47; Leibniz, 1707/1951).

Action is self determined on this interpretation of freedom in ways parallel to those noted in connection with the spontaneity conception of freedom — the agent is aware of the action she chooses and wills that the action occur by her choice. Of course, any desire which inclines the agent to the act is also *her* desire. Hence, if she freely chooses to act as prompted by this incentive then the self determination of her action which is due to the fact that the *desire* is hers is added to the self determination of the action which is due to *her* choosing to act in the way prompted by her desire. This indicates that within the indifference conception of freedom action is self determined in the further sense that the *person herself* determines her own behavior. Self determination, in this added sense, can be readily characterized using traditional metaphysical concepts — the "substantial" self causes itself to possess an "accident" or property, that is, the action (Crosby, 1996, chapter three; Korsgaard, 1989). In doing this, the substantial self may cause itself to possess a property that it is already disposed to possess by another of its own properties, that is, any desire the person might have to do the freely chosen deed. In the same terms, according to the liberty of spontaneity conception, the substantial self *is caused* to possess a property (the action) by another of its own properties (a desire). The self is functioning at most as a conveyance of causal influences (instead of as a primary initiating source of causal influence).[2]

In sum, according to this conception of radical freedom, the will is a psychological faculty or power by which a person acts.[3] An act is *self determined* in the sense that the activation of this ability (actual willing) is determined to occur by the agent whose capacity it is. An act is *free* in the sense that the agent is not determined to exercise the capacity and is not determined to not exercise that capacity, in any situation in which its activation (action) is possible. This interpretation of the will's freedom accords well with our intuition, when doing a deed, that it is within our capacity to stop what we are doing and head off in some other direction. It is also quite compatible with our intuition that supports the liberty of spontaneity conception — that we are most free when doing what we most want to do. The indifference view has been held in various forms by Anselm, Duns Scotus, Ockham, Descartes, Leibniz, Reid, and Kant. Though the conception has not been popular in this century it has had its adherents and has enjoyed something of a revival in recent decades (Bishop, 1983; Campbell, 1967; Chisholm, 1966; Donagan, 1987; Greenwood, 1988; Kane, 1994, 1996; all of the articles in part II of O'Connor, 1995; and Taylor, 1966, 1979).

Duns Scotus claimed that this type of agency is unique in the natural world since all other powers of action necessarily are activated in the presence of their appropriate "triggers" (Roberts, 1973; Wolter, 1990). Though human beings might be unique in this respect they are clearly not unique in being physical, material, bodily beings. Hence, the question arises: How could the bodily nature of human beings allow for this type of free action which is self determined and yet also undetermined? In what follows I attempt to show how a material object like the human nervous system could possess this apparently contradictory ability.

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[2]In these formulations the concept of self or substantial self need not be understood as referring to some immaterial or trans-physical entity. On either view of the will's freedom, a substance can be regarded simply as that which exists in itself and bears properties. An accident or property is simply that which exists in something else. In these senses, any individual human being is a substance and the actions and desires of that human being are features of the substance. This does not entail that human beings or any other substances have absolute self subsistence. The substances that exist in this universe might exist in themselves only relative to the set of laws that constitute this system of nature and only relative to very specific conditions within this system. Also, substances do not exist simply as such — what actually exists are substances and all of their properties. Hence, an individual existing human self, a referent for the indexical first person pronoun, "I," is both the bearer of properties and all of those properties.

[3]For a superb contemporary formulation of the traditional concept of a causal power see chapter five of Harré and Madden (1975).

The Complex Bodily Nature of Human Beings

From a naturalistic perspective, any thing capable of determining its own activities would have to be a *structured system* of physical stuff since neither unstructured "clumps" of matter nor uncompounded material elements possess such a capacity. It follows that the problem is to characterize the organization matter must have in order for a thing to have the power of self determination. Solving this task involves isolating the component functional abilities that are exercised in self determined activity and showing how an arrangement of material elements could have these constituent capabilities. Fortunately, neuroscience has revealed the human nervous system to have a functional structure that allows it to possess the requisite component abilities and hence to be capable of self determined activity.[4]

The whole nervous system is a complex organization of nerve cells.[5] The parts of this system, 100,000,000,000 neurons, are all connected to each other directly or indirectly, each neuron being connected on average to 1000 other neurons (for a total of 100,000,000,000,000 connectivities). These ele-

[4]Contemporary attempts to understand both human neurophysiology and human psychology are formulated in information theoretic terms. The hope is that using this theory in both domains will provide a basis for identifying mentalistic accounts of human behavior with physiological descriptions. The theory of information, originally developed by Shannon, Weaver, Wiener, MacKay etc, is a quantitative articulation of Aristotle's roughly hewn concept of the formal cause (as MacKay, 1980, pointed out; see also Dechert, 1965). Aristotle argued that any thing which changes (i.e., any physical thing) must be a composite of form and matter. The human being is a type of composite—the soul is the form and the body is the matter ("the soul is the form of the body"). Hence, the soul is the formal cause of the actions of a human being as a composite. This means that changes in the organization of the matter are to be explained in terms of the organization of that matter and not only in terms of the matter so organized. This is an abstract formulation of the current paradigm that informs cognitive neuro-science, namely, that the changes human beings bring about and undergo are to be described and explained as information transformations (for two interesting examples see Goldberg, 1998; Sayre, 1976). It is worth noting that this general framework is metaphysically dualistic. Information states and structures are different from their carriers or vehicles. The same information can be carried by (or embodied in or instantiated in) very different mediums. However, this dualism is not (or not necessarily) non-natural — the human being is a physical entity composed of matter and form, *like all other physical things*. This is very different from classical Cartesian dualism which is super-naturalistic — the human being, *unlike all other physical entities*, is an immaterial unextended soul stuff which is linked somehow with a quantity of extended matter. In any event, Aristotle's naturalistic metaphysical psychology was thoroughly lacking in detailed articulation of the form (of matter) that is the human soul. It is exactly this deficiency which has been made good (on a grand scale) by the last fifty years of information theoretic investigations of human psychology and neurophysiology.

[5]A complex system is one in which the parts of the system are structurally and functionally related to other parts, either directly or indirectly. The degree of complexity of a system is proportionate to the degree of interconnectedness of the elements. In systems with the highest degrees of complexity, every part is directly connected with or functionally related to every other element of the system. The activity of a whole complex system is a function of the activity of the parts that make it up and vice versa (Kauffman, 1993; Minsky, 1985).

ments are organized into larger scale groupings which are organized into yet larger scale sets, etc. through an ordered hierarchy of levels of scale up to the organized whole of the central and peripheral nervous systems. Units on any level of scale are functionally connected to units on other levels of scale — the activity of one mass of neurons is caused by the activity of some other mass of neurons and in turn precipitates activity in yet other masses of neurons.[6] If even as few as ten neurons operate as a functional unit and ten of these units act as a functional cluster and ten clusters function as a set etc., then all 100,000,000,000 neurons can be ordered into a functional whole well before the twelfth iteration of such a structuring scheme (cf., Minsky, 1985). This very roughly indicates the number of levels of functional scale in the nervous system. The grouping of neurons into these functional units undergoes continuous change — the activity of a neuron (or mass of neurons) will contribute to the functional activity of different masses of neurons over time. Some of these functional groupings are permanent and are either innate or formed early in life. Other groupings are temporary and are formed on an as-needed basis. The individual neurons organized into these systems exist within a range of activation states which lead up to electro-chemical outputs to other neurons and both the state and output of each neuron is a function of electro-chemical inputs from other neurons. When the system as a whole is active, the *dynamical* complexity is inconceivably great. This dynamical complexity is the form or pattern of the electro-chemical activity of the interconnected neurons over time (Diaz, 1997). Just as the static structure of the nervous system as a whole consists of individual neurons connected into groupings which in their turn are grouped into units, so too the activity of individual neurons is related to the activity of other neurons so as to form active functional groupings. Activity of a group on one functional level is related to activity of other groupings at that same level of scale and to activity of units on other levels of scale. The highest level of functional scale is simply the activation of the whole nervous system and the form of this mass activity is the temporal pattern of the spatial pattern of all individual neuron firings.[7] This dynamical spatio-temporal pattern of activity of the whole nervous system contains within itself relatively distinct functional sub-patterns of neural activity on various levels of scale. Because of this feature, the nervous system can possess two functional abilities that are required

[6]Edelman and Giulo (1998) developed a formalized criterion for determining whether or not a mass of neural activity is a functional unit.

[7]Features of the temporal pattern include the order, periodicity, duration and frequency of neuron activity. Features of the spatial pattern include the shape, size, and location of neural firing.

for self determined action, to wit, the capacities for being aware of the environment and for being conscious of one's own states and activities.[8]

How the Nervous System Could Possess the Capacities for Awareness and Self Consciousness

If one of the aforementioned sub-patterns of neural activity, born within the mass of activity of the whole, were systematically caused to occur by something other than the nervous system itself (by the thing acting on the sense organs, for instance) then the occurrence of and structure of that sub-pattern of neural activity would correlate with the occurrence of and structure of the object in the environment. This would amount to a correlation between two information locations or between two information structures (Dretske, 1983). This correlation would be intentional — the information state in the organism (the neural sub-pattern) would be *about* the information state in the environs (the object) — if three further conditions obtained. First, the neural pattern would have to be caused by the object in the proper way, that is, efficiently and formally (Dretske, 1983; Sayre, 1986). Second, the neural pattern would have to structure the actions of the organism vis-à-vis that object (Dretske, 1994; Millikan, 1984). Third, the neural pattern would have to be further correlated with the information structure that is the spatial location of the sense organs and that spatial information structure would also have to be contained within the organism (Pestana, 2000). If these conditions were fulfilled then the relation between a pattern of neural activity and some object in the environment would be intentional.[9] In this way, the human nervous system could possess a capacity that is analogous to, and possibly identical with, awareness of the environment. If the activity of this same system were also fractal-like then it could possess a comparable capacity for self consciousness.[10]

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[8]I use the term awareness to refer to first order acts of mind, that is, acts which have as their object extra-mental realities. I use the term consciousness to refer to second order acts of mind, that is, acts which have as their object first order acts of mind. This usage parallels the medieval distinction between first and second intentions (Poinsot, 1632/1985, pp. 48–76) and is similar to that employed by Armstrong (1968, chapter six, section nine), Rosenthal (1986) and Chalmers (1996, chapter six, part two).

[9]For problems with this causal–physical interpretation of the "intentionality of the mental" see Fodor, 1984; Loewer, 1987.

[10]I am grateful to Jeff Koperski for clarifying the distinction between "fractal," a pure geometrical object or property, and "fractal-like," a property of a physical object that instantiates to a degree the property of iterated self-similarity. Compare this distinction with that between circle and circular (Koperski, 1997). Vandervert (1995) proffers suggestive remarks concerning the fractalization of neural patterns, but does not develop them.

As is well known, fractals are geometrical forms which contain or bear within themselves, at multiple locations and at different levels of scale, other forms, which in turn bear within themselves, again at multiple locations and at different levels of scale, other forms and so on, without mathematical limit. Fractals can also bear within themselves, again at multiple locations, forms of themselves. In fact, this iterated self-similarity has been regarded as a defining feature of fractals ". . . . possessing symmetry across scale, with each part of the object replicating the structure of the whole" (Addison, 1997, p. 2). A pattern of neural activity would be *spatially* self-similar if the neurons that are firing simultaneously form in space a pattern that replicates within itself at smaller levels of scale the spatial structure of the whole. A pattern of neural activity would be *temporally* self-similar if the neurons that fire form a pattern over an interval of time in which are replicated over shorter durations the structure of the whole period (as with a melody in which a phrase is iterated within itself). Clearly, a firing pattern could be both spatially and temporally self-similar (Moon, 1992, pp. 401–406). This pattern would bear within itself forms of neural activity on smaller levels of scale that were identical to forms of its own activity on larger levels. If the pattern of the highest functional order of activity in the nervous system as a whole were fractal-like then the global activity of the nervous system would exhibit self-similarity. Furthermore, neural activity at the fractalized highest functional order could contain sub-forms of activity (information states) that were *about* that highest functional order (global information state), if causal/intentional relations existed between the iterations of self-similar patterns of neuron firing. In this way, the human nervous system could possess a capacity that is analogous to, and possibly identical with, self consciousness.[11] In addition to this functional ability (and the capacity for awareness),

[11]Self consciousness cannot be just a matter of one part of the brain monitoring another part of the brain (as in Johnson–Laird, 1983). Even if one part of the nervous system monitored another part and yet a third part of the system monitored the relation between the first two parts etc., the final monitoring system in any such series would have to be capable of monitoring itself. Otherwise, the system as a whole would not be capable of receiving information about itself as a whole since it could not receive information from or about that final monitor system. The definitive feature of self consciousness is that it is self-iterative, I can think about my thinking about my thinking about . . . . Of course, there are subjective limits to these self reflections. Note, in this vein, that the self-similar sub-patterns contained within a global self-similar pattern of activity in the nervous system necessarily would each have reduced information content. In any physical fractal-like object there is a loss of information at each iteration of self-similarity because the iterations use up elements until there are simply not enough left to further carry the pattern. Perhaps it is this loss of information with successive iterations that is being phenomenologically manifested when people experience their own incapacity to carry out, beyond three or four iterations, acts of self reflection.

self determined action requires the capacities for acting to bring about desired changes in the environment and for acting to bring about desired changes in oneself. How could the human nervous system possess these additional powers?

How the Nervous System Could Possess the Capacity for Self Determined Action

In the case of awareness of the environment, the *direction* of causality is from the world to the person and in the case of self consciousness, the *direction* is from parts of the person to the whole person. In human action, this "direction of fit" or "fulfillment" is reversed (Searle, 1983, pp. 7–13 and more recently, 1998, pp. 100–103). When she acts, a person causes her environment to conform to her mind. This activity is a function of the person's desire for an outcome, her belief that the activity will lead to the outcome and a consequent desire to engage in that behavior. Whether or not any specific desire to act results in behavior depends on the interaction of a multiplicity of co-existing conflicting desires to act (derived from a comparable multiplicity of desires for outcomes). An individual might not sense these desires at all or might vaguely experience them as felt urges or might quite self consciously identify and name them. In any event, self determined action is possible only when the agent is conscious of her impulses to act. The transition from being conscious of a multiplicity of these desires to actual behavior occurs when the person attends to one desire to the exclusion of others. In short, action follows upon a person focusing her consciousness intensely on a specific desire to act.[12] This appears phenomenologically as losing oneself in or becoming completely absorbed by the object of attention, which in this case is a deed to be performed. Behavior that occurs in this way is self determined in the sense that it is *the person* who attends to *her own* desire to act. Furthermore, since the agent attends to her desire to act *as* cause of her behavior, the resultant behavior is self-referentially caused. Obviously, in the spontaneity conception of the will's freedom, the act of attending to a desire to act is itself regarded as caused by that desire (Bricklin, 1999). According to the indifference conception, the attending would be uncaused (how this is possible will be addressed in the next section).

[12]Many philosophers and psychologists have analyzed willing as a function of attention, for example, Bricklin, 1999; James, 1890/1952; Lindworsky, 1929; Schwartz, 1999; see also Eccles, 1990.

Now, the action of any complex physical system, which is caused by itself, is a function of the activities of its parts.[13] These internal activities maintain the system in a "quasi-stationary steady state" of energy exchanges with its environment (von Bertalanffy, 1968). By a continuous process of assimilating usable energy from the environs and returning, as a by product, used up energy to the environs, complex physical systems like organisms maintain themselves in existence (precisely as such things). The dynamical process is only *quasi-stationary* because it changes as the organic system grows, develops, decays and dies. Obviously, during periods of growth there is a balance of assimilation over dissimilation and during decay the reverse obtains. Thus, organisms can increase their own internal order (increase the amount of information they embody) in these operations. Actually, organic systems always maintain themselves at a higher level of order (lower level of entropy) than obtains within their surroundings and do so at an expense of order (increase in entropy) in their environs. Hence, an organism is "far from [thermodynamic] equilibrium" with its environment, as Prigogine (1984, pp.140–145) has recently emphasized. Nonetheless, there must still be a correct rate of exchange between the system and its surroundings in order for the system to be in this *dissipative* relation. When disruption of the correct rate occurs, by internal or external causes, the system is disposed to return itself to its proper rate.[14] The general neural functioning of human beings maintains this type of exchange between the organism and its environs. Patterns of nerve cell activity that are induced by disruptions of the correct rate lead the nervous system back into a pattern of overall activity in which it sustains a proper relation with the environment. This end state acts as an attractor ("final" cause) in the phase space of the ongoing activities of the nervous system (Horgan and Tienson, 1992). In this way, the dispositions of nervous system activity to move the whole system of activity into the prop-

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[13]Here I follow up on the analysis given by Vandervert (1995) in the appendix of his article and on Kane's (1994) suggestions. The issue here is a special case of the problem in classical metaphysics of the relation between efficient and formal causality. The sequence of neural firings is a patterned sequence of forms. The most basic form of any movement through various (information) states of a system is a trajectory toward the lowest energy state of the system. In complex organic systems, this tendency is *locally* reversed.

[14]Deviations from the dissipative steady state (caused by environmental impact or by internal forces) can occur by *excess*. That is, the system is put into a pattern of activity in which it accumulates more energy from the environment than it can convert to structure or discharge into the environment (and at its particular stage of development this is deleterious to its self maintenance). This is comparable to, or even identical with, a *drive* or *impulse* which induces behaviors which succeed in discharging the accumulation. Disruption of the dissipative steady state of exchange can also occur by *deficiency*. That is, the system is put into a pattern of activity by which it discharges more energy than it accumulates or loses structure. That is comparable to, or identical with, a need or want which leads to behavior which succeeds in replenishing the system.

erly proportioned rate of exchange with its environment are at least comparable to and possibly even identical with desires.

Most of the time multiple causes are disrupting the normal relation between the nervous system and its environs and are thereby inducing a multiplicity of patterns of nerve activity each of which would tend to rectify that relation. Accordingly, the distinct neural patterns that are a person's desires interfere, sum or interact in some manner to produce behavior. The strongest desire is that tendency induced in the whole system of nervous activity by the greatest deviation from the proper rate of dissipative exchange. When a strong tendency enters consciousness, the global self-similar pattern of neural activity bears a sub-pattern that is caused by and is a pattern *of* the strongest disposition of the whole system to adjust some severe deviation from its steady state. If the person is conscious of possible courses of action that would satisfy her strongest desire then this self-similar neural pattern bears within itself sub-patterns *of* possible future sequences of activity of the whole nervous system that would lead to the adjusted state. Self determined action occurs when a specific antecedent *sub-pattern* of neural activity (that is consciousness of a disposition to rectify, by a possible behavior, a disruption of the steady state within the organism) comes to be instantiated in activity of the nervous system *as a whole* (which would be the person acting to rectify that deviation from steady state). In other words, when a person attends so intensely to a possible course of action that behavior actually ensues, the global self-similar pattern of neural activity that is awareness of the environs and consciousness of the self takes on a pattern that is the deed performed (which pattern the self-similar system previously bore at a lower level of scale).

All of this indicates how a physical system could be self determining (but cf. Searle, 1983, chapter ten). However, it is not clear how actions self determined in this way could be radically *free*.

How Nervous System Activity Could be Radically Free

According to the conception of the will's freedom as causal indifference between options, human beings are capable of action that is brought about by the person, yet is not determined to occur (is freely brought about). The latter characteristic entails that, at least, some of the actions of the human body must be *indeterminate*.

An indeterministic system is one in which the system's previous states do not completely determine its subsequent states. This means that if two indeterministic systems begin in precisely identical states then it is possible for any subsequent states of the two systems to be quite different. In other words, the previous states are not necessary and sufficient conditions for a specific subsequent state *to the exclusion of* other possible subsequent states. An antecedent state determines a set of possible subsequent states and thus is necessary and sufficient for whichever one of those (possible) subsequent states actually obtains. A deterministic system is one in which subsequent states are completely determined by previous ones. If two deterministic systems begin in exactly the same state then any of their subsequent states will be exactly the same. Previous states are necessary and sufficient for the subsequent state that obtains and no other subsequent states are possible.[15]

Twentieth century science has conclusively demonstrated that at the level of fundamental constituents of the universe, determinism does not obtain.[16] This appeared to open up the possibility that the traditional theory of a radically free will might not contradict our physical theories (but see Eddington, 1958 and Jeans, 1943). If the building blocks of the universe do not behave deterministically then perhaps human beings who are composed of such blocks do not behave deterministically either (Harkevy, 1995; Margenau, 1967).

The problem with this idea was that the micro indeterminism of elements in any physical system seemed to cancel out in the aggregation of elements into a macro level system. Thus, in spite of micro level indeterminism it appeared that determinism still held at the level of scale at which cognitive and volitive information processing occurs. This is the position of those who reject the concept of radically free willing (for instance, Dennett, 1984 and, so it seems, Searle, 1998). More recent developments in complex systems theory provide a way of understanding how micro indeterminism might not be aggregated out of existence at macro levels of scale. My account of this begins at the micro level.

Eccles (1953, 1994) has claimed experimental evidence that the firing of a neuron can be an indeterministic event. He postulates that neuron output is indeterministic when it has been "critically poised," just at the threshold of sparking an output, by the previous inputs it has received from other neurons. It follows that if two neurons are in identical critically poised states then, with identical inputs to each, it might happen that one sparks an output while

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[15]A chaotic system is one which is "sensitive to initial conditions." This means that two chaotic systems in minutely different initial states will most likely be in different subsequent states. The more chaotic are the systems, the more sensitive they are to initial conditions and the more rapidly will occur the divergence between their subsequent states (assuming again some slight differences between their initial states). It is generally held that chaotic systems are deterministic, but see Kellert (1993, chapter three) and Polkinghorne (1998, pp. 63–66).

[16]I assume the "no hidden variables" position. It seems that the majority of physicists regard the indeterminism of quantum mechanics as descriptive of reality. That is, the dynamical properties of objects at very small levels of scale are indeterminate in their actual being (at least until some act of observation or measurement determines the property). Here I rely on Capek (1961, chapter XVI). Herbert's (1985) popularization contains an accessible exposition of the various interpretations of quantum mechanics and of the problems of the hidden variables approach.

the other does not. Only some neuron firings occur indeterministically in this fashion — a neuron that has been pushed by inputs far beyond the threshold is determined to fire by those inputs. In a sense, Eccles is claiming that some neurons (perhaps those with massive connections) on some occasions (when they have been critically poised to fire) act as quantum percolators, percolating indeterministic actions at the atomic level of scale and smaller up to the level of scale of very large molecules. Several sources of this indeterminism in neuron firing have been postulated (Kane, 1994; Penrose, 1994; but see Wilson, 1999). Eccles (1986) himself claims that it is due to the quantized nature of the emission of neurotransmitters from vesicles at the synaptic cleft. Whatever the source, if Eccles is correct about this (occasional) indeterminism of neural action then another indeterminism percolator is still needed to bring this micro indeterminism up to the level of action by the whole person. This is where complexity theory enters the picture.

Recall, a complex system is one in which the activity of the whole is a function of the activity of the parts and the action of every part is a function of the action of many other parts (the parts are highly functionally connected with each other). Kane, quoting Globus, describes the complex functioning of the nervous system as follows:

> The operation of such networks is holistic in the sense that, as Gordon Globus puts it, "the influence of the whole net [of neurons affects each] individual node [each neuron] and the influence of the individual node [affects] the whole net." As a consequence, such networks can be sensitive to variations of firings of individual neurons. As Globus says, "Make a few changes in the connection weights [the excitatory and inhibitory potentials of neurons] and functionally everything changes [in the neural network] via non-linear interactions . . . the net spontaneously and probabilistically self-organizes."[17] (Kane, 1994, p. 47)

Because the indeterminism of a neuron is a function of its general internal state which, in turn, is a function of its inputs from other neurons (the action of many of which may be indeterminate), any indeterminism in the output of an individual neuron would be functionally related to indeterminism in the activity of other neurons. Therefore, due to the high degree of interconnectedness of the elements of the nervous system, it is possible that indetermination in the action of parts *need not* get canceled out in the aggre-

[17]James Garson has argued as follows: "Chaotic systems are, by definition, perturbation amplifiers. They can override the general rule that quantum mechanical indeterminacies cancel out at the macro-level" (quoted in Kane, 1994, p. 46). This is misleading. The nervous system "overrides the general rule" because the neurons are functionally and massively interconnected — the nervous system is a *complex* system. Not all complex systems behave chaotically (nor are all systems that behave chaotically, complex). Even if the brain did not behave as a chaotic system, quantum mechanical indeterminacies could still percolate up through the mass of interconnected neurons.

gating of those constituent activities into the behavior of the whole. In fact, the system as a whole might be *more indeterminate* in its functioning than in its parts — the probability that a single critically poised neuron will fire might be multiplied by the probabilities of firing of all the other critically poised neurons with which it is connected. Thus, functional aggregations of neurons could exhibit a high degree of indetermination in their massed action.

It seems possible that transitions from specific antecedent *sub-patterns* of neural activity to subsequent instantiations of those patterns by the nervous system *as a whole*, that is, self determination, could occur in this indeterministic manner. This would mean that a pattern of nerve activity that was the person's consciousness that doing X would satisfy her desire for D would deterministically cause *both* the set of neurons, the firing of which would be her doing X *and* the set of neurons, the firing of which would be her *not* doing X (the act of omission), to enter the critically poised state. The agent's actually doing X (or omitting to do X) would be determined to occur neither by her desire to do X (or to omit doing X) nor by her consciousness of the action's relation to her desire. Only the potentiality for doing or not doing X would be deterministically activated or, more generally, only the set of *possible* states of activity into which the nervous system could evolve would be determined by the history of the actual states of the system.[18]

Of course, if the nervous system were critically poised in this way, it is *determinate* that it would transit into *some* next pattern. Energy would flow through the system and the current global information state would be followed by some other global information state. So too, according to the conception of the will as radically free, in any situation of choice, it is determinate that the person will *do something*. At a minimum the agent either will choose to do X or she will choose to omit X.

Moreover, if the nervous system operated in this indeterministic fashion then its probabilistic transitions would obey laws of distribution, as in any quantum mechanical system, and, accordingly, would be explicable and predictable *in the mass*. So too, radically free actions are taken to be explicable and predictable in the mass (Campbell, 1967). In this conception of free will it is conceded that desires incline a person to will, that there are determinate causes of those desires *and* that people tend to choose in accord with their strongest desires (Donagan, 1987, pp. 170–171). Thus, different sets of very large numbers of choices between action X and action Y, where X is desired more than Y, could yield the same distributions between the two choices. To

[18]This would be a special case of the evolution of a quantum mechanical system as determined by its initial conditions and the Schrödinger equation (Mohrhoff, 1999, p. 174; Stapp, 1999, p. 157). In psychological terms, the history of a person's choices (of which motives determine his actions) determines the strength of and content of his motives in the future (Hodgson, 1999, p. 206).

this extent freely willed actions fall within ranges of explicability and predictability (and the utter randomness that Jeans and Eddington feared is greatly curtailed).

Nevertheless, in all quantum systems, lawlike distributions in the mass still leave individual actions or events indeterminate (Compton, 1935, pp. 62–63; Frank, 1957, chapter ten). In other words, though the earlier state of a quantum mechanical system is both necessary and sufficient for whichever of its later possible states actually occurs, there is no sufficient cause for one subsequent state X to be realized *instead of some other*. In the conception of the will as radically free, reasons (belief and desire sets) do account for or explain an act. To the question, "Why did you do X?," the response can be proffered, "Because I thought that doing X would cause state of affairs D and I wanted D more than anything else." However, if this questioning continues with, "But why did you do what led to D when you could have done *something else instead*, even if that would have led to a less desired state of affairs?," then no response can be forthcoming. There is no reason that accounts for, no explanation for (and no sufficient cause of) the actual course of conduct *to the exclusion of* some other possible course.

Those who reject radical freedom of will either reject this as nonsense (Dennett, 1984) or explain it in terms of non-conscious mechanisms that can cause a person to behave contrary to conscious motivations (Davidson, 1980a, 1982; Smith, 1999). Those who endorse radically free agency regard people as not determined by their desires and hence as able to act contrary to what they most want or have the best reason for doing. According to this conception of free will, then, there remains an ineradicable element of inexplicability and unpredictability in human action (Campbell, 1967, pp. 45–49; Donagan, 1987).[19] This mysteriousness would be the mysteriousness of quan-

[19]What adaptive value would a capacity for inexplicable action confer on its possessor? I will only briefly mention several responses to this question proffered by others. McCrone (1999, pp. 254–256) argues that the self determination of action would be selected for to the extent that it was adaptively advantageous for responses to be freed from control by the environment. Claxton (1999, p. 109) argues that the indetermination of action weakens the link between conditioning and response. This in turn allows for a form of highly advantageous "retarded cognizing" about future actions by which the organism is not precipitated into action. The practical syllogism only results in a probability state concerning the next act of the organism and in this last moment (just before the will is exercised) further last minute information processing can occur. Brown (1999, p. 28) argues that indeterminism in the link between conditioning and response allows for radically innovative, even mutational, responses. Structures that gave the capacity for indeterminate action would be selected for to the extent that they occasioned novel, flexible and creative responses to the environment that were more advantageous than those conferred by other structures. Finally, as Dennett (1984, pp. 66–73) indicates, the severing of determinate links between conditioning and response makes behavior unpredictable by competitors or by prey. A quantum mechanical randomizer of behavior would be selected for to the extent that it served (better than other mechanisms) to protect the organism in this manner.

tum mechanics (coupled with oddities of fractal self-similar geometries), if indeterminacies at the smallest levels of scale were being exhibited and experienced at the macro level.

This interpretation shows how a macroscopic material system could exhibit the indeterminism required for radically free will. The problem now is that the interpretation appears to contradict the previous account of how a physical system could be self *determining* in the manner required in this conception of will.

The solution to this dilemma depends on a critical difference between the indeterminism of the micro level neurons and the percolated up indeterminism of the nervous system as a whole. The whole human being is a structure that *contains information about itself, that is, about its current, previous and subsequent (possible) states*. A critically poised nervous system would determinately specify the range of these subsequent possible states. Accordingly, that critically poised state would be both a necessary and sufficient condition for the subsequent state which actually obtained. If this system of neurons were globally self-similar in its activity then any one of those subsequent states would contain information about its own previous critically poised state (in which it had been carried as a future possibility). Hence, the actual subsequent state of the system would contain information to the effect that the previous (critically poised) state of the system had been necessary and sufficient for the subsequent state to occur. But this means that the subsequent pattern of neural activity in a globally self-similar system that had been critically poised would contain information about its *current* state *as caused by* its own previous state. To put this point (clumsily) in quantum mechanical terms, if the activity of the nervous system as a whole contains information about its own "superposition" of possible states then the system as a whole can be regarded as bringing about the "collapse of its own wave function."[20] Nothing would cause a person to collapse her own wave function, she would not be caused to attend to any specific possible act by her desire to so act. And yet, this act of attending would not *just* be a matter of probabilities, would not *just* occur "by the odds," since *she* would realize that probability

[20]This formulation makes evident the extent to which my interpretations go beyond what is conventionally considered in physics for in this case a quantum mechanical system includes within itself the observer of the system. It is important to emphasize that so regarding the whole system (the person) as the cause of its entering into a subsequent state does not entail altering the probabilities of what will occur. Mohrhoff (1999, section IV) quite convincingly demonstrates that if the probabilities were so altered then laws of nature would be violated, specifically the characterization of the evolution of quantum systems according to the Schrödinger equation. Obviously, if I attend to one action possibility to the exclusion of the others then the probability for that event is changed (to unity). But this does not alter the probability distribution before I so attend.

and could have realized an other. This combination of self referential causality and indeterminism is precisely radically free willing.

Empirical Evidence and Summation

The conception of the will as radically free accords with the intuitions that we determine our own actions, that our acts are not caused by anything else and that we are always able to choose otherwise. If the human nervous system operates in the "indeterministic self determining" manner described in the previous sections then we have such intuitions precisely because we work that way.

Though there are these congruencies between our intuitions, the concept of free agency and my speculations about operating modes of the nervous system, the exercise of radically free willing would be empirically undetectable.[21] Inducing a subject to alter the probability distribution of his future possible actions by exercising his free will (and thereby detecting different effects of the operation of the power), would itself change the probabilities. Suppose my life history results in a .2 probability for my freely doing X in some circumstance. That means that as this type of situation is repeated, the number of my actual choices of X approaches 20% of the total choices I make (in those circumstances). Further suppose that I want to alter this distribution in order to prove that I have free will (and can choose X more often). Well, that very want would change the probability of my doing X to begin with. Hence, there would be no way of detecting the selection effect of my free self determining.[22]

Notwithstanding this empirical unverifiability, it appears that the traditional concept of the will as radically free can be quite consonant with our

[21]It appears that Libet's empirical work (as summarized in Libet, 1999) contradicts my speculations. However, his experimental design fails to discriminate between intentions to act and the reports of those intentions. There can be differences between and time lags between the forming of an intention to act, putting that intention into words, and then uttering aloud those words. In addition, the design of his experiment fails to distinguish between intentions of varying degrees of determinateness. Even simple intentions can range in definitiveness from "I'm going to do something or other" to "I'm going to pull this lever here right now." As Donagan (1981) demonstrates, the history of the theory of human action has involved a progressive articulation of the concept of intention. Because Libet's experiment does not (cannot?) accommodate these articulations, it is simply impossible to tell with what the readiness potential is associated.

[22]The ontological and epistemological status of the exercise of radically free will would be analogous to the action of the pilot wave in Bohm's conceptualization of quantum mechanics. The pilot wave is empirically undetectable and yet exerts causal influence (and accounts for the entanglement of particles). Of course, Bohm's pilot wave is an integral part of a rigorous and quantified theory (to wit, his version of quantum mechanics). At this stage in the development of our understanding of how the brain functions, the notion of radically free agency only "loosely" accounts for our self experience.

understanding of the universe as achieved by the sciences of physics and biology. In terms of contemporary complexity theory human beings can be understood as self determining, if the nervous system contains patterns of its own subsequent possible total states on the basis of which it enters into those states. By the addition of quantum mechanics, humans can be viewed as radically free in this self determining, if entering into any one of those subsequent states of the nervous system is not necessarily determined to occur. As Duns Scotus claimed, this type of agency would be sui generis — exhibited in the universe only by highly complex, self similar, and indeterministic physical systems.[23]

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[23]In spite of this seeming consonance with modern science, it is still possible that free will is an illusion. Hume and Spinoza and Dennett may be in the right — we think we possess radically free agency simply because, though we are aware of our actions, we are not aware of their real and *determinate* causes. There may be a hidden variable by which our actions are determined to occur. All the same, there is one important difference between Hume's and Spinoza's position and Dennett's position. The mechanistic science of Hume's and Spinoza's day was taken to contradict the conception of the will as radically free. This is part of what precipitated Descartes' desperate attempt to "save the appearance" of free will by positing a dualism of substances. In contrast to this, the science of Dennett's day need *not* be taken to contradict the notion of radically free volition. Recourse to dualism is no longer necessary to save appearances and a scientific account of the world could encompass human beings as free in the traditional radical sense.

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