A chaotic approach to free will and determinism

Gregory J. Till
University of Northern Iowa

Gregory J. Till

Senior Thesis

A Chaotic Approach to Free Will and Determinism

I. Introduction

The debate over free will and determinism presents itself as perhaps the central and most vexing problem in Western philosophy. This problem can be expressed in a single sentence: We feel we have freedom in our ability to make reasoned decisions, yet this freedom is contradicted by the belief that every event has a cause, implying that our actions are not free but are determined. This contradiction led Dr. Samuel Johnson to sum up the problem with his slogan-like statement that "All theory is against freedom of the will, all experience is for it" (Kenny, 1).

This problem has an impact on the way we view the behavior of others. Do we act with freedom or is freedom simply an illusion? Furthermore, if it is an illusion, should we be thought of as and held responsible for our actions? The importance and difficulty of this debate are suggested in the problems the sciences of human action have had in placing responsibility for actions.

This paper approaches this ancient problem by incorporating the new science of chaos. Chaos is the name given to the discovery that even "simple deterministic systems with only a few elements can generate random behavior" (Crutchfield et al., 46). Chaos shows that deterministic systems can act in ways which are not predictable while at the same time showing that many seemingly random phenomena are more explainable than once thought. By doing so, chaos alters the laws of causation upon which much of this debate rests and indicates that perhaps not all theory is against freedom of the will, despite Dr. Johnson's statement to the contrary.

The purpose of this paper is to demonstrate that while chaos improves the case for determinism, it also shows that free will might be possible in a world that otherwise appears to be governed by universal efficient causality. In showing this, the paper is broken down into five sections, the first being this introduction. The second section reviews the free will and determinism debate to establish a context for the conclusions and to develop criteria for the advancement of each argument. The third section reviews the science of chaos to establish how it may theoretically meet these criteria and to show how chaos may be detected in behavior. After that, specific evidence of the link between chaos and behavior is sought, and in the fifth section, final conclusions are drawn from this evidence to fulfill the thesis.

II. The Free Will and Determinism Debate

As just mentioned, this section will review the free will and determinism argument for the dual purposes of developing a framework for the conclusions and establishing criteria for the strengthening of both arguments. The two arguments are dealt with separately in some detail to establish these criteria. In breaking down the arguments, the philosophical beliefs will be introduced first, followed by the scientific grounds for those beliefs. As the grounds for the respective beliefs are examined, the particular criteria which must be met for each belief to be strengthened will become clear.

Determinism is the thesis that every event is the effect of an antecedent cause (Pujmon, 397), also known as the thesis of universal efficient causality. Since human actions are events, they must be governed by these causal laws as well. Our actions are therefore determined and the belief that we have control over our actions is illusory. Free will is fiction in the deterministic model, since our actions result not from it but from the laws of causality. In the words of Baron d' Holbach, "Thus it must appear, that where all the causes are linked one to the other, where the whole forms but one immense chain, there cannot be any independent, any isolated energy; any detached power" (1: 41).

Although free will does not exist in the deterministic model, this is not necessarily the case with respect to the concept of freedom. Philosophical differences over freedom split determinism into two separate beliefs. These philosophical differences over freedom can be outlined by the respective ways they make sense of the statement, "The individual could have done otherwise." The two deterministic meanings for this statement are known as hard determinism and compatibilism.

The deterministic argument known as hard determinism denies that an individual could do otherwise, meaning that our belief in freedom is false. The laws of causation dictate that everything which has happened, had to happen. As a result, our belief that for any event we could have done otherwise is unreal, and freedom does not exist.

Without the freedom to choose our actions, we cannot place responsibility for those actions, and without responsibility we cannot have morality. Despite this, hard determinism is not without support. For instance, it provides a psychologically powerful reason for religious belief, since faithful individuals whose lives are unpleasant and seem beyond their control can hope that there is a "master plan" in store for them by an omnipotent being.

A famous proponent of hard determinism was attorney Clarence Darrow. Darrow stated his belief in a "human machine" determined completely by heredity and environment (32). He believed that since our actions are determined we are not free, and that this absence of freedom means that we should not be held responsible for our actions (31). His passionate statement of hard determinism was crucial to his well-known defense of the murderers Leopold and Loeb, and he succeeded in his attempts to stave off the boys' execution.

Nevertheless, without the freedom to choose our actions, we cannot place responsibility for those actions, and without responsibility we cannot have morality. This denial of freedom and its consequences leads many to turn away from hard determinism in favor of compatibilism. Since hard determinism is not a widely accepted view, it will not be explicitly handled in this paper. Instead, compatibilism will receive most of the attention given to determinism.

Compatibilism, or soft determinism, provides a second and more subtle answer to the question of freedom. The compatibilists realize the need to bring morality back into determinism and so argue that the statement "The individual could have done otherwise," does not refer to freedom from causal laws but to the ability to act without coercion from others. For instance, a person who decides to give a dollar to charity is acting with freedom; a child who feels he has no option but to give a dollar to the bully to prevent a beating is acting without freedom.

This interpretation of freedom relies upon a distinction between voluntary acts which are free from coercion and the laws of causation which may ultimately determine those actions. The compatibilists understand our need for freedom and argue that the causal processes which determine our actions are so far removed from our experience of behavior that we do not apply physical causal explanations to them (Bertalonffy, 221). For instance, we tend to explain actions in term of thoughts, impulses, or emotions rather than by unbreakable causal laws. By explaining actions in terms of motives, the laws of causality are bypassed and freedom is allowed.

Another way of explaining the difference is by separating statements of truth into those which are ultimately true and those which are conventionally true. Ultimate truths are facts; they are beliefs which agree with the world as our minds must experience it. They are not true merely by arbitrary agreement but are more scientific in nature. They are truths which await our discovery, rather than our invention. The universality of the laws of causality has been held to be such a truth.

Conventional truths, on the other hand, are true only by consensus. They are agreed upon abstractions or terms which are useful for our existence but have no truth value in themselves at an ultimate level. For the Western tradition of morality, freedom has been one such conventional truth. It is conventional rather than ultimate because science does not show that freedom exists on a physical, scientific level. Instead, it is an abstraction, agreed upon only by convention, which is useful in effecting the actions of others by giving rise to responsibility and morality.

Compatibilists can argue that the contradiction between freedom and determinism arises when we fail to distinguish between the two levels of truth. If we attempt to equate ultimate truths with conventional truths, we lose all abstractions, including freedom. However, since science must also show it to be an ultimate truth that we have a need for abstractions, the two levels of truth must be kept separate. Thus, we can accept the conventional truth that we are free, even if ultimately our actions are determined (Sidertis, 158).

Since compatibilism allows for freedom, morality can still exist. But since freedom exists only by convention, moral standards are not considered to be absolute and utilitarianism is the norm. Rewards and punishments for actions are generally viewed in light of their effectiveness as incentives and deterrents to future behavior (Pojmon, 414). Such a view is advanced by Ted Honderich in his essay "One determinism," where he argues that people should be held responsible for their actions even if they cannot be responsible in an ultimate sense, stating that "a man is responsible for an action if his future behavior can be affected by punishment" (206).

Compatibilism has been criticized for wanting it both ways. Critics argue that we cannot be both free and determined; the two are incompatible. Despite this, determinism has some strong scientific grounds for its adoption. Having reviewed the philosophical aspects of determinism argument, its scientific basis will now be outlined in greater detail to ascertain in what ways it could be improved.

Although the debate over free will and determinism goes back to the early Greeks, the scientific basis of modern determinism rests primarily upon the work of Newton. Newton's work substantially strengthened determinism, so much so that Newtonian laws have often been put at the level of ultimate truth. Newton seemingly showed conclusively that the universe is governed by laws of efficient causality. He made the movement of bodies describable solely in terms of physical and mathematical laws that denied the possibility of any kind of causality outside of efficient causality, precluding the existence of free will. The ability to use these laws to predict the behavior of bodies gave great strength to Newton's work.

This Newtonian conviction in prediction was stated in its classic form by the French mathematician Pierre Simon de LaPlace:

> We ought then to regard the present state of the universe as the effect of its anterior state and as the cause of the state which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it - an intelligence sufficiently vast to submit these data to analysis - it would embrace in one single formula the movements of the greatest bodies and those of the lightest atom; for it, nothing would be uncertain and the future, as well as the past, would be present to its eyes (4).

Theoretical predictability has long been part of the deterministic model.

I emphasize that all actions have been considered *theoretically* predictable since for practical reasons the computation required for such a high level of precision in prediction would require far more information than any computer could handle. Still, the old model holds that the general laws which determine our behavior are knowable, and that these laws would allow fairly accurate predictions to be made from fairly accurate data. Newtonian determinism has hoped to at least come close to predicting behavior.

The Newtonian revolution made the world describable in mathematical terms that seemingly eliminated the role of purpose in the causation of events, preventing the possibility of free will. Likewise, by establishing the atomic theory as a foundation of empirical science, Newton helped us redefine ourselves as molecular people. As a result of being defined in purely physical terms, we are describable through Newtonian determinism, which means our behavior is theoretically understandable and predictable. An example of this is given in Mindwatching, a 1983 book by Hans J. and Michael Eysenck. The authors state, "What do psychologists hope to learn from their study of behavior? Ultimately, the goal is to understand why people behave as they do, so that it will be possible to predict and change their behavior" (1). Proving predictability in human behavior continues to be a major goal of science.

The problem, however, is that the sciences cannot claim that this goal has been achieved. The conclusion that we are governed solely by physical laws would be aided considerably if this could be done, but human beings stubbornly resist attempts to show that our actions are knowable in advance. This forces the determinists into the embarrassing admission of unpredictability in their model, which they excuse by saying that universal laws of human behavior do exist but we do not yet have enough information to establish them. This unpredictability has been seized upon by some as indirect evidence of the action of the contra-causal free will.

The difficulties with predictability are seen in one of the strongest forms of scientific determinism, neurophysiological determinism. It has been described well by Ted Honderich. The strength of this particular brand of determinism lies in its simplicity, since it can be described in three sentences. "States of the brain are, in the first place, *effects*, the effects of other physical states. Many states of the brain, secondly, are *correlates* [to mental states]. . . . Some states of the brain, thirdly, are *causes*, both of other states of the brain and also of certain movement's of one's body" (187).

Looking at Honderich's description in reverse order, three things should be observed. First of all, Honderich's statement that brain states determine our actions will not be contested. Honderich is simply stating that the physical processes which lead to our actions begin in the brain, and the evidence for this is so overwhelming and intuitive that it will not even be described. This claim seems on the mark.

Secondly, Honderich does not insist that our mental states are caused by the physical states of the brain, since it not necessary to do so while still defending determinism. Mental events are a by-product, if that, to brain states in neurophysiological determinism. By not trying to explain mental events, the deterministic argument is streamlined in that psychologists do not have to be able to explain actions through mental processes for determinism to be true.

Thirdly, and most importantly, Honderich's statement that brain states are determined by physical states is meant to establish a deterministic way of explaining our behavior. Nevertheless, he admits that causal laws showing how brain states are caused by physical states are lacking. "We do not know what specific connexions hold between physical states and brain states that are correlated with very specific higher mental events, such events as noticing the date or speculating that America is a plutocracy" (195). Obviously, if physical laws have not been established then prediction is impossible.

Since neurophysiological determinism cannot establish how brain states are determined Honderich cannot rule out the possibility of overdetermination, though he is "most uncomfortable" with the prospect (197). Overdetermination is the thesis that while causal laws may work in the physical world, physical processes can also be influenced by non-physical entities such as free will. Overdetermination is important to the free will argument and shall be examined further in the context of that argument.

It has been seen that unpredictability untracks attempts to complete the deterministic model, and this gives room for the claim of free will. If the determinists could show that causal laws alone could explain this unpredictability, it would enhance determinism and impair libertarianism. Therefore, a successful attempt to do so should be the criterion for judging the effectiveness of chaos in improving the deterministic model.

Having shown this, I shall turn to the libertarian argument.

The libertarian or free will argument advocates the existence of a free will which acts as a first or uncaused cause of our actions. The libertarians agree with the hard determinists in their critique of compatibilism; the soft determinists are leading a false double life by believing that freedom and causality are compatible. Therefore, we need the action of a free will to break the contradiction between freedom and determinism, for the free will does not act out of efficient causality. Instead, it acts with final causality, or with purpose.

The libertarians also differ with the compatibilists as to the meaning of freedom. The libertarians argue that the compatibilists' "freedom from coercion" does not really fit our traditional definition of freedom. The libertarian interpretation of freedom is seen in their analysis of the sentence "I could have done otherwise." The libertarians claim that in order for an individual to really do otherwise, the individual must have the ability to get beyond the binding laws of universal causality. It is only then that the individual has "true" freedom.

As opposed to the compatibilist "freedom from coercion," the libertarian version of freedom is known as "freedom of contingency." Libertarian freedom is defined as freedom from physical causality, not merely by the absence of intimidation from others. The libertarians do not make the distinction between conventional and ultimate truths that the determinists do; accordingly, they argue that if we believe our actions to be determined by causal laws, we are not free.

To avoid this problem, the libertarians propose the existence of a free will which makes our actions contingent. Actions may or may not happen, as opposed to having to happen, which is the case in the deterministic model. The libertarians argue that this contingency is necessary for the statement "The individual could have done otherwise" to agree with our traditional definition of freedom. Unlike compatibilism, this definition of freedom allows us to believe others are truly responsible for their actions, and that in turn presents a richer picture of morality.

The ability of free will to produce this type of freedom is described by Immanuel Kant, whose analysis of the debate I have found somewhat useful in defining the libertarian argument. "As will is a kind of causality of living beings so far as they are rational, freedom would be that property of this causality by which it can be effective independent of foreign causes determining it," (FMM 446).[1] The intelligible character of free will has a causality which "is determining, not determined," thus avoiding efficient causality and giving us true freedom (CPR

[1]Abbreviation for Foundations of the Metaphysics of Morals, taken from Kant Selections.

A556/B584).[2] The action of the free will is describable only in terms of purpose, or final causality.

How the free will is capable of such a causality is not explored in this paper. Arguably, any attempts to answer such a question are futile, for the free will cannot be directly examined by science. As a result, I will concentrate on showing how free will may be possible and on proposing the ways in which it may legitimately effect our behavior. This mirrors the words of Kant, who says "that nature does not contradict the causality of freedom, was the only thing we could prove, or care to prove" (CPR, A557/B586). I will stick to developing a scientific criterion for the strengthening of the libertarian argument, and not go beyond that.

In attempting to establish the possibility of free will, the libertarians are forced to critique the deterministic argument. While determinism uses scientific evidence to develop its philosophical arguments, libertarianism goes in the opposite direction. Libertarianism uses its philosophical belief that freedom from causal laws is necessary for morality as a central truth, and then looks for scientific reasons to allow for this possibility. As a result, it is necessary to attack the deterministic belief in universal efficient causality to make room for the possibility of free will.

The first move in accomplishing this is to assail the notion

---

[2]Abbreviation for <u>Critique of Pure Reason</u>. All references to this work are taken from <u>Kant Selections</u>, save one (pp. 15-16 of text).

of ultimate truth, or at least our access to it, for the notion that we have ultimate truths has already been shown to be harmful to the libertarian argument. Two different routes to achieving this are open. Immanuel Kant and Thomas Kuhn both provide separate ways of damaging the argument that we have direct access to ultimate truths.

Kant gives one answer to the question of universal efficient causality that explains our seemingly instinctive belief in it as an ultimate truth while allowing for the possibility of free will. Kant argues that causality is created by the mind to give structure to our sensory experiences. In this sense, efficient causality is an ultimate truth, at least as far as we capable of knowing; however, our senses are limited and we cannot experience things-in-themselves (noumena), only our sensory images of them (phenomena). (Form and Principles, sect. II: 392).[3] Our access to ultimate truths is limited by our senses. The limits upon our sensory abilities presents the possibility that libertarian freedom exists in the noumenal world but cannot be directly experienced as a phenomenon.

> While the effects are to be found in the series of empirical conditions, the intelligible cause [the free will] together with its causality, is outside the series. Thus the effect may be regarded as free in respect of intelligible cause, and at the same time in respect of appearances as resulting

---

[3]Abbreviation for On the Form and Principles of the Sensible and Intelligible World (The Inaugural Dissertation), taken from Kant Selections.

from them according to necessity (CPR, A537/B565).[4]
In this way, the appearance of the universality of efficient causality can be maintained while in actuality freedom can exist.

Kant holds out the possibility of some ultimate truths which we cannot directly access, and many modern philosophers of science go even further by arguing that we cannot access ultimate truths at all. This has been asserted most strongly by the influential philosopher of science Thomas Kuhn, who argues that there is no one way which we must see the world. Instead, this process is learned and we cannot say that the facts which we hold as ultimately true are so at all, since the process by which we experience the world is arbitrary.

Accordingly, Kuhn claims that scientific study is a form of "puzzle solving," settling the questions encountered by any paradigm, or set of arbitrary beliefs concerning reality (Kuhn, 234). Paradigms are judged by their ability to solve the internal puzzles that each must face.

By pushing what have been held as ultimate truths to the level of conventional truths the contradiction between freedom and determinism is revived, creating an unsolvable puzzle in our deterministic paradigm. The libertarians believe this contradiction should make us alter our notion of causality. In particular, the libertarians argue that our paradigm should be

---

[4] This quotation from the Critique of Pure Reason is taken from Smith's translation. All other references to Kant are taken from Kant Selections, which did not contain the segment quoted here.

changed to allow for something more than efficient causality; namely, final causality, the kind that free will would fall under. Allowing such a causality would break the apparent contradiction between free will and determinism. The inability of determinism to prove the free will ultimately false makes this possible and necessary.

Also, libertarians argue that belief in the free will should be adopted because it is more useful in effecting the actions of others, which is the very purpose of conventional truths. The libertarians argue that their meaning of the word freedom best fits our traditional use of that word, and compared to the more limited compatibilist interpretation it provides a richer view of morality. For these reasons, the libertarians argue that its existence should simply be presumed unless evidence shows otherwise.

By attacking the notion of our access to ultimate truths, Kant and Kuhn make some room for the libertarian argument. However, to complete their argument, the libertarians need to develop a model of their own which agrees with our experience of the world. It is here that the criteria for the improvement of the argument will become clear.

Any attempt to define how the free will can and does act must not contradict the beliefs that we have about the world, whether those beliefs be ultimately or conventionally true. A model of the free will would be much more acceptable if it does not directly challenge our experience of the world. It also make the creation of such a model a much more difficult task. Still, all that the libertarians need to show is that possibility of free will does not contradict our experience of the world, since from this its existence can be "read" into our actions.

One way of establishing this is to attack the idea of efficient causality, for the thesis of universal efficient causation is not accepted universally. Hume, for instance, was harshly critical of the idea of efficient causality and Bertrand Russell called for its abandonment altogether (Wright, 3). The reason for this is that we cannot actually "prove" or even sense efficient causality - it is only a relation between events, where the occurrence of the first event is thought to bring about the second. By criticizing the idea of efficient causality, the possibility is opened that events are produced in other ways, such as by overdetermination resulting from the action of the free will.

However, at least the appearance of universal efficient causality must be upheld, for it agrees with our experience of the world. As a result, the libertarian model must not consider the action of the free will to be physically detectable. The world at least appears to be governed by causal laws, and since the free will cannot be analyzed by science, physical indications of the free will must not be available. Such evidence would go against our experience of the world and would be proof of the free will, both of which seemingly are impossible. Instead, if the free will is to act, it can do so only where causality cannot predict behavior, since this would allow it to act without detection.

The model of neurophysiological determinism is useful in showing how this may be possible. This model holds that our behavior is determined by brain states, and that these brain states are determined through causal laws. However, no causal laws have been yet established, and this provides the necessary room for the libertarians to argue that brain states are influenced not only by causal laws, but by the free will through the process of overdetermination.

Accordingly, the deterministic belief that brain states are theoretically predictable is harmful to the libertarians, for if they are predictable it means that efficient causality alone determines brain states and the free will is a vacuous doctrine. As a result, for the possibility of overdetermination, our seemingly deterministic and predictable world must at least sometimes act in ways which are fundamentally unpredictable. It is only then that the free will can act, but the possibility of this is all that is necessary for the libertarians to claim that the existence of the free will should be presumed.

Fundamental unpredictability in brain states has been shown to be necessary for the libertarian concept of overdetermination. Showing that this is possible under our deterministic paradigm has traditionally been a problem for the libertarians. To succeed in this task would greatly aid the libertarian argument. A more specific and concrete account of how this overdetermination can take place is the problem to which I now turn.

Attempts to develop a workable theory of overdetermination date back to the ancient Greeks. In particular, the writings of the Epicurean philosopher Lucretius are informative in this regard. The Epicureans believed in an atomic theory slightly similar to the one we hold today. In particular, they believed that everything consisted of atoms which were smaller than the eye could see, and were generally governed by universal laws. Lucretius allowed for the ability of the free will to cause these atoms to randomly "swerve" in a manner that cannot be perceived, thereby altering what would have otherwise happened while not overtly breaking the laws of causality.

> For this we see to be manifest and plain, that weights, as far as in them lies, cannot travel obliquely, as far as one can perceive; but who is there that can perceive that they never swerve ever so little from the straight undeviating course?
>
> Again, if all motion is always one long chain, and new motion arises out of the old in order invariable, and if the first-beginnings do not make by swerving a beginning of motion such as to break the decrees of fate, that cause may not follow cause from infinity, whence comes this free will in living creatures all over the earth, whence I say is this will wrestled from the fates by which we proceed whither pleasure leads each, swerving also our motions not at fixed

times and fixed places, but just where our mind has taken us? For undoubtedly it is his own will in each that begins these things, and from the will movements go rippling through the limbs (lines 247-264).

This ability of the free will to change the course of the atoms is a statement of overdetermination. The free will works at an undetectable level to effect a large-scale change in what would have otherwise happened had only the laws of causality been in effect. This *Epicurean Swerve* can only be done if some deterministic events are fundamentally unpredictable, since the free will could then act without breaking the appearance of physical causality. Several endeavors have been made to develop a modern-day Epicurean Swerve, and they provide additional insight into the construction of the libertarian model.

These attempts have relied upon some of the cracks in the pillars of predictable Newtonian science which have developed this century. In particular, the Heisenburg Uncertainty Principle has been unsettling to classical determinism and it has been used by some to justify free will. The Uncertainty Principle states that the action of individual particles at the subatomic level is indeterminant: the fundamental limits on our ability to gather information at this level means we simply cannot tell whether or not causal laws apply here. (Crutchfield et al., 48).

For instance, George Prescott Scott attempts to show that the free will could act at the quantum level to affect brain states in <u>Atoms of the Living Flame</u>. Scott argued that neurons are subject to the influence of quantum indeterminacy, meaning that brain states are themselves indeterminant. Thus, universal efficient causality is avoided and the possibility of free will is open (318). John Thorp makes a similar case in <u>Free Will: A Defence Against Neurophysiological Determinism</u>, relying upon indeterminacy in the firing of individual neurons in the brain (71).

Relying upon the Indeterminacy Thesis to establish the possibility of free will has two problems. First of all, it might be wrong. Einstein was outspoken in his criticism of it, declaring that "God does not play dice!" (Pojmon, 408). The discovery of subatomic events is still fairly recent, and advances in physics could show that subatomic events are just as deterministic as those at the atomic level. Still, indeterminacy does seem to be real, since limits upon what we can learn at this level do seem to be fundamental.

Secondly, the effects of indeterminacy seem to be limited to the subatomic world. Indeterminant events at the subatomic level balance out to allow classical Newtonian physics to operate without disturbance (Pool, 893). This is particularly damaging to Scott's argument, which holds that subatomic events can influence behavior. By the same token, indeterminacy in the firing of brain cells can be expected to statistically balance out in the whole. Universal causality is maintained, and brain states are still thought of as theoretically understandable and even predictable. For this reason, Thorp's argument based upon indeterminacy in brain neurons does not seem to be enough to escape universal causality.

Scott and Thorp fail in their arguments because the unpredictability they establish is not enough to significantly alter brain states. What is needed for the possibility of free will is a mechanism which could amplify this indeterminacy into having a substantial effect upon brain states, or could act by itself to produce unpredictability in brain states. Doing so could allow for the undetectable influence of the free will to have an effect on our behavior. This is the purpose of overdetermination or the Epicurean Swerve.

The importance of demonstrating that something like an Epicurean Swerve is possible is shown in that it would allow an explanation of how the free will may effect our actions. Especially useful in sketching out this explanation is a recent investigation conducted by Dr. Benjamin Libet of the University of California at San Francisco.

Libet's experiments on voluntary action indicate that the brain may unconsciously develop options for action but that these potential actions must pass through an individual's consciousness before the action can take place. Libet theorizes that the free will acts during this brief interlude with veto power over inclinations to act, stopping some potential actions while allowing the realization of others (529). The free will does not develop ideas, it simply chooses from them. This answers a possible objection that somehow the free will works upon the mind to create potentials for action, which is full of theoretical difficulties.

Instead, the Epicurean Swerve would be used to alter brain states, randomly scattering vetoed potential actions into oblivion. This works just as effectively as the idea of a free will which directs brain states, and also means that the free will could act without being detected. Additionally, it explains why all animals can have free will but only humans can have morality, since we are the only ones who can develop the idea of it.

As the discussion hopefully shows, a way of showing that a world seemingly governed by efficient causality can allow for fundamental unpredictability is essential for the libertarian argument. This would open the possibility that the free will can exist, and the libertarians claim that if it is possible then its existence should be presumed. Accomplishing this will be the criterion for the advancing of the libertarian argument, which I will try to show that chaos meets.

Similarly, the determinists must show that causal laws alone can explain the unpredictability of behavior. By doing so, the determinists can malign the libertarian belief that unpredictability of behavior results from the action of the mysterious free will. These criteria are closely related, if not identical, and it should not be surprising to find that the meeting of one criterion simultaneously meets the other. This should be kept in mind as I turn to a review of chaos, where the theoretical groundwork for meeting these criteria will be set down.

III. Chaos

As mentioned already, chaos is the name used to describe deterministic systems which display apparently random behavior. Chaos also indicates that some seemingly random behavior is more explainable than once thought. Chaos applies to the same physical systems that Newton dealt with in establishing the modern deterministic model, and so would seem to have some theoretical relevance to the larger philosophical discussion.

This section will review the science of chaos to establish how it may theoretically meet the criteria established in the last section and to show how chaos can be detected in our behavior. More specifically, I will attempt to show in this section that chaos works as a double-edged sword in the philosophical debate, for it can theoretically be used to back the criterion established for both arguments. The ways in which it does so are outlined in the first part of this section, which reviews chaos and the way it is generated by deterministic systems.

Attempts to substantiate the theoretical conclusions drawn at the end of the first part of the section take up the rest of the paper, beginning with the second half of this section, which reviews the specific ways in which a chaotic system can be identified. The importance of identifying chaotic systems will be seen in the next section, which makes a more concrete attempt to show that chaos applies to our understanding of behavior. It is from this information that the final conclusions will be drawn.

This half of the section will establish how chaos comes about and show the theoretical ways in which it encounters the free will and determinism debate. Chaos shares with that debate an indebtedness to the work of Newton as a foundation for its arguments. Newton tried to show that nature is describable in purely physical ways. He dissected nature into closed systems which could be analyzed independently of each other. Specifically, these systems of motion (and equilibrium states) are referred to as dynamical systems, and they are mathematically describable through differential equations. Differential equations are used to deduce future states of a dynamical system (Ekeland, 21).

Newton attempted to describe nature solely through linear differential equations, which are solvable and predictable. A linear equation is one in which any two solutions added together is itself a solution (Stewart, 81). Linear equations can be displayed on a graph as a straight line or smooth curve, and allow for predictions to be made. For instance, by knowing the position and momentum of two objects, it is easy to predict where they will go, or if two objects are about to collide, their new directions and speeds are predictable.

Even now, the world is often thought to be describable through linear equations and events believed to be theoretically predictable, so great is the influence of Newton. However, this deterministic assumption is being shown to be wildly off the mark, for non-linear equations play a large role in describing nature. *Non-linear* equations have terms which are multiplied by themselves. When displayed on a graph, non-linear equations take on much more violent shapes than their linear counterparts. Many non-linear equations are unsolvable, and because of this the actions of even simple deterministic systems are unpredictable.

For example, the French mathematician Henri Poincaré showed at the turn of this century that when three or more bodies are acting upon each other at the same time, the differential equation for that system becomes formally unsolvable due to the non-linearity of the equation (Ekeland, 36). This unsolvable system is known as the "three-body problem." Establishing non-linearity at such a simple level shows that linear equations do not alone best model nature, and implies that the world is unpredictable to a significant extent. The unpredictability created by many non-linear systems is chaos.

This unpredictability is produced through a process of feedback. In a linear system, errors are magnified arithmetically and do not make a large dent in the accuracy of predictions. Non-linear systems, on the other hand, amplify errors geometrically, since nonlinear equations have terms which multiply themselves. Errors are fed back into the equation so that they produce even greater errors down the line. It is this feedback which causes chaotic systems to act unpredictably. Small errors in initial conditions rapidly "blow up," making prediction impossible.

A striking model of this can be seen within the classical model of billiards. Disregarding the supposedly negligible non-linear effects of friction and gravity, the action of the billiard balls is considered to be a closed system and perfectly predictable under Newtonian laws. However, when the supposedly negligible effects of non-linear variables are included in the equation, the paths of the billiard balls quickly becomes unworkable. Unless the gravitational pull of electrons at the edge of the galaxy is included in the equation, the path of the balls is impossible to predict after just one minute! (Crutchfield et al., 49).

In this example, chaos makes its appearance in two ways. First of all, the attempt to approximate a non-linear equation introduced errors into the setting up of the equations itself. Secondly, the inability to gather infinitely correct data for the equations introduced small errors into the computation of results. One such incorrect datum is the roundness of the billiard balls, as determined by pi. Calculation of the balls' roundness are only approximations since the complete value of pi cannot be determined (Crutchfield et al., 49). Chaos takes these infinitesimally small errors and rapidly magnifies them, destroying predictability.

The infinite sensitivity to errors in chaotic systems makes predictability a hopeless task. This is a major break with the traditional Newtonian model, which held that fairly accurate predictions would result from fairly accurate data, and has forced a reexamination of the deterministic model. G.M.K. Hunt has designed a useful dichotomy to show the effects of chaos upon this model. In particular, he notes the subdivision of *epistemically* deterministic, or predictable, systems from the whole of *physically* deterministic systems (132). Though they had once been considered one and the same, the science of chaos demands their separation.

Furthermore, epistemically deterministic systems seem to be the exception rather than the rule, for chaos has been theorized to play a role in the paths of the planets and has been documented in the unpredictable path of Saturn's moon Hyperion (Hartley, 39; "First," 998). At the other end of the spectrum, chaos has been seen at the subatomic level, hinting that such processes are governed by deterministic means after all (Gutzwiller, 78). In between, chaos even has been demonstrated in the dripping of a faucet (Crutchfield et al., 55). Chaos implies unpredictability from the most basic levels of our physical world to the largest. It is also suggestive that chaos exists in the physical processes which determine our behavior.

Along with quantum indeterminacy, chaos provides a second blow to the perfectly predictable world envisioned by LaPlace, but the impact of chaos is on a much greater scale. The universe appears to have many unpredictable secrets which can never be known because of chaos. Having established this, some theoretical answers to the free will and determinism debate can be drawn.

By showing that unpredictability is intrinsic to determinism, chaos answers the criterion that determinism explain unpredictability. Behavior that had previously been viewed as unpredictable due to a lack of knowledge can now be modelled through deterministic means. If chaos plays a role in our understanding of behavior then we may will finally be able to model the unpredictability of our behavior in a deterministic way. We will no longer have to resort to a shrug and a wishy-washy statement that Newtonian determinism will be able to explain behavior "someday."

Furthermore, the ability to better explain behavior in a deterministic fashion hurts the libertarian model. Chaos exists in systems which are deterministic, and determinism does not allow for free will. By showing that unpredictability can result through causal laws, the libertarian argument that determinism cannot explain our behavior is lost. The role of chaos in our understanding of behavior is of obvious interest to the determinists, then, and will be explored in the next section.

At the same time, chaos could aid the libertarian argument by providing the fundamental unpredictability necessary for the free will to act without detection. It could do so in one or two ways.

First, the infinite sensitivity to errors in data could enable chaos to be the mechanism to amplify the apparent indeterminacy in the brain. It will be recalled that this mechanism is necessary for overdetermination to take place. "Quantum mechanics implies that initial measurements are always uncertain, and chaos ensures that the uncertainties will quickly overwhelm the ability to make predictions" (Crutchfield, et al., 49). Chaos could operate as the tool by which the free will impacts brain states.

Second, even without quantum indeterminacy, chaos may be able to create the required unpredictability in brain states. If chaos exists in the brain, the determination of brain states as a whole could be fundamentally unpredictable. By showing that chaos can affect the brain states which determine behavior, the possibility of free will is opened. Furthermore, the infinite sensitivity to input that is characteristic of chaos could be used by the free will to alter brain states. The free will could act at a level beyond our ability to analyze and use chaos to expand this initial input.

Dr. Libet's study on the role of conscious will in voluntary action is useful in showing how chaos may be used by the free will to effect our actions. Libet's study indicated that although our initiatives to act begin unconsciously, we do have the ability to block these initiatives. The free will could use chaos to randomly scatter vetoed potentials for action through overdetermination, acting without detection. This would give us libertarian or contingent freedom. And of course, the libertarians argue that if the free will is possible it should be presumed to exist.

Attempts to prove these theoretical conclusions take up the rest of the paper. In the remainder of this section, a few tools with which chaotic systems can be identified are given. These tools will be useful in establishing the role of chaos in behavior, which will be shown in the next section.

While chaos shows that even simple deterministic systems can act in complex and unpredictable ways, it also provides science with the ability to explain seemingly random behavior in simple ways. The key to this is that chaos is marked by periods of near order intermeshed with times of apparent randomness. (Briggs, 62). This separates it from truly random behavior, in which no order is found.

An example of this is the weather, the first system shown to be chaotic, as done by meteorologist Edward Lorenz in 1961 (Gleick, 31). While the behavior of the weather never repeats, there is order to what is encountered. Certain atmospheric conditions often nearly repeat, and this allows for some degree of prediction. Even when the weather turns violent, it eventually comes back to some sort of stable state, showing how order and randomness are woven together within chaos. However, long-term predictions are often nothing more than intuition, and even short-term predictions can be terribly wrong.

Identifying a chaotic system is usually not as easy as this description might make it sound to be. Often, the output of a system simply appears random, as opposed to chaotic. Random systems can be described linearly, and remain theoretically predictable. The only difficulty in predicting a random system is the large number of variables that have to be included in the equation. The dripping of a faucet exemplifies the difficulties in telling the two systems apart. The dripping of a faucet often appears to be random, but actually is chaotic; that is, there is an underlying order behind the appearance of randomness. Fortunately, there is a empirical way of identifying chaotic systems.

This method views the output of a system in what is known as phase space. Again, the work of Newton was instrumental in the development of this dynamical tool. Phase space consists of six dimensions; three for the position of an object, three for its momentum (Gutzwiller, 80). Phase space best shows the tendency of chaotic systems to settle down into periods of relative order. Chaotic systems leave a distinguishing signature - a thumbprint, in a sense - in diagrams of phase space, known as a chaotic attractor (Gleick, 140). Chaotic systems differ from linear systems in phase space in that their identifying attractors are much more contorted than those of linear systems. Also, chaotic attractors carry a self-similarity to infinite levels of magnification. This self-similar shape is known as a fractal, and is produced in phase space only by chaotic systems (Briggs, 168).

The tendency of chaotic systems to act with varying degrees of near order and apparent randomness, combined with the ability to establish chaotic attractors, give two ways of identifying chaos. These will be of some use in the next section, which will provide the material necessary to bridge the river between the theoretical conclusions sketched out in this section and their actual relevance to human behavior.

IV. Evidence of Chaos in Behavior

The mathematical model of chaos has shown the weaknesses of the predictable, deterministic model envisioned by Laplace, which our behavior is still largely modeled by. Nevertheless, this does not necessarily mean that chaos plays a role in our understanding of behavior. It is a big jump to connect our behavior to the mathematical model of chaos, and if there is a link between the two, it must be established.

Even if chaos does work here, it may be limited in scope and allow our behavior to still be theoretically predictable. This section will attempt to back up the theoretical conclusions of the last section by searching for evidence as to what role chaos plays in our understanding of behavior. This will allow final conclusions to be drawn in the next section.

Evidence of chaos in behavior will be sought at two levels. Chaos in the action of individuals within groups, or chaos in social systems, will be referred to as the macroscopic study of chaos in behavior. At the other end of the spectrum, at the microscopic level, the role of chaos in the determination of brain states that cause our behavior will be examined. The role that chaos can be expected to play at both of these levels can be seen by reviewing the model of chaotic billiards.

At the macroscopic level, the action of the billiard balls can be compared to the action of groups of individuals. As that model shows, even the smallest of errors in quantification leads to inaccurate predictions, even though the laws that govern the action of the balls are known. The path of even one ball cannot be predicted without knowing the potential behavior of everything which may act upon it, which is impossible in a chaotic system.

In social systems, which are less quantifiable and more complex than a simple billiards table, the problem is only magnified. Even if the laws by which our behavior are guided by are known, small errors in quantifying the data to solve for these equations would explode and cause unpredictability. The role of chaos indicates that the prediction of our behavior is theoretically impossible and that only possible trends and tendencies can be identified.

How do the macroscopic studies fit into the theoretical conclusions of the last section? By establishing chaos at the macroscopic level, unpredictability could be explained entirely through causal laws. This would aid the determinists by giving a deterministic explanation to what previously could not be explained causally. On the other hand, this unpredictability does not seem to significantly aid the libertarians because it is limited to the action of groups. Macroscopic unpredictability does not seem to give the individual freedom of contingency since it exists only at the level of the group and does not seem to extend to the fundamental level of brain states, where the processes which determine an individual's behavior take place.

The macroscopic study of behavior would aid the determinists more than the libertarians, but microscopic studies of chaos in brain states provide another way of explaining unpredictability in behavior that is more beneficial to the libertarian cause. If chaos works in the brain, it may make the brain states which determine behavior as unpredictable as the chaotic billiard table. In so doing, it could push unpredictability of behavior to the most fundamental levels that science could hope to examine.

This would provide exactly the kind of fundamental unpredictability in the brain that the libertarians seek to allow for the possibility of overdetermination, and would represent a substantial improvement in their model. At the same time, however, the determinists would also be helped by providing them with another causal explanation to unpredictable behavior.

Having established the general ways that chaos may act at each of the two levels and the importance of each, evidence of chaos can now be cited. I will begin with the macroscopic studies, where some work has been done linking chaos and our behavior. For instance, David Loye and Riane Eisler of the Institute for Futures Forecasting in Carmel, California, note that chaos may fit the goals of general systems theory and appears to be a transdisciplinary tool which can be applied to social systems (55).

Evidence of the transdisciplinary nature of chaos is seen in the headway that it has made in economic theory, foreign policy, and even literature, among other fields of study (Rosser, 268; Murray et al., 1869; Hayles, 305). It also hints that chaos can be applied to the microscopic discipline of neurobiological determinism, which will be dealt with a little later.

The likely existence of chaos in social systems has been noticed by many scientists, who argue that it presents an absolute barrier to prediction. The extent of the problem is summed up by Ian Stewart in Does God Play Dice?, as he quotes a previous statement he made in conjunction with Tim Poston. Noting Poincare's work on the impossibility of the three-body problem, Stewart writes, "So the 'inexorable laws of physics' on which - for instance - Marx tried to model his laws of history, were never really there. If Newton could not predict the behaviour of three balls, how could Marx predict that of three people?" (40).[5]

Other scientists make similar pronouncements. Herbert A. Simon of Carnegie-Mellon University in Pittsburgh bluntly states that chaos means that "we must give up prediction as the primary goal of modeling" within social systems (Simon, 8). Also, Dr. Hendon Chubb, Director of the Brief Therapy Institute in West Cornwall, Connecticut, spells out his belief that control of

---

[5]Stewart quotes himself and Poston from Analog, Nov. 1981. Since he is quoting himself, I have not included Analog in the list of works cited.

behavior is impossible because of the chaotic nature of social systems. Unfortunately, he provides no empirical evidence to back this up, except for the unstated evidence that therapists are not now able to predict behavior with reliability (Chubb, 174).

More substantial proof of unpredictability comes from a study undertaken by Dr. Diana Richards of Yale University. As an indication of how recent a discovery chaos is, Dr. Richards points to her 1990 study as the first empirical and experimental examination of how well chaos works as a model in the social sciences (Richards, 213). The study analyzed the interdependent decision making habits of individuals, where the decision of one individual can affect the decision of another. The sample size was small, as only eight subjects were involved in the study. Nonetheless, of these eight, six exhibited behavior that was described as chaotic in an experimental test known as the prisoner's dilemma (Richards, 232). Because these actions are chaotic, the results of Dr. Richard's study mirror the conclusion of Dr. Chubb that behavior is unpredictable.

The examples cited above are indicative of the small but growing theoretical and experimental evidence showing that chaos works to prevent the predictability of behavior at the macroscopic level. The evidence also backs up the tentative conclusions mentioned earlier that it advances the determinist argument while not doing so with the libertarian.

However, there is another way of explaining how chaos may create unpredictability in behavior, and that is by looking to the microscopic studies of chaos in the determination of the brain states which cause our behavior. The link between chaos and behavior is more difficult to establish here, since there is no model yet that gives a thorough description of the workings of the brain.

Nonetheless, recent research into the role of chaos promises to expand our general understanding of what we do know about the brain, and shows that chaos seems to play a role in the determination of behavior. To establish this, the role of chaos in brain states will be traced from the most general hints of its existence in the brain to more specific explanations of how it works there.

One concrete indication that chaos exists in the brain is that the normal pattern of electrical behavior in the brain appears to be chaotic (Taubes, 65). This means that there is a hidden order in data that had been perceived to be random "noise" (Skarda and Freeman, 165) Furthermore, the failure of the brain waves to remain consistently chaotic has severe consequences, since evidence suggests that electrical patterns become regular during epileptic seizures (Skarda and Freeman, 189). This mirrors evidence which shows that the heartbeat is normally chaotic, and that heart attacks are often preceded by a regular heartbeat (Goldberger, 47).

Another indication of chaos in the brain comes from Arnold Mandell, a San Diego psychiatrist and dynamicist who claims to have uncovered chaos in the action of chemicals in the brain (Gleick, 298). Mandell argues that this is but a part of the larger impact of chaos in our lives, which could extend even to our personalities, a claim that will be dealt with later in this section (Briggs, 168).

The likely existence of chaos in the brain causes the task to turn to discovering what role it plays in the determination of our actions. Some interesting work in this direction comes from physicist Gottfried Mayer-Kress and his students at the Los Alamos National Laboratory's Center for Nonlinear Studies. They have developed a mathematical model of how changes in brain patterns are related to changes in behavior (Alper, 21). Their work shows a link between the two, and importantly, that the changes in brain patterns take place chaotically. Because the patterns are chaotic, this is evidence that the behavioral states they correspond to are unpredictable. However, the study does not show if chaos actually helps determine future behavioral states or if it is merely a by-product of the brain's activity. Research to prove the former will now be given.

One indication that chaos is intrinsic to the operation of the brain is given by Drs. Don Walter and Alan Garfinkel of University of California at Los Angeles. They devised a model which linked three neurons together and found that the neurons acted chaotically (Briggs, 167). The implications of this are daunting. The average brain consists of 10^{11} neurons, with 10^{4} synapses each, for a total of 10^{15} connections. This is roughly equal to the number of stars in the Milky Way Galaxy, and the connections are different with every person (Bridgemann, 57). If chaos exists here, predictability of brain states would seem to be a staggering impossibility.

Still, this is just a simple computer model, and it only gives the most general of information concerning the role of chaos in the brain. More informative studies on how chaos operates in the brain have been done by neurophysiologists Walter J. Freeman of the University of California at Berkeley and Christine A. Skarda of the Ecole Polytechnique in Paris. They have developed a theory of how the brain generates and uses chaos, and this makes their work important to any discussion of how chaos may effect the brain states which determine our actions.

Skarda and Freeman claim that the chaos is essential to the functioning of the brain. They discovered evidence indicating that chaos plays an important role in the way information is transmitted, stored, and recalled by the brain. Freeman suggests that the brain uses chaos to generate insight and creativity, and is necessary in the determination of our consciousness. By demonstrating that chaos may deeply permeate the way that the brain works, Skarda and Freeman show that chaos is critical to the creation of the brain states which bring about our actions. In doing so, this also indicates that chaos plays an important role in making these brain states unpredictable.

Skarda and Freeman focused their work on the function of perception. In particular, their studies concentrated on the olfactory system of rabbits. They analyzed this system because it is one of the brain's most well-understood systems (Skarda and Freeman, 162). Importantly, they note that they have discovered chaos not only in this system but throughout the brain. As a result, Freeman believes that lessons gained from the study of the olfactory system are applicable to other parts of the brain (Freeman, 85), and so their work will be given special treatment.

The researchers understood that even a small input from scents detected by neurons in the nasal passages could have a dramatic effect on the output of brain waves in the olfactory system, and they recognized this output to be chaotic. "Chaos is evident in the tendency of vast collections of neurons to shift abruptly and simultaneously from one complex activity pattern to another in response to the smallest of inputs" (Freeman, 78).

Skarda and Freeman believe that this chaos arises through a process of feedback (Skarda and Freeman, 171). Freeman argues that chaos can arise in the brain when two or more of its parts are communicating with one another over the same input signal but cannot agree on a common message between them (Freeman, 85). This causes the neurons in each part to become more excited and leads to further communication between the two halves. This process of feedback is characteristic of chaos.

Evidence for feedback is seen in that the chaos in the olfactory system stopped when the two parts of the system were experimentally disconnected by the researchers (Freeman, 85).

Furthermore, other researchers have established this kind of feedback between parts of the brain used in memory (Miskin and Appenzeller, 85). The discovery that feedback between parts of the brain leads to chaos is noteworthy because decision-making involves many parts of the brain (Bridgemann, 415; Cami, 277). This suggests that the brain states which determine our actions are themselves chaotic.

Furthermore, the brain seems designed to have a constant amount of chaos operating within it. In the olfactory system, the original signal from the nasal neurons is muted to remove unnecessary information as it moves between the two parts, meaning that each gets a different message. This insures disagreement over the message, generating chaos, while at the same time keeping chaos within certain broad boundaries (Skarda and Freeman, 168). Failure to keep chaos under control may cause the brain to force itself into a regular pattern of electrical activity - possibly leading to an epileptic seizure (Skarda and Freeman, 168). The ability to explain brain events outside of the sense of smell furthers Freeman's claim that chaos exists throughout the brain.

Other research which took place after Skarda and Freeman published their work has shown that it is possible to control a chaotic system in this way if the control is constantly pursued (Peterson, 60). Furthermore, the researchers who took part in this independent research claim that controlled chaos appears to be a "necessary ingredient" to the operation of the brain

(Peterson, 61). This separate research adds weight to the claims of Skarda and Freeman and shows that chaos may play a role in the creation of brain states which determine behavior.

Further evidence of the chaotic nature of brain waves is shown by the researchers' ability to display their data of brain waves in the form of a chaotic attractor. In the olfactory system, this attractor develops when the miscommunication between parts of the system begins to settle down after it is held under the influence of a scent for a short time (Freeman, 84). It will be recalled from the previous section that chaotic systems do tend to settle down into periods of relative order. Again, this is strong evidence that chaos does influence brain states.

Each chaotic attractor represents the firing of particular groups of neurons in the olfactory system and its shape changed with each new scent that the olfactory system was exposed to (Freeman, 84). The fact that a chaotic attractor has been uncovered is highly indicative that the brain uses chaos to help make sense of the data it receives (Skarda and Freeman, 168). In playing a determining role in the process of perception, chaos influences the data upon which our decisions are based.

The researchers theorize that this chaotic attractor plays a role in how the brain learns, as well. Chaotic attractors represent the pattern of the firing of particular groups of neurons. When a scent causes a particular group of neurons to fire, the connections between the neurons which represent the attractor are strengthened, and they begin to work as one in what the researchers refer to as a nerve cell assembly. These nerve cell assemblies are essential to the way that scents are learned by the olfactory system (Skarda and Freeman, 168). When a scent is detected and the olfactory system is alerted, these nerve cell assemblies allow instant recognition of familiar scents (Freeman, 68). In this way, chaos plays a role in how the brain makes interprets the information the senses present it and determines how this information is stored.

This is apparent from reading Skarda and Freeman, but perhaps a more convincing source is Bruce Bridgemann, a neurobiologist from the University of Bielfeld, Germany, who seems to have been unaware of the work of the two researchers on chaos and the brain. In Bridgemann's attempt to describe the way neurons link up, he states that "the determination of a biological nerve network is not deterministic, but neither is it random. Rather, it seems to be a kind of messy, flexible determinism, governed by organizing principles but not completely specified by them" (Bridgemann, 402). This description agrees with how a chaotically determined system might appear to an uninitiated observer.

Furthermore, the chaotic attractors representing different nerve cell assemblies all change when a unique scent is detected by the olfactory system for the first time. The evidence that these "memory maps" are capable of changing agrees with the ability of stroke patients to relearn functions that previously had been located in the damaged areas of the brain. Chaos makes the brain states which determine our behavior unpredictable by influencing the way that the information necessary for decisions is sensed and learned.

Importantly, the power of chaos in the brain is not limited to merely our interpretation of the external world but helps us look inward as well, since Freeman also suggests that chaos may be the key to our creativity. He notes that chaos is constantly able to produce new activity patterns, and the harnessing of this by the brain would allow for ingenuity and imagination (Freeman, 85). The ability of the brain to develop unique thoughts is critical for decision-making and behavior, and chaos may give us the ability to do this.

Freeman goes as far as to say that our consciousness itself may be the result of these chaotic processes (85), echoing the words of Mandell that chaos may create our personalities. If so, chaos gives an explanation for the fact that while our behavior may be unpredictable, we act with enough order that we can define individual character traits. The combination of unpredictability and order is seen in all chaotic systems. Indeed, if chaos is essential in giving rise to our consciousness, then it can play a role in determining our actions. To quote psychologist David Oakley, "Consciousness can be involved in the control of behavior at the level of the individual action and at the more molar level of the plan" (Oakley, 69).

The evidence shows that chaos could play a role in the determination of our actions, which means that those actions and the brain states which determine them are unpredictable. Chaos has been seen in the way in which we make sense of the world and in how this information is stored, and has been suggested as the source of our creativity and consciousness. Decision-making is a process which requires all of these functions. Chaos in any of these functions would probably make prediction impossible, so this thoroughly chaotic theory of the brain suggests enormous unpredictable complexity in the physical processes which determine our behavior.

Taken together, the macroscopic and microscopic studies seem to indicate that our behavior is steeped in chaos. It shows that our actions may be fundamentally unpredictable but also suggests that this unpredictability arises through a deterministic process. In so doing, this section provides evidence to back up the claims made earlier about how chaos may be used to back both the deterministic and libertarian arguments. A more thorough discussion of this is now forthcoming.

V. Conclusions

The evidence given in the preceding section indicates that chaos plays a role in behavior at both the macroscopic and microscopic levels. The existence of chaos in behavior allows conclusions to be drawn which I believe endorse the purpose of this paper, which was to "demonstrate that while chaos improves the case for determinism, it also shows that free will might be possible in a world that otherwise appears to be governed by universal efficient causality." The criteria established earlier will now be brought into play to establish my final conclusions for both the deterministic and libertarian arguments.

The criterion for advancing determinism, it will be recalled, was to develop an explanation for the unpredictability that we see in behavior. Previously, such unpredictability was claimed to be due simply to a lack of knowledge about behavior, but this left open to the libertarians the possibility that behavior is unpredictable because of free will. The role of chaos in establishing unpredictability as part of determinism holds the key to fulfilling this criterion and providing a basis for rejecting the libertarian claim.

Chaos explains the unpredictability of behavior in a thoroughly deterministic fashion. The separation of epistemic determinism from physical determinism demands that unpredictable events will occur. Theoretically, this assists determinism in that by showing that unpredictable events can take place within that model, eliminating the need for a free will. These theoretical conclusions are supported by the evidence which shows that chaos is not just a mathematical model but one that actually can be applied to our behavior.

The evidence of chaos at the macroscopic level alone is enough to prove the criterion for determinism. Chaos at the level of social systems implies that behavior is unpredictable, thus repelling the challenge of the libertarians. The evidence of chaos at the microscopic level goes even further and shows that a new understanding of the deterministic brain may be called for.

The chaos-laden workings of the brain shows that chaos plays many roles in the determination of our actions. Chaos effects the way that we unconsciously see the world and what information we draw from it. It may also give the brain the ability to look ahead to see the consequences of particular actions and to learn from those mental trial-and-error patterns. Chaos may even provide us with the consciousness necessary for decision-making. Chaos provides determinism with a new way of viewing unpredictability that previously it could not explain.

Even the libertarian claim based upon indeterminacy is attacked, because chaos seems to exist at the quantum level, hinting that the indeterminant events which take place at that level are in fact determined. All this evidence is useful for the deterministic argument, but in particular I believe it is especially strengthens the compatibilist argument. The philosophical impact of chaos on determinism can now be outlined.

First, chaos implies that we have no knowable fate. In this sense, we are free, since the decisions we make and the reasons for those decisions are our own. No one can entirely predict our actions, and no one can ever have absolute control over us. There are no Shakespearian witches with the power to see into the future and against whose prophesies we vainly struggle in attempts to change inevitable fate. Because of the difficulties with prediction of behavior, our future remains in some sense "open," as it forever hidden from us.

Second, if my actions are not ultimately free, the chaos-laden image of the brain shows that the reasons for this are so far removed from my life that they cease to be relevant. The microscopic studies of the brain show that even if our behavior is determined entirely by efficient causality, this process is so remarkably complex and unpredictable that it seems impossible for anyone to get to the bottom of it. If the truth is that we are governed by mechanical laws, I can live with and still believe myself free.

This is a central tenet of compatibilism, as mentioned earlier. Causality is not a category that applies to immediate experience and the chaotic model of determinism makes causality an even more difficult tiger to take by the tail, for even when causal laws can be established, it does not follow that predictability will result. The link between cause and effect can only be determined in retrospect, if then. Arguably, this destroys the contradiction between determinism and freedom and deflates much criticism of the compatibilist argument.

Chaos strengthens determinism by showing that the unpredictability of behavior is not a failure of the model but is rather an intrinsic part of it. However, though it improves the deterministic argument, chaos does so at the cost of meeting the criterion for the improvement of the libertarian argument as well. The contribution of chaos to the libertarian argument will now be summarized.

The steps for meeting the libertarian criterion are a little less manifest than they are for determinism. The libertarians begin by attacking the idea that determinism is an ultimate truth; instead, they argue that it is a conventional truth, one which cannot disprove the possibility of free will. However, this does not explain how the free will can be made to agree with a world which appears to be governed by universal causality.

Accordingly, the criterion for improving the libertarian model was to prove that the belief in universal causality could be circumvented without breaking its appearance. Furthermore, this must be shown to be possible at the level of the brain states which determine an individual's behavior, in accordance with neurophysiological determinism.

By separating epistemic determinism from physical determinism, chaos shows that brain states can be fundamentally unpredictable. It may also be the tool that the free will uses in vetoing potentials for action, since an unmeasurable influence by the free will could theoretically be blown up by chaos, impacting brain states. This has been referred to as a theory of overdetermination or the Epicurean Swerve. Dr. Libet's study completes the model by showing that this disruption of brain states could be the key to the action of the free will, as it vetoes potentials for action. The evidence indicating that chaos is deeply involved in the operation of the brain backs these conclusions.

The science of chaos does apparently meet the criterion set down for the advancement of the libertarian argument. We turn now to see how this may affect the philosophical debate, and the implications are clear.

Since chaos seems to allow the possibility of free will, many argue that its existence should be presumed. After all, attempts to prove the free will can only be shown not to break the laws of universal causality, and in this the libertarians can claim success. Consequently, the libertarians can argue that it is the determinists who have been defeated, not they. As a conventional truth, the libertarians argue that belief in free will is arguably more useful than any deterministic definition in breaking the supposed contradiction between freedom and determinism and also better fits our traditional definition of freedom. Therefore, its existence should simply be presumed.

This is the essential difference between the deterministic and libertarian arguments. Whereas the determinists can claim that chaos makes the free will unnecessary, the libertarians claim that chaos makes it possible and therefore necessary. In a sense, both are right, but are looking at it from different perspectives. Scientifically, the idea of free will adds nothing to our understanding of behavior, and the determinists can claim that chaos explains the unpredictability of behavior in a deterministic fashion. Since it adds nothing scientifically, our philosophical model should be adjusted.

On the other hand, the idea of free will does seem to add something to our understanding of morality and therefore the libertarians argue that the determinists must expand their model to include the causality of a free will. Furthermore, while chaos allows for a deterministic explanation of behavior, it also opens the possibility of free will. Since it is possible, the libertarians argue that free will is necessary and should be taken on faith until proven otherwise, which chaos implies cannot happen.

It has been seen that chaos opens new avenues for exploration in the free will debate. By separating epistemic determinism from physical determinism, chaos shows that it can explain the unpredictability of determinism while accommodating the need for libertarianism to get around universal causality. This must be seen as a victory for the libertarians, since science has traditionally not even allowed the possibility of their view, but the determinists have had their argument strengthened as well.

The argument over libertarianism and determinism is ancient, and perhaps this paper is just more evidence as to why it has been so difficult to come to any generally accepted conclusions favoring one argument over the other. By showing that neither side of the debate can be defeated on empirical evidence, the battle over free will and determinism may well be decided on the periphery, on theoretical arguments over the truth of efficient causation and on the purpose and form of science, for instance, or perhaps on specific versions of free will, which are not dealt with here.

Finally, I will allow that my conclusions are tentative for lack of research on the relationship between chaos and behavior. Nonetheless, I believe that as the amount of information on chaos grows it will be used by both determinists and libertarians alike to justify their claims, but it will also insure that the opposing viewpoint cannot be defeated.

WORKS CITED

Alper, Joseph. "The chaotic brain: new models of behavior." Psychology Today May 1989: 21.

Bertalanffy, Ludwig von. General Systems Theory. New York: George Braziller, 1968.

Bridgemann, Bruce. The Biology of Behavior and Mind. New York: John Wiley & Sons, 1988.

Briggs, John, and F. David Peat. The Turbulent Mirror. New York: Harper & Row Publishers, Inc., 1968.

Cami, Jeffrey M. Neuroethology. Sunderland, Massachusetts: Sinaur Associates, Inc., 1984.

Chubb, Hendon. "Looking at systems as process." Family Process 29 (1990): 169-175.

Crutchfield, James P., J. Doyne Farmer, Norman H. Packard, and Robert S. Shaw. "Chaos." Scientific American Dec. 1986: 46-57.

Darrow, Clarence. Crime: Its Cause and Treatment. 1922. London: Watts & Co., 1934.

Ekeland, Ivar. Mathematics and the Unexpected. Chicago: University of Chicago Press, 1988.

Eysenck, Hans J. and Michael. Mindwatching. Garden City, New York: Anchor Press/Doubleday and Co., 1983.

"First direct view of solar system chaos." Science 24 Nov. 1989: 998-999.

Freeman, Walter J. "The physiology of perception." Scientific American Feb. 1991: 78-85.

Gleick, James. Chaos. New York: Penguin Books, 1987.

Goldberger, Ary L., David R. Rigney, and Bruce J. West. "Chaos and Fractals in human physiology." Scientific American Feb. 1990: 42-49.

Gutzwiller, Martin C. "Quantum chaos." Scientific American Jan. 1992: 78-84.

Hartley, Karen. "Solar system chaos." Astronomy May 1990: 34-39.

Hayles, Katherine. "Chaos as orderly disorder: shifting ground in contemporary literature and science." New Literary History 20 (1989): 305-322.

Holbach, P.H.T. Baron d'. The System of Nature. Trans. H.D. Robinson. 2 vols. 1868. New York: Burt Franklin, 1970.

Honderich, Ted. "One determinism." Essays on Freedom of Action. Ed. Ted Honderich. London: Routledge & Kegan Paul, 1973. 185-215.

Hunt, G.M.K. "Determinism, predictability, and chaos." Analysis June 1987: 129-133.

Kant, Immanuel. Critique of Pure Reason. Kant Selections. Ed. Lewis White Beck. New York: Macmillan Publishing Company, 1988. Page numbers refer to A - first edition, and B - second edition of Kant's work.

---. Critique of Pure Reason. Trans. Norman Kemp Smith. 1929. London: The Macmillan Press, Ltd., 1973. Page numbers refer to A - first edition, and B - second edition of Kant's work. This translation used only once, in long quote pp. 15-16 of text.

---. Foundation of the Metaphysics of Morals. Kant Selections. Ed. Lewis White Beck. New York: Macmillan Publishing Company, 1988. Page numbers refer to Royal Prussian Academy of Science edition, 1902-1912.

---. On the Form and Principle of the Sensible and Intelligible World. Kant Selections. Ed. Lewis White Beck. New York: Macmillan Publishing Company, 1988. Page numbers refer to Royal Prussian Academy of Science edition, 1902-1912.

Kenny, Anthony. Will, Freedom, and Power. New York: Basil Blackwell, 1976.

Kuhn, Thomas S. The Essential Tension. Chicago: University of Chicago Press, 1977.

LaPlace, Pierre Simon Marquis de. A Philosophical Essay on Probabilities. Trans. Frederick Wilson Truscott and Frederick Lincoln Emory. New York: Dover Publications, Inc., 1951.

Libet, Benjamin. "Unconscious cerebral initiative and the role of conscious will in voluntary action." The Behavioral and Brain Sciences 8 (1985): 529-567.

Loye, David, and Riane Eisler. "Chaos and transformation: implications of nonequilibrium theory for social science and society." Behavioral Science 32 (1987): 53-65.

Lucretius. De Rerum Natura. Trans. W.H.D. Rouse. 2nd Ed. Cambridge, Massachusetts: Harvard University Press, 1975.

Miskin, Mortimer, and Tim Appenzeller. "The anatomy of memory."

Scientific American June 1987: 80-89.

Murray, Frank, Ramazan Gencay, and Thanasis Stengos. "International chaos?" European Economic Review Oct. 1988: 1969-84.

Oakley, David A., ed. Brain and Mind. New York: Menthuen, 1985.

Peterson, Ivars. "Ribbon of chaos." Science News 26 Jan. 1991: 60-61.

Pojman, Louis P. "Freedom and determinism: a contemporary discussion." Zygon 22 (1987): 397-417.

Pool, Robert. "Quantum chaos: enigma wrapped in a mystery." Science Feb. 1989: 893-895.

Richards, Diana. "Is strategic decision making chaotic?" Behavioral Science 35 (1990): 219-232.

Rosser, J. Barkley. "Chaos theory and the new Keynesian economics." The Manchester School of Economic and Social Studies Sept. 1990: 269-291.

Scott, George P. Atoms of the Living Flame. Lanham, Missouri: University Press of America, 1985.

Sidertis, Mark. "Beyond compatibilism: a Buddhist approach to freedom and compatibilism." American Philosophical Quarterly 24 (1987): 149-159.

Simon, Herbert A. "Prediction and prescription in systems modeling." Operations Research Jan.-Feb. 1990: 7-15.

Skarda, Christine A., and Walter J. Freeman. "How brains make chaos in order to make sense of the world." The Behavioral and Brain Sciences 10 (1987): 161-195.

Stewart, Ian. Does God Play Dice?. Cambridge, Massachusetts: Basil Blackwell, 1989.

Taubes, Gary. "The body chaotic." Discover. May 1989: 62-67.

Thorp, John. Free Will: A Defence Against Neurophysiological Determinism. London: Routledge & Kegan Paul, 1980.

Wright, Georg Henrik von. Causality and Determinism. New York: Columbia University Press, 1974.