Chaos Theory, a suggestion toward deterministic reality.

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ABSTRACT

First noticed in the sixties and then developing much in the late seventies, Chaos Theory has revolutionized certain areas in science to the extent that some consider a paradigm shift. This has a profound effect on our lives as Chaos Theory becomes popularized through application and the media. My project is an investigation as to what exactly Chaos Theory is, and also an exploration of the implications of it, concerning widespread acceptance and with respect to notions of deterministic realty.

INTRODUCTION

Chaos Theory is a popular scientific theory, which grew out of dynamical systems theory; a branch of mathematics devoted to the motions of systems. Chaos Theory is a topic of public awareness today, so that even those not in a scientific field will likely know something about it or at least have heard mention of the phrase. Chaos Theory is touched on in certain mainstream films (pi, Jurassic Park), aspects of it can be commonly found used as examples in intermediate mathematics course texts and there is even a Linux screensaver (included by default on several major distributions) which traces the path of the Lorenz Butterfly attractor. One would be hard pressed to argue that Chaos Theory hasn't sent ripples through the scientific community, some consider its significance equivalent to a paradigm shift. In addition, despite its short history, the phrase 'Chaos Theory' was first associated around 1975, the Chaos Theory craze has spurred several explicitly nonscientific approaches in the exploration of the phenomena (such as the 'pulp occult' Chaos Magic), and has grown synonymous with a plague of potential suspicion we can now harbor, that in any circumstance of disarray, a discrete, perhaps even simple, set of rules is operative. This obfuscated aspect of 'chaotic order' adds a certain charm and yet challenges us to question numerous aspects of our existence in the pursuit of a higher understanding.

Why is Chaos Theory so important? Applications from 'pure' Mathematics are fundamental to our science and technology, indeed, this shapes our very essence as an evolving culture. Chaos Theory, as an extension of dynamical systems theory, is frequently used in applied dynamics, in the context of modeling complex natural systems, which has extensive applications in all fields of science. Chaos Theory also provides a new means to bring together distant areas of science, by providing a bridge between several complex models, spread across otherwise unassociated specialities, into a unified framework of complexity, a unification of the sciences.

METHOD

This research project consisted of extensive reading through books and articles followed by contemplative periods. I will briefly outline my direction of discussion; I will first touch on some primary features of Chaos Theory as described by Dr. Edward Lorenz, who is credited with the discovery of the phenomena. Then I will proceed to examine several notions of freedom and how a consideration of Chaos Theory is significant in this regard.

RESULTS/DISCUSSION

What is Chaos and What is Chaos Theory? Before we begin with Chaos Theory we will first devote some time into what we first mean by Chaos, such as, are there different types of chaos and also what we mean when we say "chaos." Calling upon a dictionary, we are given several meanings which seem appropriate for mention, they include: 'the inherent unpredictability in the behavior of a natural system (as the atmosphere, boiling water, or the beating heat)', 'a state of utter confusion', and 'a confused mass or mixture.' All of these are adequate as an initial introduction to this topic. Further essential to the lure of Chaos Theory is resolving unpredictability, or the inability to foretell the state of something on the basis of observation, experience, or scientific reason. This unpredictability is kin to a special kind of randomness. A dictionary will tell us something along the lines of 'lacking a definite plan, purpose, or pattern,' and also lacking a 'regular procedure.' And this is adequate, although a bit too general for Chaos Theory, as least from the scientific perspective. In The Essence of Chaos, Lorenz defines randomness in the broad sense as something identical with the absence of determinism. He says that this applies to Chaos Theory chaos only in appearance. This is to say that chaos looks indeterministic, but really is not. In the same volume, Lorenz later describes "chaos" a word which 'originally denoted a complete lack of form or systematic arrangement, but now often used to imply the absence of some kind of order that ought to be present.' He further states that recently, as chaos theory has been swept into popularity, the word has acquired several 'related but distinct meanings.'

This has some profound implications if chaos is really apparent confusion that cloaks a deterministic interior. Many things appear without pattern or reason and in such approach a certain respect for their untouchableness from reductionist thinking. If the pieces of our experience which we call unknown, because they are impossible to fathom through wildness, can become known, then this implies that our world would have to be more deterministic then previously held. Such a direction stimulates a certain concern, for in understanding of our universe, we come to believe our freedom diminished. Lorenz thinking would seem to suggest this direction, as we can see in the following:

> "...I had come across a phenomenon that later came to be called 'chaos' - seemingly random and unpredictable behavior that nevertheless proceeds according to precise and often easily expressed rules. . . I shall use the term chaos to refer collectively to processes of this sort - ones that appear to proceed according to chance even though their behavior is in fact determined by precise laws." (Lorenz, The Essence of Chaos, ix-4)

This nearly suggests a reversal in the meaning of the word chaos, as by the popularity of chaos theory grows, the notion of predictable chaos may over ride this word's traditional usage and meaning.

Here Lorenz has outlined a broad definition of Chaos Theory as it pertains to scientific inquiry. This tells us that there is a difference between processes which appear to be random and others which, are in fact, random. So Lorenz would seem to suggest a world where there exists both types of processes and it is the question of being able to determine which is manifesting at a given time, in the interests of usefulness to us through science. It can be confusing, however, to think about deterministic behavior as random seeming, but Lorenz maintains this occurs through misnomers in observation. A conceptual example, consider a situation where you have a state of being which is apparent enough (meaning it may look simplistic and straightforward) and it switches suddenly to a different behavior which is completely nonsensical to the naked eye (or naked perception rather), a whole lot of insanity erupts. After some time, quite some time even, there seems to be a reversion to the previous, more simplistic pre-haphazard behavior. We may even think this is the same as the previous state, but Lorenz cautions us to that the states on either end of the frenzied period are not alike, but are only nearly alike.

Lorenz also discusses another type of chaotic behavior in which he says systems are sensitively dependent on initial conditions. In this type of behavior, you could have two completely different beginning states, which look nothing like one another and after a lapse of apparent randomness they come to resemble each other very closely.

> "An immediate consequence of sensitive dependence in any system is the impossibility of making perfect predictions, or even mediocre predictions sufficiently far into the future." (Lorenz, The Essence of Chaos, 12)

In this we have the behavior where the smallest difference in the beginning of something, no matter how small as long as it is there, will have drastically different outcomes. And herein lies our difficulty with predictability, measurement must be perfect because it lies at the heart of what is significant. If you have ever needed data to a high degree of accuracy or especially if you have worked in a lab setting you will know it comes down to a resolution of detail. To further emphasize; perhaps your cutting-edge, research, computer equipment is only capable of values to the 20 decimal places and you know that in order to get past a particular degree of sensitivity blocking your efforts to know what will happen, you need to have data which lies at 21 decimal places of accuracy. Well, then you are out of luck, as a best case scenario, the problem might be such that you could make predictions which would error rapidly after only a short period of time. Concerning the particular nature of randomness, we have the following:

> "...the present state completely or almost completely determines the future?" (Lorenz, The Essence of Chaos, 8)

In this I take it to mean that given a sequence which appears random and has a predictable outcome, that outcome is contingent on the particular sequence which lead to it and could not have been merely a collection of anything. So, in the recipe of chaos, there must exist this special relationship in a given system, in all states, the state just prior is significant.

Lorenz uses two examples in Essence of Chaos as aids in illustrating the difference between a system of mere randomness and one which is encompassed by chaos theory. I feel they are useful, so I include them here. The first is a coin toss, where you toss the coin, record the result, and so on, until you tire of it. Here our sequence of events are considered the successive resulting faces of the coin. This is randomness, there will be no chaos relationship in the heads verses tails with respect to time, because between any two tosses of the coin there is human intervention which prevents the result from one outcome from determining the next result. In a pinball machine, however, the only human interaction is prior to the initial strike of the first pin. With the pinball model, we consider an 'event' to be the particular pin that is struck, together with its position and the velocity of the ball as it leaves each pin. The path the ball takes is sensitively dependent on the initial speed the ball is struck in as follows:

> "... a ball hits only seven pins on its downward journey, a change of a millionth of a degree in its initial direction would amplify to ten degrees, but a change of a ten-millionth of a degree would reach only one degree." (Lorenz, The Essence of Chaos, 10)

What are some examples of chaos we can see?

> "Phenomena that are supposedly chaotic include simple everyday occurrences, like the falling of a leaf or the flapping of a flag, as well as much more involved processes, like the fluctuations of climate or even the course of life itself." (Lorenz, The Essence of Chaos, 5)

There is also a consideration for random arrangements in space rather than (or in addition to) random progressions in time (as Lorenz used wildflowers dotting a field to illustrate this in The Essence of Chaos.).

What is the Butterfly Effect? The butterfly effect is a popular symbol of chaos theory, however Lorenz would seem to regard it as misleadingly untrue in practice, he admits that there is uncertainty regarding what it was exactly that coined the phenomena, but notes that it arose shortly after a paper he submitted in 1972, called "Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?" In this paper he neglects to answer this question, but offers some skeptical speculation instead. He said that if the flap of a butterfly wing can cause a tornado, then it could also possibly prevent one that would have occurred otherwise, to say nothing of the catastrophic effects animals with bigger wings would have on our climate, such as birds? Another possibility for the origin of the phrase lies in the form of a certain stranger attractor (the graphical representation of a certain collection of states), which became known over time as 'The Butterfly' because it resembles one. Aside from these suggestions, Lorenz offers the following in light of the origin to the Butterfly Effect:

> "Perhaps the Butterfly, with its seeming frailty and lack of power, is a natural choice for a symbol of the small that can produce the great." (Lorenz, The Essence of Chaos, 15)

Science Isolating Chaos.

In an effort to pin chaos, Lorenz admits that it can become 'inconvenient' to define chaos in terms of notions such as sensitive dependence, because then it becomes difficult to determine if a phenomena is chaotic (because by the nature of it, sensitive dependence is very hard to determine). He also notes that the lack of periodicity has sometimes been used as a definition for chaos, in place of sensitive dependence. But conceptualizing chaos in terms of sensitive dependence he says is simplified in certain dynamical systems via a property called compactness. With compactness, you have a very limited number of possible different states, so over short periods of time, you see the same states reappearing and, by this, you have a kind of rhythm. By rhythm I do not mean to suggest periodic behavior, although Lorenz's book considered scenarios of the almost periodic. Lorenz cautions us that a lack of periodicity does not guarantee sensitive independence because you could have a behavior that is both lacking in periodicity and isn't compact, then you would not have a close repetition of states, so you could not really know for certain whether sensitive independence was present. With this in mind, it is important to note that there could be many systems of interaction in the world which go unnoticed by us. The recognition of these systems could further be essential to a better understanding of the nature of reality itself, but we would never see it if this tell-tale repetition happens too seldom for our perception of it. And speaking toward the future, it may seem harmlessly optimistic to suggest that we will one day mature our temperments enough so that we would have the ability to perceive things previously too subtle for our technological ingenuity, however in the same consideration, I doubt anyone but the most loosely anchored individual would admit to the likelihood that humanity would ever reach a state where subtle shifts over million year spans are scientifically documentable.

As an example of compactness, Lorenz modified his pinball machine model and extended it vertically an arbitrarily long distance (imagine a 75 foot pinball machine with a regular distribution of pins). Now if we observe the path of the ball as it travels down the machine, eventually we will see a (startling) near-repetition begin to emerge in the path the balls falls. This also demonstrates the potential for almost periodic behavior in chaos.

So far we have two general approaches to defining 'chaos,' a behavior which lacks periodicity and a more specific behavior which also possesses the property of sensitive dependence. Another idea that Lorenz talks about in his exploration to the meaning of chaos, is unstable equilibrium. To establish our terms, a state is in equilibrium when it remains unchanged as time advances and something is unstable if a state in which it is only slightly removed, evolves into something drastically different. Stability here is when a slight disturbance fails to cause a large subsequent effect. The example he gives is the attempt to balance a well sharpened pencil on its point. In all likelihood, the pencil will fall over in less then a seconds time. This unlikelihood is greatly intensified the longer we attempt to balance the pencil, as Lorenz states the propability of the pencil to stand up for two seconds is several million times less likely then for one second, and so forth, as follows:

> "... if every human being who ever lived had devoted his or her entire life to attempting to make sharpened pencils stand on end, it would be highly unlikely that even one pencil would have stood up for six seconds. Of course, you may have somewhat better luck if the points of your pencils become slightly worn." (Lorenz, The Essence of Chaos, 22)

In theory this pencil could remain vertical forever, if it was positioned in equilibrium, but we are far from being able to determine the difference between a pencil that is truly vertical and one that is slightly tilted. Lorenz adds that the mathematical chance for us to pick the exact vertical state among infinitely many vertical near states is zero, and even if unstable equilibrium was achieved in the real world, something would soon disturb it. But Lorenz says that chaotic systems may possess states of equilibrium that are unstable. Certainly we can see how unstable equilibrium and sensitive dependence are similar in the regard they involve the 'amplification of initially small differences.'

> "The distinction between a system that merely possess some states of unstable equilibrium and one that is chaotic is that, in a system of the latter type, the future

> course of every state, regardless of whether it is a state of equilibrium, will differ more and more from the future courses of slightly different states." (Lorenz, The Essence of Chaos, 23)

Lorenz uses the example of the pinball machine to illustrate unstable equilibrium where the ball has come to rest atop a pin, the slightest disturbance will send it quickly continuing down either to the left or right of the machine. But this lacks something in that there is no continuing process of random seeming behavior, no 'unpredictable unfolding' for us to observe, rather, this is hinging on a single event with properties of sensitive dependence. This isn't chaos, yet this is a significant element of the chaos phenomena, Lorenz concludes his exploration of an essential characterization of chaos by incorporating unstable equilibrium with sensitive dependence (giving it 'essential qualification'). In a given dynamical system, there are constants that may be unaltered if a system evolves without interference, or altered if new conditions are introduced. These introduced changes represent virtual constants and the examples used include the following: Two objects are sliding down a frictionless hill with identical velocities, and they will keep their positions relative to one another, as if standing still, unless we disturb the situation somehow, by interacting with one of the objects; causing one to radically diverge from its neighbor. Constants, by definition, are always of the same value, but here we change them and perhaps send them off on a process of change, so these constants then, with an almost paradoxical feeling of variability, become virtual constants. Another example Lorenz used, are the sides of a frictionless bowl, where speed and direction vary but the total energy is a virtual constant. Lorenz introduces two more terms in order to distinguish between different types of changes that affect the initial conditions of a system with sensitive dependence. They are exterior and interior changes, where the first type encompass changes in the set of initial conditions which will affect virtual constants, and the later are changes which do not. Lorenz redefines a chaotic system 'as one that is sensitively dependent on interior changes in initial conditions' and he adds that exterior changes by itself will not imply chaos, he further considers:

> "Concurrently, we may wish to modify our idea as to what constitutes a single dynamical system, and decide what, if we have altered the value of any virtual constant, we have replaced our system by another system. In that case chaos, as just redefined, will be equivalent to sensitive dependence on changes that are made within one and the same system." (Lorenz, The Essence of Chaos, 24)

Here he asks whether, in models of dynamic systems, we should regard certain changes as significant enough to be considered a different model altogether, and that we should come to some agreement when attempting to define what chaos phenomena is about paying a close attention to where we feel a given system is still the 'same system.' This might at first suggest to some a churning inwardness within the unpredictable behavior of chaos (the notion that it must be an inwardly changing system, for example), but it is rather an assurance of where we will find it, by selectively picking situations which make it possible for us to find. This becomes a convention to aid in the isolation of chaos, because given a system that has chaos phenomena, but also exterior changes, we could never be certain. This is clearly evident from Lorenz, from the following where he says: "?the modified definition - sensitivity to interior changes - will lead to more acceptable conclusions." However, as I interpreted

Lorenz, this is not to say chaos doesn't have the possibility to be manifest in situations of exterior influence.

Regarding how to find chaos and recognize where it occurs, there have been inquiries made toward investigations into how "normal" behavior could erupt into chaotic behavior. What could be the trigger for this insanity? The suggestion which underlies this inquiry would seem to be that the world is usually to be found in a state of regularly behaving, usual predictability; and that chaos is the fleeting, haphazard detour. We are reminded, by Lorenz among others, of the ubiquiousness of chaos in that in order to better understand our regularity, we should perhaps consider this "predictability" as something which could evolve from chaos. Chaos is truly and unfolding of seemingly unpredictable explosions of change, then perhaps calmness, then perhaps implosions of inwardly decreasing change and there is even feelings chaos "pretends" to be periodic. Lorenz describes some chaotic behavior as follows:

> "Sometimes, however, a nearly imperceptible change in a constant will produce a qualitative change in the system's behavior: from steady to periodic, from steady or periodic to almost periodic, or from steady, periodic, or almost periodic to chaotic. Even chaos can change abruptly to more complicated chaos, and, of course, each of these changes can proceed in the opposite direction." (Lorenz, The Essence of Chaos, 69)

What is a Strange Attractor?

> "The states that do occur again and again, or are approximated again and again, more and more closely, therefore belong to a rather restricted set. This is the set of attractors." (Lorenz, The Essence of Chaos, 41)

> "An attractor that consists of an infinite number of curves, surfaces, or higher-dimensional manifolds - generalizations of surfaces to multidimensional space - often occurring in parallel sets, with a gap between any two members of the set, is called a strange attractor. The name was introduced in the early 1970s by David Ruelle and Floris Takens in a paper in which they proposed that fluid turbulence is an example of what we now call chaos." (Lorenz, The Essence of Chaos, 48)

A strange attractor is really nothing more then a graphical representation of a collection of states, which may include variables like atmospheric temperature and pressure. The fascination with them, according to Lorenz, dwells around the startling appearance certain "strange" ones manifest. Phase Space is a term which refers to the hypothetical multidimensional space onto which the attractors (relationships of states) are graphed. This space can have as many dimensions as there are variables in the given system, although this seems to get very quickly impossible to visualize, this type of conceptualization is still held useful enough by those working in scientific disciplines. It is important to note that not all types of chaotic systems will have strange attractors (i.e. Hamiltonian systems).

Lorenz makes a note about the ability for us to create a theory describing some aspects of chaos using little more then pencil and paper, but he asserts that in order to demonstrate chaotic solutions of specific systems and constructing the accompanying strange attractors, there is something more required, and this is the commonplace arrival of the computer.

Without this, the computations just for trial and error experimentation would take impossibly long periods of time. So we have a feeling that as the computer became more integrated, so did the scientific interest in chaos.

In regards to how some view the economy and specifically, stock market prediction and as we especially see in the recent film pi (Artisan Entertainment), Lorenz says the following:

> "In the past many economists have assumed that the economy has an equilibrium state, and that it would settle down to this state, without and annoying business cycles, if only we would stop meddling with it - in short, if it were not subjected to variable forcing. What some chaos-minded economists are now proposing is that, as a dynamical system, the economy is chaotic, and business cycles, at irregular intervals, are inevitable. Meddling might even suppress rather than produce the cycles, but more likely it would simply shorten some recessions and lengthen others?economists have learned from experience how various aggregates of people can influence the economy. They have formulated simple systems of equations that incorporate some of the assumed interactions, and in some instances have encountered chaotic solutions." (Lorenz, The Essence of Chaos, 149)

So, we know that certain economists have been able to at least abstract the population in such a way that chaos was evident. This suggests, that is their abstractions are well enough, that our economic system is chaotic.

This exploration by Lorenz is important because it servers to outline the selective brand of chaos that most science would seem to be interested in, or regard as valid. The scientific notion of chaos, as examined here, does not encompass chaos in its entirety, even speaking about it in such abstract terms, it seems much of the notion to what chaos is, is left to the unknown. And Lorenz does not explicitly confine chaos to any caste, he merely entertains in his book, that we play with some assumptions and different definitions. What Lorenz establishes about chaos is a 'working definition,' from which to further discuss examples in the spirit of better understanding.

On contemplation, of the vast application of chaos theory, also found abundantly in the structure of life systems and suspected by some to define the distribution pattern of galaxies thousands of light years from Earth, can be identified, or at least suspected everywhere in our experience. We know that chaos can arise from apparent order and also that the reverse is possible. We also know that, especially in systems which lack the property compactness, chaos can exist on a scale which is too vast for us to identify.

Deterministic Chaos is promoted in nearly every book I've read concerning the subject, as a radically pervasive phenomena in our lives. Chaos is everywhere, and there seems no limit in the creative descriptions toward the likelihood of the phenomena. This, in conjunction with the limitation that scientific inquiry must be constrained by, in order to retain the modern day notion of scientific, opens the door for some alarming speculation. Namely, this is a suspicion that reality operates deterministically. Consider what we are capable of knowing thus far. Chaos Theory exists in a state of excitement because through its application we have a better method for solving certain obstacles then with anything prior. We regard it as valid and useful, perhaps an indicator to a more truthful state of being on some levels. We know deterministic chaos exists, numerous examples exists in support of this. We create models of chaotic systems with properties of sensitive dependence and compactness, in the interests of better understanding how the real world counterpart may operate. In addition, and in adherence with Lorenze's suggestions, we try to only utilize systems that are sensitively dependent on interior conditions because a consideration for exterior influences quickly removes the object of the experiment from any hope for practical isolation. And even considering these restrictive measures, Chaos Theory models tend to deal with highly complicated scenarios that challenge the very experts of their field. The ability to construct an applicable model is surely one of the most prized skills in this area of study, because you are challenged with the necessity of keeping your hypothetical system confined, within reason, to the capacity of whatever the most powerful computers available happen to be at the time. And perhaps in addition, although maybe a lesser extent, you must keep your model comprehenisble to yourself, or at least in such a format that you would be able to eventually to decode the results of your abstraction.

This is especially true concerning weather prediction as the reason Lorenz pointed out that we are still not capable of accurately predicting the weather very far in advance is due to complexity of the model and the machines that run the simulation. The imperfection of the global weather model, despite it being a five million variable monstrosity, is no secret. It is a waiting game until better equipment is available, and then so another, more complicated model, can be devised to peak the performance envelope of the machinery it runs on, and so on as it has been for the last 40 years. It is further interesting to note the accuracy in which weather prediction improves with every machine generation is marginally significant, despite significant enhancements to the model and equipment.

What about deterministic chaos that we can't ever hope to isolate? Lorenz admitted on several occasions in The Essence of Chaos, that there is the possibility of an operative deterministic chaos in the real world without compactness and cleanly cut sensitive dependence on interior conditions. There would be no chance we could find it. What does this mean? It means an unknown degree of deterministic chaos can exist beyond our ability to recognize it, much less prove. (It would seem then, less contemporary meanings for words like 'chaos' will still find use in our lives.) Following from this heavy uncertainty, some of us may tempted to ask the question, "Might Chaos be all there really is?" If deterministic chaos is an accurate description for the flow of existence, then wouldn't this be the same as saying reality is deterministic? Lorenz contemplates this in The Essence of Chaos, where he says the following:

> "We may believe that some phenomena is governed by deterministic laws and that it responds in a regular manner, only to discover at some point that its behavior is more irregular than we suspected." (Lorenz, 157)

This is important when we reflect that back in the early seventies and prior, when this was all very new, when people at various university environments and other scientific arenas were actively engaged in trying to localize chaotic behavior in real world behavior and mathematical constructions. Today, only a few decades later, the feeling has changed with an avid abundance in terms of chaos-awareness, it is regarded with such confidence in a nearly taken for granted significance, as we can see from Lorenz here:

> "The collection of phenomena that we recognize as behaving chaotically has become so great that it would be hard to compile a comprehensive list." (Lorenz, The Essence of Chaos,157)

The interest into whether chaos is so fundamental that even what we think of as ‘true randomness ‘ as also chaotic, is contemplated by Lorenz:

> “The question that I wish to address now is whether chaos is so ubiquitous that all or most of the processes that we still regard as behaving randomly should become recognized as being chaotic instead ... we need to consider the question of the free will of human beings, and perhaps of other animate creatures. Most of us presumably believe that the manner in which we will respond to a given set of circumstances has not been predetermined, and that we are free to make a choice.” (Lorenz, The Essence of Chaos,158)

He then goes on to speculate that our behavior in a broader sense could be considered a kind of randomness. This is to suggest that perhaps it would not matter if our actions were of true free choice, because the effects from them would radiate throughout the world anyway, adding to the total chaotic intermix (meaning, animate intervention would contribute to chaos systems, not cancel it out). The example he uses is a falling leaf from a tree as a miniscule portion of the global weather system. If someone chooses to walk by at the crucial instant, the path the leaf falls will differ from small changes in the air currents caused by the pedestrians movement. This change in turn furthers to other subtle changes and so on. The entire world would seem driven through chaotic relationships, fixated by underlying order, excepting the beacons of human intellect which swim through it. But this seems to leave a special reservation for the human mind, somehow as if it is special, or set apart from the mechanized seeming predictability of other reality.

However, there are those who feel we don’t have this independence of mind necessary for a true sense of free will, and the notion that we as people are really just products of our environment is a popular one in social science, and this is significant when reflecting on things like Chaos Theory. An excellent example of this is Burrhus Frederic Skinner (1904-1990), a psychologist who is perhaps most widely known for his contribution of Operant Behaviorism.

In the forward by Jerome Kagan to The Skinner Primer, we have an entertaining perspective for the feelings Skinner triggered with his ideas:

> “Yet here comes Skinner, a little like Copernicus, telling us that our phenomenology is defective and we are deluded if we believe that we control our actions. They are, on the contrary, under the firm stewardship of the past, continually monitored by the invisible happenings of yesterday, by changes that occurred deep within our nervous system on the many times we displayed a particular action in the situation we are in at the moment. Such a challenge to our sense of freedom and dignity has irritated and energized many and given solace to a few.”

In Operant Behavior, the fundamental message revolves around the following:

> “All organisms, including humans, are greatly influenced by the consequences produced by their own behavior - that is the basic notion of Skinnerian psychology. Its meaning embraces the following simpler statements: (1) All animals and humans are behaving creatures. (2) A given act is followed by an experience that is a conse-

> quence of the act. (3) The quality of the consequence influences further action. An important point is that the consequence arises in the outer environment. Therefore the environment holds the key to most of the changes that occur in the way a person behaves." (Carpenter, The Skinner Primer, 5)

Here we have the notion that the patterns of behavior which make up human personalities are shaped by experiences, and certainly also by our memory of past experiences and how they build on each other. Whether we are 'rewarded,' 'threatened,' or 'punished' dictates significantly our subsequent course of action. Consequently, we do not have free will the do anything we desire, we are instead highly conditioned to do certain things with respect to the course of action we take. Furthermore, Skinner's psychology is called a 'psychology of values' where the human is considered a 'value-making creature.' In this scheme, positive values are associated with experiences which are rewarding (good, those that meet the needs of survival and growth) and negative values are associated with experiences which are ... not so good (bad, considered aversive or a punishment, i.e. threat to physical safety). Natural selection then, would dictate that all of us alive today are here as a result of a certain minimum threshold sensitivity to the important consequences of the behavior which our ancestors possessed. So, in summary, what a person does often has consequences that alter his or her behavior, and these consequences arise in our environment, an environment characterized by only yielding rewards after certain actions take place (referred to as a 'contingent' environment).

It becomes easy to see how through, although admittedly this is a liberal regard, both Chaos Theory and Operant Behaviorism, one can construct an image of our world that appears highly deterministic. In mathematics, as I have been witness, you learn after a while that the linear examples, which permeate much in terms of introductry coursework, are seldom reflected in real world scenarios. More often, the relationships evident in the nature are those composed of multivariable, nonlinear systems of equations. This establishes why notions such as Chaos Theory are so expansive in useful applications of modeling natural behavior. If our natural world becomes ever more successfully depicted via deterministic description, could this suggest a future which accepts their livelihood and liberties as through an objectified, mechanistic lens?

Not entirely knowing how to deal with the sense of alarm this brings, I look to quantum theory, which suggests effecting change through observation. In quantum theory there is the idea that one cannot separate herself as a pure objective observer and it is the "attention" to certain quantum experiments which causes them to change. An overview of quantum theory can be gathered from the following:

> "The reason that both position and velocity cannot be determined simultaneously is that any system used to observe the particle interacts with particle. More specifically, there is an interchange of energy between the observing system and the object. Hence, the very act of observation alters the behavior of the particle. No clear-cut distinction can be made between the particle and the observing system because of the energy exchange between the two; their boundaries apparently fuse in some zone of interaction. This nebulous fusion means that the particle cannot be identified independent of the system of observation. It becomes part of a larger whole." (Carpenter, The Skinner Primer, 69)

This is significant because in classical physics determinism is

> "Moreover, given the current state of the art, there is not even any firm evidence for the thesis that quantum physics is important to neurophysiological research. A judgement on whether or not quantum physics is relevant on the level of brain research seems premature. What is much more, even if it were established that quantum physics is pertinant to brain research, it is not clear which, if any, would be the consequences for the philosophy of mind." (Esfeld)

LIMITATIONS

There were a number of reasons why I felt I could not use most of the acquired items on my reading list. A number of books were no longer valid after my topic grew slowly into something more appropriate as time went on. Another reason I felt constrained against using more sources ,was because a significant quantity of material served as an 'introduction' to Chaos Theory, but with some difference in quality of presentation. So there was a repetition in my sources that I handled by selecting what I felt to be the best representative material.

In addition, I don't think it's hard to see how that if my topic is rephrased with only slightly less passivity, a solution is understandably far beyond the scope of an undergraduate research project as well as demanding massively cross disciplinary communication. This effort grew quickly into an exploration of how to better approach the question in terms of whether it was an appropriate question, but this experience did provide me with an appropriate focus in a means to better understand the components that underlie my inquiry. I now know 'something of what would have to happen' for a better materialization toward an answer; untold degrees of further research and a distant future.

The essence of my questioning was simply "What is Chaos Theory and does it suggest that we live deterministically?' The answer I feel lies spread across several areas of study, although by no means restricted to the listing here, this includes what sprang out during my findings, in no particular order:

> In mathematics (dynamical systems theory, chaos theory) a further realization to the extent the ubiquious quality deterministic chaos plays in the world.
>
> In the social sciences, perhaps a reassessment as to the validity the behavioralist perspective has in explaining ourselves as the products of our environment.
>
> In physics, our further exploration of quantum theory and how the subatomic threshold translates significantly into the overlying (resulting) macro-world and also further developments concerning how physics applies in neurology.
>
> And in philosophy, to provide a conceptual framework that explicitly bridges these above furtherments, with respect to our sense of place, meaning and the why of our existence; and lastly, as a vehicle by which to offer and preserve this awareness for everyone.

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