The Theory Of Chaos Essay, Research Paper

Where Chaos begins, classical science ends. Ever since physicists have inquired into the laws of nature, the have not begun to explore irregular side of nature, the erratic and discontinuous side, that have always puzzled scientists. They did not attempt to understand disorder in the atmosphere, the turbulent sea, the oscillations of the heart and brain, and the fluctuations of wildlife populations. All of these things were taken for granted until in the 1970’s some American and European scientists began to investigate the randomness of nature.

They were physicists, biologists, chemists and mathematicians but they were all seeking one thing: connections between different kinds of irregularity. “Physiologists found a surprising order in the chaos that develops in the human heart, the prime cause of a sudden, unexplained death. Ecologists explored the rise and fall of gypsy moth populations. Economists dug out old stock price data and tried a new kind of analysis. The insights that emerged led directly into the natural world- the shapes of clouds, the paths of lightning, the microscopic intertwining of blood vessels, the galactic clustering of stars.” (Gleick, 1987)

The man most responsible for coming up with the Chaos theory was Mitchell Feigenbaum, who was one of a handful of scientists at Los Alamos, New Mexico when he first started thinking about Chaos. Feigenbaum was a little known scientist from New York, with only one published work to his name. He was working on nothing very important, like quasi periodicity, in which he and only he had 26 hour days instead of the usual 24. He gave that up because he could not bear to wake up to setting sun, which happened periodically. He spent most of time watching clouds from the hiking trails above the laboratory. To him could represented a side of nature that the mainstream of physics had passed by, a side that was fuzzy and detailed, and structured yet unpredictable. He thought about these things quietly, without producing any work.

After he started looking, chaos seemed to be everywhere. A flag snaps back and forth in the wind. A dripping faucet changes from a steady pattern to a random one. A rising column of smoke disappears into random swirls. “Chaos breaks across the lines that separate scientific disciplines. Because it is a science of the global nature of systems, it has brought together thinkers from fields that have been widely separated…Chaos poses problems that defy accepted ways of working in science. It makes strong claims about the universal behavior of complexity. The first Chaos theorists, the scientists who set the discipline in motion, shared certain sensibilities. They had an eye for pattern, especially pattern that appeared on different scales at the same time. They had a taste for randomness and complexity, for jagged edges and sudden leaps. Believers in chaos– and they sometimes call themselves believers, or converts, or evangelists–speculate about determinism and free will, about evolution, about the nature of conscious intelligence. They feel theat they are turning back a trend in science towards reductionism, the analysis of systems in terms of their constituent parts: quarks, chromosomes, or neutrons. They believe that they are looking for the whole.”(Gleick, 1987)

The Chaos Theory is also called Nonlinear Dynamics, or the Complexity theory. They all mean the same thing though- a scientific discipline which is based on the study of nonlinear systems. To understand the Complexity theory people must understand the two words, nonlinear and system, to appreciate the nature of the science. A system can best be defined as the understanding of the relationship between things which interact. For example, a pile of stones is a system which interacts based upon how they are piled. If they are piled out of balance, the interaction results in their movement until they find a condition under which they are in balance. A group of stones which do not touch one another are not a system, because there is no interaction. A system can be modeled. Which means another system which supposedly replicates the behavior ofthe original system can be created. Theoretically, one can take a second group of stones which are the same weight, shape, and density of the first group, pile them in the same way as the first group, and predict that they will fall into a new configuration that is the same as the first group. Or a mathematical representation can be made of the stones through application of Newton’s law of gravity, to predict how future piles of the same type – and of different types of stones – will interact. Mathematical modeling is the key, but not the only modeling process used for systems.

The word nonlinear has to do with understanding mathematical models used to describe systems. Before the growth of interest in nonlinear systems, most models were analyzed as though they were linear systems meaning that when the mathematical formulas representing the behavior of the systems were put into a graph form, the results looked like a straight line. Newton used calculus as a mathematical method for showing change in systems within the context of straight lines. And statistics is a process of converting what is usually nonlinear data into a linear format for analysis.

Linear systems are the classic scientific system and have been used for hundreds of years, they are not complex, and they are easy to work with because they are very predictable. For example, you would consider a factory a linear system. If more inventory is added to the factory, or more employees are hired, it would stand to reason that more pieces produced by the factory by a significant amount. By changing what goes into a system we should be able to tell what comes out of it. But as any factory manager knows, factories don’t actually work that way. If the amount of people, the inventory, or whatever other variable is changed in the factory you would get widely differing results on a day to day basis from what was predicted. That is because a factory is a complex nonlinear system, like most systems found in nature.

When most natural systems are modeled, their mathematical representations do not produce straight lines on graphs, and that the system outputs are extremely difficult to predict. Before the chaos theory was developed, most scientists studied nature and other random things using linear systems. Starting with the work of Sir Isaac Newton, physics has provided a process for modeling nature, and the mathematical equations associated with it have all been linear. When a study resulted in strange answers, when a prediction usually came true but not this one time, the failure was blamed on experimental error or noise.

Now, with the advent of the Chaos theory and research into complex systems theory, we know that the “noise” actually was important information about the experiment. When noise is added to the graph results, the results are no longer a straight line, and are not predictable. This noise is what was originally referred to as the chaos in the experiment. Since studying this noise, this chaos, was one of the first concerns of those studying complex systems theory, Glieck originally named the discipline Chaos Theory.

Another word that is vital to understanding the Complexity theory is complex. What makes us determine which system is more complex then another? There are many discussions of this question. In Exploring Complexity, Nobel Laureate Ilya Prigogine explains that the complexity of the system is defined by the complexity of the model necessary to effectively predict the behavior of the system. The more the model must look like the actual system to predict system results, the more complex the system is considered to be. The most complex system example is the weather, which, as demonstrated by Edward Lorenz, can only be effectively modeled with an exact duplicate of itself. One example of a simple system to model is to calculate the time it takes for a train to go from city A to city B if it travels at a given speed. To predict the time we need only to know the speed that the train is traveling (in mph) and the distance (in miles). The simple formula would be mph/m, which is a simple system.

But the pile of stones, which appears to be a simple system, is actually very complex. If we want to predict which stone will end up at which place in the pile then you would have to know very detailed information about the stones, including their weights, shapes, and starting location of each stone to make an accurate prediction. If there is a minor difference between the shape of one stone in the model and the shape of the original stone, the modeled results will be very different. The system is very complex, thus making prediction very difficult..

The generator of unpredictability in complex systems is what Lorenz calls “sensitivity to initial conditions” or “the butterfly effect.” The concept means that with a complex, nonlinear system, a tiny difference in starting position can lead to greatly varied results. For example, in a difficult pool shot a tiny error in aim causes a slight change in the balls path. However, with each ball it collides with, the ball strays farther and farther from the intended path. Lorenz once said that “if a butterfly is flapping its wings in Argentina and we cannot take that action into account in our weather prediction, then we will fail to predict a thunderstorm over our home town two weeks from now because of this dynamic.”(Lorenz, 1987)

The general rule for complex systems is that one cannot create a model that will accurately predict outcomes but one can create models that simulate the processes that the system will go through to create the models. This realization is impacting many activities in business and other industries. For instance, it raises considerable questions relating to the real value of creating organizational visions and mission statements as currently practices.

Like physics, the Chaos theory provides a foundation for the study of all other scientific disciplines. It is a variety of methods for incorporating nonlinear dynamics into the study of science. Attempts to change the discipline and make it a separate form of science have been strongly resisted. The work represents a reunification of the sciences for many in the scientific community.

One of Lorenz’s best accomplishments supporting the Chaos Theory was the Lorenz Attractor. The Lorenz Attractor is based on three differential equations, three constants, and three initial conditions. The attractor represents the behavior of gas at any given time, and its condition at any given time depends upon its condition at a previous time. If the initial conditions are changed by even a tiny amount, checking the attractor at a later time will show numbers totally different. This is because small differences will reproduce themselves recursively until numbers are entirely unlike the original system with the original initial conditions. But, the plot of the attractor, or the overall behavior of the system will be the same.

A very small cause which escapes our notice determines a considerable effect that we cannot fail to see, and then we say that the effect is due to chance. If we knew exactly the laws of nature and the situation of the universe at the initial moment, we could predict exactly the situation of that same universe at a succeeding moment. But even if it were the case that the natural laws had any secret for us, we could still know the situation approximately. If that enabled us to predict the succeeding situation with the same approximation, that is all we require, and we should say that the phenomenon has been predicted, that it is governed by the laws. But it is not always so; it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible…” (Poincare, 1973)

The Complexity theory has developed from mathematics, biology, and chemistry, but mostly from physics and particularly thermodynamics, the study of turbulence leading to the understanding of self-organizing systems and system states (equilibrium, near equilibrium, the edge of chaos, and chaos). “The concept of entropy is actually the physicists application of the concept of evolution to physical systems. The greater the entropy of a system, the more highly evolved is the system.”( Prigogine, 1974) The Complexity theory is also having a major impact on quantum physics and attempts to reconcile the chaos of quantum physics with the predictability of Newton’s universe.

With complexity theory, the distinctions between the different disciplines of sciences are disappearing. For example, fractal research is now used for biological studies. But there is a question as to whether the current research and academic funding will support this move to interdisciplinary research.

Complexity is already affecting many aspects of our lives and has a great impacts on all sciences. It is answering previously unsolvable problems in cosmology and quantum mechanics. The understanding of heart arrhythmias and brain functioning has been revolutionized by complexity research. There have been a number of other things developed from complexity research, such a the SimLife, SimAnt, etc. which are a series of computer programs. Fractal mathematics are critical to improved information compression and encryption schemes needed for computer networking and telecommunications. Genetic algorithms are being applied to economic research and stock predictions. Engineering applications range from factory scheduling to product design, with pioneering work being done at places like DuPont and Deere & Co.

Another element of the nonlinear dynamics, Fractals, have appeared everywhere, most recently in graphic applications like the successful Fractal Design Painter series of products. Fractal image compression techniques are still being researched, but promise such amazing results as 600:1 graphic compression ratios. The movie special effects industry would have much less realistic clouds, rocks, and shadows without fractal graphic technology.

Though it is one of the youngest sciences, the Chaos Theory holds great promise in the fields of meteorology, physics, mathematics, and just about anything else you can think of.