HISTORY OF CHAOS

When was chaos first discovered? The first true experimenter in chaos was a meteorologist, named Edward Lorenz. In 1960, he was working on the problem of weather prediction. He had a computer set up, with a set of twelve equations to model the weather. It didn't predict the weather itself. however this computer program did theoretically predict what the weather might be.

One day in 1961, he wanted to see a particular sequence again. To save time, he started in the middle of the sequence, instead of the beginning. He entered the number off his printout and left to let it run. When he came back an hour later, the sequence had evolved differently. Instead of the same pattern as before, it diverged from the pattern, ending up wildly different from the original. Eventually he figured out what happened. The computer stored the numbers to six decimal places in its memory. To save paper, he only had it print out three decimal places. In the original sequence, the number was .506127, and he had only typed the first three digits, .506.

By all conventional ideas of the time, it should have worked. He should have gotten a sequence very close to the original sequence. A scientist considers himself lucky if he can get measurements with accuracy to three decimal places. Surely the fourth and fifth, impossible to measure using reasonable methods, can't have a huge effect on the outcome of the experiment. Lorenz proved this idea wrong. This effect came to be known as the butterfly effect. The amount of difference in the starting points of the two curves is so small that it is comparable to a butterfly flapping its wings.

> The flapping of a single butterfly's wing today produces a tiny change in the state of the atmosphere. Over a period of time, what the atmosphere actually does diverges from what it would have done. So, in a month's time, a tornado that would have devastated the Indonesian coast doesn't happen. Or maybe one that wasn't going to happen, does. (Ian Stewart, Does God Play Dice? The Mathematics of Chaos, pg. 141)

This phenomenon, common to chaos theory, is also known as sensitive dependence on initial conditions. Just a small change in the initial conditions can drastically change the long-term behavior of a system. Such a small amount of difference in a measurement might be considered experimental noise, background noise, or an inaccuracy of the equipment. Such things are impossible to avoid in even the most isolated lab. With a starting number of 2, the final result can be entirely different from the same system with a starting value of 2.000001. It is simply impossible to achieve this level of accuracy - just try and measure something to the nearest millionth of an inch! From this idea, Lorenz stated that it is impossible to predict the weather accurately. However, this discovery led Lorenz on to other aspects of what eventually cam to be known as chaos theory.

Lorenz started to look for a simpler system that had sensitive dependence on initial conditions. His first discovery had twelve equations, and he wanted a much more simple version that still had this attribute. He took the equations for convection, and stripped them down, making them unrealistically simple. The system no longer had anything to do with the convection, but it did have sensitive dependence on its initial conditions, and there were only three equations this time. Later, it was discovered that his equations precisely described a water wheel.

> At the top, water drips steadily into containers hanging on the wheel's rim. Each container drips steadily from a small hole. If the stream of water is slow, the top containers never fill fast enough to overcome friction, but if the stream is faster, the weight starts to turn the wheel. The rotation might become continuous. Or if the stream is so fast that the heavy containers swing all the way around the bottom and up the other side, the wheel might then slow, stop, and reverse its rotation, turning first one way and then the other. (James Gleick, Chaos - Making A New Science, pg. 29)

The equations for this system also seemed to give rise to entirely random behavior. However, when he graphed it, a surprising thing happened. The output always stayed on a curve, a double spiral. There were only two kinds of order previously known: a steady state, in which the variables never change, and periodic behavior, in which the system goes into a loop, repeating itself indefinitely. Lorenz's equations are definitely ordered - they always followed a spiral. They never settled down to a single point, but since they never repeated the same thing, they weren't periodic either. He called the image he got when he graphed the equations the Lorenz attractor. In 1963, Lorenz published a paper describing what he had discovered. He included the unpredictability of the weather, and discussed the types of equations that caused this type of behavior. Unfortunately, the only journal he was able to publish in was a meteorological journal, because he was a meteorologist, not a mathematician or a physicist. As a result, Lorenz's discoveries weren't acknowledged until years later, when they were rediscovered by others. Lorenz had discovered something revolutionary; now he had to wait for someone to discover him.