Intro to Chaos Theory and its Application to Not-So-Sciency-Things

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In the 1960's, an assistant professor at MIT popularized one of the most catchy phrases in science: the Butterfly Effect. First mentioned in *A Sound of Thunder*, a short story by Ray Bradbury, the seemingly inconsequential death of a butterfly in the past makes a realistic impact in the future. As a literary device used to entertain, the concept suggests that our present conditions can be dramatically altered by the most insignificant change in the past.

Unlike Bradbury though, Edward Norton Lorenz used the literary device in a paper he wrote in 1972: *Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?* As a mathematician and meteorologist, Lorenz was skeptical about the linear systems being developed to predict the weather. As such, he began creating models of his own, including a 12-variable computer model used for weather prediction. While doing so, Lorenz noticed that small variations in his initial variables produced profound changes in his results. Further pursuing the idea, the meteorologist published a paper describing his findings in the *Journal of the Atmospheric Sciences*. His 1963 paper, *Deterministic Nonperiodic Flow*, is credited for laying the foundation for Chaos Theory.

Often associated with physics and mathematics, Chaos Theory has now become a field of study that examines the properties of systems that are considered "chaotic." In short, these systems are characterized as being anything that is highly sensitive to initial conditions. These initial conditions have rich interactions with each other, operate far from equilibrium, and self-organize into patterns that can develop into emergent behavior. One initial condition cannot fully understand the system. If you're still unclear, it may be easier to explain by showing you what it does *not* mean.

In 2004, Ashton Kutcher starred in a movie called *The Butterfly Effect*. If you haven't seen the movie, it depicts the life of a young man who grew up experiencing several unfortunate circumstances. Prone to black-outs, the man finds a way of re-living some of his most painful memories. By acting differently in each situation, he emerges from each black-out to a new set of circumstances. Essentially, Kutcher is able to change his current situation by changing specific decisions he made in the past.

The producers of *The Butterfly Effect* unintentionally blurred my understanding of Chaos Theory. In the movie, the "dynamic system" is the set of circumstances characterizing the life of Ashton Kutcher as an adult. As an obviously complex system, his adult life is changed by minute alterations in the past. By seeking and changing specific events in the past, he is able to produce predictable outcomes in the future. This is not in alignment with Lorenz's original intentions. The confusion comes from two misunderstandings: the one-way directionality of initial changes in dynamical systems and the confusion between the words "deterministic" and "predictable."

To Lorenz, the Butterfly Effect gives us a completely different insight. Starting from some initial point in time, a system's outcome is wholly *determined* by its set of initial circumstances. This does not mean that any initial element *predicts* the outcome. On the

contrary, no initial condition in a chaotic system can accurately predict a system fully. Similarly, we cannot look at a dynamic, chaotic system today and point to a specific cause from the past.

In a sense, the popularization and misrepresentation of the Butterfly Effect is yet another example of the growing gap between the public and scientific community. Today, we are faced with a multitude of other issues that involve highly misunderstood scientific concepts. As scientists (or non-scientists), it is our duty to recognize and educate people when it comes to various scientific concepts that can be misunderstood and propagated, whether intentionally or unintentionally. In addition, we should seek other non-sciency disciplines that may benefit from breakthroughs or ideas created by science.

Assignment

1) Please read Ray Bradbury's "A Sound of Thunder." List two worldy changes resulting from Eckels' mistake. A copy of the short story can be found below: http://www.lasalle.edu/~didio/courses/hon462/hon462_assets/sound_of_thunder.htm

2) Scan Lorenz's paper, *Deterministic Nonperiodic Flow*. Earlier, we discussed how it was almost impossible to predict outcomes from observation of initial characteristics. Although the paper is dense, what approach does Lorenz suggest to understand the influence of initial conditions on chaotic systems? (Hint: Read the last paragraph) The paper can be found at: http://eapsweb.mit.edu/research/Lorenz/Deterministic_63.pdf

3) Take a look at Lorenz's attractor: http://www.exploratorium.edu/complexity/java/lorenz.html

4) In relation to the applicability of Chaos Theory to Not-So-Sciency-Things, please describe, in a paragraph ranging from 150-250 words, some concept or discipline that exemplifies the properties of Chaos Theory. Please try to avoid subjects involving math or science. (For example, the business world is grossly obsessed with the term 'Synergy' – which is used to describe the outcome produced by two or more agents working together to achieve objectives unattainable when the same agents work individually. Or, in anthropology, culture is defined as a group of people who share the same ideas, thoughts, or goals. However, cultural identification occurs due to 'emergent properties' – properties that result from the convoluted interactions of many initial circumstances.)