The meaning of the butterfly

Why pop culture loves the 'butterfly effect,' and gets it totally wrong

By Peter Dizikes
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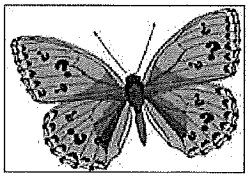
SOME SCIENTISTS SEE their work make headlines. But MIT meteorologist Edward Lorenz watched his work become a catch phrase. Lorenz, who died in April, created one of the most beguiling and evocative notions ever to leap from the lab into popular culture: the "butterfly effect," the concept that small events can have large, widespread consequences. The name stems from Lorenz's suggestion that a massive storm might have its roots in the faraway flapping of a tiny butterfly's wings.



Translated into mass culture, the butterfly effect has become a metaphor for the existence of seemingly insignificant moments that alter history and shape destinies. Typically unrecognized at first, they create threads of cause and effect that appear obvious in retrospect, changing the course of a human life or rippling through the global economy.

In the 2004 movie "The Butterfly Effect" - we watched it so you don't have to - Ashton Kutcher travels back in time, altering his troubled childhood in order to influence the present, though with dismal results. In 1990's "Havana," Robert Redford, a math-wise gambler, tells Lena Olin, "A butterfly can flutter its wings over a flower in China and cause a hurricane in the Caribbean. They can even calculate the odds."

Such borrowings of Lorenz's idea might seem authoritative to unsuspecting viewers, but they share one major problem: They get his insight precisely backwards. The larger meaning of the butterfly effect is not that we can readily track such connections, but that we can't. To claim a butterfly's wings can cause a storm, after all, is to raise the question: How can we definitively say what caused any storm, if it could be something as slight as a butterfly? Lorenz's work gives us a fresh way to think about cause and effect, but does not offer easy answers.

Pop culture references to the butterfly effect may be bad physics, but they're a good barometer of how the public thinks about science. They expose the growing chasm between what the public expects from scientific research - that is, a series of ever more precise answers about the world we live in - and the realms of uncertainty into which modern science is taking us.

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The butterfly effect is a deceptively simple insight extracted from a complex modern field. As a low-profile assistant professor in MIT's department of meteorology in 1961, Lorenz created an early computer program to simulate weather. One day he changed one of a dozen numbers representing atmospheric conditions, from .506127 to .506. That tiny alteration utterly transformed his long-term forecast, a point Lorenz amplified in his 1972 paper, "Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?"

In the paper, Lorenz claimed the large effects of tiny atmospheric events pose both a practical problem, by limiting long-term weather forecasts, and a philosophical one, by preventing us from isolating specific causes of later conditions. The "innumerable" interconnections of nature, Lorenz noted, mean a butterfly's flap could cause a tornado - or, for all we know, could prevent one. Similarly, should we make even a tiny alteration to nature, "we shall never know what would have happened if we had not disturbed it," since subsequent changes are too complex and entangled to restore a previous state.

So a principal lesson of the butterfly effect is the opposite of Redford's line: It is extremely hard to calculate such things with certainty. There are many butterflies out there. A tornado in Texas could be caused by a butterfly in Brazil, Bali, or Budapest. Realistically, we can't know. "It's impossible for humans to measure everything infinitely accurately," says Robert Devaney, a mathematics professor at Boston University. "And if you're off at all, the behavior of the solution could be completely off." When small imprecisions matter greatly, the world is radically unpredictable.

Moreover, Lorenz also discovered stricter limits on our knowledge, proving that even models of physical systems with a few precisely known variables, like a heated gas swirling in a box, can produce endlessly unpredictable and nonrepeating effects. This is a founding idea of chaos theory, whose advocates sometimes say Lorenz helped dispel the Newtonian idea of a wholly predictable universe.

"Lorenz went beyond the butterfly," says Kerry Emanuel, a professor in the department of earth, atmospheric, and planetary sciences at MIT. "To say that certain systems are not predictable, no matter how precise you make the initial conditions, is a profound statement." Instead of a vision of science in which any prediction is possible, as long as we have enough information, Lorenz's work suggested that our ability to analyze and predict the workings of the world is inherently limited.

But in the popular imagination, that one picturesque little butterfly became a metaphor for the surprising way that long chains of events unfold. A SmartMoney.com market analysis from 2007 cites Lorenz, then suggests that hypothetical problems at Sony could affect a string of shippers, retailers, and investors: "One butterfly, in this case a Japanese butterfly, sets off the entire chain." Even applied to society, rather than nature, such claims merit skepticism.

That we imagine the butterfly effect would explain things in everyday life, however, reveals more than an overeager impulse to validate ideas through science. It speaks to our larger expectation that the world should be comprehensible - that everything happens for a reason, and that we can pinpoint all those reasons, however small they may be. But nature itself defies this expectation. It is probability, not certain cause and effect, that now dictates how scientists understand many systems, from subatomic particles to storms. "People grasp that small things can make a big difference," Emanuel says. "But they make errors about the physical world. People want to attach a specific cause to events, and can't accept the randomness of the world."

Thus global warming may make big storms more likely - "loading the die," Emanuel says - but we cannot say it definitively caused Hurricane Katrina. Science helps us understand the universe, but as Lorenz showed, it sometimes does so by revealing the limits of our understanding.

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