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Heeding the Consistent Portfolio of Warning Signals that Presage Disaster

Crashes, Crises, and Calamities: How We Can Use Science to Read the Early-Warning Signs. *By Len Fisher, Basic Books, New York, 2011, 256 pages, $23.99.*

BOOK REVIEW
By James Case

Len Fisher describes himself as a "surface chemist," by which he means that he spent years of his life investigating ways in which the surfaces of materials affect their properties and behavior. In the course of his career, he has also hosted radio shows, been profiled in *Newsweek*, *The Washington Post*, and *Scientific American*, and written a number of popular science books. His 2002 book *How to Dunk a Doughnut* was named Best Popular Science Book of the Year by the American Institute of Physics. Born in Australia, Fisher now divides his time between Australia and England.

In the book under review, Fisher examines the scientific means available for predicting significant disasters, such as bridge failures, the death of coral reefs, the break-up of interpersonal relationships, the collapse of commercial fisheries, the demise of once-flourishing industries, climate change, and financial crises. His overall conclusion is that, although there is no hope of predicting them all, there are warning signs that—if heeded—could substantially improve our ability to predict some of the worst. Moreover, the same list of warning signals seems to be applicable to all forms of crisis.

The book begins with a true story: On April 1, 2009, the toads around Lake Ruffino in central Italy disappeared from their traditional breeding grounds. Five days later, an earthquake struck the area, killing more than three hundred people. The day after that, the toads returned. The event was recorded by British ecologist Rachel Grant, who was there to study the toads' mating behavior. This made her the first scientist able to confirm the legion of anecdotal reports—extending back over centuries—of animals acting strangely just before a natural disaster. If animals can sense impending disaster, Fisher says, we can learn how they do it and do the same thing ourselves.

Fisher is careful to distinguish between phenomena subject to physical laws, such as the collapse of bridges and the bursting of dams or levies, and those affected by human behavior, such as financial crises and/or the destruction of commercial fish populations. Yet he is cautiously optimistic that warning signs can be detected even in the latter cases, and he points out that those he identifies are associated almost as closely with human-made as with naturally occurring calamities. The difficulty is not so much in recognizing the warning signs—for doom-sayers are never in short supply—but in separating the substantive from the fanciful, and persuading leadership to heed the former. Skeptics are fond of pointing out that economists have successfully predicted eleven of the last seven recessions.

Because catastrophe theory clarifies the nature of many disasters—even if it isn't much help in predicting them—the book contains numerous diagrams of low-dimensional (fold and/or cusp) catastrophes. After citing René Thom's seminal book on the subject [2], Fisher hastens to remind his readers (as did Thom) that many of the ideas had appeared in D'Arcy Thompson's 1917 book *On Growth and Form* [3] and to credit Christopher Zeeman for explaining what Thom's theory is really all about. (It seems to have far less to do with biology than Thom supposed, and far more with physical phenomena.) Fisher quotes Francis Crick to the effect that Thom impressed him as an able mathematician with powerful biological intuitions, virtually all of which were wrong!

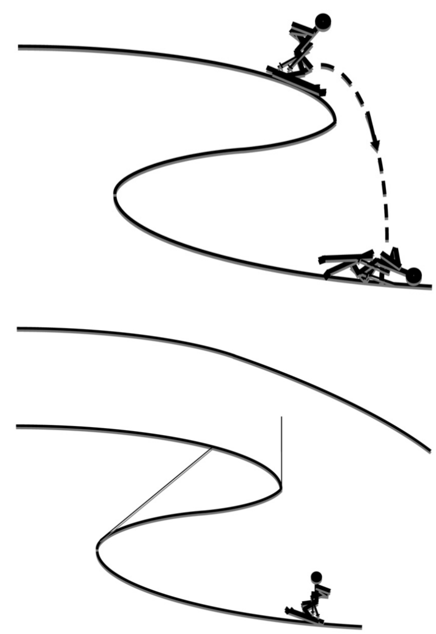

Figure 1. *Fold catastrophe: Top, the skier cannot avoid a fall; bottom, the skier needs only to steer to the left of the cusp. From* Crashes, Crises, and Calamities.

A key aspect of "the" fold catastrophe is the "loss of resilience" experienced as a subject approaches the point of no return. If the skier shown at the top in Figure 1 slipped inadvertently to the right while far from that critical point, it would be relatively easy to return to the original position. But because the pitch of the slope increases rapidly as the skier approaches the overhang, it may be impossible to recover from a slip made closer to the edge. This loss of resilience on approaching even the simplest catastrophe is central to Fisher's understanding of critical transitions.

Fisher dwells at length on the nature and significance of mathematical models, and provides a list of tests for separating the reliable few from the worthless many. He devotes several pages to the discrete version of the logistic population growth model, which he presents in the form

$$P_{n+1}/P_{\max} = r \times (P_n/P_{\max}) \times (1 - P_n/P_{\max}).$$

In contrast to the continuous version, in which the population at time t approaches its upper limit $P_{\max}$ monotonically, the discrete population in time period n (call it P_n) exhibits qualitatively different behavior for different values of the parameter r. For $r < 3$, the values P_n tend to $P_{\max}$ monotonically, more or less as in the continuous-time model. But for $r = 3.3$, they oscillate between an upper and a lower value, and for $r = 3.5$, they cycle through 4 different values. For only slightly larger values of r, they cycle through 8, 16, 32, . . . until, for about $r = 3.5699$, the behavior becomes chaotic.

Perhaps surprisingly, Fisher gives high marks to the World3 model on which the first (1972) report to the Club of Rome based its predictions. It was a simple model, not so very different from the one employed by Thomas Malthus more than two hundred years ago to predict that the human population would eventually overshoot the Earth's carrying capacity. World3 differed only in using real data for measured trends and conditions, and in including obvious feedback effects between key elements of the global economy and the biosphere.

Like the report, the 1972 book [1] offered three possible scenarios, differing mainly in the vigor and alacrity with which humankind is presumed to act to avoid Malthusian disaster. Since then, subsets of the original four-author team have issued two follow-up reports—in 1992 and 2004—showing that events have so far followed the path predicted by their "business-as-usual" scenario fairly closely. Should that continue, the global economy seems destined to collapse midway through the 21st century.

In his penultimate chapter, "Warning Signs," Fisher asserts that—as in the approach to a fold catastrophe—a loss of resilience precedes all or most calamities. By that he means that the system at risk gradually loses its ability to absorb minor shocks until an event that might once have gone unnoticed triggers terminal dysfunction. Mathematicians, he says, have identified five key warning signs that presage a loss of resilience: Along with (1) increasing occurrence of extreme states and (2) fluctuations between quite different states are (3) critical slowing down, (4) changes in spatial patterns, and (5) increasing skewness in the distribution of states. Sketchy though they are, his explanations of items (3)–(5) are too lengthy for inclusion here.

All five, Fisher concedes, are statistical measures that can require sifting through and analyzing a great deal of data. And even with adequate data, it is seldom easy to distinguish between false positives and genuine causes for alarm. Yet experience confirms that the distinction can be—and often is—successfully made. Whereas the experience to which Fisher alludes comes largely from studies of real and model ecosystems, he expresses confidence that the same portfolio of warning signs is equally applicable to a host of other socially significant "critical-transition scenarios." While far from conclusive, the arguments with which he defends that thesis are by no means insubstantial.

References

[1] Donella H. Meadows, Dennis Meadows, Jorgen Randers, and William W. Behrens, *The Limits to Growth*, Universe Books, New York, 1972.

[2] René Thom, *Structural Stability and Morphogenesis*, Benjamin-Cummings, Paris, 1972.

[3] D'Arcy Thompson, *On Growth and Form*, 1917, revised edition, Dover Publications, 1992.

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