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What Biology Can Teach You about Today's Market:

An Interview with Doug Erwin

The extraordinary recent market activity and associated discussion prompted me to pose the same questions many are now asking:

- What is the role of free markets?
- Can overseers structure regulation so as to encourage progress while discouraging poor behavior?
- How can we achieve greater stability, provided that is a worthy goal?

Like others, I have opinions on these issues. But as these questions rolled in my mind, it occurred to me that we have a similar system—nature—that has been coping with the very same issues for roughly 3 billion years. That is probably sufficient time to allow for some insights.

One of the great aspects of an affiliation with the Santa Fe Institute (SFI) is the opportunity to exchange ideas with world class scientists who are self-selected to be curious about the world. Doug Erwin, a highly respected paleobiologist at the Smithsonian and a member of SFI's resident faculty, is a great example. (Doug's full biography is at the end of this interview.) While an expert in his field, Doug reads and thinks broadly and can intelligently discuss just about any topic you can think of.

So rather than share my views, I thought it would be useful to interview Doug. Note that I lured him into this discussion precisely because he is *not* a finance expert. That said, the parallels between the biological world he describes and the markets are vivid and provocative. I begin with a summary of our dialogue, then follow with the complete interview.

Summary of ideas:

- *Parallels between reproductive and investment strategies*. Doug mentions three reproductive strategies. The first two, the r-selected and the K-selected, are well known. The r-strategy—have lots of offspring and hope for the best—is similar to diversification. The K-strategy opts for fewer offspring but invests much more in each, comparable to constructing a concentrated portfolio. The third strategy, anti-z, was new to me. That strategy seeks to build reserves in good times to allow for better performance in bad times. This is akin to insurance or, in the extreme, strategies that take advantage of fat-tail events (e.g., deep out of the money put and call buying). But, as he mentions, since crises happen infrequently, most species are unable to adapt to the challenging conditions.

- *Exogenous and endogenous shocks*. Some extinctions are the result of exogenous shocks, like an asteroid hitting the earth. Markets have similar events like terrorist attacks or sharp changes in political regimes. But many extinction events arise from the inner workings of the system: pinpointing a specific cause is a challenge. Likewise, in markets most crises are endogenous, not exogenous. The lethal combination of human nature and leverage assure that excesses—both on the upside and downside—occur periodically. [1] Managing the market requires taming human nature. It is unclear any organizational structure has fully succeeded in that task.

- *You cannot manage a complex adaptive system*. By definition, a complex adaptive system has many interconnections. While financiers and politicians seek to help the system, chances are extremely high that any move will have unintended consequences. Biologists have consistently failed to manage systems like national parks and wetlands where the network structure is, if anything, simpler than that of markets.

- *Surviving the crisis is different than thriving post-crisis.* Because ecosystems are rebuilt after a crisis, those species that survive the crisis may not do well after it. Likewise, following a financial and economic crisis the strategies that worked in a prior time may no longer be in favor. Crises close down old opportunities while creating new ones. Participants who can identify and exploit new niches stand to benefit.

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MM. Hi, Doug. Thanks for taking some time to share your perspectives with us. With the current financial crisis, there have been a lot of questions about the role of free markets, the importance of diversity, and how to best foster progress. Biological systems have been addressing similar problems for billions of years. Can you discuss how biological systems cope with these issues?

DE. Hi, Michael, happy to join you. There is probably no better way to start an argument among ecologists and evolutionary biologists than to introduce the topic of stability and diversity. Part of the problem comes from the abundance of definitions of each term: an ecologist recently counted over 360 different uses of the term “stability”. At the simplest level the problem is stability of what? Are you interested in stability of a species, perhaps akin to a firm? Or stability of an ecological community? Stability of a community often masks considerable turnover among the species that comprise a community.

One place to start is with the strategies that different species use. In a simplified fashion biologists often distinguish between r-selected and K-selected strategies (r being the symbol for rate of growth and K for carrying capacity in a standard equation of population dynamics). An r strategist reproduces fast and puts most of its energy into reproduction rather than individual growth: think of weedy opportunists; these often dominate in unstable environments. K-selected species invest in the growth of each individual so that they can compete effectively for limited resources. They reproduce more slowly, and often have larger body sizes. Large trees are a good example of K-strategists. This simple division has some holes in it and some species don’t really seem to follow either course.

A paper by Mark Boyce in 1979 described an additional strategy (anti-z) for species in highly fluctuating environments.[2] In this case, the best strategy is actually to accumulate reserves against inclement conditions, but critically, the nature of these reserves differs from those in K-selected species, which are better in a constant environment. Whales, curiously, turn out to be a better example of an anti-z strategist than a K-strategist. Both the rate of population growth (r) and the maximum population size (K) are lower than with r- or K-strategies, respectively, but your probability of living to fight again another day is greater.

MM. Let me continue on this theme of stability. The success of the reproductive strategy a species uses seems to be associated with the community’s stability; some strategies do better in stable environments, others in more turbulent environments. But what happens when there’s an extinction event? Do all strategies fail? And, from an ecological perspective, is an extinction event bad?

DE. Mass extinctions and smaller biotic crises have been a regular occurrence over the past 600 million years, but they happen too infrequently for organisms to actually adapt to those sorts of conditions. And independent of the actual causes of the crises, they come in two very different flavors: some are a single sharp shock, such as the impact of an asteroid that killed off the dinosaurs (except of course for birds!) 65 million years ago; we call these pulse extinctions. But there are also longer-lasting events, press extinctions, which may last for a long enough period of time that organisms can actually adapt to the inhospitable conditions.

As to strategies, in many cases those that increase one's likelihood of success during periods between crises are no longer helpful during a crisis, and others are more helpful. This sort of alternation of regimes is controversial and rather puzzling but there are some good examples of this. The success of particular strategies depends a bit on the nature of the extinction.

To me, the really interesting aspect of all this is the dynamic *after* an extinction event, during the recovery. Paleontologists used to believe that life just got better after an extinction event was over. In fact, we have found that there is a very interesting dynamic to recoveries where some organisms that survived the extinction then disappear during the recovery. For the groups I have studied this largely seems to happen because ecosystems are rebuilt in a different way after a crisis, and there is, in a sense, no longer "room" for some of the survivors. So some species may "win" the extinction, but "lose" the recovery and disappear.

Just as interesting are what we call Lazarus species. These are species that disappear from the fossil record for millions of years, and return at the end of the recovery. They don't really disappear, of course, but their population sizes and geographic range are so small that they do not get fossilized.

Extinctions are pretty bad if you are going through one, but from a larger perspective they can actually be fairly positive. I study the end-Permian mass extinction of 252 million years ago, and in many ways that was the best thing to happen to life since the origin of animals. In the aftermath of wiping out perhaps 80-90 percent of all species, communities became far more complex, with greater diversity and more sophisticated adaptations—turtles, dinosaurs and mammals all appeared during the recovery. Life was actually a lot more interesting after the extinction than it had been before.

MM. You mentioned a couple different types of extinction or crises events. What percentage of extinctions have a "cause"? And how do you think about, or explain, crises that arise from within the system—endogenous crises?

DE. Only about 1-2 percent of all species extinctions over the past 550 million years have occurred during the major mass extinction events. So for the overwhelming majority of extinctions we usually do not know what caused the disappearance. We may be able to say generally "climate change was probably responsible", or the like, but generally that is as far as we can go.

For mass extinction events we can do a bit better, but only in the sense of saying that the evidence suggests that the cause of this crisis was massive volcanism, or anoxic ocean waters. But if you ask me what caused a particular species to go extinct—that is usually a question we can't answer. Notice the previous examples all involve external shocks to the system as the cause of extinction. It isn't that we don't recognize the possibility that an ecological system could collapse from endogenous causes. However, it is very hard to test endogenous causes so our default assumption is that an external cause is more likely. In almost all cases of large mass extinctions we can identify an external cause. Moreover, mass extinctions are essentially global phenomena affecting many different species in a variety of environments. So it seems unlikely that an endogenous cause could trigger so extensive an extinction. It is more likely that smaller collapses could be endogenous, but here again, showing this is far more difficult.

MM. Let me shift gears somewhat. We are in the midst of a challenging financial crisis, and governments around the world are trying to improve conditions with policy moves. If you grant that the economy is a complex adaptive system, what can you say about the ability of outsiders to manage a complex adaptive system? Are there lessons from biology worth considering?

DE. At the Santa Fe Institute we often think about complex adaptive systems in terms of a network, with the nodes of the network being actors (companies, or species, perhaps) and the connections between the nodes being the connections between the actors. For biologists the problem is that it is relatively rare that we know all the components of the network, much less the strength of the connections between the nodes (and of course these connections can often be asymmetric, with A more strongly linked to B than B is to A). So we make lots of simplifying assumptions, and often can learn quite a bit about how the system operates.

But then we come to trying to restore or recreate a wetland, say. And most of the time the success rate is very low, generally, I suspect, because we really haven't understood the relationships between all the parts of the network well enough to understand how to rebuild it. And that's just a simple ecosystem. As paleontologists study larger biodiversity crises, another problem comes into play. As I mentioned before, these recovery processes appear to have a dynamic all their own, so that they build a new ecosystem rather than restore the old one.

From this I would draw two lessons: First, the ability to "manage" a complex system is low. One might as well try to "manage" the weather. So a degree of humility might be appropriate. And second, the nature of the post-crisis system may well be very different than that before the crisis. We are learning more and more about how species in an ecosystem do not just respond to an environment, but actively construct their own environment (although their ability to do so differs greatly between species). So I suppose the question is to what extent can one construct a profitable post-crisis environment?

MM. You have done a lot of work in the area of innovation. Can we say anything about the role of regulation in encouraging or discouraging innovation (or progress)? How do we think about the issue of how much regulation is right for a given system if we want to encourage progress?

DE. As you know innovation is the topic of a lot of my research, but it is also the area of probably the biggest difference between natural and human systems. We can decide, for various perfectly valid societal reasons, that we want to regulate certain human activities. Natural systems are regulated as well, but through positive and negative feedbacks through the network. As such, regulation may lead to a drop in abundance of a species, but also plays out as death or extinction. In regulating economic systems we use a combination of tools that both feed back through the system (I suppose the recent addition of liquidity is such an example) and impose exogenous controls on the network. It would be fascinating to know the impact of such a dual control system on network dynamics—does this increase stability or decrease it?

In terms of innovation, I am primarily interested in innovations that, to use a biological perspective, change the carrying capacity of the system. I actually don't believe in long-term carrying capacities, but it is a well-understood metaphor. Here the principal problem is how does the system capture the benefits from an innovation? We have developed the patent system to do that; and heredity plays a similar role for organisms. The species that develops a new adaptation captures the benefit of that adaptation. But what about innovations that create ecological spillovers that have an impact on other species?

As you know, Paul Romer has done some fascinating work in this area, and we see the same thing happening in biology.[3] The oxygen we breathe is the waste product of plants (think about that with your next breath!) but it has been an enormous boon to many organisms—a positive spillover. Of course 2.4 billion years ago, during the Great Oxidation Event (as we call it) when oxygen first built up in the atmosphere it was a poison to most of the microbes. Over the course of evolution, most of the major evolutionary transitions have occurred when some group of organisms figured out how to get the benefits of these ecological spillovers: Those that could develop tools to utilize it benefited considerably. Some organisms constructed new specific adaptations or specializations (an enzyme called superoxide dismutase helps deal with that poisonous oxygen), but in some ways the most interesting avenue was that adopted by lots of microbes in which they developed consortia, sort of a little linked ecosystem, in which different microbes each brought a specific tool. But it was the combination of each of the different microbes that was required for success.

Curiously enough, we (and all other complex organisms with DNA in a nucleus—what biologists call eukaryotes) are an example of this. The powerhouses in our cells are mitochondria, and they are the remnants of a bacterium that took refuge in a host cell over a billion years ago. The combination turned out to be more than the some of the parts, just as a host cell, a bacterium and blue - green algae became the foundation for plants. These are much more like a conglomerate than a takeover, however, as each entity retains a great deal of individuality even after the symbiosis occurs.

I am not sure what this means for regulation, beyond the obvious point that societies need to ensure the continuing supply of innovations that produce positive spillover effects, and to provide a robust system to allow inventors to capture the profits, which is the point of a patent system. That is a tricky one because too constrictive a patent system will inhibit other spillover effects. Imagine a system where Newton (or Leibniz) had been able to patent calculus. King’s College Cambridge might have wound up fabulously rich, but other innovations would have been stifled.

MM. I'll wrap up by putting you on the spot. Do you, as a biologist, have any observations on the current financial crisis? What can market participants and policy makers learn from a paleobiologist?

DE. Well the obvious response is: probably nothing! But I would toss a question back at you: I have heard discussion of “systemic risk” in terms of the current crisis, which I interpret to mean a risk of collapse to the financial system (and more).

In 1986 a friend of mine, David Jablonski of the University of Chicago, published a paper in *Science* in which he showed that the attributes of organisms that facilitated survival during mass extinctions were different than those facilitating survival between crises—so-called background intervals. The paper was titled “Background and Mass Extinctions: The Alternation of Macroevolutionary Regimes” and many of us have shown the same patterns for other groups during other mass extinctions. [4] This pattern indicates that a group really can't adapt to the conditions of a crisis, because the characteristics which enhance survival (primarily broad geographic range of a group of related species, but not single species) do not enhance survival during background intervals.

This raises two questions: First, does a similar alternation of financial regimes occur, with different conditions favoring survival of a firm during the crisis, and two, are we now in such a crisis?

MM. I would argue that there are alternating regimes in financial markets. Most of the time, the markets behave "normally" and traditional ideas from finance and investing apply well. These regimes also imply a high degree of market efficiency. However, episodically we see bursts of volatility where strategies that were effective during the normal times fail and less-practiced strategies prevail. This idea is really at the core of Nassim Taleb's *Black Swan* argument: rare and surprising events occur that have a material impact on the world. Getting lulled by the normal times sets people up for shock in the turbulent times. He has worked with a couple of firms that try to capture upside from Black Swan events.

We have only seen today's degree of volatility a few times in the last couple centuries of U.S. equity markets. So, yes, this feels like such a crisis. One big challenge is that diversification fails in these regimes. As they say in the business, "the only thing that rises in a bear market is correlation."

Thanks, Doug.

DE. Thanks, Michael. This has been fun.

Endnotes

[1] Hyman P. Minsky, *Stabilizing An Unstable Economy* (New Haven, CT: Yale University Press, 1986).
[2] Mark S. Boyce, "Seasonality and Patterns of Natural Selection for Life Histories," *The American Naturalist*, Vol. 114, No. 4, October 1979, 569-583.
[3] Paul M. Romer, "Endogenous Technological Change," *The Journal of Political Economy*, Vol. 98, No. 5, October 1990, S71-S102.
[4] David Jablonski, "Background and Mass Extinctions: The Alternation of Macroevolutionary Regimes," *Science*, Vol. 831, No. 4734, 10 January 1986, 129-133.

Biography

Doug Erwin is a Senior Scientist and Curator of Paleobiology at the National Museum of Natural History of the Smithsonian Institution in Washington D.C., as well as a part-time Resident Faculty member of the Santa Fe Institute. His research involves a variety of aspects of the history of life and evolution, including ecological and developmental aspects of the origin of animals, the causes and consequences of the great end-Permian mass extinction some 252 million years ago, and the evolutionary history of really old snails. His latest project is a book on evolutionary innovation through the history of life, which will also explore the similarities and differences between economic and biological innovation. Various field projects have taken Doug repeatedly to China, South Africa and Namibia, and he has done geological field work in various other regions as well.

Erwin received an A.B. from Colgate University in 1980 and a PhD from the University of California, Santa Barbara in 1985. He is the author or editor of six books, including *Extinction: How life nearly died 250 million years ago* (Princeton University Press, 2005). Doug has been Co-Editor of *Paleobiology* and is a member of the Science Board of Reviewing Editors and the editorial boards of a number of other journals. He has served in a variety of advisory capacities to the Smithsonian, NASA, NSF, the NRC and other agencies, and as Interim Director of the National Museum of Natural History.