Are We Ready for Complexity?

Cynthia F. Kurtz

Independent Consultant

cfkurtz@cfkurtz.com

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Note: This document differs from the journal publication in one respect: in the journal, an incorrect indent makes it look like the first part of the "folklore" quote from Gleick was written by the author. That error is corrected here. Otherwise (putting aside translations of the abstract) the two versions are identical.

Abstract

This paper describes a series of explorations into scientific concepts related to complexity and chaos and how they have been translated into the world of business and organizations. In each of three cases, a story of uncertainty was rewritten into a story of certainty. The butterfly effect, which describes the impossibility of ascertaining cause and effect in complex patterns, was transformed into a story about a plucky little underdog who changes the world. The story of the keystone species, a critical ecological player defined by its apparent unimportance, was repurposed into a story about the benevolence of huge multinationals. The struggle of populations to survive in an uncertain world was converted into a story about an inevitable march to evolutionary perfection. The author investigates each of these "second stories" and ponders what they tell us about our readiness to benefit from the not-always-comforting insights of complexity theory. The paper ends with constructive suggestions for getting ready to understand and benefit from complexity.

Keywords

complexity; chaos; business; organizations; narrative; culture

In this paper, I will explore three scientific concepts related to complexity and how they have been used (and misused) in the world of business and organizations.

In my professional career, I have seen complexity theory from three perspectives: as an evolutionary biologist, as a science educator, and as a researcher in organizational and community narrative. For example, a decade after I applied complexity theory to the evolution of social behavior (Kurtz, 1991), I applied it to organizations (Kurtz and Snowden, 2003). As I kept coming back to complexity theory through new doors, I noticed some surprising things. I pondered them for about a decade, and then I just had to write something down. The result was this paper, which first appeared on my blog in 2010, and which I have revised for this publication.

The Butterfly and the Underbutterfly

Many know the story of how meteorologist Edward Lorenz reran his simple weather simulation and for convenience copied the starting values of some variables from a previous printout (Lorenz, 1963). Because of rounding in the printout, he left the last few digits off one of the variables (instead of 0.506127, he entered 0.506). Lorenz went to get a cup of coffee and returned to find that the repeat simulation had generated a vastly different weather pattern. He called this phenomenon "sensitivity to initial conditions," meaning that small differences at the start of a process (one with a particular set of chaotic characteristics) could be amplified into large differences later on.

The idea of sensitivity to initial conditions was over half a century old when Lorenz wrote about it. Mathematicians such as Maxwell and Poincaré pondered it around the turn of the twentieth century. For example, Maxwell said in an 1873 lecture (as quoted in Campbell & Garnett, 1882):

> [W]hen an infinitely small variation in the present state may bring about a finite difference in the state of the system in a finite time, the condition of the system is said to be unstable. It is manifest that the existence of unstable conditions renders impossible the prediction of future events, if our knowledge of the present state is only approximate and not accurate. (p. 440)

Poincaré (1903) wrote:

> [S]mall differences in the initial conditions may generate very large differences in the phenomena. A small error in the former will lead to an enormous error in the latter. Prediction then becomes impossible, and we have the fortuitous phenomenon. (p. 66)

While Lorenz did not discover the possibility of sensitivity to initial conditions, he was the first to create it in practice. Maxwell and Poincaré would have been as surprised as Lorenz to find such unpredictable systemic behavior in the simple repetition of a handful of calculations.

Lorenz's 1972 talk on the topic was titled "Predictability: Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" His answer was an emphatic "impossible to say" (Lorenz, 1995):

> If a single flap of a butterfly's wings can be instrumental in generating a tornado, so also can all the previous and subsequent flaps of its wings, as can the flaps of the wings of millions of other butterflies, not to mention the activities of innumerable more powerful creatures, including our own species. . . . If the flap of a butterfly's wings can be instrumental in generating a tornado, it can equally well be instrumental in preventing a tornado. (p. 181)

It was Laplace (1814) who put forth the idea that if a magical demon could know everything there is to know about every atom in the universe, that demon could predict the future with perfect accuracy. Lorenz did not disprove Laplace's idea (an omniscient demon would not round numbers), but he did show us that the demon would have to be far more omniscient than anyone had expected to have predictive power even in a simple, small simulation.

Gleick (1987) described the butterfly effect perfectly:

> [S]uppose the earth could be covered with sensors spaced one foot apart, rising at one-foot intervals all the way to the top of the atmosphere. Suppose every sensor gives perfectly accurate readings of temperature, pressure, humidity, and any other quantity a meteorologist could want. . . . The computer will still be unable to predict whether Princeton, New Jersey, will have sun or rain on a day one month away. At noon the spaces between the sensors will hide fluctuations that the computer will not know about, tiny deviations from the average. By 12:01, those fluctuations will already have created small errors one foot away. Soon the errors will have multiplied to the ten-foot scale, and so on up to the size of the globe. (p. 21)

Now let me quote some lines from a few business books on complexity. From Goldstein (1994):

> The butterfly effect refers to how air currents from a butterfly flapping its wings in Asia are amplified to influence the weather in North America! (p. 29)

Merry (1995) explains it thus:

> The inescapable conclusion is reached that man is living in a world in which under certain conditions, tiny causes can have enormous effects. This is called the butterfly effect. . . . The flapping of the wings of a butterfly in Hong Kong can affect the course of a tornado in Texas. (p. 30)

Wheatley (2006) says:

> Edward Lorenz, a meteorologist, first drew public attention to this with his now famous "butterfly effect." Does the flap of a butterfly wing in Tokyo, Lorenz queried, affect a tornado in Texas (or a thunderstorm in New York)? Though unfortunate for the future of accurate weather prediction, his answer was "yes." (p. 121)

These excerpts, and almost all business explanations of the butterfly effect, transform it from a story of tiny actions compounding in unpredictable ways to a story of tiny actions having predictable, controllable impacts. I have taken to calling this second story *the underbutterfly effect*, because its hero is an underdog who changes the world. The underbutterfly simply refuses to fall in line with the millions of other butterflies (not to mention innumerable more powerful creatures) whose feeble flaps are lost in the sea of uncertainty in which we live.

Finding the exact place where the underbutterfly first opened its wings would be an arduous task, but my suspicion is that the second story arose almost immediately. Gleick (1987) describes an incident in which Lorenz explains the butterfly effect to a colleague.

> "Prediction, nothing," he said. "This is weather control." His thought was that small modifications, well within human capacity, could cause desired large-scale changes.
> Lorenz saw it differently. Yes, you could change the weather. You could make it do something different from what it would otherwise have done. But if you did, then you would never know what it would otherwise have done. It would be like giving an extra shuffle to an already well-shuffled pack of cards. You know it will change your luck, but you don't know whether for better or worse. (p. 21)

Another curiosity is that even though Gleick illustrates the butterfly effect so well in his metaphor of sensors covering the earth, he also tells the underbutterfly story—seemingly without noticing it (Gleick, 1987).

> [S]ensitive dependence on initial conditions was not an altogether new notion. It had a place in folklore:
>
> "For want of a nail, the shoe was lost;
> For want of a shoe, the horse was lost;
> For want of a horse, the rider was lost;
> For want of a rider, the battle was lost;
> For want of a battle, the kingdom was lost!" (p. 23)

Nowhere can I find this nursery rhyme used to convey the impossibility of knowing which of the millions of horseshoe nails (not to mention innumerable more powerful objects) might have been involved in the loss of the kingdom. Alchin (2003) describes the rhyme as "often used to gently chastise a child whilst explaining the possible events that may follow a thoughtless act" (p. 21). It is not used to gently explain that it is *impossible to say* what effect a thoughtless act will have on possible events.

The Keystone and the Topstone

Robert Paine discovered the phenomenon of the *keystone species* in an experiment during which he removed a single species of sea star from a small area of shoreline and found that it had far-reaching effects on species diversity. Significantly, the effect produced by the removal of the sea star was *out of proportion* to its relative abundance in the community.

Keystone species, by definition, are nearly impossible to identify without observing what happens when they are removed. Said Paine (1969):

> The two keystone species discussed above have little in common. *Pisaster* is abundant and is somewhat of a trophic generalist; *Charonia* is rare and a food specialist. . . . Both are starfish feeding on a variety of prey. . . . The significance of these carnivores could not have been guessed beforehand, since other carnivores coexist with them. (pp. 92–93)

As with the butterfly effect, this first story is about a system in which complex relationships among small influences produce large difficulties in prediction. Again, a second story arose, and again it favors certainty. What I have come to call the *topstone story* discards the inconvenient aspects of the keystone concept, those having to do with retrospective discovery.

Soon after Paine introduced about his concept, wildlife conservationists started trying to identify keystone species (without removing them) in order to wisely use limited conservation budgets. Political, cultural, and special-interest complexities joined the mix, and the keystone species concept widened and weakened as the second story rose up to counter the first. For environmental study, retrospective discovery might suffice, but for environmental action, people wanted predictive certainty.

In the mid-1990s, a group of scientists self-dubbed the "Keystone Cops" was concerned enough about erosion of the concept to convene a special session (Power et al., 1996). They restored the keystone species concept to intellectual rigor with a new definition, as follows:

> [W]e define a keystone species as one whose impact on its community or ecosystem is large, and disproportionately large relative to its abundance. (p. 609)

Soon after, Piraino and Fanelli (1999) reminded ecologists to adhere to that definition:

> Putting keystones and key species in the same melting pot, as Khanina (1998) does, should be avoided. Therefore, trees and bisons are not keystones, just as the original keystone species identified by Paine was not the dominant mussel, but its starfish predator. (para. 1)

Such a strong correction makes you curious to see what Khanina (1998) said, does it not?

> [O]nly trees can be considered as keystone species of forest communities (detritus ecosystems), and bison, for example, can be considered as keystone species of grassland communities (pasture ecosystems). . . . [K]eystone species "are responsible" for the existence of an ecosystem of a certain type. The type of ecosystem will alter when keystone species disappear for some reason, or when new "stronger" keystone species come. (para. 3)

This was a serious misunderstanding of Paine's concept—it made keystone species seem like winners in a gladiatorial contest—and it merited the level of correction applied to it. Through many such discussions, the topstone story was chased out of science by the turn of the century. However, it is *still* the story being told in almost all non-scientific uses of the keystone species concept.

In their book *The Keystone Advantage*, Iansiti and Levien (2004) describe keystone species in the business ecosystem as something like superheroes:

> [F]irms that follow keystonelike behavior are important in business domains that are characterized by frequent or significant external disruptions. The diversity they support serves as a buffer, preserving the

> overall structure, productivity, and diversity of the system. . . . For example, the successive waves of transformation that have spread through the software industry . . . resulted in significant changes in the software ecosystem, but its overall structure, productivity, and diversity have been unhurt, and its keystones—among them Microsoft, IBM, and Sun—have persisted. (p. 71)

None of these software giants could be called keystone species by the term's original or current scientific definition. Not only are they large in all possible biomass equivalents, but their importance to the system is easy to see up front. They are *key* species, not keystones.

Another problem lies in the use of the term "keystonelike behavior," which implies that being a keystone is something a species *does* rather than the conditions it happens to find itself in. This error was specifically warned against in a seminal paper by Mills et al. (1993):

> [T]he term *keystone species* is misleading because it indicates the existence of a species-specific property of an organism, when in actuality the keystone role is particular to a defined environmental setting, the current species associations, and the responses of other species. (p. 222)

In other words, there is no such thing as keystone-like behavior. There are only keystone-like *conditions*.

Here is another example of the keystone species concept applied to business, from Moore's (1997) *The Death of Competition*:

> Wal-Mart hardly has a choice about taking up this mantle. It has become a keystone species—and the center of one of the most important ecosystems on its continent. (p. 188)

Again, one of the largest companies in the world has been given as an example of a keystone species, entirely missing the point that to *be* a keystone species, it must have a *disproportionate* impact on the ecosystem. Similarly, Göthlich and Wenzek (2004) say:

> The keystone strategy derived from the business ecosystem model poses a feasible alternative to aggressive dominator behaviour with reasonable prospects of success since they nourish diversity and reduce the dangers of ecosystem-wide spread of failures and contagion. (p. 19)

This seems to say that the big guys can be keystones if they play nice—again placing the emphasis on behavior rather than conditions. In general, the keystone species concept seems to have been appropriated in the business world as an apologia for the dominance of large firms. It is not unreasonable to transfer metaphors from one world of inquiry to another; but choosing only one meaning—and failing to mention that it has been corrected out of existence by experts in the original field—seems disingenuous.

A better candidate for a keystone species in business might be found in an incident mentioned in a report on semiconductor manufacturing (Peach, 1995):

> One Japanese company, Sumitomo Chemical, provides over 50 percent of the world requirements for epoxy resin, which is used in semiconductor

> manufacturing. . . . A July 1993 explosion within the Sumitomo plant curtailed production, and as a result has slowed several semiconductor manufacturing plants that rely on this source of resin. A shortage (real or imaginary) of DRAMs has resulted, and the price of these chips has escalated to as much as 150 percent of the price just prior to the explosion. (pp. 17–18)

Sumitomo Chemical might have been a true keystone species in the semiconductor ecosystem at that time, both because of the disproportionate impact of its temporary removal and because of the difficulty in identifying it as a keystone species beforehand.

The Wandering Climber and the Easy Roller

Sewall Wright's adaptive landscape metaphor (Wright, 1932) has its limits, but many evolutionary theorists find it a useful way to think about genetic change. In the adaptive landscape, the (greatly simplified) genetic makeup of populations is represented by X and Y locations on a landscape. The height of each point describes the fitness of a population with that particular combination of genetic variables.

Fitness may depend on many things: unalterable aspects of the larger environment, such as changing climate patterns; impacts of the population on its environment, such as the effects of beaver dams on the ecosystem; and epistatic relationships between variables, such that their co-occurrence enhances or reduces their combined fitness. To put it more plainly, the landscape does not sit still. It shifts constantly, on its own and in reaction, and the locations of its adaptive peaks keep changing.

The struggle of individuals to survive and reproduce is multiplied as the population endeavors to pass on its genes. Mutations provide the benefit of a random walk near the population's current location. Deleterious mutations die out, but advantageous ones lead to increased fitness, which moves the population up the slope. Once at an adaptive peak, a population has some probability of descent in any direction. Most mutations, however, are small hops, so populations can get stranded on lower-fitness peaks because the valleys between peaks represent such low fitness that few populations are able to cross them without dying out entirely. The more rugged the landscape, the more peaks will be available, and the more likely populations will be able to make the journey required to reach optimality (for a while).

In the days in which I thought of myself as an evolutionary biologist, the adaptive landscape was a comfortable, well-worn tool in my mindset. Imagine my surprise when I returned to complexity and evolution through the organizational door to find people talking about fitness landscapes—but referring to something quite different. They drew their landscapes with deep "wells" and "basins of attraction." Curious to find out where this upside-down view of evolution came from, I started to look around. As with the other two patterns I have described here, the story I discovered has to do with certainty.

The idea of flipping the adaptive landscape seems to have arisen in several places. The first mention I can find of it is from Templeton (1982), who said:

> Consider turning an adaptive landscape upside down. . . . Now, put some lateral motion into the balls by randomly shaking the inverted landscape. This causes the balls to roll around, even up the sides of the pits against

> the force of gravity, just as random genetic drift causes demes [local populations] to move around the adaptive landscape, even in directions opposed by natural selection. . . . During this shaking process, some balls will actually roll up the side of a pit and over a ridge, at which point gravity once again causes the balls to roll to the bottom of a new pit. (p. 25)

In Templeton's landscape, both of the forces that make up evolution (variation and selection) are represented by actual forces. Still, gravity is the dominant force of the two, because in the only world we know, gravity eventually wins every argument. Thus, the model implies that every population must inevitably reach optimality, and that is not what we see in the fossil record.

Merrell (1994) shared my concern about Templeton's inversion:

> Templeton (1982), for example, suggested that Wright's adaptive landscape should be turned upside-down. . . . The trouble with this analogy is that it suggests that adaptive evolution is inevitable, as easy as rolling downhill, and it is difficult to avoid thinking of an adaptive pit as an evolutionary sinkhole rather than as an evolutionary pinnacle of successful adaptation. (p. 134)

If we had kept Templeton's shaking force, and kept it nice and strong (maybe with a magical demon doing the shaking), his metaphor might have overcome its inevitability bias. However, his shaking force seems to have either weakened to a gentle jostling or disappeared entirely. As a result, a second story, which I have come to call the *easy roller story*, has grown up. In this easy-listening version of evolution, selection appears not only more powerful than other evolutionary forces but more certain as well. Instead of a population balanced precariously on a peak and facing a multitude of possibilities, a ball near a well faces a *collapse* of possibilities to one still small point. The inversion may have led to an erosion of popular understanding about how evolution works, leading to statements such as this one (Fogel, 2008):

> [Some] have suggested that it is more appropriate to view the adaptive landscape from an inverted position. . . . Such a viewpoint is intuitively appealing. Searching for peaks depicts evolution as a slowly advancing, tedious, and uncertain process. (p. 5)

Evolution *is* a slowly advancing, tedious, and uncertain process. That is the whole point of the word "struggle." Evolutionary adaptation is not a carefree stroll along a sunlit path; it is more like a dash through a mine field.

The *Principia Cybernetica Web* entry on fitness landscapes explains the flip in this way (Heylighen, 1999):

> It is unfortunate that the convention in physics sees systems as striving to minimize a potential function, whereas the convention in biology sees systems as striving to maximize a fitness function. Although this tends to be confusing, the two types of representation are equivalent apart from an inversion of the sign of the function. (para. 1)

However, "an inversion in the sign of the function," when *people* are thinking about the function, is *not* equivalent. In a world of tiny people stuck to a giant ball, you cannot just flip the landscape and have it not matter. Height-value relationships are strong in human communication because they are strong in human experience (Lakoff and Johnson, 2003):

> Spatialization metaphors are rooted in physical and cultural experience; they are not randomly assigned. A metaphor can serve as a vehicle for understanding a concept only by virtue of its experiential basis. (p. 18)

Consider the possibility that the flip in the adaptive landscape was not randomly assigned. Consider the possibility that it arose from a deep-seated yearning for certainty in the face of new revelations about complexity.

Murray Gell-Mann (1995) describes the flip thus:

> Biologists conventionally represent fitness as increasing with increasing height, so that maxima of fitness correspond to the tops of hills and minima to the bottom of pits; however, I shall use the reverse convention, which is customary in many other fields, and turn the whole picture upside-down. (p. 249)

When he says “which is customary in many other fields,” he is referring primarily to the free-energy landscape used in physics, where the X and Y dimensions describe characteristics of materials and the vertical axis describes the amount of energy available to do work. In this landscape, pits represent conditions of maximum entropy from which it is difficult to shift materials at rest. However, there is no clean mapping between evolution and entropy. For example: does mutation increase entropy? In the short term, yes; but in the long term, no, because it increases a population’s chance of surviving in a changing environment.

In the next paragraph, Gell-Mann admits the difficulty posed by the flipped landscape:

> If the effect of evolution were always to move steadily downhill—always to improve fitness—then the genotype would be likely to get stuck at the bottom of a shallow depression and have no opportunity to reach the deep holes nearby that correspond to much greater fitness. At the very least, the genotype must be moving in a more complicated manner than just sliding downhill. (p. 249)

That is *precisely* the problem with flipping the adaptive landscape: things that were complex and uncertain become simple and certain.

Now let us examine a case from the literature on complexity in organizations. From *The Edge of Organization* (Marion, 1999):

> In a coevolving system of potential energy landscapes, actors perturb each other's landscapes and knock each other out of their holes. Imagine marbles on a vibrating potential surface. Typically they will pop in and out of holes, but as they work their way into ever deeper holes it gets increasingly difficult to pop them out. Eventually marbles find a hole so deep that the vibrations no longer dislodge them. Similarly, actors on coevolving landscapes are not allowed to rest on their laurels. They perturb one another; new actors enter the stage and existing ones leave it;

> and in the process, actors work themselves into deeper and deeper holes.... (p. 248)

I can see several misunderstandings about coevolution in that quote, some of which could have been caused by flipping the landscape. (Marion does include Templeton's shaking force, though it is much weakened.)

1. Coevolving species do not *only* "knock each other out" of optimality: sometimes they boost each other *into* it. This is harder to imagine when a boost towards greater fitness looks like a nudge over a cliff.
2. A population that reaches a state of locally maximized fitness is *not* just as likely to "pop out" out of that state again, because "locally maximized fitness" means higher fitness surrounded by lower fitness. That is, *life surrounded by death*. Such a state is easier to imagine when you view optima as peaks. (*Yea, though I walk through the valley of the shadow of death, I will fear no evil.*)
3. No population is ever so perfectly adapted that changes in its environment "no longer dislodge" it. Just ask the dinosaurs. That is why the vision of a mountain peak, with its multiplicity of paths and crumbling erosion, is such a useful representation of the uncertainty inherent in evolution. Mountains *and* holes erode, but when we *think* of erosion we think of mountains.
4. Coevolution does *not* cause actors to "work themselves into" increasingly optimal states. The best that can be said is that things *change* because of coevolution. Whether the change is adaptive or maladaptive depends on context and history. The image of marbles falling into deeper and deeper holes makes such an increase seem certain, but it is not.

Flipping the adaptive landscape opens the door to a different set of explanations about evolution, one that tends toward increased certainty and teleology. Evolution, however, is anything but certain. In the story of any population, some organisms live to reproduce and some die first, and the ones that lived were more likely to live, and we can see that because they . . . lived. It is obvious only in retrospect, like Paine's keystone species, and like Lorenz's butterfly.

Unpopular Stories

We have now looked at three patterns in the interpretation of concepts from scientific fields related to complexity and chaos. Taken together, these interpretations present a picture of people holding up a screen to filter the truth. They seem to be saying: "We are not ready to go there yet."

When I think about these patterns, I keep remembering a conference I once attended on complexity in organizations. In one session, I found myself sitting in a room with eight or ten other people, in a circle. We were given copies of a handout with a flow diagram on it. On the diagram were two boxes connected by semicircular arrows. One box was labeled "productive collaboration." The other box was blank. We were asked to take a few minutes to sit quietly and write something in the other box. I wrote "unproductive collaboration."

Afterwards we went around the circle, and everyone showed their diagram to the group. I was amazed to discover that every other person had written in their box something people could *do* to create productive collaboration. The boxes said things like "foster better communication skills" and "create productive dialogue."

When we got around to me, I showed my diagram. There was dead silence. I felt a strong sense that the group . . . wanted me to go away. They did not want to hear the story I told. They wanted to hear the story of how complex systems respond to the earnest efforts of good people. They wanted to hear the story about the underbutterflies who flap their wings in the dappled light of the fractal forest and change the world.

I was happy with my diagram. I am the proud owner of many and varied mistakes, and I have collected abundant evidence that unproductive—well, anything—can lead to more productive anything. I have developed several aphorisms about it. *Now that I am finished, I am ready to start. If you want to be patient, just wait a while, and you will be. The worst way to find a thing is to look for it.* It seems to be a fundamental property of life itself that you have to go down to go up.

Every time I think about complexity in organizations, I remember the strange, stony reception I got that day. The people at that conference could not stop talking about fractals and bifurcations and "order for free" and all the lovely things we were supposed to get from complexity. What they did *not* want was the uncertainty that comes with it.

We have been conditioned since an early age to believe in this equation:

uncertainty + science = certainty

When we meet an equation like this:

uncertainty + science = *more* uncertainty

We react, and a second story arises. We say: That cannot be right. There must be another explanation. That is what Edward Lorenz said when his computer generated a new weather system based on what he thought were the same inputs. He called in the hardware engineers to fix the broken vacuum tube.

A *Boston Globe* article on the butterfly effect (Dizikes, 2008) says it well:

> 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. (para. 5)

Manageable, Magical, Powerful

Authors who write about complexity in organizations know that they are writing to the people who oversee businesses and governments. They know that nobody wants to hear about complexity *adding* uncertainty to an already overwhelming world. They know that those in charge are not going to buy a book that does not help them *stay* in charge. What are authors to do?

According to my surely biased reading, there are three ways the authors of business books on complexity provide reassurance. One is to *drain the power* out of the major discoveries that lie behind our current understandings of complexity by highlighting the *second* stories, which do exist in science and so can be called scientific: the underbutterfly, the topstone, the easy roller. The first stories can be waved away as internal disputes that do not matter.

The second way authors make complexity palatable is to make it seem *magical*. That is why the phrase "order for free" is so wildly attractive, and it is why people love to throw around terms like "strange attractor" and "coevolution." These are magic words of power that seem to promise something for nothing. Even nonlinear effects are spoken of as something small going in and something big and beneficial coming out, when they could just as well go the other way. Consider the way people talk about coevolution. Nearly every treatment of business coevolution I have read has talked about it like nothing can possibly go wrong. In real coevolution, however, things can and do go horribly wrong at times. Distortions like this make complexity seem like an over-hyped fad and spread confusion about the true utility of complexity-based approaches.

The third tool in the business complexity writer's toolkit is that *the sky is falling*. You *need* this, say the business books, because the world has changed in such dramatic ways that you cannot possibly survive without it. People who use this tool ramp up the fear quotient by making claims such as that "an organization is a complex adaptive system"—the implication being, and you had better find out what that means, and quick.

The problem lies in the fact that organizations are *not* complex adaptive systems. More precisely, they are not *only* complex adaptive systems. An organization is a group of *people*. Those people interact with each other in many ways, some of which are complex and some of which are not. Organization and self-organization are inextricably bound up together in organizations, and saying that an organization "is" one without the other is usually meant to entice (or control) rather than inform. There are no only-complex patterns in human life. Every gathering of ten huts has a chief. Every lunch meeting takes place in an engineered space. Every forum has rules. That is what we do. *We organize and self-organize* at the same time.

Instead of telling people that everything is suddenly complex and no longer complicated, authors should explain that everything has always been and will always be both complex *and* complicated—*complexicated*, I like to call it. The good news is that organization and self-organization can work to mutual benefit. I saw a perfect example of this when I worked at IBM. The smart people there knew how to recognize the complex and the complicated, which to use when, and how to combine them. Smart people have been doing that for millennia.

When we can stop seeing complexity as a whole new world dominated by a falling sky or a feast of opportunity, we can put away our over-simplified stories about it. We can learn to recognize complex phenomena, work with them, and welcome them—with open eyes—as old friends.

Another Generation to Sink in

If we tell second stories about complexity because we are not ready for the first stories, I think our children *are* ready. In many of my narrative projects, I ask people about the predictability of events in stories. I use the question to map perceptions of stability and instability across conceptual space. I have noticed a pattern: Older people are more likely to associate instability with negative outcomes in stories. Younger people are more likely to mark stories as both unstable *and* positive.

One day I was thinking about this while watching a movie with my son. It was called *Clifford's Really Big Movie*. In it there was a lovely song called "Until I Go" (Gordon, 2007), which my (then) six-year-old understood immediately. The song goes, in part:

> You've gotta get lost if you wanna get found
> Gotta wind up to get unwound
> Things only look up from down below
> And I can't come home until I go

When I heard these lyrics, I was immediately reminded of my productive-unproductive system diagram, and of the uncertainty of the butterfly, the keystone species, and the wandering climber. It made me wonder if our children will come to terms with complexity in ways we cannot.

In the novel *Voyage to Yesteryear* (Hogan, 1999a), a ship filled with robots and genetic material travels to a new planet. The children who grow up there create an entirely new society with new expectations (mainly of a gift-based economy). When people from Earth arrive years later, the new generation has shed its progenitors' worldviews. Hogan (1999b) says the idea for the book came from a conversation about the conflicts in Northern Ireland. He thought that only by separating children from their parents might deep prejudices be unlearned. Thankfully, peace came to Northern Ireland without such drastic measures, but his point—that big changes need time to sink in—may apply here.

Getting Ready

What can we do if we are not content to leave complexity to the next generation? How can we make use of complexity theory without distorting its discoveries into safer but less useful versions? I can think of three things we can do.

1. Spend more time with complexity. Complex patterns emerge where interaction meets iteration. Independent (or semi-independent) entities interact at a local level, without central direction. Those interactions repeat over time, in the sense that an interaction at time t affects the state of an entity at time $t+1$, which in turn affects the next interaction. Emergent patterns arise from the relationships among entities and interactions.

Now stop for a moment and think of a recent time when you saw entities interacting locally and without central direction. You might find it difficult. Central direction, of laws and designs and deadlines, is an inescapable part of our modern lives. Still, we can find situations in which the *balance* between organization and self-organization is tipped to the side of complexity, if we look for them.

There are many ways to seek out complexity. Sit in a public park and watch people mill around. Walk in the same forest every week and watch trees interact. Set up a fish tank. Put aside a portion of your garden and let nature take its course. Watch patterns of buying and selling on the stock market; the spread of infectious diseases; rumors on the Internet. Play a game in which players interact with each other but not with any centralized authority. Find Conway's Game of Life on the Internet and play with it.

Choose an activity outside your normal sphere of attention, because it can be hardest to see complexity where you are used to asserting control. If you are a doctor, for example, you *could* study complexity in the spread of diseases; but you will get farther if you look elsewhere first, then return with a new perspective.

In any of these situations, pay attention to local interactions and to states affected by them. When A jostled B's elbow, how did B react? How did C react? What did A do next? Look for patterns that surprise you. See if you can figure out how they happened. The more time you spend with complexity, the more you will develop a sense of how it works and what it means.

2. Find the complex in the everyday. What if you are too busy to set up a fish tank or play a silly game? You can take note of complexity (and complication) as you go about your daily business. When you are at the grocery store, or on the train, or walking the dog, think about *aspects of the situation* that are complex and complicated. How can you tell which aspects are which? Try this. If the word "should" makes sense, it is a complicated aspect of the situation. If the word "usually" makes sense, it is a complex aspect. An architectural plan is a great big box of should. A roomful of puppies is a lovable bundle of usually.

Here is an example to get you started. I used to drive to work on a parkway that had a service road: a smaller, parallel road that everyone knew they could shunt over to when traffic slowed. One day, I was driving along a particular curve in the road when traffic slowed even more than it usually did just there. Fearing a traffic jam ahead, I prepared to switch to the service road. Several other drivers had the same thought, and we all squeezed ourselves into the left turning lane. After a long wait, I arrived at the intersection where I could get to the service road, only to discover that there *was* no traffic jam beyond the intersection. We had created the jam we were trying to avoid.

The complicated aspects of that situation were put in place by whoever designed the parkway route and its intersections (in that case, too close to the preceding curve to allow drivers to see whether there was *actually* traffic ahead). The complex aspects of the situation had to do with the people driving on the road, some of whom were clueless and doomed to create the same jam over and over, and others who understood that the whole thing was a mirage. I joined the latter group on that day, but my revelation did not help much, because new clueless people joined us all the time.

Developing the habit of noticing such patterns, teasing out their complex and complicated aspects, and keeping them in mind as you read about complexity can help you think critically about the things people say about it.

3. Talk to people who spend more time with complexity. I said above that we do not spend much time with complexity today, but some people still do. Farmers still do. (Percent of U.S. population employed as farmers in 1800: 83. Percent today: 2). Also, foresters, ecologists, hunters, and (to a lesser extent, due to authorities and procedures) day care workers, teachers, firefighters, emergency crews. When you meet someone who spends more time with complexity than you do, ask them questions, listen, and learn from the way they think.

I happened upon an example of this in a *New Yorker* article just as I was preparing this paper for publication. Mukherjee (2017), an oncologist, described his conversation with an ecologist:

> [E]cologists are a frustrating lot, at least if you're a doctor. Part of the seduction of cancer genetics is that it purports to explain the unity and the diversity of cancer in one swoop. For ecologists, by contrast, everything is a relationship among a complex assemblage of factors. (p. 48)

As a former ecologist I had to laugh, because I have experienced that same frustrated reaction from people I have talked to in my organizational work. I too have met people who taught me how to better appreciate and understand complexity. Most of us can find someone who can teach us more about living with complexity.

The more time we spend with complexity, the better position we will be in to put down our simplifying filters and confront it as it is. If we can do this, I think we can achieve several goals in our lifetimes. We can stop artificially isolating complexity from other forms of order and learn to make better sense of the complexicated world we live in. We can stop seeing complexity as a magical gift (order for free!) or impending crisis (wicked problems!), and we can understand that (like our children) it is a little of both. We can explore the ways in which people have been thinking about complexity for millennia. Finally, we can learn to see complex phenomena such as the butterfly effect, keystone species, and evolutionary adaptation not as threats to be subdued, but as fundamental insights into the way our world works.

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