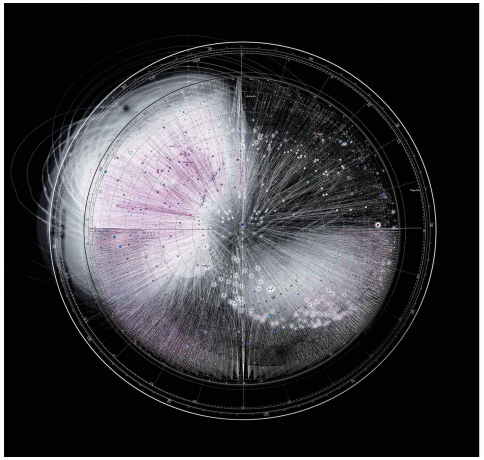
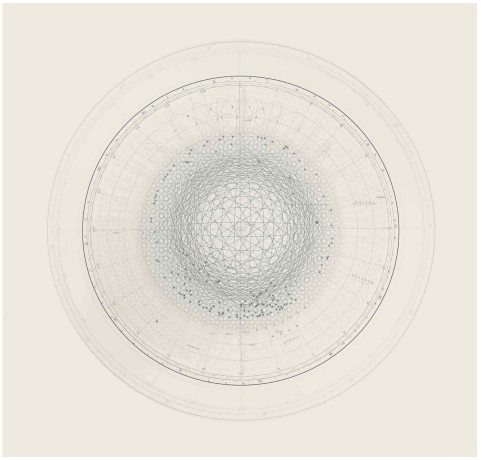




OPERATIONS

Taming Complexity

by Martin Reeves, Simon Levin, Thomas Fink, and Ania Levina

From the January–February 2020 Issue

In business, complexity gets bad press. That's not surprising. It can be cognitively demanding to understand how a system or organization made up of many very different interconnected elements actually works. But the fact that such systems or organizations are difficult to understand doesn't make them inherently bad. In addition to its more obvious costs, complexity confers critical benefits, especially in dynamic and uncertain environments. In the following pages we draw on our experience and perspectives in business,

biology, and physics to offer some reflections on the nature, benefits, and costs of complexity and provide some guidance on managing it in business organizations.

What Is Complexity—and What Is It Good For?

"Complexity" is one of the most frequently used terms in business but also one of the most ambiguous. Even in the sciences it has numerous definitions. For our purposes, we'll define it as a large number of different *elements* (such as specific technologies, raw materials, products, people, and organizational units) that have many different *connections* to one another. Both qualities can be a source of advantage or disadvantage, depending on how they're managed.

Let's look at their strengths. To begin with, having many different elements increases the *resilience* of a system. A company that relies on just a few technologies, products, and processes—or that is staffed with people who have very similar backgrounds and perspectives—doesn't have many ways to react to unforeseen opportunities and threats. What's more, the redundancy and duplication that also characterize complex systems typically give them more buffering capacity and fallback options.

Ecosystems with a diversity of elements benefit from *adaptability*. In biology, genetic diversity is the grist for natural selection, nature's learning mechanism. In business, as environments shift, sustained performance requires new

offerings and capabilities—which can be created by recombining existing elements in fresh ways. For example, the fashion retailer Zara introduces styles (combinations of components) in excess of immediate needs, allowing it to identify the most popular products, create a tailored selection from them, and adapt to fast-changing fashion as a result.

Another advantage that complexity can confer on natural ecosystems is better *coordination*. That's because the elements are often highly interconnected. Flocks of birds or herds of animals, for instance, share behavioral protocols that connect the members to one another and enable them to move and act as a group rather than as an uncoordinated collection of individuals. Thus they realize benefits such as collective security and more-effective foraging.

Finally, complexity can confer *inimitability*. Whereas individual elements may be easily copied, the interrelationships among multiple elements are hard to replicate. A case in point is Apple's attempt in 2012 to compete with Google Maps. Apple underestimated the complexity of Google's offering, leading to embarrassing glitches in the initial versions of its map app, which consequently struggled to gain acceptance with consumers. The same is true of a company's strategy: If its complexity makes it hard to understand, rivals will struggle to imitate it, and the company will benefit.

The Costs of Complexity

Of course, the costs associated with complexity are not to be sneezed at. To begin with, creating and maintaining a variety of elements can be significantly more expensive than using standardized ones, reducing an organization's *efficiency.*

In addition, as complexity increases, a system's *understandability* decreases. This may be no problem for natural systems, but it can be challenging for business leaders, who may struggle to grasp and navigate the system—as anyone who has tried getting an IT problem fixed in a large corporation or resolving a banking problem through a customer call center can attest.

Lack of understandability can lead to *unmanageability.* As complexity increases, identifying the value and function of any individual element—and where and how to intervene to manage performance—gets harder. The organization becomes less like a machine responding precisely to the operator's instructions and more like a complex natural system with a life of its own.

This, in turn, leads to *unpredictability,* whereby spontaneous and unexpected behaviors can emerge from the system, and interventions can lead to unintended effects. For example, building more roads to relieve congestion may in fact exacerbate it, because more roads tempt more people onto the road. Systems theorists call these phenomena *emergent properties;* they create problems in safety-critical contexts such as nuclear power generation and air transportation, where a high degree of reliability is critical. That's why organizations in those sectors invest time and resources in safeguards such as error margins, redundancy, and fallback plans—to mitigate uncertainty.

As companies grow, leaders lose grasp of how all the elements are intertwined.

History provides many graphic examples of the dangers of excessive complexity. The release of radioactivity at the Three Mile Island nuclear reactor in 1979 can, at least in part, be attributed to the reactor's complexity. In the article "After Three Mile Island: The Rise and Fall of Nuclear Safety Culture," Christian

Parenti wrote that the crew at the plant panicked and couldn't interpret signals or follow procedures when the "complex control panels" of the plant "went wild with blinking lights and loud alarms." A seemingly rudimentary issue—a coolant-draining valve got stuck—was obscured by layers of notifications and alarms, resulting in confusion. In *Normal Accidents: Living with High Risk Technologies,* Charles Perrow concludes that the accident at Three Mile Island was due to the system's immense complexity.

Why Complexity Gets Out of Hand

Creating and reducing complexity may sound like perfect opposites. But in fact fundamental asymmetries exist between the two. The process of adding new elements (creating complexity) is essentially local: Someone in an organization tries something new in a specific context. If successful, the innovation is shared or imitated and then gets baked into the mental models, actions, and work processes of other actors within and beyond the organization—often in unintended ways.

At that point, eliminating the new element becomes difficult. Coordinated action is required in the many places and contexts where it has been incorporated. As a result, decluttering is much harder than elaboration in business systems. One can experience this firsthand when trying to close a Facebook account. Facebook strives for omnipresence by partnering with other companies to allow people to use their Facebook login instead of creating a unique one for each app. Whereas setting up a Facebook account requires only one action (creating a password), trying to delete Facebook may require many (resetting passwords for all the previously connected apps).

An Interview with Carsten Rasmussen, COO of Lego

Martin Reeves: How can complexity be valuable?

Carsten Rasmussen: Innovation often requires adding complexity—but just because you are adding complexity doesn't make it valuable. You have to build wisely. For example, when we created the Friends line to better serve girls, the initial proposal was for multiple new colors and components. But eventually we managed to make the new SKUs we needed with many fewer new colors and components, to create a hugely successful business line.

How do you know if complexity has gotten out of hand?

If the top line is growing but the bottom line isn't, and service levels are declining, you've added too much complexity. You can also look to see if inventory turns are declining. If so, and if SKUs and components are growing in number at a faster rate than the top line, you almost certainly have a complexity problem.

The opacity that increases with complexity exacerbates this problem. As companies grow, leaders have less understanding of how each element is intertwined with others; thus they may be unable to assess the impact of removing any one element. What's more, the connections and elements that produce complexity cannot be easily divided into "good" and "bad." An initially ineffective or bothersome new product feature can often show serendipitous effectiveness in a different situation and become widely adopted. Think of Viagra (sildenafil) and Rogaine (minoxidil), both of which were originally developed as cardiology drugs. The "side effects" discovered during their development later became their principal indications: the treatment of erectile dysfunction and hair loss, respectively. Because leaders don't know which elements are useful and which are not, they may default to making no changes at all.

Additionally, a sense of urgency rarely attaches to reducing complexity. The benefits of creating any one capability

How do you manage complexity?

You look at the whole picture and make sure that every time complexity is added, it has a clear strategic purpose. You focus on controlling it where that matters most—in our case, the number of molded colors, resins, and components. You create the variety of SKUs you need with a controlled number of modular components. You manage different parts of the value chain differently: high standardization and simplicity in the capital-intensive upstream manufacturing, and more flexibility and variety in the more labor-intensive downstream packaging operations. With the upstream components you make sure you subtract some complexity every time you add some.

What makes complexity hard to manage, and why does it tend to increase?

Most people in the company will have a local perspective. They see the benefits of adding complexity but not the broader ramifications. You can manage complexity only by looking at the whole picture, and that's really the job of senior management—which probably tends to spend insufficient time that way, because it's never urgent. But over time it's extremely important.

or process may be obvious and immediate (and a customer or a boss may be demanding the innovation in short order), so the organization mobilizes quickly to make it happen. In contrast, the costs of complexity accumulate and manifest slowly or episodically, so removing an element is unlikely to be a priority.

Even when leaders contemplate initiatives to reduce complexity, the organization often resists them—in part, perhaps, because of an inherent psychological resistance to change, as memorably illustrated by the huge outcry when Coke tried to alter its long-standing recipe. This is usually compounded by political considerations: Existing structures attract resources and power, which leaders are understandably reluctant to give up. Dysfunctional though excessive complexity and opaqueness may be, they preserve the status and power of insiders and experts. Finally, removing complexity very often directly threatens jobs, stiffening the resistance to change.

For all these reasons, organizations tend to accumulate complexity over time. As a result, the larger and older a company is, the less likely it is to be able to reinvent itself and grow sustainably. So what can leaders do?

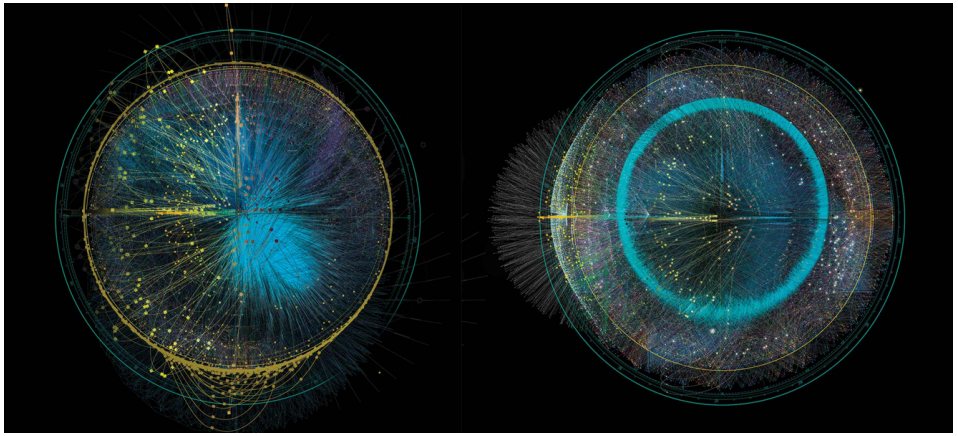
Striking a Balance

Fortunately, runaway complexity is not inevitable. A few organizations have developed the following strategies—many of which have parallels in nature—to mitigate complexity's growth:

Create modular structures.

Robust complex organisms have a modular structure: Each functioning part operates with a degree of independence from the rest. That's why it's possible to transplant hearts and livers. The advantage of a modular structure is that it allows separate systems to evolve and adapt as needed. And if they eventually become redundant, they can more easily be changed without disrupting the other systems.

Similarly, businesses can build structures to be modular rather than fully interconnected so that elements can be changed or removed later. This also increases resilience by ensuring that failures are contained at a local level rather than allowed to spread across the entire organization. And modularity facilitates evolutionary innovation, because modules can be interchanged without undermining the viability of the whole. Furthermore, a small number of modules can yield a great variety of innovative combinations, increasing the cost-benefit of complexity.



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For example, Apple's iOS is designed to be modular—each function of the iPhone is handled by a separate app, and the apps are generally not very interdependent. Therefore, the failure or removal of any one app won't prevent the phone from performing the rest of its functions, and it is easy to adapt any one function as needed. Because Apple Maps was originally designed and installed as a modular app, for example, users can easily replace it with Google Maps if they choose.

Use simple, common operating principles.

Typically, businesses introduce new ideas, methods, and structures in response to challenges as they arise. A specific solution is tailored to the problem and then melded with existing structures and processes, often creating significant complexity. A large pharma company looking to explore new treatment avenues might buy a promising biotech venture started by a group of PhDs and then encounter difficulties integrating the exotic new unit, as a result either failing to capitalize on the synergies of the acquisition or, worse, destroying value the target had going into the deal.

Nature takes a better approach. All organisms are derived from not only a handful of unique molecules but also a remarkably common set of biochemical processes. These molecules and processes form the basis and diversity of all life. From these common building blocks, nature builds both bumblebees and elephants.

In a business organization, the equivalent is a set of simple underlying principles with which all elements and connections must comply. That increases the chances that new elements and connections will fit comfortably into the organization and also contains complexity.

A good example is provided by the hedge fund Bridgewater, which runs its business on 16 foundational principles. One of these is transparency, and all processes and protocols that Bridgewater puts in place must be transparent. Managers are penalized if they withhold information, for example, and all meetings are recorded and shared. The basic principles—or values—are also used in determining what new elements or connections to add. Suppose the fund is considering hiring a new stock analyst. In interviewing candidates, Bridgewater managers will routinely assess whether they are good at sharing information. They will not hire someone who comes across as likely to hoard information in order to compete with colleagues.

Structures and processes become ossified as company employees adapt to them.

When you introduce a new element or connection that in some way changes how your organization works, it's important to codify its utility, because with tweaking it may potentially enable others to solve a different problem without starting from scratch. A precise description of the new mechanism will make it

easier for people in your organization to recognize when it can be a solution for them and understand how to adapt it accordingly. In our work at the BCG Henderson Institute, we routinely codify where our highest-impact ideas came from and how they were developed and shared. On the basis of this knowledge we can scale up and replicate proven methods and modify them in light of new experience.

Embed a bias for change.

Nature has a bias for change, rooted in its reproductive programming; elements and connections are constantly evolving through genetic mutations and recombination. Successful mutations are favored by natural selection, and a new, superior mutation may appear at any time. This process reinforces both the fitness of species and the resilience of populations. Constant mutation ensures continuous adaptation and the existence at any time of variants that can most likely survive some external calamity. But complexity is contained, because redundant or unfavorable mutations gradually disappear through selection.

Unfortunately, mutation doesn't happen automatically in businesses. In fact, organizational dynamics tend to resist change. Structures and processes become ossified as employees adapt to them. To prevent this ossification, organizations need to embed a behavioral bias for change.

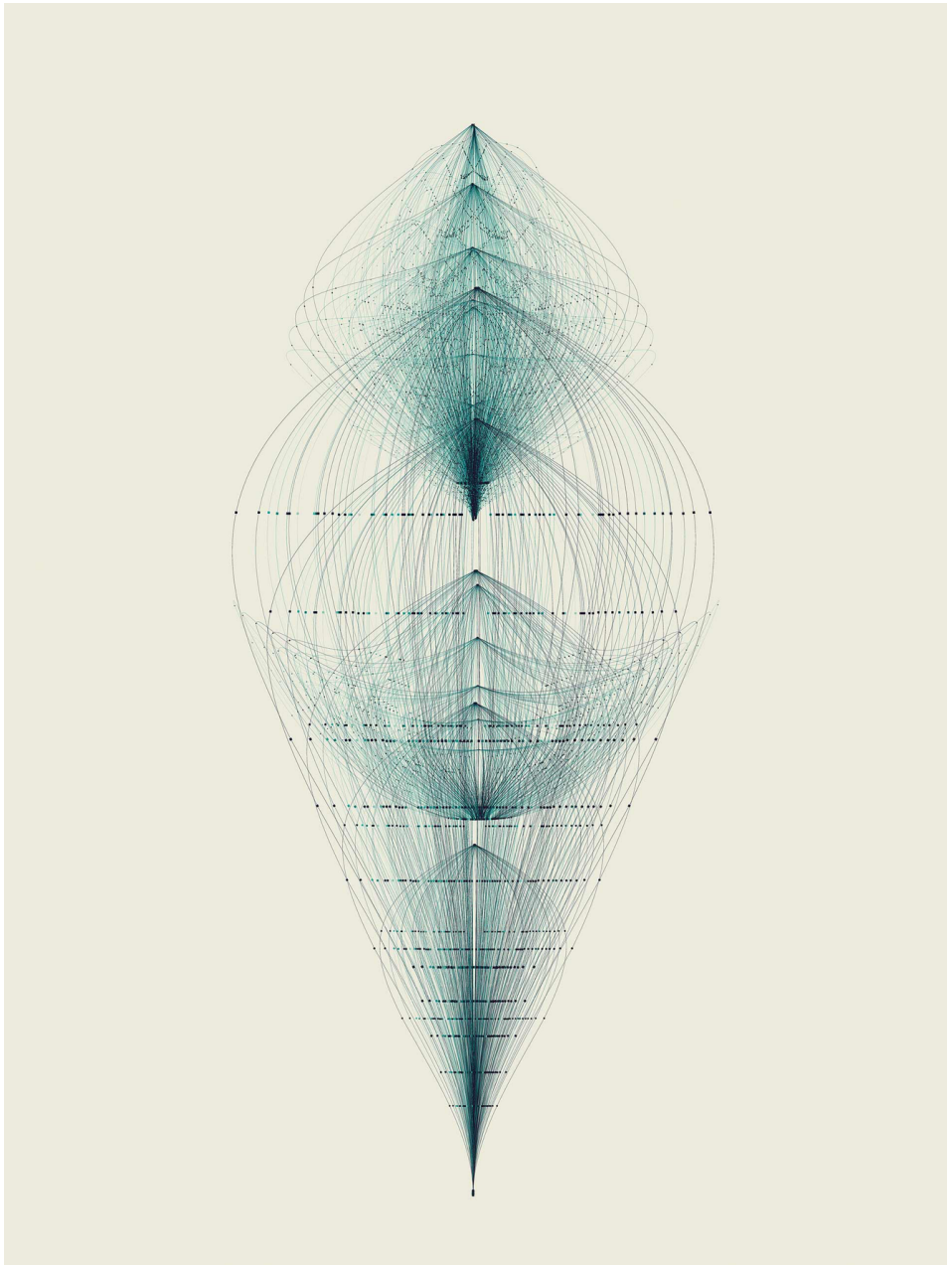
Consider the Chinese tech giant Alibaba. One of its six core values is "embrace change," and Jack Ma, a cofounder and the former executive chairman, believes that "change is the best equilibrium." Unless there is a good reason *not* to change an element or process, Alibaba will proceed to do so. For example, in 2012 it rotated its 22 most-senior business unit managers across departments to break down silos and demonstrate its commitment to flexibility. In practice, the company changes constantly, and today's Alibaba looks very different from the

Alibaba of just three years ago. The principle is also applied to hiring decisions, and the company carefully assesses its new recruits' experience of and comfort with change.

Relax control.

Human beings have a natural propensity to assert control. But especially for complex or dynamic problems, an emergent solution is often superior to a designed and micromanaged one. That's perhaps why Ming Zeng, Alibaba's former chief strategy officer, has said, "Never let an MBA near a marketplace that can run itself."

Instead of micromanaging each decision, smart companies realize that allowing individuals the freedom to engage in constant, iterative experimentation can lead to more-powerful outcomes than can deliberately designing and tightly managing each step. This is particularly true in organizations whose environments are evolving in unpredictable and unprecedented ways.



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Relaxing control reinforces modularity and facilitates the emergence of innovations. The more that autonomous small teams are experimenting with new elements and connections, the more options they create for the organization—as long as the innovations are properly codified and made available to all teams and groups. Toyota provides a good example of how this works. All the company's employees are encouraged to experiment freely, but they are required to specify their recommendations and predict outcomes, and management's role is largely to serve as an enabler and a sounding board for the experimenters rather than to direct them precisely. (See, for example, "Decoding the DNA of the Toyota Production System," HBR, September–October 1999.)

Let the market judge.

As we've noted, nature is governed by the invisible hand of natural selection. Successful mutations survive in the wild, and unsuccessful ones do not. Business needs to submit itself to an equivalent discipline. This may not come easily to individual decision makers, who may use every social advantage they have to achieve the outcome they want—benefiting their own careers and status, but not necessarily guaranteeing good outcomes for the organization. The market will, of course, eventually discern the weaker outcomes, but often too late and long after those responsible have moved on.

To resolve this agency problem, companies need to bring the market into decisions as early as possible. This rule should apply not only to products and services but to the business model, the operating systems, and the direction of the company itself.

Uber provides an example. Not only are everyday decisions—such as where to allocate supply or how much to charge riders—determined by market forces, but the company has developed an experimentation platform on which to rapidly test innovations in the market. It is running more than 1,000 experiments at any given time, which may range from which actions will appease dissatisfied customers to the feasibility of an entirely new service model.

Optimize globally.

In natural organisms, healthy cells don't multiply unnecessarily, because that would crowd out other cells whose functioning is required for the organism's survival. That is precisely what happens in a cancer.

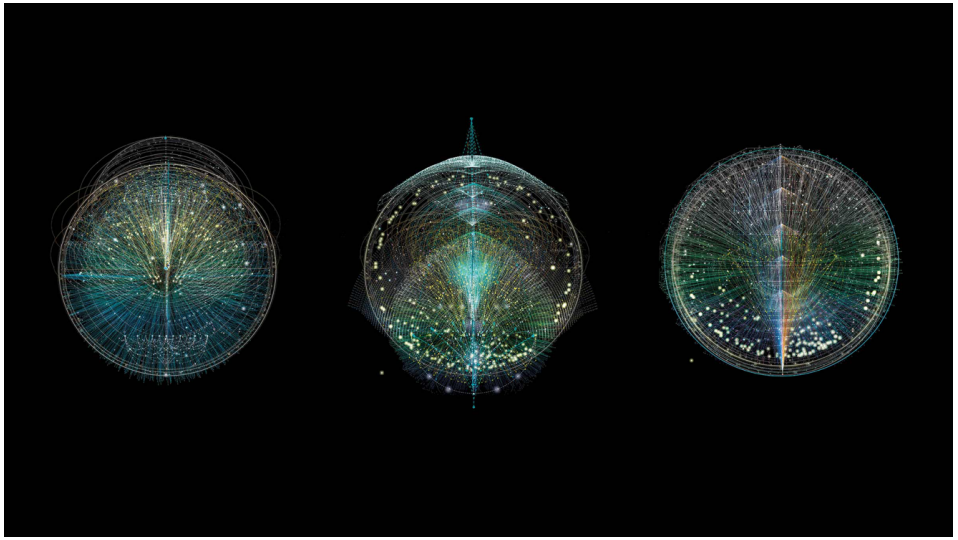
For the same reason, it is essential that the evaluation of new initiatives, processes, and structures be based on their impact not only on a certain group or product but also on the organization as a whole and its collective purpose. This helps balance the trade-offs of complexity—because the benefits of any single component may be concentrated in one small area, whereas the complexity costs may be distributed across the organization. A holistic view of all potential costs and benefits is needed: Companies that measure efficiency and profits but not flexibility, for example, won't be fully aware of the benefits of complexity.

Jeff Bezos, the CEO of Amazon, is acutely conscious of this trap. In his 2016 letter to shareholders he wrote that in order to maintain vitality, leaders must "resist proxies." What he meant was that measuring proxies for success, such as unit sales or project milestones, inevitably focuses attention on a specific goal or group, potentially damaging the company's larger interests. Results should always be measured against the company's purpose and ultimate objectives as well.

Fix, repair, and prune.

Nature has built-in repair mechanisms. At the cellular level, antibodies identify and neutralize foreign matter that doesn't belong. On a larger scale, small forest fires keep a forest healthy and reduce the likelihood of a major fire by preventing its spread with burnt-out patches. And more recently it has been shown that forgetting is a critical function of intelligent organisms, requiring its own active processes and mechanisms.

Organizations can replicate those mechanisms by creating protocols and social norms that encourage people to look out for and eliminate obsolete processes. At Netflix, for example, the company's famous "Reference Guide on Our Freedom & Responsibility Culture" stipulates that it is the duty of managers to eliminate unnecessary rules. This principle enables the company to continue to develop new products and processes while avoiding a continual increase in total complexity. It is also credited with increasing the general level and pace of innovation. In the absence of an explicit injunction like this, managers might allow procedures and rules to reach the point where nobody has a complete understanding of them.



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About the art: Tatiana Plakhova, the creator of Complexity Graphics, uses mixed-media software to harmonize the aesthetic experience of visual art with patterns from mathematics, science, and nature.

Sometimes complexity accumulates until it is intractable and hard to reduce through incremental action. In such situations, organizations should have explicit processes for retiring obsolete units and recycling resources to emerging opportunities. One way of achieving this is to establish new structures with a finite time horizon, identifying exit strategies in advance. By building in exit options at the beginning, rather than subjecting legacy elements to endless modification, leaders can avoid the accumulation of excessive complexity. Pharmaceutical companies take this approach because they know that patent coverage for new products will expire at some point. Product teams therefore have a finite, knowable life.

CONCLUSION

Managers may prefer simplicity over complexity, but the truth is that complexity is increasingly necessary for viability and competitiveness in today's dynamic, unpredictable business environment. If your industry is prone to technological change and rapid obsolescence, then the package of resilience, adaptability, coordination, and inimitability becomes more attractive than the package of efficiency, understandability, manageability, and predictability. Maintaining complexity within productive bounds, however, is a difficult task involving challenging trade-offs. Fortunately, we can learn from a handful of pioneering businesses—and from biological systems—how to harness complexity on a sustainable basis.

A version of this article appeared in the January–February 2020 issue of *Harvard Business Review*.

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