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COMPLEXITY

On July 31, 2012, one of the largest blackouts in history swept across North India. It started as a single power line in the state of Madhya Pradesh became overloaded and tripped. Within minutes, the disruption had spread through the electrical grid, as system after system struggled and failed to pick up the slack. In the ensuing chaos, over six hundred million people found themselves temporarily facing a future without power.

While power outages are not uncommon in India, the sheer number of people affected by the 2012 blackout is a testament to the unpredictability of complex systems such as power supply grids. As with many such networks, North India's system depends on maintaining a fine balancing act between supply and demand, as unpredictable expectations push a complex web of generating stations, transmission lines, and distribution networks to the limit. And, like all complex systems, the line between normal operations and failure is devilishly hard to spot.

Unlike the predictability of, say, tossing a ball, complex systems are defined in part by their unpredictability. Complexity tangles the threads between cause and effect

to such an extent that some future effects simply cannot be predicted, even if we know everything we think we need to know about the causes we believe contribute to them. Despite the future being the result of cause and effect, complexity conspires to obscure our view of the pathways between them.

For a species that has learned to transcend its evolutionary roots through mastering the links between cause and effect, this is a rude awakening. It goes against everything we've come to understand about how we're connected to the future, and how we can design and engineer it.

It was the mathematician and meteorologist Edward Lorenz who provided some of the earliest insights into complex systems and their sometimes chaotic nature. Lorenz was fascinated with predicting the weather, and fervently believed that, with enough data, this should be possible. After all, it was just physics. Yet the more he tried to model trends in weather patterns, the more he realized that seemingly insignificant variations in his starting conditions led to profoundly different outcomes. Try as he might, he simply could not draw a straight line between initial causes and final effects.

This apparent disconnect is popularly known as the butterfly effect, after the idea that the flapping of a butterfly's wings on one side of the world can lead to a chain of events that results in a tornado on the other. This

is something of an exaggeration, but we now know that the more complex a dynamic system is, the harder it becomes to predict the outcomes of seemingly insignificant chains of events. And at some point, it becomes impossible to predict what the future will look like, despite our best efforts to design, engineer, or hack it.

Of course, there remains a lot that we can predict. We can predict where and when the sun will rise, and the flow of the seasons. We're able to predict the likely outcomes of unhealthy eating and drinking habits, or the consequences of not vaccinating large numbers of people. And we can predict—in broad terms at least—how human activities are adversely impacting the environment. These are all possible because of our unique combination of reason, imagination, and inventiveness. But it's in the details that the devil of complexity hides. The more precise we try to be with our predictions of the future, the less likely they are to be accurate. And in some cases, irrespective of how much we think we know, complexity results in a future that utterly confounds us.

The danger, of course, is that we become so enamored with our brilliance that we choose to overlook this, and act as if the future is something we can fully control.

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