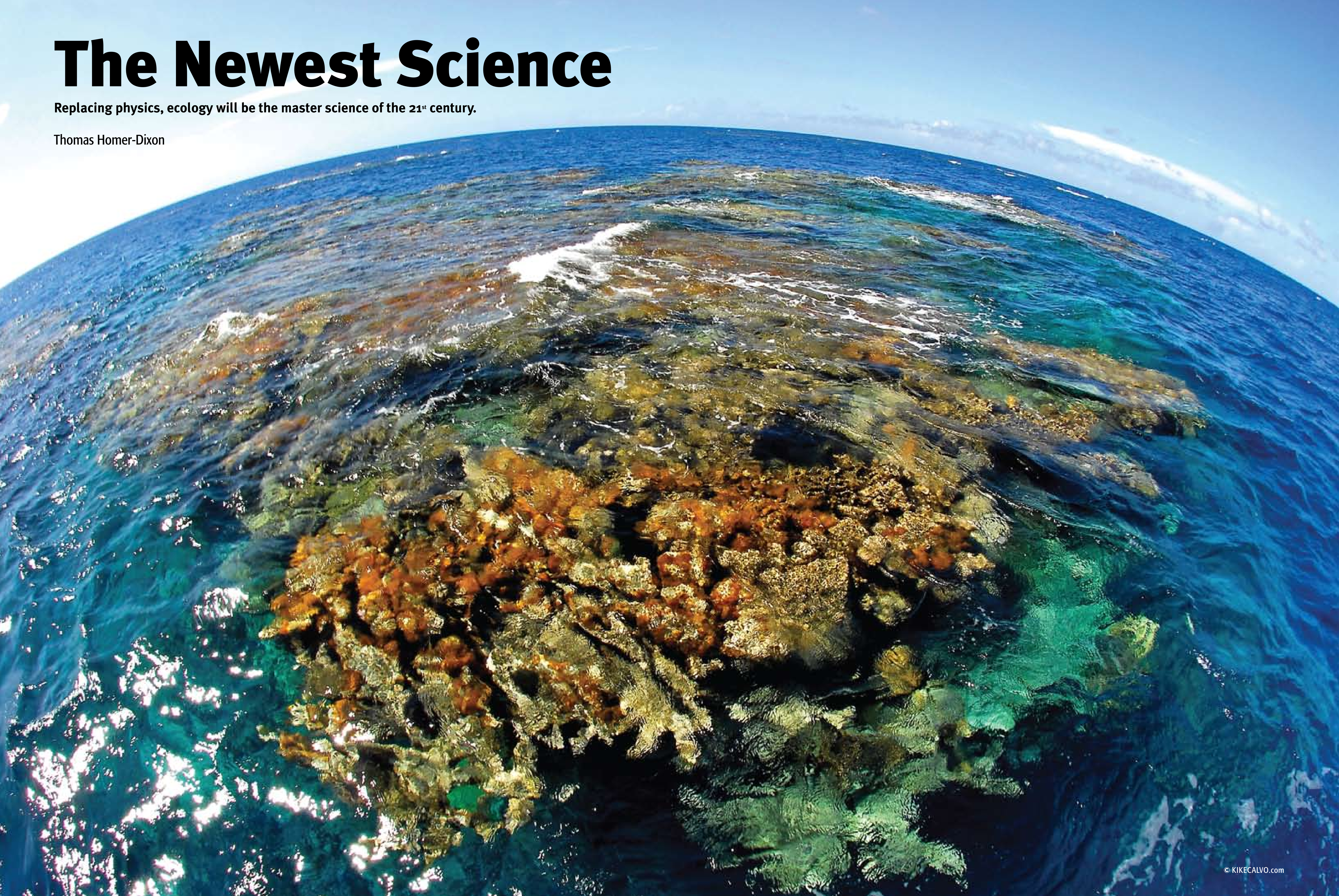
The Newest Science

Replacing physics, ecology will be the master science of the 21st century.

Thomas Homer-Dixon



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PHYSICS was the master science of the 20th century. Ecology will be the master science of the 21st century.

What do I mean by master science? A master science is, in part, the dominant scientific discipline of a historical epoch. It is the prototypical science of the time – the discipline that people think of first when they consider science. It's also likely to have produced the most spectacular discoveries and technologies. More importantly, a master science generates and orders the concepts through which society understands itself and its relation to its surroundings.

Arguably, chemistry was the master science of the 18th and 19th centuries. From Antoine Lavoisier's discovery of oxygen's role in combustion, through Friedrich August Kekulé's dream about benzene rings, to Alfred Nobel's invention of dynamite, chemistry – emerging from the centuries-old practice of alchemy – produced the bulk of scientific breakthroughs during this period. It also generated the technologies of metallurgy and warfare – especially for guns, both large and small – which determined the rise and fall of the great modern empires.

In the 17th century, Isaac Newton laid the foundation for the ascendancy of physics. Although Newton's ideas were enormously sophisticated, they nevertheless assumed that the universe resembled a machine. This machine's behaviour was, Newton maintained, governed by laws that could be stated in precise mathematical formulae, making it predictable and potentially manageable. This notion of a law-governed, mathematically tractable, machine-like universe resonated within societies in the throes of the early Industrial Revolution, because everywhere machines were reordering economies, production processes and social relations. During the 18th and 19th centuries, physics also provided critical breakthroughs bearing on these machines' motive power. Sadi Carnot's analysis of the efficiency of steam engines, which laid the foundations for modern thermodynamics, was one such example.

But physics didn't come to dominate all other natural sciences until the 20th century. By 1920, Einstein's relativity had captured the imagination (if not the understanding) of educated classes. As Western civilization's old order disintegrated in the wake of World War I and the Fordist economic boom that followed (a boom that was in many ways the Industrial Revolution's apogee), the notion that reality's bedrock components, such as time and position, weren't absolute helped make sense of the turmoil and uncertainty that people saw all around them.

Yet it was physics' astonishing success in unleashing the atom's power that propelled the discipline to unchallengeable pre-eminence. The obliteration of Hiroshima and Nagasaki established in everyone's minds – vividly and brutally – the idea that atomic scientists were the unquestioned elite of the scientific world. In the popular imagination, nuclear physics became a zone of encounter with nature's most mysterious workings and even with the eternal forces of good and evil. To stop the demons of national socialism and Japanese imperialism, atomic scientists had made a Faustian bargain in its purest form. They had released one of nature's most elemental powers and touched the mantel of God. Nothing would be the same again.

By the 1950s, nuclear physics and its quantum-mechanical offspring were strutting their stuff for all the world to see. In the process, modern physics' notions of relativity and causal indeterminacy (the latter, which means the absence of a clear link between an event and any prior cause, had often been derived, in the popular mind, from a muddled interpretation of Werner Heisenberg's uncertainty principle) caused upheaval in metaphysics and moral philosophy.

At the same time, somewhat bizarrely, older, mechanistic and largely deterministic analogs of Newton's concepts of force, mass, acceleration and equilibrium were infiltrating the social sciences. During the middle and last half of the 20th century, social scientists increasingly depicted human beings and the societies they constituted as machine-like systems governed by Newtonian-like laws. Lewis Richardson used a system of differential equations to represent the dynamics of arms races between countries. Karl Deutsch and Samuel Huntington proposed that social systems break down when too much stress overloads their institutions and coping capacities. Kenneth Waltz argued that a few simple principles describe the structure and constituents of the interstate system and that the behaviour of states in this system flows ineluctably from these principles.

At the core of much of this theory was the general notion that human beings are rational decision makers interpreting a stream of incoming data and acting, in response to that data, to maximize their benefits according to a clear set of preferences. This view, which is at the heart of modern economics, once again conceives of humans as being machine-like – in this case as old-style adding machines. So, while physics was rapidly moving away from simplistic ideas of causal determinism and a clockwork universe, the most intellectually powerful communities of social scientists – those with great sway over both public policy and popular perceptions of how societies work – were moving in the opposite direction by becoming increasingly wedded to a mechanistic view of social behaviour.

We're ignorant of our own ignorance.

Towards the end of the 20th century, this worldview's shortcomings became vividly clear. The first signs appeared in startling failures of policies to manage large, living, natural-resource systems such as fisheries and forests. Calculations of these resource systems' sustainable yields, based on simple models of a managed equilibrium between reproduction and harvesting, justified extraction rates that sometimes helped cause systemic collapse – most dramatically with the cod fisheries off the northeast coast of North America. In a matter of years, one of the world's most productive ecosystems reconfigured itself in an unexpected and far less productive form. It had flipped to a new equilibrium – an outcome neither anticipated nor understood within conventional and mechanistic resource-management models.

Global economic events provided perhaps the most dramatic evidence that a mechanistic worldview was no longer adequate, if it ever had been. The stock market crash of 1987 and the Asian (and later, the world) financial crisis of 1997 and 1998 led some of the most august members of the world's economic-policy elite, including then-chair of the US Federal Reserve Alan Greenspan, to admit that their understanding of modern economic systems was at best impoverished – and at worst simply wrong. Alas, Greenspan's warnings were almost entirely ignored. In the subsequent decade, financial wizards, believing that they were operating in a mechanistic world in which risk could be precisely estimated, invented a bewildering array of financial instruments such as collateralized debt obligations, structured investment vehicles and credit default swaps. They then used these instruments to build a towering edifice of credit that spanned the globe. What they didn't anticipate, though, is that in the process they were creating an economic system that no one remotely understood, let alone controlled.

Today, we're living with the consequences of this hubris.

Times of crisis, however, create opportunities for new ideas to flourish. Just as the dominant mechanistic worldview is being discredited, an alternative perspective – complex adaptive systems (CAS) theory – is emerging. This theory tries to make sense of a messy world, especially those parts of it (immune systems, economies and the like) that have evolved the ability to adapt to rapid change. But CAS theory doesn't neurotically eliminate all the mess with Newtonian-like laws or systems of equations. As befits a theory that has grown at the intersection of disciplines as diverse as mathematics, molecular biology and economic geography, CAS is messy itself – in fact, it's not yet clear whether it truly qualifies as a "theory," in a strictly scientific sense.

The discipline that most effectively captures the core ideas of CAS theory is ecology, and ecology has in turn contributed much to the development of CAS

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Ecology Behind the Lens

Kike Calvo

The recipient of Art Wolfe's 2008 International Conservation Photography Award in the underwater category, Kike Calvo is making a difference with his camera. Born in Zarágoza, Spain, Calvo has exhibited his photos in New York, Phoenix, Chicago, the Philippines, Spain and more. Passion for his craft and the natural environment has taken him to 65 countries, ranging from the US to Egypt and from Belize to Thailand.

In the foreword to Calvo's gorgeous book, *Habitats*, Jean-Michel Cousteau writes, "What Kike has done so well is not only inspire us with vivid images of habitats around the globe, but hold up a mirror to us. We must see ourselves in nature and be connected to it."

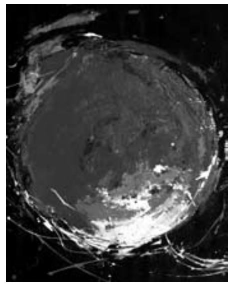
Calvo's photo of a coral reef on page nine is taken from his underwater series, which can be viewed by visiting his website at **www.kikecalvo.com**. His photos are available as stock to corporations and other institutions.

half is that burning this valuable resource is releasing vast quantities of greenhouse gases that are having a significant impact on our planet. Homer-Dixon and Garrison refer to it as an "existential" crisis: one that makes us question who we are and where we are heading as it affects billions of people, as well as countless other species. Echoing Jaccard, they conclude that putting a realistic price on carbon is probably our only hope if we are to proactively and positively address the world our children will inherit.

So there you have it – a diverse, sometimes contradictory, but readable series of essays purporting to answer the question of how oil depletion and climate change will define the future. But does the book solve the challenge it poses? Not really. It provides a variety of opinions on energy prices, carbon pricing, public attitudes and government policies. If anything, a reader looking for a solution will come away from the book thinking that humanity may not be able to reconcile the challenges of energy scarcity and climate change because we haven't fully agreed that they are interdependent and, therefore, inseparable.

If the reader approaches this book in the spirit of exploring the issue as a complex problem for which there is no simple solution, however, then the essays reinforce the conclusion that it will take all of our ingenuity, will and perseverance to prevent catastrophe. In the words of Ronald Wright, who wrote the lively foreword to *Carbon Shift*, "…a swift transition to much cleaner energy is our only hope of escaping the dire consequences of our runaway success."

After spending eight years as the CEO of Mountain Equipment Co-op, Peter Robinson has taken up responsibilities as the head of the David Suzuki Foundation.



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theory. Ecologists realized long ago that simple mechanistic notions of balance and equilibrium (between populations of predators and prey, for instance) cannot represent the subtle and unpredictable dynamics of ecological systems. Unlike with machines, we cannot easily draw a line around ecological systems to demarcate which factors or variables we've determined are important and which aren't. They are, in other words, characterized by "causal openness." They tend to exhibit "emergent properties," which means that they do things we don't expect even when we know a lot about their constituent parts. They are also replete with self-reinforcing and self-counteracting feedback loops.

As a result of these characteristics of ecological systems, an effect is often disproportional to its cause. Small events sometimes cause big changes, while big events sometimes cause hardly any change whatsoever. Specialists say such systems exhibit "non-linear behaviour." They have the capacity to flip suddenly from stability to turbulence, or from one equilibrium state to another. A classic example of this is a pristine pond that seemingly overnight becomes clogged with algae.

These ideas seem to resonate much better with today's chaotic, weird world – where once-in-a-lifetime surprises seem to be happening once a week – than the older, yet still dominant, mechanistic perspective. Whether we admit it or not, in today's tightly connected world, which is subject to staggering demographic, resource and economic stresses, and in which information moves between us at the speed of light, we're now surrounded by unknown unknowns. Oftentimes, we don't know what questions to ask about the key social, economic and environmental systems that affect us. We may not be aware that we should ask questions at all. We are ignorant of our own ignorance.

In a world of unknown unknowns, we can't hope to precisely predict the behaviour of critical systems, and we shouldn't presume that we can manage that behaviour with precision either. Ecology and CAS theory therefore put a premium on prudence in policy. They tell us that we shouldn't be surprised by surprise and that systemic crisis and even systemic breakdown are inevitable features of evolving complex systems. But no one wants such breakdown to become catastrophic – as, unfortunately, could happen with the world's current economic crisis. To avoid catastrophe, a complex-systems perspective suggests that we should build "resilience" into our critical technological, social and natural systems, so that they don't fall apart when hit by significant shocks.

Perhaps most importantly, as ecology becomes humanity's master science and, more generally, a complex-systems perspective begins to influence elite and popular ways of seeing the world, our relationship with expertise will change: we will learn that we shouldn't rely so much on "experts" to manipulate the systems around us since these elites have little real understanding of how those systems work. As the 21st century progresses, ecology's best lesson may be that we need to learn to take more responsibility for our own well-being.

Thomas Homer-Dixon, author of ***The Upside of Down*** *and* ***The Ingenuity Gap****, recently joined the University of Waterloo, where his interest lies in studying resilience and innovation.*

The Resilience Alliance, a multidisciplinary research group, explores complex adaptive systems. Its website, which includes extensive resources, research information and a blog, can be found at **www.resalliance.org**.

www.alternativesjournal.ca

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