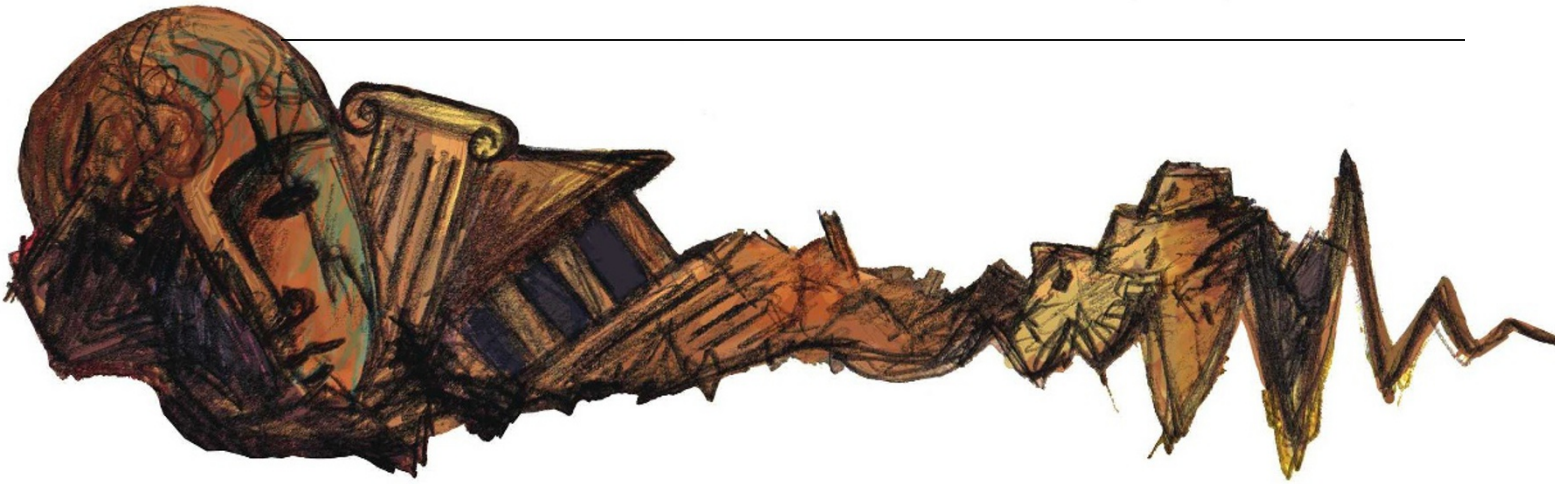
SPRING BOOKS



Shaking the foundations of archaeology

Did earthquakes trigger the collapse of ancient civilizations?

Apocalypse: Earthquakes, Archaeology and the Wrath of God
by Amos Nur and Dawn Burgess
Princeton University Press: 2008. 304 pp. $26.95, £15.95

Andrew Robinson

At 5:04 p.m. on 17 October 1989, Stanford University geophysics professor Amos Nur was sitting in his office in California when it started to shake. His steel bookcases toppled and crushed his chair. Ducking under his desk, he somehow escaped injury. Nur had just experienced the Loma Prieta earthquake that devastated parts of the San Francisco Bay Area.

Nur has long been interested in archaeology. Growing up near Haifa in Israel, he walked behind his father and two mules as they ploughed the family's field. "I remember picking up shards of ancient glass," he writes, "pieces of simple mosaics and little squares of pink or white limestone exposed in the turned earth." On a few rare occasions, the plough struck a massive object: a rough block of stone about 1 metre tall and 25 centimetres square in cross-section. "Probably a Roman mile marker," they thought. Much later, Nur discovered that the field was on the *Via Maris*, the ancient Roman highway connecting the Mediterranean to the East.

A twin passion for seismology and archaeology drives Nur's deeply researched and compellingly written book, *Apocalypse,* co-authored with Dawn Burgess. In it he asks how earthquakes might be detected in the archaeological record, by analysing geological formations, faults, structural movement, human remains, the collapse of pillars and walls, and inscriptions. Nur wonders if earthquakes played a part in the collapse of ancient civilizations. Might they explain the enigmatic and quick disappearance of so many Bronze Age civilizations in the eastern Mediterranean during a mere 50 years around 1200 BC?

Most archaeologists today say that earthquakes have had little to do with historical demises. They prefer to attribute the collapse of civilizations to human agency: war, invasion, social oppression, environmental abuse and so on. The conventional explanation of the Bronze Age collapse involves maritime invasion by the mysterious Sea Peoples, whose identities have long eluded scholars. There are notable exceptions of academics who were sympathetic to the idea that earthquakes could crush civilizations — Arthur Evans at Knossos in Crete, Carl Blegen at the Turkish city of Troy and Claude Schaeffer, for instance — but the majority are sceptical.

Robert Drews took pains to quash any earthquake explanation in *The End of the Bronze Age: Changes in Warfare and the Catastrophe ca. 1200 BC* (Princeton University Press, 1993), as Nur is contemptuously aware. Jared Diamond made no mention of earthquakes or volcanic eruptions in *Collapse: How Societies Choose to Fail or Succeed* (Viking, 2005). If earthquakes really have had so great an influence, the sceptics ask, then where is the hard evidence?

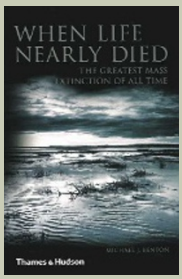
In reply, Nur and Burgess cite several powerful instances. The seismic destruction of the Portuguese capital of Lisbon in 1755, which provoked Voltaire to write *Candide*, shook the pillars of both religious faith and Enlightenment optimism. "By striking at a time when there was a particularly delicate balance of power between church and state, and between science and religion, the earthquake tipped the scales and changed society around the world," the authors argue.

In Venezuela, an earthquake in 1812

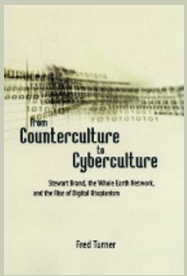
ILLUSTRATIONS BY C. ALLEN-FLETCHER

NEW IN PAPERBACK

When Life Nearly Died: The Greatest Mass Extinction of All Time
by Michael J. Benton (Thames & Hudson, $24.95)
The end-Permian extinction 250 million years ago destroyed 90% of Earth's life. Delving into geological history, Michael Benton investigates the science that documents the event, how its true scale was discovered, and discusses evidence for the possible cataclysm that caused it.



From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism
by Fred Turner (Univ. Chicago Press, $17)
By focusing on the life of ethical entrepreneur Stewart Brand and the influential Whole Earth Network, Fred Turner shows how alternative culture ideas in San Francisco, California, gave rise to the networked world.



precipitated the collapse of Simón Bolívar's republic by his own reckoning. This ultimately led to Bolívar freeing Colombia, Ecuador, Peru and Bolivia from Spanish rule.

In Japan, the Great Kanto earthquake of 1923, which reduced two-thirds of Tokyo to ashes, spawned political and racial turmoil that contributed to the rise of militarism and, ultimately, to the Pacific war. If the Tokyo area experiences another such earthquake in decades ahead as seismologists expect, its repercussions will surely make the global financial system tremble. Were it to strike at a time of economic depression, its effects might be globally catastrophic.

Apocalypse focuses mostly on the ancient world, with a distinct emphasis on biblical archaeology. It discusses earthquake evidence from the Middle East, including Jericho, Megiddo (Armageddon), Jerusalem and Qumran, the location of the 2,000-year-old Dead Sea Scrolls.

In the caves at Qumran, Nur has considerable field experience, which he deploys to illuminating effect. He was part of an expedition from Jerusalem's Hebrew University that excavated the rubble in the Cave of Letters, in the hope of finding a previously glimpsed skeleton and other evidence of habitation buried by the collapse of the roof in an ancient earthquake. Nur is convinced — a little like Howard Carter in the Valley of the Kings — that there remain sealed caves that were not looted by the Bedouin who first reported the scrolls' existence in 1947. "These places, undisturbed since their destruction by earthquakes, may provide the means to unravel the complicated and emotionally charged story of the Dead Sea Scrolls."

Apocalypse is a winning combination of cautious interdisciplinary investigation and interpretation, writing suitable for a general readership, and excellent illustrations (including a striking photograph of Nur's own crushed office chair). Although it will deliberately irritate many archaeologists, it should also provoke a serious reconsideration of the archaeological record. As with the evidence for human activity in climate change, the evidence for earthquakes in prehistorical change may be staring archaeologists in the face. ■

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Brave new bioethics

Life As It Is: Biology for the Public Sphere
by William F. Loomis
University of California Press: 2008.
272 pp. $24.95

Eugenie Scott

Science's task is to explain the natural world: what it is, how it works and why it is the way it is. Ethics is about the oughts and the shoulds. Most ethicists — religious and secular — agree that knowledge of the natural world helps us make better, or at least better-informed, ethical decisions. But, as David Hume, Thomas Henry Huxley and G. E. Moore have noted, a particular understanding of nature does not dictate a unique moral stance. For every Alexander Pope declaring "Whatever is, is right," there is a Rose Sayer (from the film *The African Queen*) retorting, "Nature ... is what we are put in this world to rise above!"

It is the complicated interplay of moral decisions and biological sciences that motivates cell biologist William F. Loomis. His brief book, *Life As It Is*, is a tour of the brave new biology relevant to such social issues as abortion, euthanasia, the use of embryonic stem cells, cloning, overpopulation and global warming. Loomis holds that scientific evidence should be taken into account when making socially important decisions. He provides a fascinating, if occasionally disjointed, survey of topics that bear on these decisions: the nature and evolution of life, and current scientific thought regarding consciousness, psychology and social behaviour.

Sometimes it is questionable whether the scientific aspects of a situation are most relevant to the ethical decision. Is it ethically permissible to destroy the surplus human embryos created for *in vitro* fertilization (IVF), for example? Loomis believes the answer should be shaped by a better understanding of the nature of cells.

Loomis emphasizes that at the cellular level life is cheap: at any given moment, billions of bacteria in our body are dying. A human zygote is merely a single cell, so shouldn't we think of it as such rather than the multicellular, functioning, conscious and precious baby into which it might develop? If a zygote is just a cell, and cells die regularly, then the answer to whether it is ethically permissible to destroy it is yes. But this argument comes after the ethical question of whether a zygote is just a cell, which is one that science cannot answer.

The ethical status of a human zygote or early-stage embryo turns on the issue of personhood. For those who believe in a soul, the moral standing of the zygote is largely unaffected by the nature of life at the cellular level. Belief in souls is a first principle, unlikely to be either proved or disproved by science.

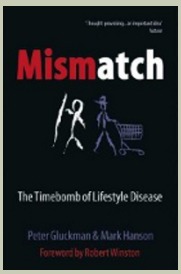
By contrast, as Loomis correctly notes, science may provoke a rethinking of religious dogma. Catholic theology holds that a soul is infused into a fertilized egg. So if an eight-celled embryo can be made to produce eight separate human beings, do they share a soul, or are seven new souls somehow generated?

This conundrum has led some Catholic theologians to contend that the soul is infused not at fertilization, but only when cells of the dividing organism lose their plasticity. Other theologians try to accommodate scientific facts about cells in other ways. Although scientific facts about the nature of a developing embryo may have profound consequences for Christian (or at least Catholic) thinking about souls — as a first principle, the concept of a soul is unlikely to be abandoned, and will be a factor in ethical decisions about many issues that biology touches on.

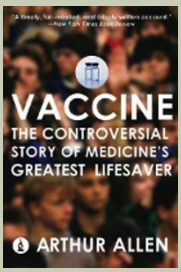
Policy-makers deciding between contending positions are ultimately forced to make political decisions, not scientific ones. Science — ideally, and in most cases — influences the thought of the proponents of the contending positions, and they in turn influence the policy-makers. But science is rarely the deciding factor. In many cases, such as the example of the human embryos in IVF, the contenders on both sides can agree on the science and disagree on the policy, owing to a disagreement about whether (and which) religious concerns are most relevant. And such disagreements are beyond the competence of science to adjudicate.

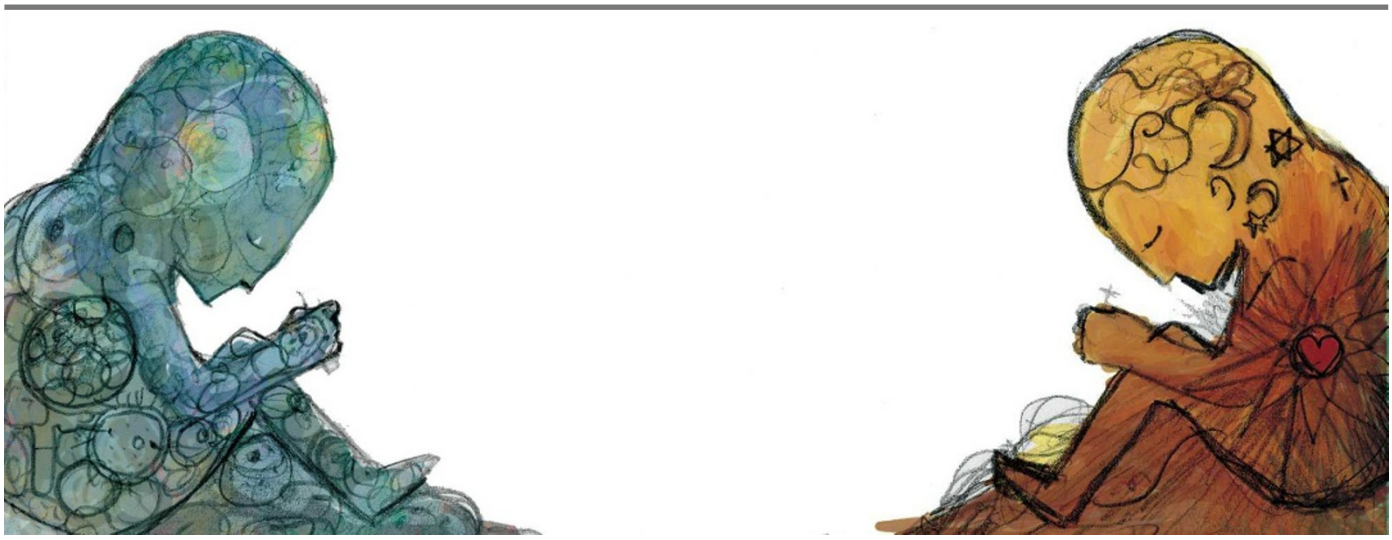
Refreshingly, Loomis's discussion of ethical issues roams beyond the comparatively narrow issues of abortion and euthanasia and the

Mismatch: The Timebomb of Lifestyle Disease
by Peter Gluckman and Mark Hanson (Oxford Univ. Press, £8.99)
The bodies we have now are the product of evolution. Peter Gluckman and Mark Hanson argue that they are mismatched to our needs in society today, and that this divide has increased the rate of lifestyle diseases such as diabetes and obesity.



Vaccine: The Controversial Story of Medicine's Greatest Lifesaver
by Arthur Allen (W. W. Norton, $17.95)
Journalist Arthur Allen investigates the history of vaccination, covering three centuries' worth of controversies. Reviewing the hardback edition, Michael Oldstone wrote that, "What becomes clear ... is that, when facts tangle with culture, culture often wins" (*Nature* **448,** 137; 2007).





like. He devotes a final important chapter to sustainability. In the face of pollution, global warming and population increase, how will it be possible to ensure an adequate supply of food, water and energy for all of Earth's people while maintaining respect for the well-being of other creatures? Loomis recommends a programme of voluntary population reduction, requiring both political leadership and a radical change of public opinion.

Loomis identifies the source of his title *Life As It Is* — his wife apparently — but not its significance. The idea that a realistic understanding of biology will usher in a paradise of ethical correctness is naive: the panoply of extra-scientific considerations that influence ethical decision-makings cannot be ignored or minimized. A weakness of Loomis's book is his comparative neglect of such considerations. But if his intention is less ambitious, namely that a realistic appreciation of biology ought to inform ethical decision-making, then that is incontrovertible. ■

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Engines of life

Energy in Nature and Society
by Vaclav Smil
MIT Press: 2008. 512 pp. $70, £45.95

Tim Lenton

The explosion of myriad life-forms throughout Earth's history has been fuelled by their ability to collect and process increasing amounts of energy. Thus organisms have become ever more complex, culminating in humans and our technology. In *Energy in Nature and Society*, Vaclav Smil describes in quantitative detail the evolutionary and technical innovations responsible, from photosynthesis and respiration to solar cells and steam turbines.

The first living things probably accessed chemical energy by breaking down large molecules into smaller ones. By 3.7 billion years ago, the first photosynthesizers evolved. These organisms could capture energy from sunlight and use it to split simple molecules and liberate electrons, which they used to make sugars from carbon dioxide. Their ingredients probably included electron donors — hydrogen (H_2, then H_2S) and later iron (Fe^{2+}) — that were in limited geological supply. This restricted global productivity to at most a tenth that of the modern marine biosphere.

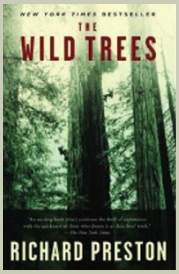
Next came the greatest energetic innovation in the history of the planet: oxygenic photosynthesis, the ability to capture enough energy from sunlight to split water, thus liberating oxygen gas. This evolved in cyanobacteria more than 2.7 billion years ago. Initially, oxygen production was confined to microbial mats and sunlit surface waters; 2.4 billion years ago it rose in the 'great oxidation' of the atmosphere.

When oxygen reacts with organic matter during aerobic respiration, an order of magnitude more energy is liberated than was available for earlier anaerobic respiratory pathways. Ultimately, this source of power allowed the evolution of larger and more mobile organisms, including humans.

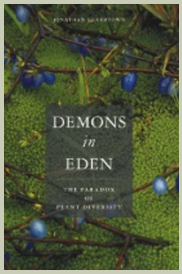
Smil is brief on the history of the biosphere. He gives a fascinating assessment of its present energetic state, quantifying global energy capture in photosynthesis and the uses that all organisms, including humans, put it to. Then he shifts the focus to human technological innovations that have progressively increased the capture and conversion of energy into forms that are useful to us. *Energy in Nature and Society* tells this story wonderfully, from hunter-gathering to traditional agriculture, the shift from human to animal power, the invention and refinement of water wheels and windmills, improvements in roads and ship design, and to charcoal production and its use in metallurgy. The fossil-fuel age takes off with exponential global increases in coal, then oil, then gas extraction and consumption.

In a feat unprecedented for a single animal species, humanity's total energy use has now exceeded that of the entire ancient biosphere before oxygenic photosynthesis, reaching about a tenth of the energy processed by today's biosphere. Almost half of the world's total primary energy supply is consumed by the rich

The Wild Trees
by Richard Preston (Random House, $16)
A dramatization of the lives of Californian botanists, Richard Preston reveals the hidden world of the coastal redwood trees, the tallest organisms the planet has sustained. Science, adventure and a passion for trees are combined.



Demons in Eden: The Paradox of Plant Diversity
by Jonathan Silvertown (Univ. Chicago Press, $16)
How is plant biodiversity maintained and why is the world not overgrown by aggressive weeds? Jonathan Silvertown explores the dynamics of the plant world and suggests that "tasting the fruit of evolutionary knowledge may provide us with a ticket for readmission to the Garden of Eden", according to Peter Moore's review (*Nature* **438,** 27; 2005).



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G8 nations, despite their having only 12% of the world's population. The poorest quarter of humanity consumes less than 3%. For them, even modest increases in per capita energy consumption significantly reduce infant mortality and increase life expectancy. Above about 60 gigajoules per capita (the amount used, for example, by citizens of the French city of Lyon in 1960) these benefits level off, indicating that profligate energy use bears little on quality of life. Consequently, Smil advocates that rich people should reduce their energy consumption to allow poorer people to increase theirs.

Today's high-technology societies mostly rely on fossil fuels. These concentrated reserves of stored ancient sunlight — the remnants of past organisms — are finite, and the products of their combustion have undesirable consequences, from respiratory problems to climate change. Smil argues that we should stop the seemingly endless growth of energy consumption while we switch to cleaner and more sustainable sources of power.

In the long term, Smil's solution is solar power, because the total supply of sunlight at Earth's surface exceeds current global fossil-fuel consumption by more than a thousand times. Until then, he supports a careful transition away from fossil fuels and points out that carbon capture and storage have limited capacity. He dismisses most renewable energy sources because their power densities are too low to supply the needs of the present global population, let alone future ones. This includes first-generation biofuels, where their poor energy returns could ultimately mean feeding cars in place of people. In *Energy in Nature and Society*, Smil contends that power from nuclear fission would become limited by uranium supply until a viable commercial fast-breeder reactor is available, and fusion power is too far from commercial deployment. All of which implies a difficult transition period involving substantial carbon dioxide emissions and climate change.

If we are to have a long and happy future on this planet, we need to follow life's example and find more efficient ways of extracting free energy from sunlight. But energy isn't everything. The successful major transitions between past biospheres also required increases in material recycling, because the organisms capturing energy built their bodies from elements whose supplies were restricted. In contrast, to maintain our present high level of energy transformation in society, we increase the inputs of many elements, mostly by mining them from finite reserves in Earth's crust. We thus perturb global biogeochemical cycles. A wiser strategy in the long term would be to increase the recycling of materials that accompany the capture and use of energy.

I would like to encourage Smil to strengthen this link between energy processing and material cycling in the next edition of his book, and to address whether the combination of solar power and recycling might allow energy transformation by humans and the biosphere to grow again. For now, the energy required to read this comprehensive and scholarly tome is extremely well spent. ■

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Biology from the bottom up

What Is Life? Investigating the Nature of Life in the Age of Synthetic Biology
by Ed Regis
Farrar, Straus & Giroux: 2008. 208 pp. $22

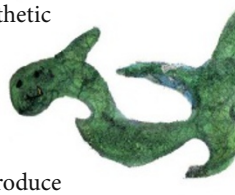
Steven Benner

Book titles should display ambition, and Ed Regis' latest certainly does that. Implicit is progress between two areas of biology. *What Is Life?* recalls Erwin Schrödinger's famous book of the same name that encouraged many physicists to begin working in molecular biology in the 1940s; synthetic biology is the fast-moving area today.

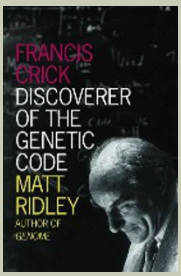
The term synthetic biology was coined in 1974 by Waclaw Szybalski to describe the modification of organisms by adding and subtracting genes. In those days it was known as 'genetic engineering' or 'recombinant DNA technology'. By altering the genes, the organisms act in new ways.

At the time, Szybalski's synthetic biology prompted fear. The city of Cambridge, Massachusetts, banned genetic engineering entirely. A conference was convened in Asilomar, California, to decide how to manage the new ability to create artificial organisms.

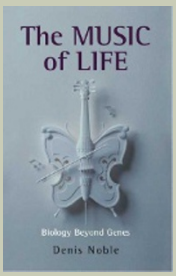
Three decades of experience have shown the risks to be negligible but the rewards enormous. Today, the field of synthetic biology is expanding, spawning new university departments, such as the one that hosts Jay Kiesling's laboratory at the University of California at Berkeley in which bacteria are created to produce



Francis Crick: Discoverer of the Genetic Code
by Matt Ridley (Harper Perennial, £7.99)
The story of Francis Crick extends beyond the discovery of DNA. Matt Ridley's biography details how he came to study biology, sets in context his controversial ideas and gives a glimpse into the character of one of the most famous scientists of the twentieth century.



The Music of Life: Biology Beyond Genes
by Denis Noble (Oxford Univ. Press, £7.99)
Instead of taking a blinkered view based on genes and genomes, Denis Noble argues, we must realize that life is a process. To see its workings, we should look at interactions on every level — genes, cells, the body, systems and the environment.



pharmaceutical intermediates. Craig Venter, a driver of innovation in contemporary genomics, and whose personal genome can be found on the Internet, is going further by proposing reorganization of the natural parts of natural genomes. Some of these restructured microbes are so scrambled that they deserve to be viewed as new species.

The remit of synthetic biology has widened as other researchers have adopted the label. In 2000, Eric Kool of Stanford University, California, used it to describe the construction by chemists of unnatural molecules that can operate within natural living systems. To Drew Endy and others at the Massachusetts Institute of Technology, it means the process of creating, mostly by modifying existing biomolecules, units that can serve as interchangeable parts in larger assemblies. Stephen Wolfram and others view "artificial life" as a computer program that yields output behaviour that is analogous to the behaviour of living systems.

What is Life? captures these differing perspectives well. As expected from a science writer with Regis' record, the book is an easily readable review of the development of contemporary biology, including the first-generation model for DNA structure, the foundation of metabolism, and the elucidation of the genetic code. Furthermore, it captures interactions between scientists who approach synthetic biology differently, providing a brief and entertaining glimpse into the competitive aspects of modern science. For example, one experimenter (Norman Packard of Protolife, based in Venice, Italy), trying to get a real cell made out of real chemicals to work in a real laboratory, sets these activities above trying to write computer programs that simulate parts of biological chemistry. Another (Francis Collins, who heads the National Human Genome Research Institute in Bethesda, Maryland) is quoted asking, in essence: what's new? Isn't this just the 30-year-old field of genetic engineering sporting a catchier trademark?

There is one disappointment. The book only incompletely conveys why efforts to rebuild life from the ground up ('synthesis') offer new avenues for discovery that those dissecting life from the top down ('analysis') do not.

The analytical approach to biology was born a few centuries ago, when those wishing to answer the question, 'what is life?', realized that observation alone was insufficient. Their investigations began by killing some unfortunate organism. After dissecting the spilled guts, tissues were named, maps were drawn and parts were catalogued. Much was learned; much of it practical. But the essence of 'life' did not emerge. With the invention of microscopes, the dissection went further, to cells. This time a new theory (cell theory) did emerge. As Regis' book emphasizes, cells are even today viewed as a defining attribute of life.

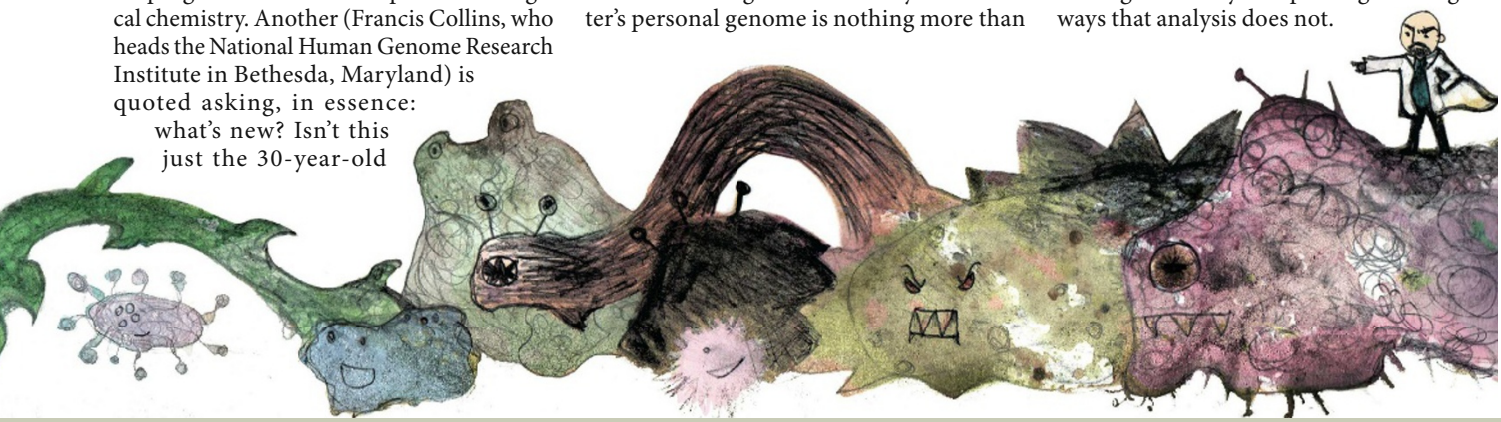
The so-called 'age of biology' came not from biologists but from chemists, who carried the dissection of living matter further. Karl William Scheele, in the late eighteenth century, crystallized the first organic molecule (barium lactate) from sour milk, and realized that the molecular parts of living organisms could be analysed. This led to structure theory, which holds that the arrangement of atoms in constituent molecules determines the behaviour of all matter. Biological chemists spent the next 150 years figuring out atomic arrangements in every biomolecule they could get their hands on, even DNA.

An unbroken line runs from Scheele to the human genome. It involves great technological innovation, but no conceptual innovation that can be thought revolutionary. Even Venter's personal genome is nothing more than a map of how its atoms of carbon, oxygen, hydrogen, nitrogen and phosphorus are arranged.

Even if the analytical strategy applied to biology is ever completed, biology will remain hollow. Living systems cannot be explained solely as a series of molecular structures, even when their interactions are described mathematically (as attempted in systems biology). Reflecting this, microbiologist Carl Woese wrote that the "strange claim by some of the world's leading molecular biologists that the human genome is the holy grail of biology is a stunning example of a biology that has no genuine guiding vision".

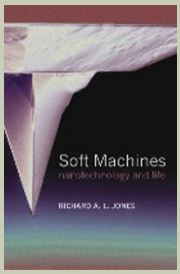
Synthesis offers a different strategy. The deliberate creation of new forms of matter from the bottom up, rather than the top down, gives us new ways to test nature. Chemists today use synthesis routinely. Having benefited from being first to gain the tools, they tested structure theory by building molecules with structures designed to target predictions of the relationship between molecular structure and behaviour. In a virtuous circle, they simultaneously built up their molecular toolkit and improved structure theory, further empowering synthesis. Chemists know that if one truly understands a phenomenon, one should be able to synthesize another, different system that generates that phenomenon.

Because building something requires a deep understanding of its parts, synthesis also stops scientists from fooling themselves. Data are rarely collected neutrally during analyses by researchers, who may discard some, believing the data to be wrong if they do not meet their expectations. Synthesis helps manage this problem. Failures in understanding mean that the synthesis fails, forcing discovery and paradigm change in ways that analysis does not.



Sustainable Fashion and Textiles: Design Journeys
by Kate Fletcher (Earthscan, $48.95, £24.95)
Fashion is ephemeral by nature, but Kate Fletcher describes how clothing manufacture could be turned into a sustainable industry. Her detailed book assesses systems as well as products, examining possible solutions from raw material to final design.

Soft Machines: Nanotechnology and Life
by Richard A. L. Jones (Oxford Univ. Press, £9.99)
The principles of nanotechnology may have more in common with biology than engineering, argues Richard Jones. He describes the science of the minuscule, and explains how the demands of working at this scale may shape nanotechnology into something more organic.



Now that genetic engineering is available, biologists are benefiting. By attempting to create synthetic genetic systems, we will learn more about how natural genetic systems work; by attempting to create synthetic metabolisms, we learn about how natural metabolisms work; by attempting to create synthetic regulatory circuits, we learn about how natural regulatory circuits work.

Will we ever understand what life is? Just as with Schrödinger's book, Regis' text will not be the last word. It is, however, a good place for a lay reader to start, one who welcomes the ambition of its title. ■

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Bottling the nuclear demon

Why Nuclear Disarmament Matters
by Hans Blix
MIT Press: 2008. 97 pp. $14.95, £9.95

On Nuclear Terrorism
by Michael Levi
Harvard University Press: 2007. 210 pp. $24.95, £16.95

Martin van Creveld

Right or wrong, nuclear proliferation is much in the news. These two works tackle the problem head on. The first is a somewhat emotional call to prevent proliferation from proceeding further and, if possible, to reverse it. The second deals with some of the problems to which it may give rise.

To the readers of *Nature*, as well as anybody who is familiar with the origins of the second Iraq War, Hans Blix needs no introduction. In 2002–04, the elderly, genial Swedish diplomat, former foreign minister and former head of the International Atomic Energy Agency, found himself at the head of the UN Monitoring, Verification and Inspection Commission (UNMOVIC), charged with finding weapons of mass destruction in Iraq. Announcing that he had failed to discover any and that they almost certainly did not exist, he had to confront the full wrath of the Bush administration — a story that throws an ugly light on that administration while showing Blix himself in a very positive one.

A reader looking at the title of Blix's new work might be forgiven for thinking that he provides a retrospective account of several decades-worth of effort to put the nuclear demon back into the bottle from which it had escaped. He does nothing of the kind. First, contrary to his promise, he does not focus on nuclear weapons alone but widens the discussion — and, to my mind, weakens his case — by including chemical and biological ones too. Second, part of the book has little to do with nuclear disarmament but constitutes a polemic against the Bush administration's attempt to develop a national strategy based on pre-emption. Given how slim the volume is — in reality, it is just a brochure — this leaves little room for a serious discussion of nuclear disarmament, why it matters and what steps towards its realization should be taken next.

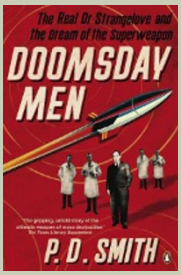
Furthermore, Blix is what the Germans call a *Gutmensch* — a do-gooder. From his perch in lucky Sweden, he observes the world with a benign smile and gently seeks to teach other benighted people how to improve it. One may certainly respect this position. On the other hand, it is neither the only one possible nor necessarily the one best suited for dealing with future nuclear-armed Adolf Hitlers, Joseph Stalins, and, yes, Saddam Husseins as well.

To put it bluntly, Blix is no strategist. As he himself comes very close to saying at the beginning of this book, he thinks in terms of morality and well-being, not of power. Not once does he mention deterrence. In other words, the fact that, had it not been for nuclear-weapons proliferation, World War Three might very well have broken out long ago and perhaps obliterated both his native country and himself.

A much younger man than Blix, Michael Levi is almost unknown. The cover of his book merely says that he is "Fellow for Science and Technology at the Council on Foreign Relations, New York". From an Internet search, we learn that he is an academic who has worked here and there and published this and that. Yet anyone who reads his work cannot but be impressed by his deep understanding of nuclear terrorism and the possibilities of dealing with it.

Levi's work is written in a calm, unemotional and somewhat dry manner. Those looking for hair-raising accounts of how

Doomsday Men: The Real Dr Strangelove and the Dream of the Superweapon
by P. D. Smith (Allen Lane, £8.99)
In the 1950s, humans became capable of destroying life. Smith describes the first weapons of mass destruction and how the doomsday bomb became a symbol of science's destructive power. "The book is as much a history of modern science as of modern weaponry", wrote Gregg Herken (*Nature* **448,** 868; 2007).



The Soulful Science: What Economists Really Do and Why It Matters
by Diane Coyle (Princeton Univ. Press, $19.95)
Economics is not a dry science but a human one, says Coyle. By incorporating psychology, evolution and complexity, economists are in the best position to model human society. Frances Cairncross wrote: "To understand how the big ideas of the past half-century fit together ... read this book" (*Nature* **447,** 1057; 2007).

bad terrorists almost succeeded in blowing up the world but were prevented from doing so at the last moment by good policemen and other intelligence personnel will be disappointed. Indeed it is one of Levi's strong points that, from beginning to end, he does not engage in any kind of mystery-solving or moralizing. What he does provide is a step-by-step account of the many possibilities of using nuclear bombs and materials for terrorist ends and of at least some of the things that can be done to prevent those possibilities from being realized.

To cut a long story short, Levi sees many serious obstacles standing in the way of would-be nuclear terrorists. They start with the near impossibility of producing (as distinct from purchasing or stealing) high-grade uranium and plutonium; they end with the fact that any nuclear weapon a terrorist may build will almost certainly be crude, very heavy (and thus difficult to conceal and to move) and, quite possibly, unreliable as well. Other possibilities such as a 'dirty' bomb also exist, but compared with a full-scale bomb they are relatively harmless.

That is the good news. The bad news, Levi tells us, is that nuclear terrorism is not impossible in principle. Nor will any set of precautions, however well considered, provide 100% security against it.

Levi's argument may be boiled down to five propositions. First, policy-makers should make "the strongest possible efforts to improve controls over nuclear weapons and materials and prevent their further spread". Second, strategic assessments of the threat should avoid the mistake of concentrating solely on the worst possible scenario. Instead, they should also consider the most likely ones and, to encourage thought and cooperation, as far as possible those assessments should be made public. Third, if nuclear terrorism is to be prevented, it is necessary to set up a global system. The more governments cooperate and the more numerous and varied the obstacles they confront terrorists with, the greater the chances of success. Fourth, even imperfect countermeasures are better than none, because they may well sound the alarm.

Fifth and perhaps most controversial, it is important that thought be devoted, and steps taken to reduce damage from nuclear terrorist acts after they have taken place — given that, in Levi's view, some such steps should be able to dramatically reduce casualties.

Levi's measured text does not rely heavily on mathematics, and he has hidden the few equations he uses in the appendix. Still, here and there the book, with its flat tone and relatively few verbs, is not altogether easy to understand. Moreover, as he notes, there are certain things that might be useful to terrorists and that, accordingly, he cannot say. These are minor shortcomings if, indeed, they are shortcomings at all. Although the volume will not enjoy a wide readership, for anyone with a serious interest in the possibilities of nuclear terrorism and how to prevent it, *On Nuclear Terrorism* is a must.

Both authors assume that nuclear proliferation is bad. In Blix's case, this is because it just is so; in Levi's, because it increases the chances of nuclear terrorism. Neither gives a thought to the possibility that proliferation and the balance of terror have actually been excellent things — perhaps the best that ever happened to mankind. The difference between them is that, given Levi's theme, his ignoring this entire question is apt. In the case of Blix, it is certainly not. ■

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How music speaks to us

Music, Language, and the Brain
By Aniruddh D. Patel
Oxford University Press: 2008. 528 pp. $59.95

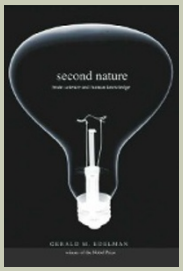
David Poeppel and Elika Bergelson

This book is an intellectual tour de force, raising many more issues than recent popular works by, for example, Oliver Sacks and Daniel Levitin. Not one for the bus, beach or bathtub, *Music, Language, and the Brain* requires focused engagement, but its rewards are rich. Aniruddh Patel offers a thorough analysis of music cognition and its relation to language, and outlines an ambitious and innovative research programme that deepens our understanding of cognition in general.

Music and speech share basic sound elements, and Patel starts by highlighting the similarities and differences between how auditory signals work. The book then delves into five topics: rhythm, melody, syntax, meaning and evolution. Each topic is examined within the context of music and language, to see how key cognitive processes overlap or diverge. By evaluating the latest empirical evidence, the author proposes further studies to test or extend previous results — experimentation, he says, is crucial in moving this field forward. Clearly, Patel has particular theories that he favours, but he describes fairly the ideas of others. The book is admirably clear in stating what has been done, and what needs to be done.

The belief that there are fundamental similarities in the processing of music and language is largely intuitive and worth testing. Both have been argued to be unique to humans. The book

Second Nature: Brain Science and Human Knowledge
by Gerald M. Edelman (Yale Univ. Press, $13, £8.99)
Nobel prizewinner Gerald Edelman offers a new theory of knowledge based on brain science. He shows how advances in neuroscience and physiology have led to a greater understanding of the brain, consciousness and creativity.



Skin: A Natural History
by Nina G. Jablonski (Univ. California Press, £9.95)
Nina Jablonski explores skin's many purposes, such as its role in touch and emotional display, and explains them as the result of billions of years of evolutionary compromise. "*Skin* is not just about biology, but also the way we live," wrote John Galloway (*Nature* **445,** 367–368; 2007).

emphasizes the particulate nature of music and language — both assembled from discrete elements — and suggests that these two domains may share a set of brain structures. By contrast, studies of brain lesion data (from patients with deficits that follow specific brain damage) and brain imaging results are also consistent with a view that music and language processing are, at least in part, segregated.

Patel thinks that there are more general, perhaps computational, links between the two. For example, when discussing rhythm, he proposes that the processing of non-periodic signals is similar in both music and speech. In the section on syntax, he argues that the brain uses similar neural resources to integrate the hierarchical organization of music and language. When discussing evolutionary and developmental similarities, the notion of 'beat-based rhythm processing' emerges as a crucial feature that may underlie music and speech.

Patel's perspective is laudably cross-linguistic and multicultural, citing extensive work from non-Indo-European languages and non-Western-based musical systems. On the website accompanying the book (http://tinyurl.com/2z2cve), Patel provides stimulating sound and video examples that clarify the phenomena described in each chapter.

Music, Language, and the Brain is much more than a textbook by one of the field's most influential practitioners. Each chapter can serve as a stand-alone monograph, and can be read at many levels. There is enough clarity for the general reader to follow the lines of argument, while the specialized reader will discover Patel's sophisticated and well-researched positions. Ideal for students of music cognition and language, the book outlines numerous experiments and hypotheses — many unusual — that draw together psychology and neurobiology.

If one can criticize anything, it is that Patel's discussion of the neurobiological foundations of auditory cognition is less nuanced and inspirational than his treatment of behavioural research. That said, we know little about the neuronal bases of complex psychological phenomena. Our understanding of auditory cognition is still mostly informed by behaviourally based psychological research, and in that domain, Patel's discussion is second to none.

In this definitive analysis of music cognition and its relationship to language, Patel gives us a work of exceptional scholarship and clarity. Much needed, it elevates the discussion to a level that these exciting areas merit. ■

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Catching a ride on sunshine

Solar Sails: A Novel Approach to Interplanetary Travel
by Giovanni Vulpetti, Les Johnson and Gregory L. Matloff
Springer: 2008. 250 pp. £16.50

Stuart Clark

Conceptually simple and romantic, solar sailing is an enchanting technological solution for space exploration. When a large reflective sail is unfurled in space, photons of sunlight collide with the sail fabric, imparting pressure and causing the sail to move. Such photons are not the electrically charged particles that constantly flow from the Sun to create the solar winds, they are the actual sunlight itself. The angle of the sail to the Sun and its direction of travel determine whether a propelled craft speeds up or slows down, just as a yacht changes course on the sea.

Solar Sails: A Novel Approach to Interplanetary Travel is the latest book to explore this topic, one that has been tackled only a handful of times in the past 20 years. Aimed at undergraduates, the book convincingly captures the history of ideas about solar sails, their current state of play and their future promise.

Moving according to the constant interplay of gravity and the pressure of sunlight, spacecraft pushed by solar sails are highly manoeuvrable. They can skate along unusual interplanetary trajectories that traditional point-and-shoot rocket-propelled craft would find difficult, if not impossible, to navigate. In the flexibility stakes, the only current competition is from the newly tested but expensive ion-drive engine that powers the SMART-1 Moon mapper built by the European Space Agency (ESA) and NASA's Deep Space One asteroid probe. These propulsion modules run by expelling charged particles, or ions, and can operate using less fuel than standard chemical engines; however, they are technologically trickier and thus expensive to build.

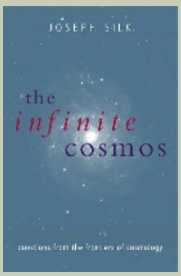
The idea that sunlight exerts pressure has been around for more than a century, since physicist James Clerk Maxwell proposed it in the 1860s. In the 1970s, metre-long solar sail fins — rather like the fins on a 1950s American car — were attached to the Mariner 10 Mercury space probe to adjust its alignment. Today, some satellites are steered with small sail vanes, a technology patented by the aerospace company EADS Astrium. The extra force of sunlight is a hindrance when fine control of movement is required, as with the next generation of formation-flying spacecraft in ESA's proposed Darwin interferometry mission to search for life on extrasolar planets. Such vessels must instead be designed to minimize displacements or, at least, to all suffer the forces equally.

Despite the opportunities, solar sails have yet to be used for propulsion in space. The pressure of sunlight is so slight that a vast sail area would be needed to carry a worthwhile payload of instruments through space. Deploying such a sheet presents an equally vast challenge, and has remained the solar sailor's Achilles' heel.

With useful sails being many tens to hundreds of metres long, these mighty structures must be packed into the equivalent of a suitcase for launching and then faultlessly unfurled once in space. If the sail snags, tears or fails to deploy, the mission is over. This risk deters many potential users; according to one project scientist at the ESA: "Why jeopardize your science by relying on an untested technology?"

Scientists and space agencies have, until recently, been resistant to solar sailing. This negative attitude was reinforced by the failure of the Planetary Society's Cosmos-1 sail, launched atop a converted Russian intercontinental ballistic missile on 21 June 2005 from a submarine in the Barents Sea north of Russia. The upper-stage rocket motor failed,

The Infinite Cosmos: Questions from the Frontiers of Cosmology
by Joseph Silk (Oxford Univ. Press, £9.99)
Summarizing the latest thinking on the Universe and its fate, Joseph Silk muses on the scientific discovery process and the history of ideas about the cosmos. "Black holes, galaxy formation, dark matter, time travel, string theory and the cosmic microwave background all get a mention" (Peter Coles, *Nature* **441,** 285; 2006).



King of Infinite Space: Donald Coxeter, the Man Who Saved Geometry
by Siobhan Roberts (Profile Books, £14.99)
Donald Coxeter helped to bring geometry back into the mainstream at a time when it was unpopular even with mathematicians. Siobhan Roberts' biography describes his personal and professional life and shows how his impact can be felt in architecture, cosmology, crystallography, immunology and more.

dooming the mission to failure before the sail mechanism could even be tested. Although the test was inconclusive, the perceived lack of success reflected badly on the solar-sail initiative itself.

Now the tide is beginning to turn. Ground-based tests in Europe and the United States have successfully deployed sails of about 20 square metres thanks to improvements in sail-opening mechanisms. The German Aerospace Centre has used plastic booms reinforced with carbon fibre, and NASA has used inflatable booms that harden when exposed to the coldness of space. Even more impressively, the Japanese space agency JAXA has carried out two successful sub-orbital deployment tests. Made of reflective films 7.5 micrometres thick and some 10 metres in diameter, the sails were flown to an altitude of 122 kilometres, where one opened up like a clover-leaf, the other like a fan. JAXA followed this up two years later in 2006, with a successful 20-metre-wide sail deployment from a balloon at an altitude of 35 kilometres.

Some space missions can be performed efficiently only with solar sails. Placing a satellite in a polar orbit around the Sun using a rocket requires a large expenditure of energy, and hence fuel. A craft propelled by a solar sail would take only five years to fly there from Earth but would require a huge sail area of 25,600 square metres (160 metres by 160 metres: larger than five American football pitches side by side) to provide the necessary thrust. Because sunlight holds the sail in space, it can be angled so it hovers like a kite over the poles of a planet, making solar-sail craft ideal anchors for communications and remote-sensing satellites.

Of course, there are limitations. Solar sails lose their power and manoeuvrability when they are far from the Sun, out beyond Jupiter. They are also unable to assume low orbits around planets with atmospheres because the sails are susceptible to drag.

Suitable for aerospace students and keen enthusiasts alike, this book may one day inspire some of them to build a solar-sail-powered vessel. Although there is still a long way to go, this useful volume will help speed up that day. ■

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Imaging the unseen

Six Stories from the End of Representation: Images in Painting, Photography, Astronomy, Microscopy, Particle Physics, and Quantum Mechanics, 1980–2000
by James Elkins
Stanford University Press: 2008.
320 pp. $65

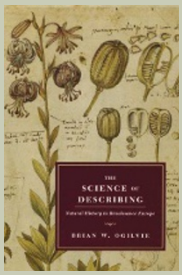
Felice Frankel

In *Six Stories from the End of Representation*, James Elkins makes a brave and laudable attempt to address in parallel the communication of ideas in both the sciences and the humanities.

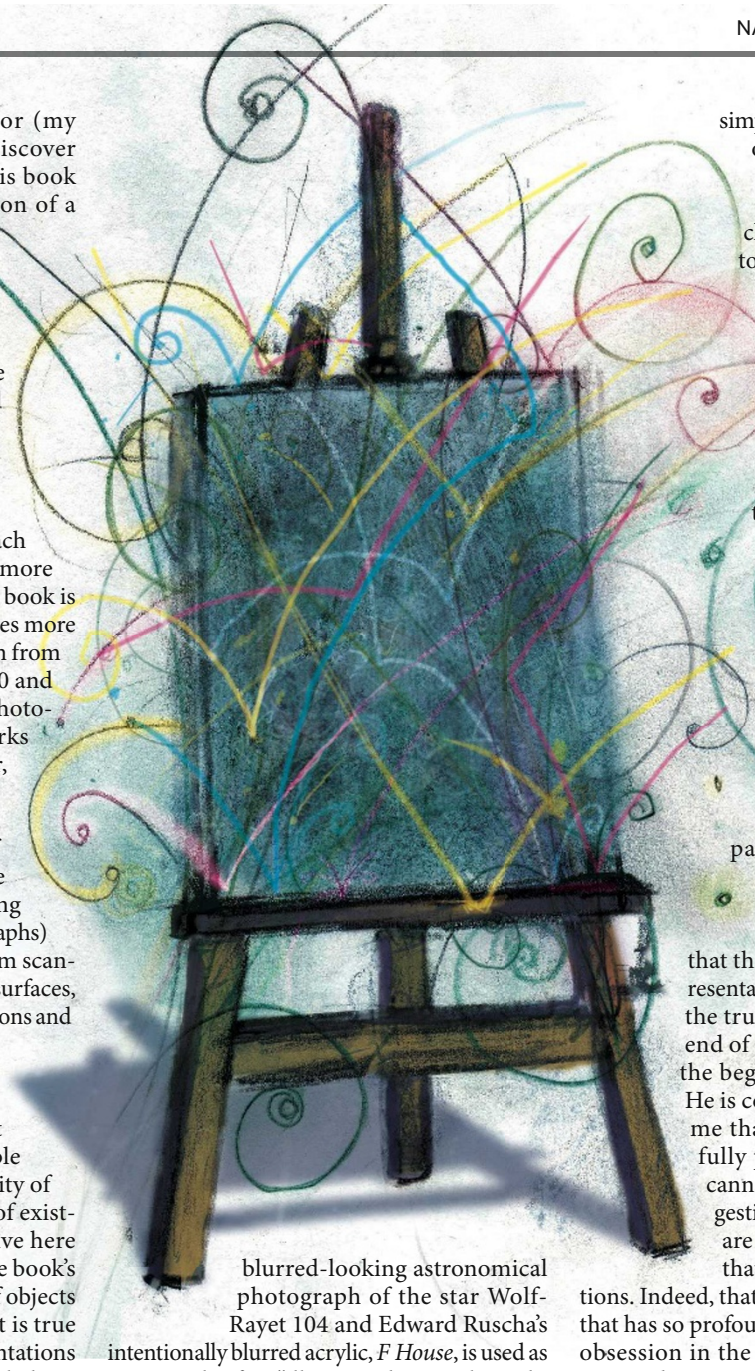
"I believe that the clearest, most fruitful response to the abyss between the humanities and the sciences is to set out the disciplines, in detail, side by side, and let them tell their stories in their own languages. As far as I can see, that is the only way to produce a book that can be read by scientists and humanists without the creeping feeling that their disciplines are better explained — or explained away — by someone who does not really understand them," he writes.

Elkins' approach struck me as exciting. A respected and prolific scholar, he promised a view of scientific images distinct from that taken by other art historians. I was eager to see the images to which he was going to introduce us, and how they were to "tell their own stories". After all, Elkins declared that "the images came first" in preparing the book, and that the images "are among the best that have been made in the last several decades".

Science of Describing: Natural History in Renaissance Europe
by Brian W. Ogilvie (Univ. Chicago Press, $27, £14)
In the mid-sixteenth century, naturalists developed tools for observing and describing nature, enabling them to assess and share their findings with others. Interpreting this change over four generations, Brian Ogilvie "has written the story of how science constantly reinvents itself, seen through the lens of the pre-linnaeans", wrote Sandra Knapp (*Nature* **442,** 871; 2006).



Digital Art (Revised Edition)
by Christiane Paul (Thames & Hudson, £8.95)
The digital format offers new possibilities for artistic expression. In an updated volume, Christiane Paul addresses how viewers interact with such works, and explores links with artificial life and intelligence, activism and networks, as well as the collection, presentation and preservation of digital art.



So I can imagine Elkins's horror (my response, were I in his shoes) to discover the publisher's plan to illustrate this book of images by means of the insertion of a small collection of colour plates smack in the middle of the edition, forcing the reader to hunt through the text for reference to them, with the remaining majority of the images placed within the narrative but reproduced in grainy black and white on cheap paper. Surely publishing a book about seeing images warrants allowing the reader to see the images?

Beyond the layout, Elkins's approach offers a new way of making us look more closely at how we depict objects. The book is spread across six chapters, and includes more than 100 visual representations drawn from art and science created between 1980 and 2000. The art collection includes photography, sculpture and painting: works by Agnes Martin, Gerhard Richter, Sol LeWit and Jasper Johns, among others. The science collection is also broad, ranging from representations of the very small (particle physics) to the very large (astronomy), and including TEMs (transmission electron micrographs) of influenza virus, STMs (images from scanning tunnelling microscopes) of gold surfaces, Feynman diagrams of particle interactions and Hubble Space Telescope images of the galaxies.

Elkins informs us that these images are "objects that literally don't exist ... abstractions of abstractions, feeble symbols of objects that have no reality of their own". Leaving the philosophy of existence to other experts, I will not delve here into an argument of how many of the book's science images are representations of objects that do have a reality of their own. It is true that all images in science are representations of data of some sort, but I'd like to think those data derive from evidence of existence, even if transitory.

In telling his *Six Stories from the End of Representation*, Elkins stops short of making explicit links between images. He uses what he calls a "non-causal narrative", where "it is the reader's task to decide what threads might tie the images together and just how tightly they should be pulled". His juxtaposition of the blurred-looking astronomical photograph of the star Wolf-Rayet 104 and Edward Ruscha's intentionally blurred acrylic, *F House*, is used as an example of an "illusory coherence brought on by certain habits of seeing" — blurring, I suppose in this case.

For Elkins, "it became clear that the images were the results of investigation into the limits of representation. Few of them contained sharp or well-defined objects, and in most it was difficult to understand what was being taken as adequate representation. They seemed to have a common theme: they were images that did not simply depict objects, but demonstrated how some objects resist depiction."

There is much I might challenge in Elkins's attempt to get the two cultures to talk to each other — first and foremost is his selection of "the most important" images. His choices are, after all, personal, and the book seems to be more a journal collection of his favourite things rather than a thesis. To my mind they are a haphazard collection. Perhaps this reviewer has seen too many cloud-chamber images of sub-atomic particle traces; although we must always remember that those stunningly intriguing patterns — chosen for the cover of the book — are not the particle itself.

The title's suggestion that this period is the end of representation cannot be further from the truth. At least in science, the end of the twentieth century was the beginning of representation. He is correct in saying: "It strikes me that those makers are most fully preoccupied by whatever cannot be put in a picture," suggesting the representations they are creating are so inadequate that they lead to further questions. Indeed, that is precisely the frustration that has so profoundly informed our present obsession in the laboratory with new and extraordinary visual expressions of science. We are living in an exciting time, in which we continue to ask how we might represent the unrepresentable. ■

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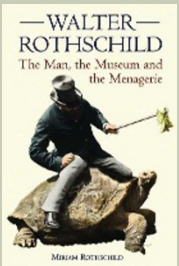
Walter Rothschild: The Man, the Museum and the Menagerie
by Miriam Rothschild (Natural History Museum, £9.99)
Walter Rothschild, one of Britain's most famous zoologists and eccentrics, amassed a huge collection of animals. His life, work and family are honestly and affectionately documented by his niece, the late Miriam Rothschild.



Evolution for Everyone: How Darwin's Theory Can Change the Way We Think About Our Lives
by David Sloan Wilson (Delta, $15)
Covering subjects from dung-beetle infanticide to human religion, this book emphasizes the role of group selection in evolution in modern human life. "It is a delicate and subtle debate and Sloan Wilson's popular accounts ... make for enjoyable and thoughtful reading," wrote Mark Pagel (*Nature* **447,** 533; 2007).