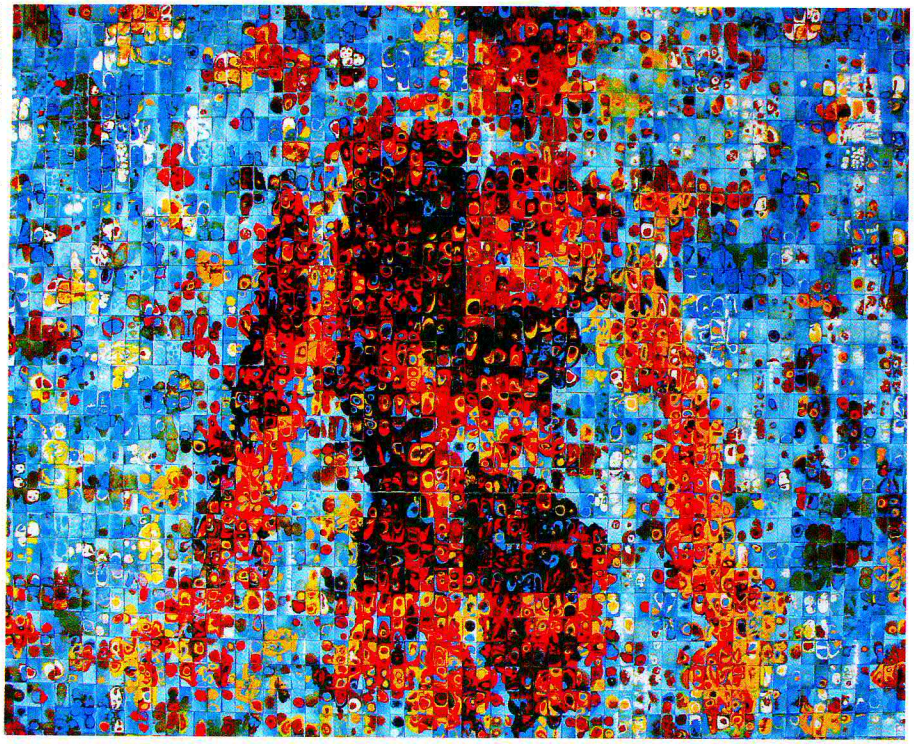
SPRING BOOKS



COURTESY OF THE ARTISTS AND JAYJAY, SACRAMENTO, CALIFORNIA

Size Matters: Figure 2 **(2007) by Ian Harvey and Koo Kyung Sook.**

EXHIBITION

Size Matters

San Jose Institute of Contemporary Art, California.
Until 18 June 2011.
www.sjica.org

This Spring Books special issue displays a selection of works from *Size Matters*, an exhibition featuring ten North American artists who address ideas of size and scale. The works view the world from unusual perspectives, from Ian Harvey and Koo Kyung Sook's wall-sized enamel and shellac mosaics of human figures to the miniscule sculptures of Dalton Ghetti, carved from the graphite points of pencils. Expressed in a range of media, including photographs, paintings and video, the works comment on biological building blocks, knowledge, emotions and the environment.

BIOLOGY

A revolution in evolution

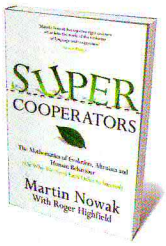
Manfred Milinski enjoys Martin Nowak's paean to the power of cooperation to shape animal and human societies.

Leading evolutionary theorist Martin Nowak sees cooperation as the master architect of evolution. He believes that next to mutation and selection, cooperation is the driving force at every level, from the primordial soup to cells, organisms, societies and even galaxies. Without cooperation, he says, our predecessors would still be RNA molecules. He sets out his groundbreaking ideas in *SuperCooperators*.

Co-authored with science journalist and editor of *New Scientist* Roger Highfield, *SuperCooperators* is part autobiography, part textbook, and reads like a best-selling novel. Nowak celebrates his oeuvre on the evolution of cooperation and challenges the mathematical basis for theories of kin selection and punishment. He is correct that this part of evolutionary theory needs revisiting, but it is too soon to tell whether his bold ideas will hold up to empirical testing.

Game theory is central to Nowak's work and the book highlights five ways to work together for mutual benefit: direct reciprocity, indirect reciprocity, spatial games, group or multilevel selection and kin selection. Direct reciprocity is the tit-for-tat exchange of resources, which may be generous but is open to exploitation. Nowak believes that indirect reciprocity, where I help you and someone else helps me, is the most important mechanism driving human sociality. It enforces the power of reputation, gained by helping or refusing help, which is spread through gossip, thus selecting in evolutionary terms for sophisticated language. "Indirect reciprocity is the midwife of language and of our big, powerful brain," he says.

NATURE.COM
For another book review on cooperation, see:
go.nature.com/82iaph



SuperCooperators: Altruism, Evolution, and Why We Need Each Other to Succeed
MARTIN A. NOWAK WITH ROGER HIGHFIELD
Free Press: 2011.
352 pp. $27

Cooperators can prevail through exchanges that are played out across and between networks and clusters of individuals, he explains. Multilevel or group selection follows among

communities that are small, numerous and isolated; mediated for example by tribal wars for resources. However, the migration of individuals between groups can undermine cooperation — egoists might take over pure altruist groups. *SuperCooperators* notes that there is plenty of evidence for group selection at the cellular level, such as strains of the bacterium *Pseudomonas fluorescens* that collectively produce a mat of polymer that allows the group to float on liquid surfaces.

More contentious is Nowak's approach to kin selection, or nepotism, in which individuals cooperate to ensure the success of genetic relatives in preference to strangers. Nowak set out his objections to this theory last year in a controversial *Nature* paper, co-authored with Corina Tarnita and Edward O. Wilson (*Nature* **466,** 1057–1062; 2010). They question the theoretical basis of kin selection, or inclusive fitness theory: one of the cornerstones of the evolution of social behaviour.

Nowak and Highfield defend this view in *SuperCooperators*. After reviewing the history of evolutionary ideas about kin selection, including the lives of pioneering evolutionary theorists Bill Hamilton, George Price, John Maynard Smith and J. B. S. Haldane, Nowak criticizes key equations and calls them a recipe for disaster. He argues that the predictions of Hamilton's rule, which quantifies whether or not a gene for altruistic behaviour towards relatives will spread in a population, almost never hold. And he decries Price's fundamental equation, on which current inclusive fitness theory is based, as the mathematical equivalent of tautology.

In place of inclusive fitness theory, Nowak sketches a new model for the evolution of sociality, in which relatedness, he says, is a consequence rather than the cause of social behaviour. By assuming only one mutation — one that causes offspring to stay in the nest rather than leave — he claims to explain why progeny happen to be around to help their related mother. This model implies that offspring would help any unrelated elder in whose nest they were born, irrespective of a genetic link, and it does not explain why parents insist on caring for their own offspring rather than others. Here, in my view, relatedness is essential. Many experimental results support this, such as the sex ratios in colonies of different ant species.

In ant species in which the queen mates only once, for example, a preponderance of female reproductive offspring benefits the workers more than it does the queen: the non-reproductive workers support their mother to produce sisters, to which they are more closely related (75%) than is the queen (50%), thus more effectively perpetuating their genes than if they raised their own offspring. By contrast, in slave-maker ants, in which workers are stolen from other species and are therefore unrelated, the queen manipulates them to produce an equal sex ratio in her offspring for her own benefit. I anticipate that a better mathematical formulation of social evolution theory will be found that includes relatedness, is compatible with existing evidence and includes Hamilton's rule as a rule of thumb. Nowak himself states that "kin selection is a valid mechanism if properly formulated".

COURTESY OF THE ARTISTS AND JAYJAY, SACRAMENTO, CALIFORNIA

***Size Matters*: Detail from *Figure 2* (2007) by Ian Harvey and Koo Kyung Sook.**

In another assault on established views, Nowak strongly disputes the effectiveness of punishment as a method for promoting cooperation. Here he splits from his erstwhile colleague, game theorist Karl Sigmund, who accepts that the stick can be as useful as the carrot. Nowak, the theorist, describes how he performed experiments. In a version of the prisoner's dilemma game — in which two isolated players may choose to cooperate and both benefit, or one defects and receives a greater reward, being eventually punished by the other — he showed that those who do not punish gain most. No one has yet showed that punishers can gain from punishing, so it is not clear why punishing exists.

NOWAK BELIEVES THAT COOPERATION HOLDS FOR 'ANY AND EVERY GAME IN THE COSMOS'.

Nowak performed another experiment that, alas, failed to prove that reward rather than punishment promotes public cooperation. Clearly, the jury is still out on this question.

SuperCooperators is also Nowak's autobiography. After attending an all-boys school, he relates how he met his wife on his first female-dominated pharmacology course. And he recounts moments shared with his supporters: mountain climbing with chemist Peter Schuster; walking through the ancient forests of Austria's Rauriser Urwald with Karl Sigmund; playing soccer with theoretical ecologist Bob May; or dining on a Caribbean beachfront with Jeffrey Epstein, the Wall Street tycoon who funded Harvard University's Program for Evolutionary Dynamics, of which Nowak is director.

Nowak finishes with his concern for our planet, and of how Mahler's symphony *Das Lied von der Erde* (The Song of the Earth) carries a deep resonance for him. He worries about the climate game that everyone is now playing. "I believe that climate change will force us to enter a new chapter of cooperation," he writes, but his research does not provide a recipe.

A pleasure to read, *SuperCooperators* offers an explanation of the evolution of cooperation and shows where the experts disagree. Yet Nowak's faith in cooperation is so great that he believes his approach holds for "any and every game in the cosmos" — for all evolutionary processes on Earth, in our Galaxy and others, in "agglomerations of ancient stars that lurk in the faintest, farthest reaches." We will see. ■

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PHYSICS

Fundamental Feynman

An account of the physicist's work reminds **Leonard Mlodinow** of the gulf between theory and experiment.

In 1981, shortly after I arrived in the physics department at the California Institute of Technology in Pasadena, I heard a strong voice resonating down the corridor: "Hey Schwarz, how many dimensions are you in today?" The answer then was 10; it was once 26; it is now 11. Richard Feynman, who was teasing John Schwarz — one of the founders of string theory — didn't think much of any theory in which it wasn't four, for that is all we observe.

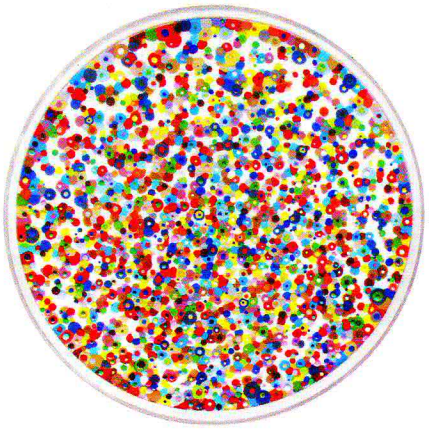
Quantum Man, by theoretical physicist Lawrence Krauss, focuses on the intimate connection that Feynman, like other physicists of his era, felt should exist between theories and experimental data. Writing to his third wife Gweneth from a gravitation and cosmology conference in Warsaw in 1962, he complained: "Because there are no experiments, this field is not an active one, so few of the best men are doing work in it. The result is that there are a host of dopes here (126) and it is not good for my blood pressure."

Today, gravitation and cosmology attract many of the best minds, who between them have produced so many unproven and competing theories of the multiverse that string theorist Brian Greene was able to write a long, popular account of them in *The Hidden Reality* (Allen Lane, 2011). Meanwhile, most scientists who study that cousin of cosmology, elementary particle theory, work in string theory despite its undetected dimensions and other apparent disconnects with reality, issues that current experiments cannot resolve.

By contrast, as Krauss recounts, when Feynman first presented his then-incomplete ideas on quantum electrodynamics (QED) describing the interaction between light and matter to the physics community in the late 1940s, he had "calculated almost every quantity one could calculate in QED" to ensure his results agreed with other methods and experiment as far as was known. Much of the book concerns the intellectual journey that culminated in that work — a reformulation of quantum theory itself. It is a welcome addition to the shelf of Feynman biographies.

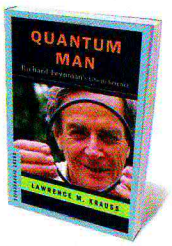
The story begins at Princeton University in New Jersey, with Feynman "in love" with the problem of the self-energy of the electron. Because like charges repel, each portion of a ball of negative charge exerts a repulsive force on every other portion. As a result, a ball of charge has a certain electric energy associated with it. The problem is, an electron is a point particle, but when you shrink the ball down to a single point, the repulsive energy becomes infinite.

Feynman thought that infinity had its roots in the way electromagnetic theory was formulated. This line of reasoning led him to recast the theory of electromagnetism in terms of an 'action principle', an exotic mathematical form that involves only the paths of charged particles over time, with no need to consider electric and magnetic fields. But the importance of what is now called Wheeler–Feynman electrodynamics (also named after US physicist John Wheeler) lies not in the theory itself, but in what it inspired Feynman to seek: a way to develop quantum mechanics around an action principle.



***Size Matters: Large Petri Test 3* (2011) by Klari Reis.**

COURTESY OF THE ARTIST



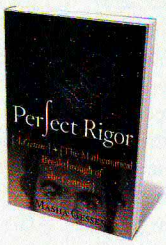
Quantum Man: Richard Feynman's Life in Science
LAWRENCE M. KRAUSS
W. W. Norton: 2011. 368 pp. $24.95, £19.99

Feynman proposed a revolutionary new understanding of quantum reality. Imagine a particle that moves through some point A. According to classical physics, as it continues on its way, the particle will follow a definite path. Now consider another point, B. If B is positioned properly, the particle will eventually arrive there, but if B is located off the path, the particle won't. According to Feynman, the key difference in quantum theory is that the particle does not follow the classical path, or any single path. Rather, it samples every path connecting A and B, collecting a number called a phase for each one. Each of these, in concert, determines the probability that the particle will be detected at B. This novel approach, called the path integral or sum over paths, yields predictions equivalent to those of traditional quantum mechanics. Yet, as Feynman wrote, even if different theories are equivalent, "they are not psychologically identical when trying to move from that base into the unknown", meaning that they lead to different mental pictures, which can suggest different new ideas.

The unknown arena that Feynman moved into was the issue of how to fit quantum mechanics and special relativity into a single theory (we still don't know how to do this for general relativity, although string theory is a candidate). That synthesis, when applied to the electromagnetic force, is QED. In those days, QED, like string theory today, was a hard theory to make sense of. Quantum-physics pioneer Wolfgang Pauli wrote: "The risk is very great that the entire affair loses touch with physics and degenerates into pure mathematics." But in this case, Krauss points out, there were plenty of experimental data to guide and inspire Feynman, and after years of work and thousands of pages of calculations, he built a consistent and infinity-free theory

NEW IN PAPERBACK

Highlights of this season's releases



Perfect Rigor: A Genius and the Mathematical Breakthrough of the Century
Masha Gessen (Icon Books, 2011; £14.99)
In 2002, reclusive mathematician Grigory Perelman solved the Poincaré conjecture, one of the world's greatest intellectual puzzles. Shunning all publicity, he refused to accept the prestigious Fields Medal for his achievement and vanished from the public gaze. Journalist Masha Gessen attempts to discover more about him by travelling to Russia to interview Perelman's colleagues and teachers and discussing his behaviour with psychologists.

of QED. The result was so powerful that, according to US-based physicist Freeman Dyson, Feynman could do a calculation that once took several months "in half an hour" on the blackboard.

When he won his Nobel prize in 1965, Feynman felt his methods were merely useful, not profound. Today, his approach is considered a more fundamental way to look at quantum theory than the formulations of its founders, such as Niels Bohr, Werner Heisenberg and Erwin Schrödinger. It is the basis of how physicists think about particles interacting, exchanging carriers of force, fluctuating in and out of existence. It is also, ironically, the basic tool of both string theory and quantum cosmology.

Krauss does a good job of imparting Feynman's fascination with all physical phenomena, and goes on to describe Feynman's later groundbreaking work in other fields — on the weak interactions, the theory of liquid helium and his parton model, which provided evidence for the existence of quarks. Intertwined with the physics are snippets of Feynman's personal life, including his habit of working on physics in a strip club, and his undying love for his first wife Arline Greenbaum, who died from tuberculosis in 1945, just a few years after they were married.

As Krauss acknowledges, the book contains little that is new. Jagdish Mehra's *The Beat of a Different Drum* (Clarendon Press, 1994) is a far more detailed account of Feynman's science, equations and all; and James Gleick's best-seller *Genius* (Little, Brown, 1992) covers Feynman's personal life in greater depth. Still, I found the account of Feynman's hard work, passion and discoveries inspirational, and, for a physicist at least, good bedtime reading. For those without a strong physics background, however, the prose can be tough going, especially the more technical passages. Personally, I love being talked to that way. ■

Leonard Mlodinow *is author of* The Grand Design *(co-authored with Stephen Hawking),* The Drunkard's Walk *and* Feynman's Rainbow.
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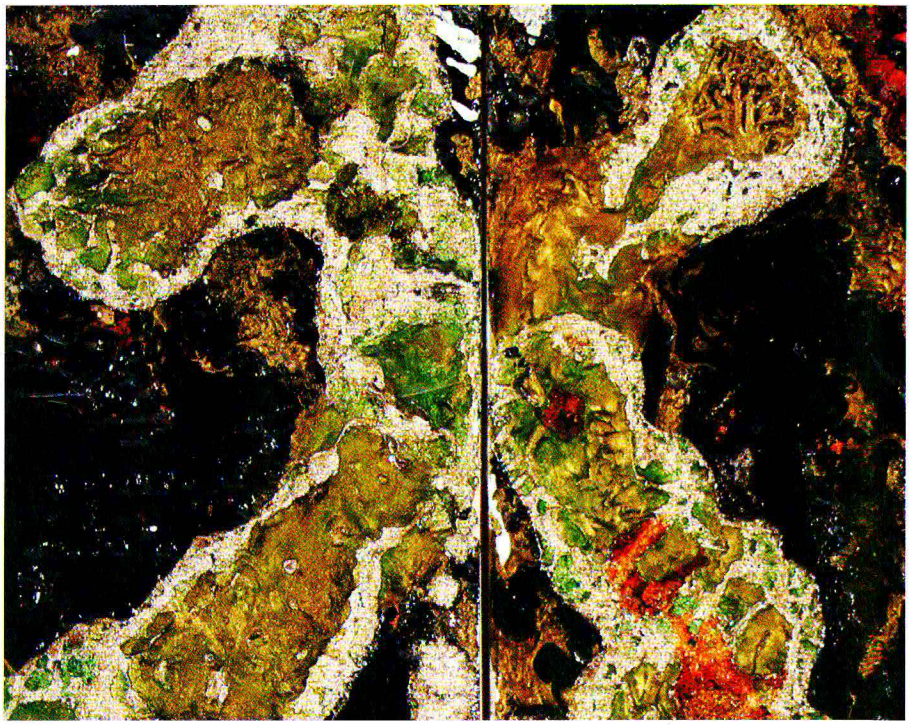


COURTESY OF THE ARTISTS AND JAYJAY, SACRAMENTO, CALIFORNIA

***Size Matters*: Detail from *Figure 6* (2008) by Ian Harvey and Koo Kyung Sook.**

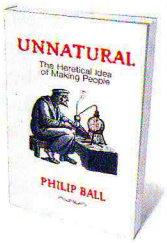
BIOTECHNOLOGY

Making people

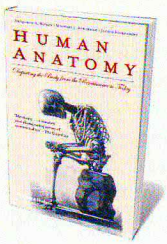
Today's wariness of reproductive technologies stems from myths, legends and Hollywood, finds **Chris Mason**.

Stem cells, cloning, regeneration and life extension are frequently in the news. When they are, the media often resort to sensationalist clichés — invoking Frankenstein to conjure up a stereotypical mad scientist 'playing God' by creating out-of-control monsters. Whereas the creation of non-human artificial life, such as Craig Venter's engineered microbes, gets a mixed press, the making of humans is invariably controversial. Clearly, human life has a special moral status.

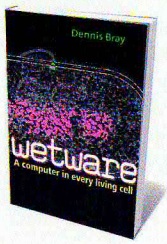
In *Unnatural*, science writer Philip Ball explores the history of our fascination with — and fear of — creating artificial people, from ancient folklore to today. Tracing a clear path from medieval alchemists' homunculi to routine assisted conception is a feat. Through his impeccable research, Ball successfully argues that the tenacious myths of the past that surround the making of people or 'anthropoeia' (his coinage) affect life-science research today.



Unnatural: The Heretical Idea of Making People
PHILIP BALL
Bodley Head: 2011. 384 pp. £20



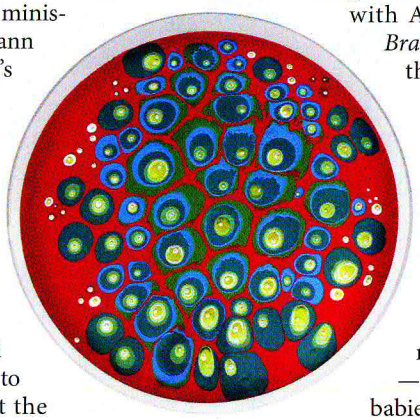
Human Anatomy: Depicting the Body from the Renaissance to Today
Benjamin A. Rifkin, Michael J. Ackerman and Judith Folkenberg (Thames & Hudson, 2011; £19.95)
This beautifully produced book presents more than 500 years of anatomical illustration. It charts how our knowledge about the body has changed along with our interpretation of what we see within it.



Wetware: A Computer in Every Living Cell
Dennis Bray (Yale Univ. Press, 2011; $18)
By treating a single-celled organism as a computational system, biologist Dennis Bray explains how it balances internal chemistry, responds to light and hunts prey — all without a nervous system. He sees cells as unique molecular circuits that perform logical operations.

Ball traces the concept that nature is good and *techne* is bad back to Aesop's and Ovid's Prometheus, maker of humanity from earth and water, and provider of technology to man. After Prometheus came recipes for making miniature humans called homunculi. Starting in the Middle Ages, initially as a cure for childlessness, the art of homunculi-making evolved into a debate over whether the miniscule men had a soul. Johann Wolfgang von Goethe's nineteenth-century poetic play *Faust* raises this spectre. Deploying the biological equivalent of alchemy, Faust's former assistant, Wagner, creates his homunculus: a tiny super-being with magical powers who is trapped in a glass vessel, doomed to remain captive without the capacity to become a proper man. In 1818, Mary Shelley published *Frankenstein*, appropriately subtitled 'The Modern Prometheus', in which her eponymous scientist unintentionally constructs a monster, by unexplained means, from human parts. There are also golems — the animated beings of Jewish folklore, made from clay and brought to life by religious magic for the purpose of imitating God's creation.

Ball distills out of all this a set of universal myths surrounding anthropoeia that are deeply ingrained in society, resulting in the widely held view that artificial people-making is unnatural and deeply wrong — heretical, as in the book's subtitle. His thesis is that humans fear that uncovering forbidden knowledge will result in either divine or other retribution. Prometheus, Faust and Frankenstein all pay a heavy price for their transgressions into anthropoeia. Even today, Ball points out, societal and cultural debate is pervaded by the belief that technology is intrinsically perverting and thus carries certain penalty. Views that human cloning will be used for social engineering, eradicating one gender or resurrecting undesirable figures from the past, for example, all reflect age-old fears about the consequences of meddling in the 'unnatural'. Ball warns that, as there is no global ban on human reproductive cloning, there is a strong chance that it will happen. It is thus likely to become a de facto reality without the well-informed debate it deserves.



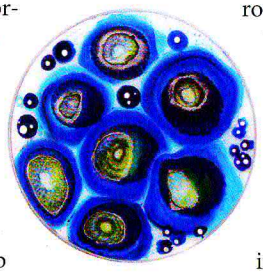
As scientific knowledge accumulates and makes some acts of anthropoeia more and more plausible, the challenge for the public will be to separate fact from fiction. For example, Ball ends his literary tour with Aldous Huxley's novel *Brave New World*. In 1931, the book's *in vitro* production of embryos in the Central London Hatchery and Conditioning Centre was pure conjecture by Huxley, based on the scientific forecasts of his day. Today, *in vitro* fertilization (IVF) is mainstream medicine — more than four million babies have been born using this technique. But the technology still has its critics, including within the Vatican. On the awarding of the 2010 Nobel Prize in Physiology or Medicine to IVF pioneer Robert Edwards, Ignacio Carrasco de Paula, head of the Pontifical Academy for Life, stated that the award was "completely out of order", as without IVF there would be no market for human eggs "and there would not be a large number of freezers filled with embryos in the world". For some, such words conjure up images of unscrupulous profiteering and factory-like storage of human lives, generating fears that human procreation will be reduced to mere money and industrial bioprocessing.

Huxley was more futuristic in including humans conceived and grown entirely outside the body. As Ball explains, the artificial womb remains fiction, albeit moving slowly towards fact. Its leading exponent, Hung-Ching Liu, at the Center for Reproductive Medicine and Infertility in New York, has grown human uterus lining (endometrium) and thinks it will eventually be possible for fetuses to be grown outside a woman's body. Progress has been made in other species, including mouse embryos gestated to almost full term in 'bubbles' of endometrial tissue and premature goats kept alive by artificial placentas.

Meanwhile, headlines about three-parent human embryos and mice with two fathers continue to fuel science fiction. Back in 1978, the film *Boys from Brazil* imagined Nazi physician Josef Mengele attempting to resurrect Adolf Hitler by reproductive cloning. Some 20 years later, in *The Matrix* (1999), countless humans are bred and kept in pods so that their body heat and electrical activity can be harvested as energy for the machines that have taken over the world. More recent films, such as *The Island* (2005) and *Splice* (2009), have further built on the science fiction of reproductive science.

The challenge for innovative biological research is that, until it translates into real benefits, it is often viewed with mistrust and worse-case scenario imagery. In reality, once products and services are released into society, they are adopted by a few enthusiasts and then, if successful, by the wider community. In the 1970s, for example, anxieties were rife about the unfounded threat that IVF posed to human welfare and dignity, let alone whether a test-tube baby could ever be wholly human. Yet the first IVF baby, Louise Brown, was just like everyone else, so IVF became socially acceptable. We cannot predict whether human cloning will proceed in the same manner, so the past is our only pointer.

For scientists, clinicians and biotechnology business people, understanding deep-rooted ideas, however irrational, is vital for successful dialogue with the public. The fiasco of genetically modified (GM) crops came about because of the failure to predict that the media would label GM products as 'Frankenfood' — together with the moral judgement it would infer. Today, stem cells and cloning are under the media spotlight. *Unnatural* is therefore a must-read for all stakeholders of these advanced technologies. ■



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LARGE PETRI TEST 2 (2011) BY KLARI REIS. COURTESY OF THE ARTIST

PETRI TEST 1 (2011) BY KLARI REIS. COURTESY OF THE ARTIST

ANATOMY

How to get ahead

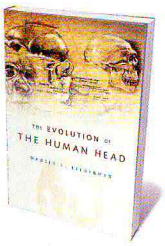
A thorough review of how the human head evolved shows how hominins outpaced apes, finds **Henry Gee**.

Almost everything we know of our world comes through one structure — the head. Our organs of sight, hearing, smell, taste and balance huddle in this crowded tenement, which comprises just 8% of our body's mass. Meanwhile, down in the basement, air flows in and out; food is swallowed and processed; and sounds emerge — from belches to Beethoven. All this activity is coordinated by the brain, the head's largest and most mysterious organ.

Given this foam of business, it is amazing that we get any peace. That we do is testament to the integration of the head — despite sharing such a small space, all its tenants get on famously. This integration, says Daniel Lieberman in *The Evolution of the Human Head*, his thorough review of the head's anatomy and development, is key to the powerful ability of the human head to evolve. A small amount of tinkering in one part can lead to a more comprehensive reorganization, as the various sections of the head mould themselves to new circumstances.

The head divides into three parts: the brain and the cranial vault that houses it; the cranial base on which the brain sits; and the face, hafted to the front of both. Each influences the others, explains Lieberman, a professor of human evolutionary biology at Harvard University in Cambridge, Massachusetts. Together the three parts determine the look of modern humans compared with other apes. A larger brain needs a more flexed cranial base to support it, thus shortening the face, which is retracted under the braincase. So our heads appear less extended than those of our closest animal relatives.

A shorter pharyngeal cavity relative to the neck gives us a system of tubes that produces more intelligible speech sounds than a longer one could. Our short, round tongue decouples the epiglottis from the soft palate, giving more access for odorants to nasal epithelia. A shorter face means a smaller jaw, all the better for chewing cooked foods, thus getting more energy per morsel, necessary for maintaining a large brain. This positive feedback loop contributes to the continuing success of *Homo sapiens*.



The Evolution of the Human Head
DANIEL E. LIEBERMAN
Belknap Press: 2011. 768 pp. $39.95

Lieberman does well to steer a course away from the blurry and disputed details of hominin lineages. Instead he focuses on the basics of how the head develops. He sets out the elegant certainties of biomechanics: how the strains of chewing influence bone deposition and resorption; how the mechanics of jaw shape interact with the cranium and the associated tendons and musculature to integrate the head's components; how the shape of the nose promotes turbulent airflow and thus efficient detection of odorants, and moderation of heat loss and water resorption; and how the dimensions of the ear canal attenuate some frequencies while amplifying others.

Lieberman's thoroughness especially enriches the final quarter of the book — a tour of human evolution in terms of the detailed changes wrought on head anatomy over the past few million years. Climate change was to blame: the drying, cooling climate forced forest apes to either retreat farther into the trees or adopt more marginal lifestyles.

NATURE.COM
For a review of Neil Shubin's *Your Inner Fish*:
go.nature.com/yb2sk8

A bipedal life, however, forced certain compromises. The lack of lengthy canines in early hominins might be less to do with sexual selection than the imposition of a shorter face (with less room for long teeth) on a head seeking balance atop an upright carriage. Some early hominins became better at subsistence on the marginal fare of roots and seeds, evolving immense teeth and powerful, crushing jaws. Others, the descendants of which became *Homo*, found that although nutritious fruits were scarce on the savannah, nutritious ungulates were common — but they needed to be caught.

The hunting imperative led to a suite of features suggesting that humans, uniquely among primates, became excellent long-distance runners. No chimpanzee, for example, could attempt a marathon across the Sahara Desert. Yet human athletes do this, and survive. Running imposes many constraints and demands on the head of a biped, connected with stabilization and protection from shock, which are seen in the anatomy of humans but not in apes. One such feature, the nuchal ligament that links the back of the skull to the neck, finds parallels in other chasers-of-prey such as dogs.

Most pursuit predators and scavengers work at dusk, dawn or at night. Even before the evolution of Englishmen, early humans found that the midday Sun offered a vacant niche. Because humans can maintain a pace that exceeds the walking speed of many quadrupeds, even in the heat of the day, the quarry is forced to stand its ground or run and risk collapsing from hyperthermia. Bushmen adopt such a hunting strategy to this day. Its use by early *Homo* could have promoted the many adaptations seen for long-distance running, as well as the thoroughgoing changes in the structure of the head and face that set humans apart from all other apes.

By rooting his study in the basics of tissue mechanics and functional morphology, Lieberman does the spadework to which all such studies aspire but few achieve — and makes that task seem elegant and effortless. ■

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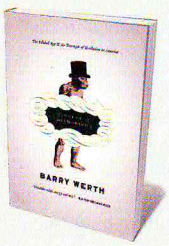
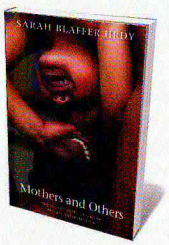


Banquet at Delmonico's: The Gilded Age and the Triumph of Evolution in America
Barry Werth (Univ. Chicago Press, 2011; $19)
Philosopher Herbert Spencer took Charles Darwin's ideas to the United States in 1882. Barry Werth focuses on the influential diners at a banquet held in Spencer's honour, describing how they used evolutionary ideas in an attempt to improve society.



Mothers and Others: The Evolutionary Origin of Mutual Understanding
Sarah Blaffer Hrdy (Belknap Press, 2011; $19.95)
In her provocative book, anthropologist Sarah Blaffer Hrdy argues that because human infants are too expensive to be raised by mothers alone, both parents must invest heavily in social skills to bargain with other group members for resources.

TECHNOLOGY

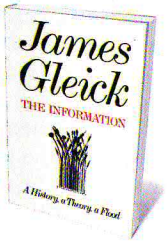
The medium is the message

Thomas J. Misa enjoys a history of communication tools, from talking drums to Twitter.

Information is the paradigm of our time. Economies that once manufactured goods now create value by processing information. Global flows of money, ideas and news determine which countries engage with global society and which are left silently on the sidelines. A skein of pervasive mobile computing keeps us connected — instantly, continuously, incessantly. James Gleick's latest book, *The Information*, examines the genesis of the information society and the roots and consequences of information theory.

Gleick is no stranger to demanding scientific topics. His blockbuster *Chaos* (Penguin, 1987) popularized Edward Lorenz's mathematics of complexity. He is also the biographer of physicists Richard Feynman and Isaac Newton. In *The Information*, he highlights the great surge of classifying and calculating often labelled as the industrial and scientific revolutions, and he profiles leading theorists, notably US mathematician Claude Shannon.

Gleick acknowledges that the concept of information and its impacts are difficult to grasp, yet explains our fascination with seeing information as the driver of just about everything.



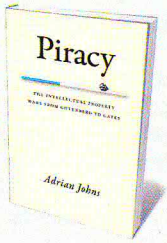
The Information: A History, A Theory, A Flood
JAMES GLEICK
Pantheon/Fourth Estate: 2011. 544 pp. $29.95/£25

Rather than telegraphs or telephones, Gleick begins with 'talking' African drums. Because African languages had hundreds of sounds, it seemed impossible to European observers that complex messages could be conveyed using drums that made only two sounds, pitched high and low. Yet for centuries, almost all African people could understand the messages that were broadcast by skilled drummers.

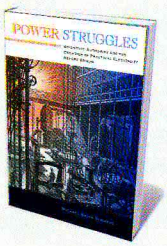
After decades of European puzzlement, John Carrington's 1949 book *The Talking Drums of Africa* revealed all. There was no telegraph-like Morse code within drumming. African languages relied only partly on unitary sounds or 'phonemes' and more fundamentally on their intonation. Simply altering their tones could transform the phonemes for 'he watched the riverbank' into 'he boiled his mother-in-law'. With drum tones expressing the rising and falling pitches of African speech, drummers could accurately convey a complex message. And anyone whose ear was attuned could understand it. Using this accessible analogy, Gleick deftly introduces the concepts of information channels, intentional redundancy of messages and the importance of error correction.

Gleick's more technical treatment of Shannon and information theory is a recurring thread of the crucial middle chapters. He serves up enlightening side views

COURTESY OF THE ARTIST; PHOTO: S. HOWARD



Piracy: The Intellectual Property Wars from Gutenberg to Gates
Adrian Johns (Univ. Chicago Press, 2011; $22.50)
Intellectual piracy, as historian Adrian Johns explains, is nothing new. From the invention of the printing press to modern file-sharing, Johns explores the wars that have arisen over intellectual property rights. (See Steven Shapin's review: *Nature* **466,** 563; 2010.)



Power Struggles: Scientific Authority and the Creation of Practical Electricity Before Edison
Michael Brian Schiffer (MIT Press, 2011; $19)
Behavioural archaeologist Michael Schiffer investigates electricity technologies before Thomas Edison's success. He shows why some made an impact while others failed, and the role of scientific authority in determining their fate.

***Size Matters*: *Alphabet* (2005) by Dalton Ghetti.**

to Babylonian mathematics, the *Oxford English Dictionary*, Charles Babbage's mechanical computers, telegraph codes, the 'completeness' of formal mathematics, wartime cryptography and especially the telephone system, which provided a focus for Shannon's work. He also gives apt summaries of Walter Ong, Marshall McLuhan and other commentators on the information age.

The narrative of Shannon's place in information theory is well known to historians. Shannon, a distant relative of Thomas Edison, grew up in rural northern Michigan, studied electrical engineering and mathematics at the University of Michigan, then went to the Massachusetts Institute of Technology (MIT) in Cambridge. Here, after operating Vannevar Bush's massive mechanical differential analyser and working at Bell Telephone Laboratories during the summer break, he started work on his master's thesis: 'A Symbolic Analysis of Relay and Switching Circuits'. It was accepted by MIT in 1937 and published a year later. Psychologist Howard Gardner called it "possibly the most important, and also the most famous, master's thesis of the century". Telephone switching systems at the time were composed of thousands of electromechanical relays; within two decades or so, they had evolved into electronic computers.

Shannon was the link between algebra and switches. He saw that the on–off states of telephone relays resembled the algebra originally conceived by George Boole in the 1850s, with its now-familiar notation of ones and zeroes and 'and', 'or' and 'not' operators, and that immense systems of telephone relays could be analysed through Boolean algebra. Shannon also showed that logical problems, such as adding two binary numbers together, could be modelled exactly using telephone relays — and, soon enough, vacuum tubes, transistors and semiconductor chips too. Having grounded modern computing in this way, Shannon created 'An Algebra for Theoretical Genetics', as his doctoral thesis was titled, in 1940.

A full-blown information theory arrived soon after. Following a year at the Institute for Advanced Study in Princeton, New Jersey, Shannon joined Bell Telephone Laboratories full-time in 1941 and worked on wartime cryptography and fire-control projects. Shrouded in secrecy, the wartime work introduced him to British computer scientist Alan Turing (they had tea together for two months but could not discuss their code work), and linked his thinking with mathematician Norbert Wiener's broadly similar theory of the role of randomness or 'entropy' in information. All communication, Shannon decided, resembled coded messages sent through a noisy channel: distortion and noise battled against redundancy and bandwidth. He defined these terms mathematically. Shannon gained international acclaim after publishing two famous technical articles in which he named the bit (short for 'binary digit', first coined in a Bell Labs memo by statistician John Tukey), and after writing a popular book with engineer and mathematician Warren Weaver, *The Mathematical Theory of Communication* (University of Illinois Press, 1949).

Having engagingly assembled information theory, Gleick might have examined its many ramifications in the mathematics of coding theory, data compression and error correction that underpins everything from mobile phones to DVDs. Instead, he treats information more metaphorically, covering the founding of cybernetics, the genetic code of DNA and the birth of quantum information science and the allure of quantum computing. His asides on the editing history of Wikipedia articles, although entertaining, begin to stretch the interpretive framework. A final substantive chapter surveys our predicament of information overload, the flood of the book's subtitle: too many genomes, sky surveys and climate models, let alone e-mails. He confronts social media such as Twitter, describing it as "banality shrink-wrapped, enforcing triviality by limiting all messages to 140 characters".

Gleick admirably raises the question of how information relates to meaning and semantics, which Shannon specifically ruled out of scope in his theory, yet Gleick mostly inclines towards instances of verbal and mathematical thinking. "The written word — the persistent word — was a prerequisite for conscious thought as we understand it," Gleick suggests. An anecdote from Feynman opens up this tidy world: "Thinking is nothing but talking to yourself," he once remarked. "Oh yeah?" countered a friend. "Do you know the crazy shape of the crankshaft in a car? Now tell me: how did you describe it when you were talking to yourself?" Thinking in this spatial way, Feynman set the stage for nanotechnology in his article in *Popular Science* in November 1960, titled 'There's Plenty of Room at the Bottom: How to Build an Automobile Smaller than this Dot.' Semantics and spatial thinking might be considered for a new, generative theory of information to enhance Shannon's. ■

CHAIN (1997) BY DALTON GHETTI. COURTESY OF THE ARTIST; PHOTO: S. HOWARD

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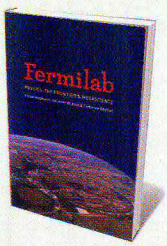
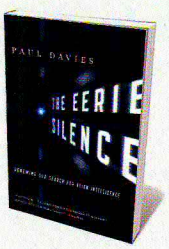
e-mail: tmisa@umn.edu



Fermilab: Physics, the Frontier, and Megascience
Lillian Hoddeson, Adrienne W. Kolb and Catherine Westfall (Univ. Chicago Press, 2011; $30)
For 40 years, the Fermi National Accelerator Laboratory in Illinois has stood at the frontier of high-energy physics. The book charts the rise of this institution, detailing the difficulties of balancing pioneering science with tightened budgets.



The Eerie Silence
Paul Davies (Mariner Books, 2011; $15.95)
Astrophysicist Paul Davies describes the 50-year Search for Extra-Terrestrial Intelligence project. He proposes other approaches, from scouring Earth for microscopic aliens to seeking intelligence on planets beyond the Solar System. (See Chris McKay's review: *Nature* **464,** 34; 2010.)

PSYCHOLOGY

Holding on to happiness

Sonja Lyubomirsky welcomes a call for society to encourage people to 'flourish'.

The premise of positive psychology — that it is as important to investigate wellness as it is to study misery — has reached the mainstream. Discussed routinely by politicians, educators and mental-health professionals, the field's influence has grown rapidly. Martin Seligman, director of the Positive Psychology Center at the University of Pennsylvania in Philadelphia, is the scholar, educator and charismatic leader who has championed these ideas passionately for more than a decade. In *Flourish*, his most personal and boldest book so far he argues that we should set aside "happiness" as a goal, and embrace a broader measure of well-being, which he calls "flourishing".

Seligman shares a wealth of insights and stories, mostly compelling and sometimes maddeningly digressing, which cast light on his passions and pet peeves. His wisdom and audacious opinions explain why he has attracted legions of both followers and high-profile critics, including writer and columnist Barbara Ehrenreich and *New Yorker* journalist Jane Mayer.

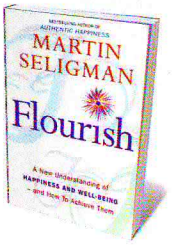
Two themes run through the book. The first is that the study of optimal human functioning must be grounded in rigorous science. The second is more controversial: positive-psychology researchers have a duty to make the world a better place. Seligman's book is a paean to applied science, a blueprint for how to translate empirical evidence from the laboratory to the real world.

Seligman describes several applied initiatives that he has conceived and shepherded. In education, he has created and implemented curricula to develop character strengths (such as kindness and leadership), build grit (passion and perseverance) and enhance positive emotions (happiness and gratitude) in schoolchildren and undergraduates. For example, children at risk of depression are guided to identify their top signature strength (such as loyalty) and use it in a new way at school each week. Seligman also teaches the theory and research behind positive psychology to individuals in a range of occupations — from life coaches and entrepreneurs to policy wonks and fitness instructors.

The most impressive effort Seligman discusses is the Comprehensive Soldier Fitness programme now being implemented across the US Army community. The programme, profiled in a special issue of *American Psychologist* this January, involves measuring "psychosocial fitness" and building resilience in several life domains: emotional, social, family and spiritual. For example, sergeants are trained to avoid thinking the worst when faced with adversities, and soldiers are taught to identify emotions in others. This is a rare opportunity to change the culture of a huge institution that is not known for prioritizing emotions, to prevent suffering (including suicide and post-traumatic stress) and bolster both flourishing and effectiveness in military roles.

Size Matters: Alces alces (moose email) **by Dana Harel, 2009.**

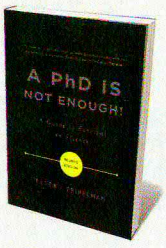
COURTESY OF THE ARTIST/FREY NORRIS GALLERY, SAN FRANCISCO



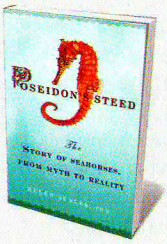
Flourish: A Visionary New Understanding of Happiness and Well-Being
MARTIN SELIGMAN
Free Press/Nicholas Brealey Publishing: 2011. 368 pp/408 pp. $26/£14.99

It is no accident that this book is titled *Flourish* yet Seligman's preceding best-seller was called *Authentic Happiness*. He professes that he now detests the word "happiness", for three reasons: it is overused and nearly meaningless; it is measured subjectively; and it connotes smiley-faced cheerfulness and hedonism. However, the alternative terms proffered by Seligman — flourishing, well-being, meaning, love and growth — are no more likely to elude these problems.

Setting out a new theory of well-being, Seligman posits that flourishing has four elements or pillars: positive emotion (happiness, satisfaction, engagement); meaning; positive relationships; and accomplishment (mastery). It is hard to argue with this intuitively appealing thesis. However, it has its weaknesses. First, Seligman's theory confuses the elements of well-being with the contributors and consequences of well-being. For instance, people who report that they are happy are more likely than their less-satisfied peers to have meaning, good relationships and accomplishment in their lives. These factors may be sources of happiness — having a good marriage makes one more happy, for example. Or they may be outcomes — happier people are likely to forge satisfying relationships.



A PhD is Not Enough! A Guide to Survival in Science
Peter J. Feibelman (Basic Books, 2011; $14.95)
Climbing the scientific career ladder is difficult, and the first steps from doctoral student to postdoc are the most precarious. Drawing on his experience as a physicist in academic and government labs, in his new edition Peter Feibelman offers career guidance to those entering the research job market.



Poseidon's Steed: The Story of Seahorses, from Myth to Reality
Helen Scales (Gotham Books, 2010; $15)
The weird world of the seahorse is explored by marine biologist Helen Scales. She describes its peculiar biology and the threats it faces, and reveals its importance to humans, from its role in Chinese medicine to ancient seahorse myths.

Second, although the four pillars are correlated, they do not necessarily amount to a single structure: they need not occur together and may originate and evolve differently over time. For example, a public servant who is passionate about his work may experience a great deal of positive emotion and meaning over the course of his career, but his relationships may suffer if he overworks. A selfless Mother-Theresa type may have meaning, accomplishment and fulfilling relationships, but experience little joy. These examples point to a third concern: it is not clear whether Seligman's conceptualization of well-being is shared among cultures.

Third, there is no empirical evidence that constructs such as meaning or love can be measured more objectively than happiness. If happiness is "all in one's head", as Seligman asserts, then so are some of the four pillars. Terms such as flourishing and well-being are useful shorthand, but calling the four pillars a theory is premature.

Seligman's ideas have a great deal of merit, but it is too soon to dispense with happiness. Research reveals that happy people are not self-centred, gratification-seeking hedonists whose lives are lacking in meaning or fulfilment. On the contrary, hundreds of studies have shown that happiness relates to outcomes such as creativity, productivity, effective coping, satisfying marriages, close friendships, higher earnings, longevity and strong immune systems.

Seligman's galvanizing goal for positive psychology is for 51% of the world's population to be flourishing by the year 2051. Unlike many authors, he offers detailed and tested solutions as well as compelling arguments for how societies can aim to raise the amount of positive emotion, meaning, good relationships and accomplishment in their citizens. Even if his four pillars don't quite make a theory, everyone stands to benefit from his initiatives. If they are happy, flourishing or enjoying well-being, people won't care about the labels that researchers attach to those good feelings. ■

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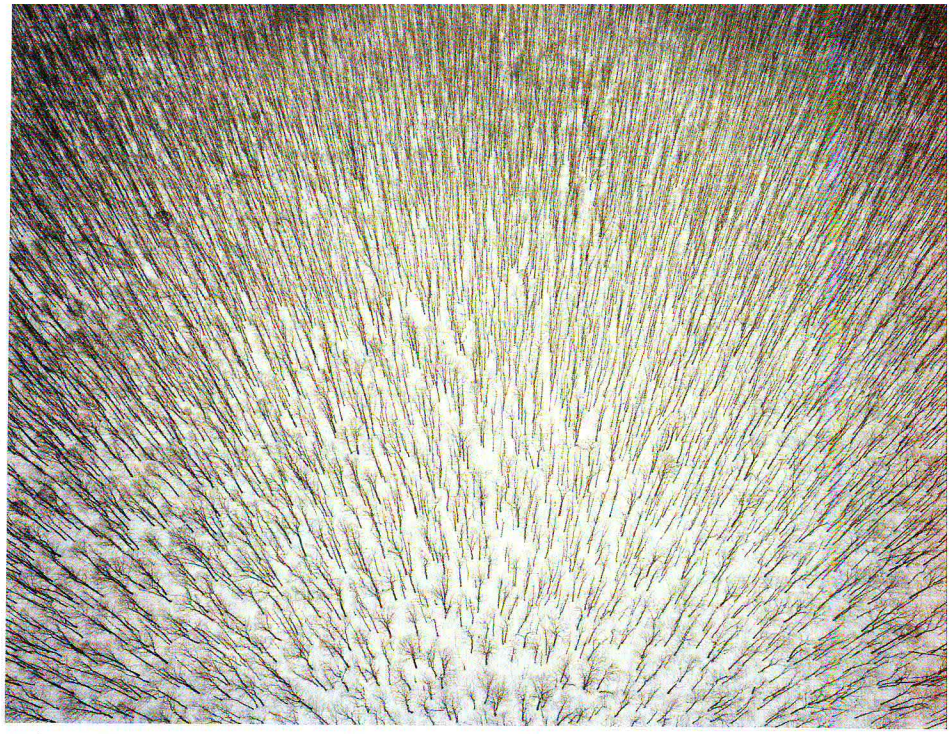


***Size Matters: Second Growth Forest* (2008) by Eamon MacMahon.**

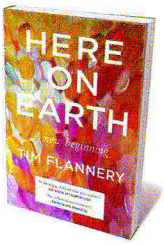
EARTH SYSTEMS

The biosphere rebooted

Michael J. Benton finds hope for the future in a study of humanity's cooperation with the environment.

Many recent books about the fate of life on Earth muse on fragility, tipping points and crises. But some writers see a more hopeful future for the planet. Without ignoring the monumental threats posed by humans, interdisciplinary studies may be offering reasons to be cheerful about the resilience of life in the face of change, and our chances of surviving this and the next century. Australian palaeontologist Tim Flannery's *Here on Earth* follows in this optimistic vein.

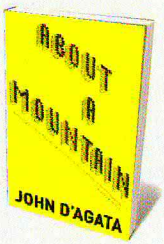
By tracing the great shifts in Earth's geochemical and biological systems through time, he argues that life generates evermore-sophisticated responses to varying planetary conditions. In particular, he notes, "from the most intense competition for survival, cooperation has emerged". Such natural transformations hold lessons for future challenges. He develops his theme through parallel accounts of the history of Earth and of life, harnessing an impressive mix of research in geology, chemistry, biology, palaeoanthropology and sociology.



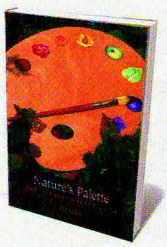
COURTESY OF THE ARTIST

Here on Earth: A New Beginning
TIM FLANNERY
Allen Lane/Atlantic Monthly Press: 2011. 336 pp/288 pp. £14.99/$25

Flannery moves deftly through some difficult science. Early in the book, he espouses British environmentalist and chemist James Lovelock's Gaia hypothesis that life stabilizes the planet and makes it habitable. He explains how chemical cycling during



About a Mountain
John D'Agata (W. W. Norton, 2011; $14.95)
Writer John D'Agata investigates the US government's plan to store nuclear waste beneath Yucca Mountain in Nevada. He documents the history of the project, its supporters and detractors, and muses on atomic-bomb tests and Las Vegas's diminishing water supply and high suicide rate.



Nature's Palette: The Science of Plant Color
David Lee (Univ. Chicago Press, 2010; $22.50)
The science of plant colour is explored by botanist David Lee, from the decorative use of plant dyes to the chemistry of plant leaf colour. "A compelling case that botany is full of intellectual challenges, many shamefully neglected," wrote Philip Ball in his review (*Nature* **449**, 982; 2007).

the Precambrian era — the first 4 billion years of Earth's existence, until 542 million years ago — led animals, including humans, to develop the ability to absorb and store poisonous elements such as mercury, cadmium and lead. He explores how the early evolution of life built the atmosphere; and how continental drift and mid-ocean hydrothermal vents known as black smokers maintain the salinity of the sea for marine life.

Flannery then switches to human evolution and migration through Australia, Asia, Europe and the Americas, focusing on human ancestors' impacts on the land. He shows, for example, how the slaughter of mammoths in the Siberian tundra effectively destroyed the productivity of this terrain. Tundra plants must be eaten for the carbon they contain to be recycled, otherwise they simply freeze and the nutrients are locked in. Mammoths were the greatest eaters of this modest plant cover, bulldozing the snow aside with their baroque tusks and redepositing the digested remnants as copious urine and droppings, which fertilized the land. With the demise of the mammoths, the tundra's productivity also declined.

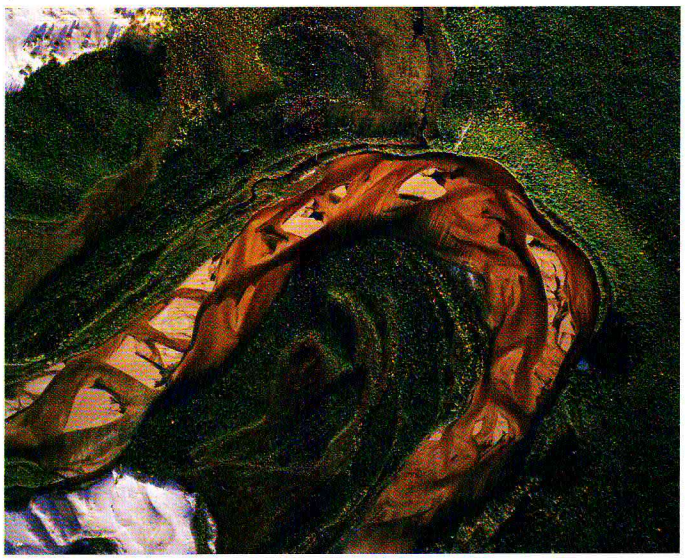
Yet human behaviour in prehistory, and in non-industrialized societies today, was not always environmentally destructive. Flannery relates how Australian Aboriginal people learned that nutrients were recycled when vegetation was burnt in small patches — in contrast to the vast interior deserts created by mechanized agriculture on the continent today. Through taboos over eating certain rare species, indigenous New Guineans effectively preserved local biodiversity.

Central to Flannery's optimism is cooperation, including that between humans and the environment. He looks to insect colonies — sometimes termed 'superorganisms' because they can act as one unit — in which individual members follow pheromone messages to fulfil tasks that meet group objectives. Comparing insect communities to human societies, Flannery shows how cooperation has increased the lifespan and benefits of modern humans compared with our ancestors, who — although they were able to tackle almost any task — had short and painful lives.

Flannery acknowledges our persistent efforts to destroy Earth and ourselves: nuclear proliferation, agricultural spraying with toxic weed killers and insecticides, persistent organic pollutants and industrial effluent of metals and carbon dioxide. The narrative in each case of big business, disease and death, research and eventual regulation has been told many times, but rarely as thoroughly and dispassionately. The biggest threat of all, Flannery contends, is overpopulation.

Yet he agrees with United Nations estimates that humans will self-regulate at about 9 billion individuals by 2050, thanks to rising standards of living and decreasing family size. Improving economies will also strengthen people's reasons to invest in their future. As individuals and corporations stop "discounting the future" by taking a reckless view of their own and their community's survival, they will adopt more sustainable lifestyles, in which conspicuous consumption is mocked rather than admired. In support, Flannery notes the rise in the number of democratic countries from 40 to 123 in the past 50 years, the beginning of international negotiations about sustainability and the rise of the Internet and mobile phones, which make secrecy hard to maintain.

THE SLAUGHTER OF MAMMOTHS IN THE SIBERIAN TUNDRA EFFECTIVELY DESTROYED THE PRODUCTIVITY OF THIS TERRAIN.



***Size Matters*: *William River* (2008) by Eamon MacMahon.**

COURTESY OF THE ARTIST

Despite the tendency for people to ignore the inevitable, and to become immune to doom-laden prophecies, Flannery believes that humanity will act before New York, Shanghai and London sink beneath the waves. A combination of effective recycling of carbon back into the soil, rewilding of vast areas and natural stabilization of human populations could present a long-term model for survival. It is a clear and rational proposal. However, many futurists would deny his optimism: reversing levels of current carbon usage, for example, would require an unimaginable change in cooperative behaviour worldwide.

Although some might quibble about his reliance on speculative concepts such as Gaia, Flannery's command of evolution, environmental chemistry, civilization and human motivations strengthens his case. His buoyant futurology is a hopeful counterpoint to the short-term denial and inertia of so many current decision-makers. ■

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