

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. ■

**Sonja Lyubomirsky** is professor of psychology at the University of California, Riverside, California 92521, USA, and author of *The How of Happiness*. e-mail: [sonja.lyubomirsky@ucr.edu](mailto:sonja.lyubomirsky@ucr.edu)



**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.

**M**any 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 ever-more-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



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

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.

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

COURTESY OF THE ARTIST



**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 re-depositing 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:

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. 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, rewinding 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. ■

**Michael J. Benton** is professor of vertebrate palaeontology at the University of Bristol, Bristol BS8 1RJ, UK.  
e-mail: [mike.benton@bristol.ac.uk](mailto:mike.benton@bristol.ac.uk)

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



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

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



### Living at Micro Scale: The Unexpected Physics of Being Small

David B. Dusenbery (Harvard Univ. Press, 2011; \$22.95)  
The size, shape and behaviour of tiny organisms are challenged and constrained by physics. Biologist David Dusenbery describes how factors that larger organisms can ignore — such as the viscosity of water or air — affect microorganisms.



### Diversity and Complexity

Scott E. Page (Princeton Univ. Press, 2010; \$19.95)  
Complex systems respond to diversity in sophisticated ways — some of which enhance system performance. Theorist Scott Page explains how diversity affects biological, ecological and social systems from tropical environments to the economy.