

gross domestic product as its main indicator of national success, and to promote new measures of social progress.

Three concepts are fundamental to the success of such policies. First, the creation of well-being requires more than the remediation of problems — this merely reduces ill-being. It requires that the whole population is shifted towards flourishing. Second, sustainable happiness results from what we do, not what we have; we need to be able to create our own well-being and contribute to that of others. Third, we cannot assume that translating the evidence into interventions will produce

a flourishing society; we must commit to rigorous evaluation to find out what works, for whom, for how long, for which outcomes and in what contexts.

Rigorous evaluation must include analysis of long-term economic benefits. Preliminary analysis of the economic benefits of shifting a population — such as children with behavioural problems — towards flourishing suggests that relatively low-cost interventions may produce substantial long-term savings by reducing the need for crisis management, imprisonment or the treatment of disorders. Developments in the measurement of well-being, such as the

"Happiness and social well-being are likely to bring economic prosperity."

National Accounts of Well-being initiated by the London-based New Economics Foundation, will have a central role.

We may have been wrong to believe that economic prosperity would bring happiness, but the evidence suggests that happiness and social well-being are likely to bring economic prosperity. Moreover, where prosperity arises from post-materialist values, it has the potential to enhance well-being without costing the earth. ■

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Signatures of life on other worlds

How to Find a Habitable Planet

by James Kasting

Princeton University Press: 2010. 360 pp. \$29.95, £20.95

In the 15 years since the discovery of the first planet around a star other than our Sun, we have found more than 400 such exoplanets — but there is still no place like home. In *How to Find a Habitable Planet*, James Kasting extends knowledge of the planets in our Solar System to searches for distant Earth-like exoplanets that could harbour life.

Kasting is a visionary best known for his computer models that established the concept of 'habitable zones' around stars — regions where planets could host conditions conducive to life, such as liquid water. His research is wide ranging, from modelling ancient runaway glaciations on a 'Snowball Earth' to examining a distant future in which our planet might, like Venus, forever lose its precious oceans. The likelihood of discovering Earth-like planets around other stars in the next few years motivates Kasting to hunt for chemical

signatures of life that might be detected in their atmospheres.

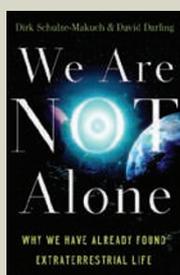
The search for extraterrestrial life is often equated with one project, the Search for Extra-Terrestrial Intelligence, or SETI. Its goal of detecting radio transmission from advanced technological civilizations is laudable — the cost is low and even a null result has an enormous pay-off in terms of understanding our place in the Universe. Whether the signal comes from potential predators, friends or the distant, unreachable echoes of other life forms, this is a story that humanity yearns to hear. However, it is a good bet that most life in the Universe will be simpler than us and mimic that on Earth, where single-celled organisms constitute the bulk of the biomass.

Discussing Earth's history, Kasting explains how prokaryotic cyanobacteria transformed the early anaerobic atmosphere on Earth into an oxygen-rich environment. These simple organisms paved the way for more complex species, but they also imprinted on our



atmosphere a chemical signature of a living world: oxygen. Observations of exoplanet atmospheres will cast a wide net in the search for varied forms of life.

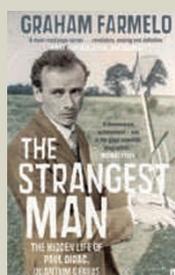
Another clue would be pooled water on



We Are Not Alone: Why We Have Already Found Extraterrestrial Life

by Dirk Schulze-Makuch and David Darling (Oneworld Publications, £12.99)

This provocative book asserts that extraterrestrial life exists — and that there is evidence to prove it. Describing how even the most hostile environments on Earth can support life, the authors look at how it might have evolved outside the Galaxy or on other planets and moons, including Mars, Venus, Europa and Titan.



The Strangest Man: The Hidden Life of Paul Dirac, Quantum Genius

by Graham Farmelo (Faber & Faber, £9.99)

This highly praised biography sheds light on the life of physicist Paul Dirac, who is little known by the public despite his high regard among scientists. "The effortless writing style shows that it is possible to describe profound ideas without compromising scientific integrity," wrote Frank Close (*Nature* 462, 988; 2009).

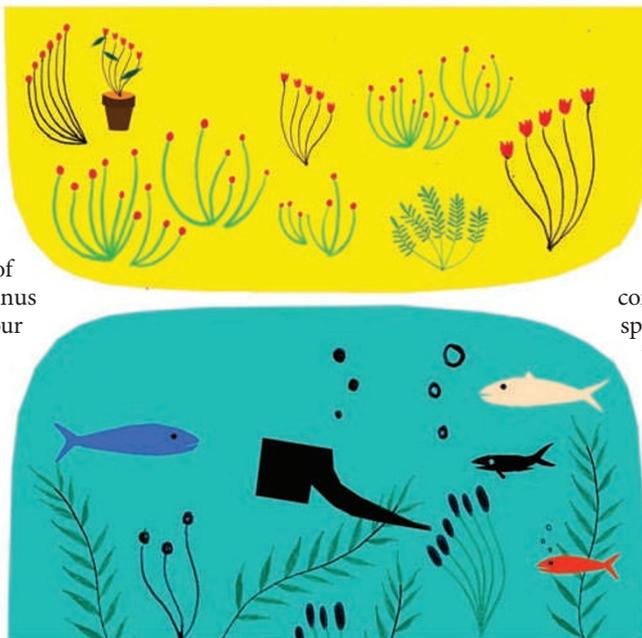
the surface of a planet, which could provide a solvent for prebiotic chemistry. Kasting's habitable zone is often couched as a Goldilocks story: planets capable of hosting life must be neither too hot such that liquid water evaporates, nor too cold such that it freezes, but just right, allowing liquid water. In our Solar System, Earth sits snugly inside the inner boundary of Kasting's habitable zone, whereas Venus orbits too close to the Sun, dooming our near twin to be waterless and lifeless.

The case of Mars illustrates that there is more to habitability than a planet's distance from a star. Freezing temperatures render the red planet lifeless today. But there is evidence that liquid water once flowed on its surface, sculpting gullies and river beds. Impact craters from the heavy bombardment period of the Solar System overlay these twisting features, dating them to at least 3.8 billion years ago.

Kasting notes that this interpretation of the surface morphology on Mars is not universally accepted, but it is appealing. The possibility of a liquid-water phase in the planet's history raises the question of whether life might have had an early start there with a thicker atmosphere that trapped heat. Any surface water has long since evaporated because the planet was too puny to hang on to its atmosphere.

In recent years we have progressed from being able to detect only massive gas giants around other stars to discovering a handful of smaller rocky worlds a few times the mass of Earth. Kasting reviews the astronomical techniques involved. Ground-based telescopes can detect a planet through its influence on the motion of the parent star, revealed through Doppler velocity shifts and changes in the timing of pulsar flashes for neutron stars, or through brightness changes caused by gravitational microlensing and planetary transits.

From space, the Kepler mission, which launched in 2009, is now taking a census of stars to determine the fraction that have



Earth-sized planets. The Hubble Space Telescope has detected abiotic atmospheric features on other planets, such as water and methane derived from physical processes, and the Spitzer Space Telescope has measured wind speeds in gas-giant exoplanets. Future missions will measure the mass and orbits of Earth-like planets and trace the motions of clouds.

Kasting deftly charts a course through planet formation, detection and geochemistry to introduce readers to what is likely to be the next big discovery: the detection of oxygen, water or methane in the atmospheres of exoplanets, signalling the possibility of life. Challenging the notion that life elsewhere is rare, he makes a strong case that simple life forms will contaminate atmospheres in ways that are spectroscopically detectable. But he cautions that abiotic sources of oxygen and methane can lead to false positives.

The key will be finding a convincing set of conditions. For Kasting, finding both liquid water on the surface and oxygen in the atmosphere would be enough. "I would be 99 per cent sure that life was present if I saw this combination of planetary characteristics," he says. Such signatures of life could be detected in the coming decades.

How to Find a Habitable Planet will fascinate those who care about the evolution of Earth's climate and wonder about how we will eventually detect life — even simple cellular life — elsewhere.

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Education as a global commodity

The Great Brain Race: How Global Universities Are Reshaping the World

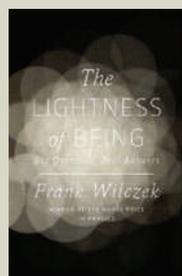
by Ben Wildavsky

Princeton University Press: 2010. 248 pp.
\$26.95, £18.95

Globalization is rapidly changing both the way universities operate and the idea of what a university is. In particular, there is increasing worldwide competition for the best students

and scholars, and an expanding global market for educational credentials. In *The Great Brain Race*, journalist Ben Wildavsky, a former education editor of the *U.S. News and World Report* college rankings, argues that this is as an opportunity rather than a threat and urges universities to embrace globalization "not with fear but with a sense of possibility".

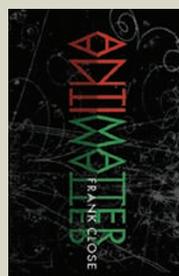
Wildavsky examines five aspects of globalization in higher education: the increasing mobility



The Lightness of Being: Big Questions, Real Answers

by Frank Wilczek (Penguin, £9.99)

Our understanding of the essential nature of reality has changed dramatically in recent decades. In *The Lightness of Being*, physicist Frank Wilczek presents a clear synthesis of modern physics, pointing to areas in which fundamental discoveries are likely, including particle physics. He articulates a vision for a new 'golden age' in physics.



Antimatter

by Frank Close (Oxford Univ. Press, £7.99)

Antimatter explores a strange mirror world where particles have identical yet opposite properties to those that make up the matter we encounter daily; a world where left becomes right and positive becomes negative. Frank Close separates the facts from the fiction about antimatter, and explains how its existence gives profound clues about the origins and structure of the Universe.