only kind of inflationary patch that can support our existence. The grand design is unnecessary. One is reminded of Winston Churchill damning the United States with faint praise — they get it right after they have exhausted all the alternatives.

The multiverse is possibly the most important idea of our time, and may even be right, but it gives me a headache. Is it science if we cannot test it? The different patches are incommunicado, so we will never be able to observe them. The multiverse displaces rather than answers the question about choice and who chooses, and does not explain why there is something rather than nothing. Hawking and Mlodinow argue that negative gravitational potential energies allow something to arise from nothing — but that still begs the question of why there is space, time and M-theory at all.

Hawking has not ruled out the existence of God, or even the odd possibility that our creator is a physics student in an advanced civilization carrying out a routine lab experiment. He has strengthened Laplace's argument that, although some assembly process is required, no creator is necessary. It is well known that Hawking is no fan of religion, but it was the media who took "no necessity for God" to mean "no God".

Hawking and Mlodinow's book is one of many works by big thinkers on the multiverse concept — including Leonard Susskind's *The Cosmic Landscape* (Little, Brown, 2005), Alex Vilenkin's *Many Worlds in One* (Hill and Wang, 2006) and Martin Rees's *Our Cosmic Habitat* (Princeton University Press, 2001). But when Hawking speaks, people listen. His clear, direct approach and his willingness to be provocative are enjoyable whether or not you agree with the details of his argument. With strong statements such as "philosophy is dead", he implies that it is now the duty of physicists to take up the big metaphysical questions.

Yet *The Grand Design* reminds me, as I tell my students, that science doesn't do 'why' — it does 'how'. Physicist Richard Feynman discussed the dangers of 'doing why' in his 1964 Messenger Lectures. He warned that should we achieve the Ionian goal of finding all the laws, then "the philosophers who are always on the outside making stupid remarks will be able to close in", trying to explain why those laws hold; and we won't be able "to push them away" by asking for testable predictions of those ideas. Time will tell if we are on to something big with the multiverse, or if we are becoming the philosophers that Feynman warned about. ■

Michael Turner *is director of the Kavli Institute for Cosmological Physics at the University of Chicago, Illinois, USA.*
e-mail: mturner@uchicago.edu
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ANIMAL BEHAVIOUR

The wisdom of the bees

Swarms teach us that leaders should create conditions for collective decisions, learns **John Whitfield**.

You can never tell when apparently blue-sky science will be useful, as biologist Thomas Seeley's career shows. His knowledge of honeybees, for example, helped to defuse a cold-war confrontation in the 1980s, when he showed that yellow dots on Thai jungle foliage were not residues of Soviet chemical weapons but bee shit. And he has run his own department by the rules that swarms use to select a new home. *Honeybee Democracy* describes Seeley's quest to understand collective decision-making in social insects and humans.

Bee swarming is impressive and mysterious. Early in summer, a queen honeybee flies from her hive with a retinue of about 10,000 workers, leaving the home of her birth to be inherited by a daughter. The swarm might bivouac on a handy surface for several days before invading a new nest site in a tree hollow or building cavity. The collective must quickly decide where to settle, because it is risky to hang around in the open as food reserves dwindle. And it is important to pick the right spot — a colony that chooses poorly is unlikely to survive the winter.

Bees communicate through dancing. In the 1940s, German biologist Karl von Frisch decoded the waggle that worker bees perform to recruit foragers to food sources — the dance shows the direction, distance and quality of the food. His student, Martin Lindauer, noticed that during swarming some dancing honeybees were not covered in pollen, as were returning foragers, but in brick dust. He suspected that they had returned from potential nest sites, and were advertising them to their swarm-mates. By reading that dance, he worked out the site's probable location, and confirmed his hunch by following the swarm through the streets of Munich to its new home.

Honeybee Democracy
THOMAS D. SEELEY
Princeton University Press: 2010. 280 pp. $29.95

Seeley picked up the baton in the 1970s. *Honeybee Democracy* describes how, in a series of ingenious experiments, he deduced what kind of site bees prefer — a cavity of about 40 litres with a small entrance that faces south — and how a swarm homes in on the best of many possible nest sites. His story's heroines are the scout bees, a few hundred workers who trigger the swarm's departure, seek out nest sites, debate their merits, come to a decision, rouse the swarm and guide it to the new home.

A scout converts knowledge of a particular nest site into a waggle dance. The better the site, the longer and harder she dances. If another scout bumps into a dancing bee, she goes off to inspect the site. If she likes it, she too will dance. But any bee only

T. SEELEY

Tracking individuals in a swarm reveals how they turn house-hunting into a democratic process.

advertises a site for a few hours, even if she has found a dream home.

This stops the swarm jumping to a premature conclusion — a vital delay, as the best site is rarely found first. Eventually, the dynamics of dancing cause about 20–30 scouts to arrive at a single, high-quality nest site. Once this quorum is reached, the scouts stop the debate and communicate their decision to the swarm with high-pitched piping sounds and by running amid the other bees buzzing their wings, a preflight routine. The swarm then warms up and moves off, the scouts pointing the way.

This form of decision-making is extremely robust. Each bee's job is simple. Even if one makes a mistake, the rules that transform individual deeds into collective behaviour set the swarm back on course. Other systems have independently evolved the same tricks. A neuron, for example, carries little information. But by using similar rules to bees, cells combine to enable our brains to do clever things, such as tracking a moving object.

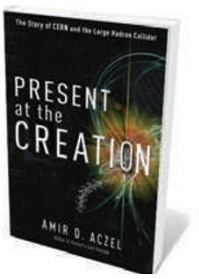
In the final chapter, Seeley lists his bee-derived rules for good human decision-making, and describes how he applied them as head of Cornell University's neurobiology and behaviour department in Ithaca, New York. He points out that groups make the best decisions when leaders interfere as little as possible. Individuals are then free to explore and debate options, and are most likely to arrive at the best decision. The wise leader, he advises, manages the process of decision-making and lets the product take care of itself.

In his own community, Seeley ensured that all possibilities were considered and that everyone had his or her say. He then stepped back to let the group make up its own mind by secret ballot. Such a process (discovered by several human societies independently) ought to work well in situations where a group with a common interest chooses between many options, from friends choosing a holiday destination to a government poised to invest billions in a defence system.

However, this rule about leaders facilitating decisions rather than making them is also the one humans find hardest to apply. Why struggle to the top if you can't push your own agenda? Or why pick leaders if they don't make their presence felt? In a crowd-sourcing exercise this year by the new UK government, for example, the public was asked to propose policy ideas and money-saving tips. Thousands of suggestions came in. But people were not asked to choose between the proposals. The decisions remained with those at the top. Humans prize their power and expertise — and that, Seeley's splendid book suggests, may be a cause of many of our problems. ■

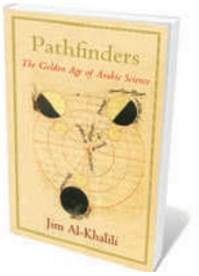
John Whitfield *is a science writer based in London. His book about reputation will be published in 2011.*
e-mail: j.a.whitfield@gmail.com

Books in brief



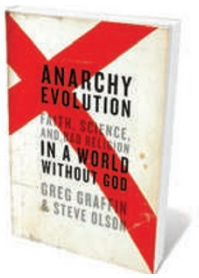
Present at the Creation: The Story of CERN and the Large Hadron Collider
Amir D. Aczel CROWN *288 pp. $25.99 (2010)*
Mathematician and author Amir Aczel describes the origins and science of the Large Hadron Collider at CERN, Europe's particle-physics lab near Geneva. Conveying his excitement at visiting the game-changing machine, Aczel's odyssey includes the voices of key scientists. After explaining the history of the standard model of particle physics, he looks ahead to string theory, the identity of dark matter and tests of the Higgs mechanism for conferring mass. But the real gems, he believes, will be beyond our imagination.

Good Faith Collaboration: The Culture of Wikipedia
Joseph Michael Reagle Jr MIT PRESS *256 pp. £20.95 (2010)*
Joseph Reagle, a computer-science historian, looks at the collaborative culture behind online encyclopaedia Wikipedia. He charts the technology-driven attempts in the 1930s to collect the world's knowledge and bypass elite publishers, such as Paul Otlet's information indexing system and H. G. Wells's proposal for a World Brain stored on microfilm. Wikipedia, Reagle argues, comes close to the goal of a universal encyclopaedia owing to the openness of its users in assessing knowledge. But there are downsides to inclusivity — for example, censorship, lawsuits and bureaucratization.



Pathfinders: The Golden Age of Arabic Science
Jim Al-Khalili ALLEN LANE *336 pp. £25 (2010)*
Physicist, author and broadcaster Jim Al-Khalili celebrates the forgotten pioneers of early Arabic science. His focus is the House of Wisdom, a great centre of learning established in the ninth century by the caliph of Baghdad, Abu Ja'far Abdullah al-Ma'mun. Among its wise alumni are Syrian astronomer Ibn al-Shatir, whose work inspired Nicolaus Copernicus's heliocentric model of the Solar System; Andalucian physician Ibn al-Nafees, who described blood circulation 400 years before William Harvey; and zoologist al-Jahith, who proposed natural selection 1,000 years before Charles Darwin.

The Planet in a Pebble: A Journey into Earth's Deep History
Jan Zalasiewicz OXFORD UNIVERSITY PRESS *256 pp. £16.99 (2010)*
Every pebble holds the story of Earth, shows geologist Jan Zalasiewicz. He extracts from a humble stone evidence of the violent formation of the Solar System, in which our embryonic planet was dusted with the detritus of supernova explosions and the elemental litter of the Big Bang. Trapped, too, is the tale of Earth's evolution — the lives and deaths of disappeared plants and animals, volcanic eruptions and long-vanished oceans. Zalasiewicz explains how oil and minerals form and how geologists use clever chemistry to sniff out the resources on which we depend.



Anarchy Evolution: Faith, Science and Bad Religion in a World Without God
Greg Graffin and Steve Olson IT BOOKS *304 pp. $22.99 (2010)*
Greg Graffin's memoir, co-authored with science writer Steve Olson, offers an unusual perspective on evolution. As an evolutionary biologist and lead singer of punk band Bad Religion, Graffin argues that research and punk rock have much in common: both require an open mind and look to evidence and rationality. Bucking authority and the religious views of his family, Graffin explains how he has developed a personal philosophy that celebrates the power of nature.