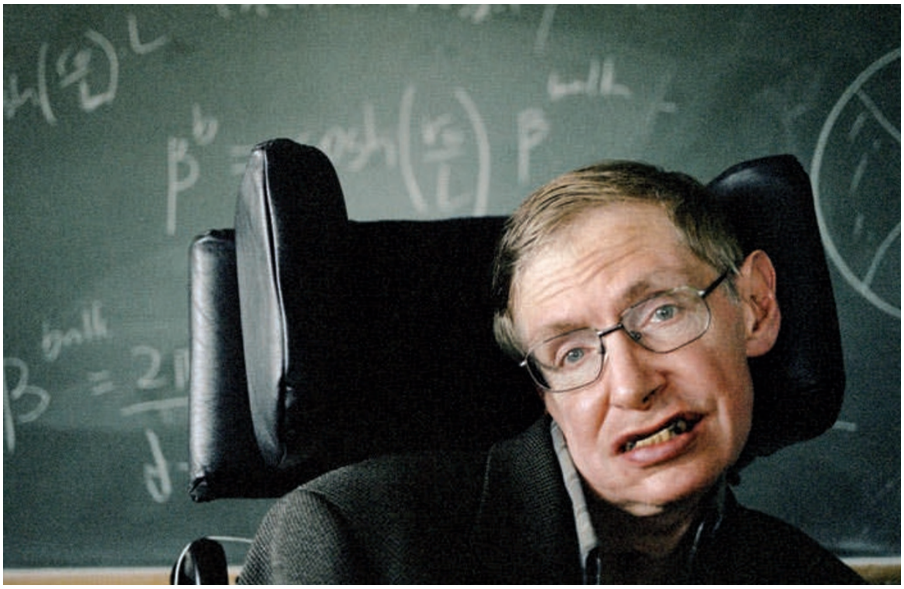

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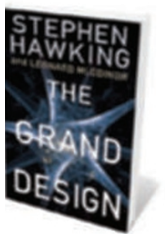
COSMOLOGY

# No miracle in the multiverse

Stephen Hawking and Leonard Mlodinow suggest our Universe isn't all that special, finds **Michael Turner**.

Despite publicity to the contrary, *The Grand Design* does not disprove the existence of God. Science has not had much new to say about God since mathematician Pierre-Simon Laplace remarked to Napoleon that he had no need for "that hypothesis" when asked why he had neglected the deity in his treatise *Mécanique céleste* (*Celestial Mechanics*, 1799–1825). Rather, theoretical physicists Stephen Hawking and Leonard Mlodinow offer a brief but thrilling account of some of the boldest ideas in physics — including M-theory and the multiverse — and what these have to say about our existence and the nature of the Universe.

*The Grand Design* traces the history of science from the sixth-century Greek philosopher Thales of Miletus to the present, with six crucial touch points: the assertion by the Ionians around 600 BC that the world is governed by laws; the discovery of the first simple laws by Archimedes around 200 BC; and Isaac Newton's mathematical expression of his laws of motion and gravity in the 1680s. Then follows Laplace's assertion in the nineteenth century that the world is deterministic and does not need God to run it; Albert Einstein's question in the early twentieth century of whether a creator would have a choice about the laws of nature; and today's expression of those laws in the standard model of particle physics and the theory of general relativity.



**The Grand Design: New Answers to the Ultimate Questions of Life**
STEPHEN HAWKING AND LEONARD MLODINOW
*Bantam Press: 2010. 208 pp. $28, £18.99*

Many think that the standard model and general relativity together come close to encapsulating the full set of rules that the Ionians hoped to find. These theories jointly describe everything from biochemistry to the large-scale structure of the Universe. Yet the mismatch between the deterministic nature of general relativity and the probabilistic quantum approach of particle physics points to a grander theory. Finding this theory — and unifying all the forces and particles — has been the holy grail of modern theoretical physics. Hawking and others held out hope that the ultimate theory's uniqueness would answer Einstein's question and reveal that no, the creator didn't have a choice.

Meanwhile, physicists of a philosophical bent concern themselves with another puzzle of the fundamental laws: their apparent specialness. Hawking and Mlodinow describe the "miracle" that the laws of physics allow for a hospitable Universe — one in which there is an excess of matter over antimatter, where galaxies host stars that last billions of years and harbour planets, and in which carbon-based organisms evolved. Such a miracle would not have occurred if the constants of nature had been slightly different. This has led some (myself not included) to promote the anthropic approach to the Universe: the laws of physics are what they are because if they were not, life would not have evolved to discover them. In a theory of everything, the fact of our existence should fall right out.

In searching for the holy grail, Hawking and others pinned their hopes first on supergravity and then on string theory. Both are now seen as different regimes of a grander mathematical framework called M-theory, where M is yet to be determined — is it master, miracle or mirage? M-theory unifies gravity with the other fundamental forces (weak and strong nuclear and electromagnetism), predicts seven additional dimensions of space and suggests that space and time might be emergent phenomena rather than fundamental. It is exciting and important, but much of it remains to be explored.

Besides the absence of any compelling experimental evidence for M-theory, there is another difficulty — its predictions are far from unique. There are $10^{500}$ different ways to curl up the extra seven dimensions and hide them, and how they curl up determines the fundamental constants and what we four-dimensional creatures see as the laws of physics. So even if M-theory is the only theory of everything available, there remain $10^{500}$ possibilities for the laws of physics we observe.

As Hawking and Mlodinow explain, inflationary cosmology turns this embarrassment into a virtue, partially answers Einstein's question and eliminates the need for a miracle. Cosmic inflation is the process by which a small part of the very young Universe blows up into a vast, geometrically flat and almost-smooth patch large enough to encompass all we can see and more, thereby accounting for the Universe around us today. Inflationary theory is on firmer ground than M-theory — it makes a number of predictions that have been verified. Yet because of quantum mechanics, inflation is not a one-time event but occurs continuously. Enormous bubbles of space-time are constantly being spawned, each one causally disconnected from the others and harbouring its own laws of physics.

Thus, say Hawking and Mlodinow, there is no miracle — inflation plus M-theory equals multiverse. Our special Universe is a selection effect: all possibilities have been tried and we find ourselves in the ▶

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. ■

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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.**