

*Encyclopaedic Dictionary* is devoted far more to environmental science and climate reconstruction than to environmental change, but a certain concession to the vogue of the day does no harm and might increase sales.

Of course, even an encyclopaedic dictionary cannot replace a textbook. So if you are thinking of working in the environmental sciences following a degree in another field (mathematics, in my case), you will still need to work your way through the more involved explanations provided in specialist books.

For example, the explanation of the “Coriolis force” spans only eight lines, and does not go into how it works, why it exists or when it is important. But then, when you read a paper outside your own field of expertise and the words “Coriolis force” pop up, you might not want to know all of this anyway. *The Encyclopaedic Dictionary* does tell you that the Coriolis force deflects air flow to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, and that its magnitude is proportional to the velocity of the air mass and the sine of the latitude. It omits to mention that the same holds for ocean currents, which might have been useful. Nevertheless, the explanation should help you to carry on reading your paper with a good idea of what is meant.

The dictionary emphasizes techniques and methods and contains invaluable accounts of the many ways of constructing past, present and future climates from terrestrial and marine archives as well as from models. Given that most of our knowledge of past climate is based on the interpretation of a wide range of complementary proxies — records such as tree rings — which give indirect information, this is perhaps the most important use of the book. Modellers can learn what speleothems can tell us, and soil scientists obtain an understanding of how foraminifera can record climate.

The coverage seems to be pretty complete; at points, the editors even go a little overboard. For example, 4.5 pages of entries with the prefix “eco” (including “ecofeminism”, unknown even to the *Encyclopaedia Britannica*) are not strictly necessary, and instead of three terms starting “geoeco” (geocology, geocosphere and geocosystems), a single one would have been enough. On the other hand, three entries for “hotspot” (“in biodiversity”, “in geology” and “in remote sensing”) are utterly justified and very useful.

All in all, *The Encyclopaedic Dictionary of Environmental Change* helps to make sense of the babel that can be so characteristic of the literature and conferences in the environmental sciences and gives excellent support when reading across the disciplines. But beware: if, like me, you enjoy following up cross-references, this book may bind your attention longer than you had intended. ■  
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## Science in culture

### Godwin's galaxies

The illustrations in Stephen Hawking's *The Universe in a Nutshell*

Martin Kemp

Illustrations accompanying popular science are rapidly becoming a genre of art in their own right. The most valiantly ingenious are those in books by theoretical physicists and mathematicians who take us on dizzying voyages through multi-dimensional space. The classic dilemma of how to represent figures of more than three dimensions on a flat surface remains the greatest technical challenge, allied to the task of visualizing the kinds of space that evolution has ill-equipped us to ‘see’.

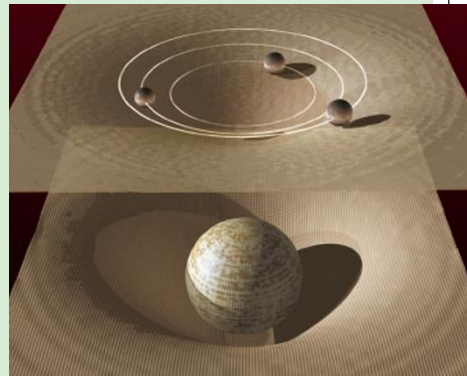
The latest contender in the quest to portray the strange world of theoretical physics is the artist, illustrator and author Malcolm Godwin, whose works are included in such prestigious collections as the Museum of Modern Art in New York and the Tate Gallery in London. Until the 1970s he worked as a sculptor, using translucent materials to explore the representation of complex spaces. As an author-illustrator, he has been responsible for books such as *Who are You? 101 Ways of Seeing Yourself* (Carroll & Brown, 2001), *The Lucid Dreamer* (Simon & Schuster, 1994) and *Angels: An Endangered Species* (Simon & Schuster, 1990).

Having collaborated with Stephen Hawking on *The Illustrated Brief History of Time* (Bantam, 1996), he has now provided the extraordinary suites of images for Hawking's *The Universe in a Nutshell* (Bantam, 2001). Although credited in person only at the very end of the ‘Picture Acknowledgements’, his depictions occupy at least as much space as Hawking's text, and bear a very substantial part of its communicative burden.

Hawking began by signalling where he thought illustrations should be provided, initially envisaging many more than could eventually be included. Godwin, for his part, provided twice as many as were eventually used, and each design was either accepted, returned for revision or rejected by the author.

The range of illustrative techniques is remarkable. There are photographs and images of people, literal depictions, mnemonic representations of objects (such as clocks and guns), poetic evocations of concepts, suggestive analogies and metaphors, representations of two- and three-dimensional space, and illusionist tricks to conjure up visions of multi-dimensional space, as well as the diagrams, graphs and formulae expected in a physics book. Conventional figures are hugely outweighed by those that use visual evocation to depict concepts that cannot be represented in a direct manner.

Not the least of the problems is the disjunction between the language of theoretical physics and that of the illustrator. This applies literally, in that a term such as ‘axis’ has a



Brane new worlds: Godwin's depiction of two adjacent brane worlds, one of them our own.

different meaning for an artist than for a theoretical physicist studying black holes. It also applies more broadly to the way that physicists exploit a quasi-diagrammatic and mathematical language that is internal, part of their own conceptual world. Indeed, Hawking does not demand that his mathematical models correspond to physical reality as experienced in any obvious sense. As a self-declared positivist, the existence of extra dimensions has meaning for him only insofar as the mathematical models of  $n$ -dimensional space serve as good descriptions of the Universe.

An excellent example of how Godwin has responded to something that cannot be envisaged as straightforwardly ‘real’ is his illustration of the influence of one ‘brane world’ on another. In brane theory, largely the creation of Hawking's colleague Paul Townsend, a brane (as analogous to ‘membrane’) is defined as an object that has a variety of dimensions. Thus, a  $p$ -brane possesses length in  $p$  dimensions, whereas a 1-brane is a string, a 2-brane is a membrane, and so on.

The illustration evocatively shows two adjacent ‘brane worlds’, our own and another. The nearby brane world is not visible from ours because light is trapped within the dimensions of each brane. However, gravitational forces are envisaged as operating across the gap, and the existence of the mass of the nearby ‘shadow brane’ can only be detected through its gravitational effect on the behaviour of objects in our own Galaxy. The orbital paths of our stars are thus literally overshadowed by sources that are irredeemably dark to us.

The reader, perhaps struggling to understand when told how brane theory is part of M-theory, might turn to the glossary. This duly informs us that M-theory “unites all five string theories, as well as supergravity, within a single theoretical framework, but which is not fully understood”. A tough job indeed for the illustrator. ■  
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