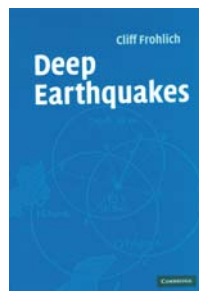


is broad—from specialists on deep earthquakes to geophysics researchers and graduate students to scientifically literate nonscientists. The book succeeds in offering results and explanations that are up-to-date and, though occasionally technical, still accessible. And I know of no other text devoted to deep earthquakes, or even one that treats them in depth.

Earthquakes in general occur in subducting slabs down to about 670 km below Earth's surface, but those that occur below 50 km present a seismological puzzle. Eighty years after their discovery, deep earthquakes remain mysterious—that is, researchers still do not understand the physical processes behind the seismic signals that have delivered most of the current knowledge of Earth's interior structure. Brittle failure and frictional sliding, the processes that generate shallow earthquakes, are strongly inhibited below depths of about 50 km by the intense stresses produced by the great weight of overlying rock, while ductile flow and deformation are prompted by the high temperatures of depth.

Over the decades scientists have suggested numerous mechanisms for deep earthquakes, including dehydration embrittlement, transformational faulting, thermal shear instability, and frictional melting. But whatever mechanisms operate in those inaccessible depths, the seismic signals emitted indicate sudden, sharp failure and differ only subtly from those of shallow earthquakes, which we geophysicists think are better understood. The research terrain is necessarily interdisciplinary, since the physics of deep earthquakes is related to the disciplines of seismology, geodynamics, and mineral physics through several physical processes, including phase transformations in mantle minerals, mantle circulation, plate tectonics, formation and hydration of the oceanic crust, and subduction of sediments and water.

Frohlich is associate director of the Institute for Geophysics at the University of Texas at Austin. A well-known seismologist with particular expertise in deep earthquakes and global seismicity, he has written a score of papers on deep earthquakes, focusing particularly on their statistics and the geometrical orientation of the seismic sources. He explains that as a graduate student at Cornell University, he “imprinted on deep earthquakes” in the way a duckling imprints on its mother, following



her relentlessly. Frohlich admits he has remained obsessed with the topic.

Deep Earthquakes is a lengthy volume, enriched with numerous black-and-white figures, many from current literature and some created expressly for the book. The casual, sometimes quirky tone is unusual for a scientific narrative but refreshing and appropriate for the intended broad audience. All aspects of the topic are covered, some more thoroughly than others, and there is an emphasis on statistical significance throughout. In addition to long chapters on the discovery, properties, physical mechanisms, and relevance of deep earthquakes, an extensive chapter 10 geographically summarizes by subduction zone hundreds of significant deep earthquakes. The chapter also includes deep lunar seismicity, which seems even more mysterious than deep seismicity here on Earth.

For the general audience, the book provides thoughtful descriptions and explanations of the phenomena, including earthquake numbers and sizes, rupture processes, subduction zone structure, and effects of ambient conditions—mainly pressure and temperature—on possible physical processes. Although the book contains no problem sets and is not a textbook, it could be quite useful for a graduate-level topical seminar because of its overview of numerous processes and its synthesis of relevant concepts. For the specialist, the comprehensive literature review and geographic summary are particularly valuable.

Overall, *Deep Earthquakes* is quite an accomplishment. Bottom line: If, like many geophysicists, you are curious about this mysterious phenomenon, check out Frohlich's book. It will most likely answer some questions and raise many others.

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I Am a Strange Loop

Douglas Hofstadter
Basic Books, New York, 2007.
\$26.95 (412 pp.).
ISBN 978-0-465-03078-1

Douglas Hofstadter, the son of physics Nobel laureate Robert Hofstadter and once a solid-state physicist himself, became instantly famous with his first book *Gödel, Escher, Bach: An Eternal*

Golden Braid (Basic Books, 1979). In it, Hofstadter, now a professor of cognitive science and computer science at Indiana University, Bloomington, exhibits a veritable obsession with the theme of self-reference. That obsession culminated in his fascination with the notion of a “strange loop,” a concept he found as a unifying theme in the work of his three protagonists: mathematician Kurt Gödel, artist Maurits C. Escher, and composer Johann Sebastian Bach. Beyond the originality of its theme, *Gödel, Escher, Bach* has become a classic of popular science because of Hofstadter's inimitable personal style: He explains difficult ideas with a mix of dialogue, autobiography, jokes, asides, and endless analogies and metaphors.

In *I Am a Strange Loop*, the dialogues have largely disappeared, but the book is still vintage Hofstadter. The fundamental message, already implicit but mostly overlooked in his 1979 book, according to Hofstadter, is the following: First, the notion of “I,” and the associated phenomena of consciousness, thinking, and the soul that Hofstadter broadly identifies, arises because of a “strange loop” inside the brain. Second, that notion turns out to be an illusion, somewhat comparable to the marble one imagines feeling between a large stack of envelopes pressed together.

By definition, a strange loop is a “level-crossing feedback loop” (page 102). What that description means is best illustrated by the example that has motivated Hofstadter since his teenage years. A large part of known mathematics, particularly number theory, can be formalized using the logical system (*PM*) of the *Principia Mathematica*, published from 1910 to 1913 by Bertrand Russell and Alfred North Whitehead. Now, the crux is that number theory by itself is sufficiently rich to encode logical reasoning, as was famously shown by Gödel in 1931. The reinterpretation of certain number-theoretic statements as logical propositions is the level-crossing called for in the definition of a strange loop. In particular, *PM* can be encoded within number theory, so that *PM* is able to reflect on itself. That concept is the feedback in the strange loop at hand.

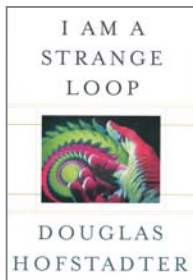
In the strange loop of the brain that gives rise to consciousness, the role of the lowest level, analogous to *PM* in the mathematical example, is played by the microstructure of the brain, whereas the highest level, which would be comparable to Gödel's reinterpretation mentioned above, consists of the internal symbols representing coarse-

grained reality. In vivid imagery, Hofstadter describes such high-level brain activity as a dance of symbols. According to him, the essential feature of humans, as opposed to animals, is that this representational system is universal in the sense that any pattern can be simulated by the brain, including the "dance of symbols" itself. He sees a perfect analogy with Gödel's strange loop. However, that mathematical loop closes because the highest-level formulation reflects on the lowest level; but in the human brain, the highest level reflects on itself. Ironically, in scientific papers on neurons, the highest level, the dance of symbols does reflect on the lower one, the neuron itself—but such papers neither explain nor give rise to consciousness.

Hofstadter continues his analysis by claiming that the "I" conceived as a strange loop is actually a "hallucination hallucinated by a hallucination" (page 293). His claim hinges on the fact that the dance of symbols, and hence its self-reference, is a collective effect (philosophically an epiphenomenon, like temperature) that evaporates down at the neuronal level. In a similar vein, the high-level world of classical physics could be said to be a mirage created by the underlying low-level world of quantum physics. But it is hard to see what one gains by regarding epiphenomena as illusory. In any case, with that stance Hofstadter especially challenges Cartesian and modern dualism, and he insists on a monistic, purely physical description of consciousness.

The genre of the book is philosophy of mind. There is not a single reference to a serious laboratory experiment, and Hofstadter even claims that the physical structure of the brain is as irrelevant in the explanation of consciousness as the chemical composition of molecules in the air would be to the sensation of music. He thus makes no effort whatsoever to show how the brain is able to sustain his strange loop; he even blames neurobiologists for looking for the "I" at the wrong level.

Hofstadter's approach seems to turn vice into virtue. I regard the purely philosophical nature of the book, which is entirely based on analogies and metaphors, as a serious weakness. Also, apart from a sneer here and there to his intellectual antagonists and occasional praise of kindred points of view from other scholars, the author makes almost no attempt to relate the arguments to the pertinent literature. Admittedly, although Roger Penrose's book about



consciousness, *Shadows of the Mind* (Vintage, 1995), also heavily relies on Gödel's work, it hardly overlaps with *I Am a Strange Loop*. But much more could have been said in Hofstadter's book in terms of relating his own ideas to others involved in mainstream philosophy of mind. Nonetheless, *I Am a Strange Loop* contains many profound and unique insights on the question of who we are. In addition, it is a delightful read.

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New Superconductors From Granular to High T_c

Guy Deutscher
World Scientific, Hackensack, NJ,
2006. \$52.00 (222 pp.).
ISBN 978-981-02-3089-0

Superconductivity, a spectacular phenomenon known since 1911, has too many strands to be covered in any one book. This is especially true since the groundbreaking 1986 discovery by J. Georg Bednorz and K. Alexander Müller of high- T_c superconductivity in a novel class of oxides. The challenge of understanding the physical mechanism for high- T_c and recognizing the significant opportunities for technological applications of high- T_c materials has, however, prompted an audience willing to forgo comprehensive treatments for useful insights and alternative approaches. Those readers should be served well by Guy Deutscher's *New Superconductors: From Granular to High T_c* .

Deutscher correctly recognizes that high- T_c superconductivity can best be understood when compared against the backdrop of conventional superconductivity, as described by the Bardeen-Cooper-Schrieffer (BCS) theory. The book is thus launched with a discussion of the Landau criterion for the critical velocity of a superfluid. The discussion evolves into a clearly articulated comparison of the two modes of pair condensation: BCS, which takes place in conventional superconductors, versus Bose-Einstein (BE), which possibly occurs in the underdoped regime of the high- T_c superconductors.

Throughout the book Deutscher effectively uses the distinctions between BCS and BE condensation to highlight the link, anticipated by the book's title, between granular and



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