his pioneering *Modern Theory of Solids* (McGraw-Hill) was published in 1940.

Critical historical questions that the authors set out to answer include: How did crystalline silicon become available for very early wireless telegraphy experiments? Why did the Bell Telephone Laboratories focus on the development of semiconductor triodes or transistors immediately after the Second World War? How did it happen that the invention of the integrated circuit occurred in two start-up companies? *Electronic Genie* answers these queries, and more broadly describes with authority the historical course of development of silicon technology, the principal driver of the modern information revolution.

The book begins with the discovery of the element silicon in the early nineteenth century and concludes with a capsule summary of future prospects. The development of silicon technology is attributed to both the push of fundamental advances in materials science, and the pull of communications, radar and computer systems requirements. Perhaps the most fascinating pathway that is traced begins with the introduction, near the turn of the century, of metallurgical grade silicon. It was originally refined for use in iron–silicon alloys or steel, for such applications as electric power transformers. In electronics it was first used to fabricate rectifying diodes for early twentieth-century wireless telegraphy receivers.

Interest in silicon for electronic devices remained relatively dormant until the early stages of the Second World War, when it was recognized that a chip of silicon in contact with a fine rod of tungsten — a combination known as a 'cat whisker' — provided the critical crystal rectifier needed for effective return signal detection in ground-based and airborne radar receivers. Radar systems using silicon diode detectors proved to be of enormous advantage to the Allies.

In 1948, the point contact bipolar transistor, which uses two proximate cat whiskers forming electrical point contacts on a chip of semiconductor material, was invented at the Bell Telephone Laboratories. In short order, the PN junction was discovered in an ingot of highly purified zone-refined silicon; aligned point contacts on opposite sides of a thin layer of germanium demonstrated a 'two-sided' point contact bipolar transistor; and the bipolar junction transistor was invented, marking the birth of modern microelectronics.

A decade later the invention of the integrated circuit enabled the interconnection of several transistors to form a functional circuit within a single silicon microchip. This momentous achievement presented the opportunity to take advantage of the operating speed, power, size, reliability and cost advantages of the transistor relative to earlier vacuum-tube electronics.

*Electronic Genie* is a resounding success in providing a highly informative and stimulating account of this story. □

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# The mother of all questions

**The Fifth Miracle: The Search for the Origin of Life**
by Paul Davies
*Allen Lane: 1998. 260pp. £18.99*

**Stefan Bengtson**

It may be that *The Fifth Miracle* is a misnomer, and the creation of life was only the Third Miracle. (Biblical scholars told Paul Davies that the creation of the Universe, as recounted in Genesis, wasn't really a separate miracle; and shouldn't we just write off the creation of dry land as a mere mopping-up act — leaving the creation of light and of the firmament as the first two?) The three miracles might then correspond to the classic subdivisions of science: physics, chemistry and biology. That these are deeply entangled we already know. If we can figure out in what way they are entangled, we will understand something fundamental about life, the Universe and everything.

Davies's book is a small miracle in itself. In a little more than 200 pages he pursues the Mother of All Questions — "What is life?" — in a way that should be deeply satisfying to physicists, chemists and biologists alike, and he does this in a clear and potent style that should make the book equally stimulating to non-scientists. (Whoever says that you cannot write about science both simply and accurately hasn't read Paul Davies.) A few slips-of-the-keyboard remind us that the writer is not an expert in natural history (or Nordic languages), but this professed "simple-minded physicist" still demonstrates a better grasp of the complexity and uniqueness of living systems than most scientists, biologists included.

The cover shows Earth and Mars in close apposition. Too close, to be exact, but this is to illustrate one of Davies's ideas, that Earth and Mars are not quarantined and never have been. Rocks travel from Mars to Earth (one of them killed a dog!) and probably in the other direction too, and microorganisms thrive in rocks, as we have lately become aware. Some rocks travel the distance in only a few thousand years, so the possibility of cross-contamination with hardy microorganisms is considerable. This is fascinating in itself, but whether or not it means that we are all Martians or that the Earth's biosphere extends (or has extended) to the asteroid belt or beyond, it makes the issue of life on other planets in the Solar System almost trivial.

There is then the greater question, whether or not we are alone in the Universe. Davies has little patience with those who take for granted that as soon as there are Earth-like conditions, life will sprout. This may be true, he says, but then we're making a gigantic assumption that should not be taken lightly. To explore this assumption, he takes the reader on an intellectual joyride up and down the entropy slope, along the way pointing his sharp flashlight at often murky concepts, such as order, organization, chance, randomness, specificity, language and semantics.

The question of where the information content of life ultimately comes from is, of course, not answered fully, but Davies speculates that gravitation plays a crucial role by particularizing otherwise uniform matter, and that the famous wave–particle duality of quantum mechanics reflects a software–hardware entanglement built into the Universe itself. Biological order may then be ascribed to emergent properties of complex systems, with Darwinian selection serving to distil information from the environment. Natural selection adds information by removing possibilities.

Is life then also the final miracle? Hardly. Just as physics does not fully explain chemistry and chemistry does not fully explain biology, so life does not fully explain consciousness, and consciousness does not fully explain human culture. Davies dwells only briefly on mind and consciousness, but his book is a wonderful example of science as an expression of human culture, and so it truly belongs to the Fifth Miracle. □

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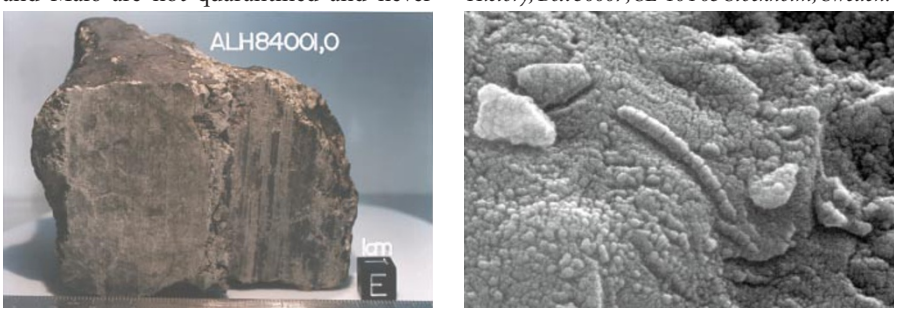


NASA

**Rock folly: bug-like forms, above right, one-thousandth the width of a human hair, once raised hopes that life existed on Mars before the 4.5 billion-year-old rock, above left, fell to Earth.**