Smolin's excellent portrayal of the quest. In its expansiveness of vision, his book stands far above any other account that I know of for a general audience. Readers may find themselves struggling on occasion, but one can skate over some of the trickier pages and still emerge with a clear picture of the intended goal. That picture is, in one or two places, quite breathtaking in its elegance and power.

Whether Smolin's optimism turns out to be justified, only time (or whatever time becomes, in quantum gravity) can tell. Not all physicists, he admits, share his sunny outlook, and others will disagree entirely with his view of where this research is going. Nevertheless, Smolin has made a wonderfully persuasive case that the quest for quantum gravity is not just alive, but positively humming. ■

David Lindley, author of Boltzmann's Atom: The Great Debate That Launched a Revolution in Physics *(Free Press,* 2001*), is a writer currently living in Arlington, Virginia, USA.*

Follow the Building Block Road

The Wizard of Quarks: A Fantasy of Particle Physics
by Robert Gilmore
Springer: 2000. 202 pp. £14.95, $24

Christine Sutton

When Dorothy sets off on a subway ride in the Big City with Uncle Henry and Aunt Em, she little expects to find herself in a land of witches, with a scarecrow, a tin man and a lion for company. Even less does she expect to learn about wavefunctions, amplitudes, nuclear binding energy and gauge theory.

If the setting sounds familiar, that is no mistake, for Robert Gilmore has chosen L. Frank Baum's children's story, *The Wizard of Oz*, as an allegory of our present understanding of the elementary particles of matter and the forces that act on them. The result is a strange (pun intended) *mélange* of corny humour and rather laboured analogy, interlaced with some excellent non-mathematical explanations of a broad range of sub-atomic physics.

Like her earlier namesake, Gilmore's Dorothy makes a journey through an imaginary land populated by remarkable characters. But, rather than learning to appreciate home life in Kansas like the original Dorothy, she finds out about many of the major discoveries of modern physics. From an encounter with the Witch of Mass ("You may call me G"), via the Wizard of Quarks, the travellers follow the Building Block Road until they arrive at the Planck Energy.

Their route mirrors the twentieth century's journey from atoms to quarks, during which particle physicists have discovered that matter is more peculiar than they could ever have imagined. Tiny quarks lie imprisoned within protons and neutrons, to be freed only in the company of additional quarks (or antiquarks), in the guise of new particles. The quarks (and the seemingly unrelated leptons) interact through forces that are understood in terms of further particles, the gauge bosons, which act like balls in a game of quantum catch. So does it help to have the fabulous reality of particles and forces explained in terms of a storybook fantasy?

There is little to fault in Gilmore's non-mathematical descriptions of difficult physical concepts, and he succeeds in covering a great deal of ground, from atomic spectra to the Standard Model. But the descriptions — whether voiced by Dorothy's erudite companions or set out in separate explanatory paragraphs — are not for someone with no previous knowledge of the basic ideas of atomic physics and quantum theory. A story that has introduced the four fundamental interactions and Planck's constant by page 13 is not for the faint-hearted.

Similarly, the attempts at humour will often be lost on a reader who does not already know the physics, and the simple punning begins to wear thin — for example, the half-man, half-horse that the travellers meet in the Kingdom of CERN is the Visitor Information Centaur.

So, if not for the complete beginner, will the allegory work for someone who already knows a little modern physics? Even then, there is a danger that the effort to recall Judy Garland's celluloid progress down the Yellow Brick Road to the Emerald City will distract from the careful explanations of concepts in theoretical physics.

This is the third book by Gilmore that seeks to explain modern physics through characters from familiar stories; readers previously joined *Alice in Quantumland* and were treated to *Scrooge's Cryptic Carol*. So it must be an allegorical style that works — but for whom? Or does this reader lack a sense of humour? Bah, humbug! ■

Christine Sutton is in the Nuclear and Astrophysics Laboratory, University of Oxford, Keble Road, Oxford OX1 3RH, UK.

KOBAL COLLECTION

Can Dorothy's celluloid progress work as an allegory for the discoveries of modern physics?

Subtended by evolution

Who Wrote the Book of Life? A History of the Genetic Code
by Lily E. Kay
Stanford University Press: 2000. 441 pp. $60, £37.50 (hbk), $24.95, £15.95 (pbk)

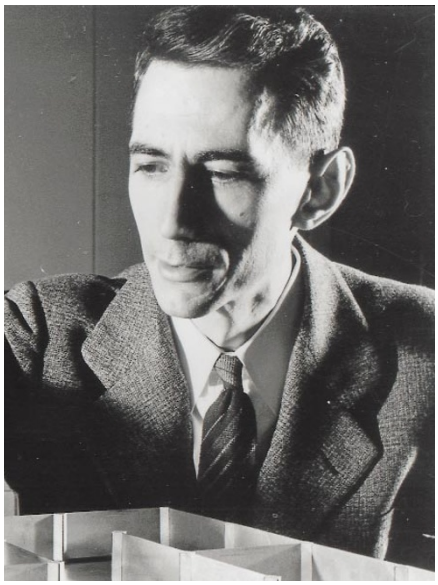
Horace Freeland Judson

The title is the give-away. The idea of the book of life, or more generally the book of nature, goes far back, of course. Charles Darwin began the *Origin of Species* by quoting Francis Bacon from the early seventeenth century: "Let no man out of a weak conceit of sobriety, or an ill-applied moderation, think or maintain, that a man can search too far or be too well studied in the book of God's word, or in the book of God's works." The classic notion was that God wrote both books, and therefore that what we call scientific research is not heretical. But that's not the meaning of Lily Kay's title. The authors of Kay's book of life are the scientists whose competition put together the genetic code.

Who Wrote the Book of Life? attempts two things, which cannot be disentangled. First, and centrally, it presents research into the origins of molecular biology in the 1940s and 1950s, culminating in a reconstruction of the intense competition to break the genetic code — that is, to identify the exact list of the 64 three-base sequences (codons) in DNA that, by way of RNA intermediates, specify the 20 amino acids essential to proteins. It is best to be explicit here, for the definition of the genetic code is one of Kay's concerns.

Some of the research is Kay's own, from interviews and her scrutiny of scientists' notebooks. But Kay has heroically synthesized her own findings with a vast mass of published literature. And she sets this competition in the context of the press and public excitement it generated. The resulting narrative is in some ways new and in some passages thrilling, especially the account of that intense competition. Characters involved include Marshall Nirenberg and Heinrich Matthaei, who in 1961 co-discovered the first two codons, Severo Ochoa who discovered many more, and a host of more minor players, with Francis Crick setting the


A. BARRINGTON BROWN/SPL


HULTON DEUTSCH

Francis Crick (left) and Claude Shannon: pioneers of two very different kinds of information transfer.

theoretical framework and scolding them for their sloppiness.

Kay has gone rather overboard in her admiration of Nirenberg. His desperate ambition and *faux-naïve* enthusiasm displayed in his notebooks and later interviews evidently resonated with her. She undervalues the achievements of Har Gobind Khorana, who shared the Nobel prize with Nirenberg in 1968.

But she sets her best material in two larger, theoretical contexts. The simpler of these is the rise, in the 1940s and 1950s, of information theory — the mathematical study of how information can be transmitted as streams of sequences of symbols. But did information theory really play an important part in the rise of molecular biology and in particular in the elucidation of the genetic code during those same years?

Kay produces impressive evidence to show that molecular biologists knew about information theory and were familiar with its terminology. Yet, as she indeed explains, this theory had its roots in the wartime mathematical analyses of cipher-breaking by Claude Shannon and others, and in Shannon's attempts after the war to apply the analysis to the transfer of signals, such as voice transmission by telephone and the transmission of television images.

But this sort of information is in bulk, treated statistically. It entails the ideas of entropy — the degradation of order — and of redundancy, necessary to restore order. A few physicists in the early 1950s tried unsuccessfully to apply such ideas to biological processes.

The meaning of information in molecular biology is totally different: no bulk messages, but rather individual sequences and their related control elements. Information in that sense was defined by Crick with elegant parsimony in his celebrated talk delivered to the Society for Experimental Biology in September 1957, where he formulated the sequence hypothesis and the Central Dogma: "The Central Dogma ... states that once 'information' has passed into protein *it cannot get out again*. ... Information here means the *precise* determination of sequence, either of the bases in the nucleic acid or of amino acid residues in the protein."

So, yes, this is information, but not information theory *sensu stricto*. Furthermore, for biologists both at that time and today, the term is a simple metaphor — useful shorthand, but no divining-rod. Despite Kay's elaborations, the differences between the two meanings of the word information remain distinct and opposed. In some passages she acknowledges this.

Then, that other context. At this point, the book becomes difficult to discuss. This is partly because Kay's treatment is extremely complex and the terminology and systems of analysis she uses are dense and specialized, even hermetic. But the difficulty arises also because a coterie of historians of science whom she tried with only limited success to impress during life will now flock to her defence. For Lily Kay died last December, of cancer. Kay was luminously optimistic — lean, hair scraped back tight, face scrubbed, eyes shining — and was a woman of great and unaffected courage at all levels. The people she wanted to please can be characterized loosely as the post-modernist, social-constructionist historians of science.

And so Kay attempts to place her story of the genetic code in that fashionable context. We get references to Lucretius and St Thomas Aquinas, to the I Ching and Chomsky. Suddenly in the final chapter we get lengthy discussion of the linguist Roman Jakobson. We get aporias, instantiations, aphoristic energy, autopoiesis, and more of the same. And we get repeated attempts to distinguish meanings — notably, four different meanings of 'the genetic code', when in fact these are no more than four aspects of one idea.

Yet Kay also delivers cautions and concessions. Towards the end of the book there is the wonderful observation by François Jacob, the most rigorously intellectual of all the founders of modern genetics: "Language studies the messages transmitted from an emitter to a recipient. Now there is nothing of the kind in biology: no emitter, no recipient. The famous message of heredity transmitted from one generation to the other, no one has ever written it; it is constituted by itself, slowly, painfully traversing the vicissitudes of reproductions subtended by evolution." Here, then, is the answer to the question in Kay's title. ■

Horace Freeland Judson is at the Center for History of Recent Science, George Washington University, Washington DC 20052, USA.

A rare diversion

The Best American Science Writing 2000
edited by James Gleich
Ecco Press: 2000. 258 pp. $14 (pbk)

Rogene M. Eichler West

It is difficult enough for scientists to find the time to keep up with the technical publications in their field, much less to squeeze in the consumption of a book that can't be cited in a grant proposal. But *The Best American Science Writing 2000* may be worth making an exception for.

For those aspiring to science writing (essays by researchers and journalists are fairly evenly represented), this collection contains a variety of styles that might be categorized and dissected to reveal their underlying principles of form and function.

A number of pieces typify familiar genres: specifically, biographies, the recasting of one's research into layman's terms, and news reporting. Yet other pieces challenge conventional classification. One example is "When doctors make mistakes" by the physician and writer Atul Gawande. Gawande escorts the reader into the operating theatre of an emergency room during a crisis, into the amphitheatre where the entire medical staff meets to scrutinize the events of the past week, and through the ongoing process of uncovering and correcting systemic causes of error. Although his story is, at one level, a tale of process and chance, it is by providing the reader with glimpses into the culture of the medical profession, its rites and rituals, that his story acquires the power to convince.

In "Einstein's clocks: The place of time",