

angles with the leg, but some were set askew, and a couple were almost upside down. Their hulls were dark green, and they had bright red masts that were topped with orange sails. They did not seem seaworthy. Each one had a small porthole with crosshatched lines in its side, and each had a little pink rudder, and a pink point at its prow.

At five places on the legs there were five little whales. They were the same size as the boats, and they too floated on little waves. They were pink in color, with curvy tales, and they each spouted a curl of water from their blowholes. They each had a little eye and little green lines for smiles. Near the slit of both front pockets, but not printed in a symmetrical way, there were two dolphins. These were the same size and general shape as the whales, and only their color (they were blue) seemed to distinguish them. But at a closer look, which the Chair had taken before buying the pants, one could see that the dolphins, though they sat on similar waves, had no blowholes or curls of spout, and they were not, like the whales, riding the waves but were arched in mid-dive, halfway between the exit from one wave and the entrance into another. They didn't seem to have any pupils in their happy eyes.

There's more to *Seaview*, certainly, than a fascination with pinning down the visual details. Melinda's arduous journey to her death in her place of birth, Bob White's quest to reclaim the land where his people had their origin, and Alan's inevitable progression toward a primitive and absurd confrontation with Richard are all pulled together by the trip back across the breadth of the country and by golf, which here takes its place alongside baseball as the quintessential American game. But in the end, this is very much a poet's novel. The images that are captured, the patterns they form, and the ideas they yield are the basic materials, and the final structure stands or falls by them. *Seaview* is a novel that's wrought with a great deal of serious care, and for that alone it deserves its fair share of our attention. If it required the extreme intervention of a prize to save it from an early death, then all honor to it.

TOVA REICH

Tova Reich is the author of *Mara* (Farrar, Straus & Giroux), a novel.

century science, the quark was a product of pure reason. Even now it is more an idea than an artifact. Physicists who are quite confident quarks exist nonetheless give odds that one will never be seen in isolation. According to the prevailing conjecture, the quark is "confined" or "enslaved" within larger composite particles and can never be extracted. It is an invisible presence, all around us and even within us, and yet forever intangible; it has roughly the same status in physics as the soul has in theology. No wonder the idea took so long to establish itself.

THE QUARK was introduced into physical theory almost twenty years ago by Murray Gell-Mann of the California Institute of Technology. (A similar proposal was made at about the same time by George Zweig of the same institution; evidently the idea was in the air, if only in the hallways at Cal Tech.) It would not be quite accurate to say people laughed, but I think in the early years the idea was considered more diverting than illuminating. At the time no one was looking for an explanation of the internal structure of protons and neutrons; indeed, there was not even a hint that protons and neutrons had an internal structure. To all appearances they were smooth, featureless globes. Gell-Mann was suggesting that each such particle has within it exactly three smaller particles, and he assigned to them certain bizarre properties and equally bizarre names. They were to be called the up quark, the down quark, and the strange (or sideways) quark.

In emphasizing the oddity of the quark model I do not mean to suggest that it is a crackpot idea or was ever considered one. On the contrary, it offered a solution to an important problem in the theory of elementary particles, and the solution was recognized from the outset as an extraordinarily elegant one. The idea simply seemed a little too good and too rich to be true.

The problem Gell-Mann and Zweig addressed was an overabundance of basic building blocks of matter. The proton and the neutron are representatives of a family of related particles. For a time they were the only known members of the family, but by the early 1960s a great many more had been discovered, and it was becoming awkward to consider all of them equally elementary states of matter. A quite adequate

THE HEART OF THE MATTER

Quarks: The Stuff of Matter by Harald Fritzsch

(Basic Books, 281 pp., \$19)

Breaking things open to see how they work is a passion seldom indulged after a certain age. A child with a screwdriver can find a rainy day's reward poking at the springs and ratchets of an alarm clock, or even at the messy innards of a flashlight battery; the adult merely asks if it can be put together again.

One could make too much of childlike wonder as an animating spirit in the sciences, but it does seem that the urge to pry off the lid has survived into the maturity of modern physics. In the past one hundred years or so four layers in the structure of matter have been peeled away, just to see what's inside. First the solidity and continuity of the world were undermined: all matter was shown to be a lacework of atoms, held

together by the hooks and threads of chemistry. Next the atom itself was revealed to be a thing of parts: it has a hard pit—the nucleus—embedded in a pulp of electrons. Then the nucleus too turned out to be a composite object: it is a cluster of protons and neutrons, an atom within the atom. With the hierarchy of structures thus set forth, the latest findings are not hard to guess. The proton and the neutron are also hiding something: they are made up of still smaller particles, the ones called quarks.

The progression from atom to nucleus to proton and neutron to quark is obvious only in retrospect. Every step had its impediments, and the last step was unquestionably the hardest. More than any other invention of twentieth-

world could be built out of just a few kinds of particles, and to have so many extras offended one's sense of economy of means. The alarm clock had been re-assembled, and it worked, but there were parts left over.

The quark model handily eliminated the supernumerary particles. The proton and the neutron and their roughly one hundred relatives could all be accounted for as combinations of just three species of quarks. Two fundamental rules governed the construction of composite particles out of the quarks. A particle could be built either by binding together three quarks or by binding one quark to one antiquark; no other combinations were possible. In this way all the known members of the family could be accounted for. Furthermore, with one exception, every allowed combination of quarks corresponded to a known particle of matter; the exception was a particle predicted by the model and discovered within a year.

THE QUARK model and the argot associated with it have become substantially more elaborate since 1964. A fourth kind of quark has been introduced to carry a property of matter that has been called charm. Two more quarks (for a total of six, so far) have been designated top and bottom, and they embody properties labeled truth and beauty. It is now commonplace in *Physical Review Letters* to see papers discussing "bare bottom" and "naked beauty" and other notions of equally distressing cuteness. The various properties that distinguish one quark from another are referred to as "flavors," and, in addition, every quark is now assigned a "color," such as red, green, or blue. Lest the literal-minded be misled, let me add that flavor and color do not have their usual, sensory meanings here; a quark could not be tasted or seen even if it could be isolated.

Harald Fritzsch, who is professor of theoretical physics at the University of Munich, has been one of the hunters of the quark. He takes up the story beginning at the turn of the century, with the first developments in the theory of the atom, and he supplies a brief review of the central ideas that form the context of all modern physics: quantum mechanics and Einstein's special theory of relativity. Then the successive veils of atomic and nuclear structure are parted, revealing the never-never land deep inside the proton.

Fritzsch's account is even tempered and scrupulously fair. Physics is unusual among the sciences in having two communities of investigators, the theorists and the experimentalists, whose relations are characterized by something resembling interservice rivalry. Fritzsch is a member of the theoretical camp, but he is careful not to slight the experimental one. He cites as the crucial event in the evolution of the quark model an experimental result obtained in 1974: the discovery of the first particle made up of charmed quarks. It was this event that persuaded many doubters. Later experiments are also chronicled, and the imposing machines of high-energy physics—the particle accelerators that now approach the scale of a small town—get their due both in words and pictures.

Reading *Quarks* will not be easy for those who are making their first acquaintance with the odd little fellows. Fritzsch writes that "One aim of this book is to show that anyone with an elementary knowledge of physics can comprehend what physicists have accomplished in the last thirty years." I am quite sure he is right that any reader with sufficient interest and stamina can follow his argument, but interest and stamina are definitely needed. They are also rewarded: anyone who pushes through to the end will get the story straight.

I SHOULD like to end with a philological note. It was once the custom to give the particles of matter Greek names; Gell-Mann is largely responsible for changing the practice. Among all the whimsical terms introduced since he first named a quantum property "strangeness," the most interesting is "quark" itself. Gell-Mann found the word in *Finnegan's Wake*, in the line "Three quarks for Muster Mark!" One reason he chose it is surely the importance of threeness in the quark model: originally there were three species of quarks, and any three quarks can combine to form a composite particle. There have been more elaborate exegeses of Gell-Mann's allusion; Fritzsch gives one that I find unconvincing.

I have my own tentative gloss. In the novel it is clear the line is spoken by gulls circling over Dublin, but it is less obvious what they mean by "quarks." Others have pointed out that in German "quark" is a soft cheese, rather like cottage cheese, and that Joyce knew of

the German meaning. From this clue I think I can guess what the birds were doing (rather than saying) over Dublin. I submit that my inference is supported by Joyce's well-known tendency to scatology and by talk a few lines further on about "speckled trousers." "The Stuff of Matter" is dreck.

BRIAN HAYES

Brian Hayes is the associate editor of *Scientific American*.

BRIEF REVIEWS

Roughneck: The Life and Times of "Big Bill" Haywood by Peter Carlson

(Norton, 352 pp., \$17.50)

The quotations that open Peter Carlson's lively, readable biography attest to William D. Haywood's legendary status, even in his own lifetime, as a two-fisted, rough-and-ready American radical, the champion of labor and scourge of capital. Haywood enjoyed his reputation and was happy to make fun of it to serve the cause. "I'm a two-gun man from the West, you know," he'd tell the crowd at a stop on one of his countless cross-country lecture tours to raise money for the Industrial Workers of the World. After a dramatic pause, he'd pull an I.W.W. membership card out of one pocket and a Socialist Party card out of the other, as the audience roared with delight.

Big Bill was a more complex man than his tough-guy image suggested. His innate pragmatism was often at war with a strong streak of romantic idealism, and the struggle between the two had repercussions for the I.W.W.'s history as well as Haywood's personal life. Carlson notes the contradiction, but unfortunately never analyzes it in detail. He does, however, provide a colorful, accessible narrative of Big Bill's action-filled history, including almost every major confrontation between capital and labor from 1896, when Haywood joined the Western Federation of Min-