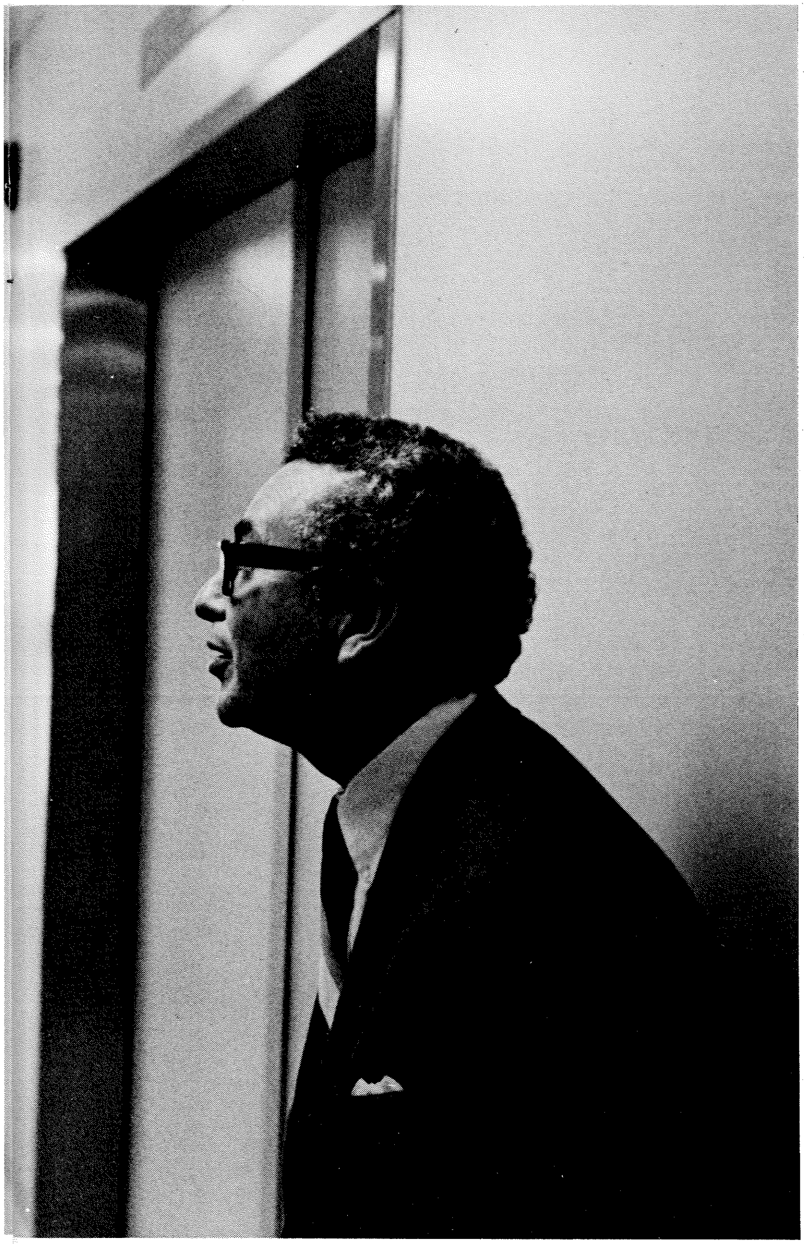

Gell-Mann: Order Out of Chaos

His three major contributions have given hope that man may someday understand what matter is really made of

Biologist Max Delbruck and physicist Murray Gell-Mann become the Institute's twelfth and thirteenth winners

"What is really at the bottom of everything?"
"'Quarks."
"Quarks?"
"Quarks."

Aside from scientific insight, a capacity for hard work, and a touch of genius, the quality that seems to set Nobel Prizewinners apart from their peers is the courage to walk to the beat of a different drum—the daring to challenge accepted concepts in order to find their own answers to the mysteries of the universe.

Murray Gell-Mann, professor of theoretical physics at Caltech, had this special quality almost from the day he entered Yale at the age of 15 and chose physics, by a narrow margin over archaeology, as his pursuit in life. Gell-Mann, 40, has been in the running for the Nobel Prize since 1953 when he published the first of his contributions to particle physics at the age of 24.

In welcoming Gell-Mann to the faculty as an associate professor of physics in 1955, Caltech president Lee DuBridge said, "Dr. Gell-Mann is one of those exceptional

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theoretical physicists who have attained great stature at a very young age. He will be invaluable to our program of training new scientists and carrying on research at Caltech."

When he introduced Gell-Mann at a press conference last month on the morning of the Nobel Prize announcement, Robert Bacher, Caltech provost and the former chairman of the division of physics, mathematics and astronomy, said: "Dr. Gell-Mann has contributed probably more than anyone toward bringing order out of chaos in high-energy physics . . . We have all been expecting this man to win the Nobel Prize, so it doesn't come as a surprise to us. It was just a matter of when."

And Richard Feynman, a Nobel Laureate in his own right, who was largely responsible for Gell-Mann's coming to Caltech and who has worked closely with him ever since, said about his friend and colleague:

"This event marks the public recognition of what we have known for a long time, that Murray Gell-Mann is the leading theoretical physicist of today. The development during the last 20 years of our knowledge of fundamental physics contains not one fruitful idea that does not carry his name . . . If further confirmation is needed that some scientists can be as sensitive and as active toward human problems as any humanist, we are proud to exhibit Gell-Mann."

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Gell-Mann, who earned his PhD in physics at MIT and went on to study at Princeton under Oppenheimer, has devoted his scientific career to finding the ultimate elementary building block of matter, a search that has been compared to looking for the bottom of a well extending into infinity.

The quest for the bottom of the well has led Gell-Mann through an Alice-in-Wonderland world of "strangeness" and the "eightfold way" to the wondrous "quark." Although he is the first to admit that the search is not over, his selection for the Nobel Prize is worldwide recognition that Gell-Mann has brought man a giant step closer to understanding the elemental nature of matter.

Sweden's Royal Academy of Science, when it announced the 1969 Nobel Prize for physics, which carries with it a cash award of $72,800 (the highest in history), explained:

"Dr. Gell-Mann has produced fundamental work in nearly all domains of his field, and his contributions have, in many cases, been of decisive importance for the further

Nobel Prizewinners Gell-Mann and Richard Feynman (shown here in 1960) have been "working together separately" at Caltech since 1955.

Gell-Mann does his best to explain "strangeness, eightfold way, and quarks" to television newsmen on October 30, the day the Prize was announced.

development of physics. This is particularly true of his discoveries concerning the classification of elementary particles and their interactions."

In pointing out the significance of Gell-Mann's first discovery concerning particles with strong interaction, the Royal Academy stated:

"An epoch-making discovery of new particles had been made in 1947 by two researchers, Butler and Rochester. The new particles discovered by them were produced so copiously in collisions between nucleons and pions—another strongly interacting particle group—that one was forced to conclude that they had strong interaction with other particles. Therefore they ought to have a very short mean lifetime.

"However, experiments showed they had considerably longer lifetime. This seemingly strange behavior, which gave rise to the name 'strange particles' for these entities,

Three-fourths of the household: wife Margaret, Gell-Mann, and son Nicholas, 6. (Nobel Prize or not, tomorrow is Halloween.) Daughter Lisa, 13, is elsewhere.

resisted many attempts at an interpretation until it became explained through the theoretical discovery published by Gell-Mann in 1953."

The basis of Gell-Mann's theory is that each particle in the nucleus of the atom can be assigned a degree of "strangeness" according to the number of steps in its disintegration, and that each particle can be distinguished in this way from its neighbors, just as a neutron is distinguished from a proton by its different electric charge. (Unknown to Gell-Mann, a Japanese physicist, Nishijima, came to the same conclusion in Tokyo at about the same time.)

Gell-Mann's second major contribution to the understanding of matter was the Eightfold Way theory that he introduced in 1961. This theory was also advanced independently by Yuval Ne'eman of Tel-Aviv University.

By the time Gell-Mann introduced the Eightfold Way, more than 100 particles had been produced by bombarding atomic nuclei with the use of high-energy accelerators. No longer was the term "elementary" reserved for the proton, neutron, and electron; and physicists searched for relationships that would at least enable them to classify the particles. The hope was to produce a theoretical structure comparable with Mendeleev's periodic table of the elements. Gell-Mann's Eightfold Way theory was the greatest breakthrough in this effort. It provided a scheme for classifying subatomic particles into several families of eight or ten members each, according to such characteristics as spin, parity, and electrical charge.

When the known particles were arranged according to the scheme of the Eightfold Way, one family that should have had ten members was found to have only nine. One particle required by the theory was missing, but Gell-Mann was able to predict all of the distinguishing characteristics of the particle.

Working from Gell-Mann's predictions, a team of 33 scientists at the Brookhaven National Laboratory set out to look for the missing particle, using the 33 BeV proton accelerator. Since the particle could not be found without knowing exactly what to look for and where to look for it, the discovery of the missing particle, omega minus, by the Brookhaven team in 1964 was widely acclaimed as a striking confirmation of the Eightfold Way. Gell-Mann's theory had passed a test that could mark a turning point in particle physics.

Of all the strongly interacting particles that participate in the nuclear force, which are the basic building blocks? What are they made of? Gell-Mann's answer, which suddenly put all the physics textbooks out of date, was the "quark." In his third major contribution to his field, Gell-Mann theorized that all particles are made up of quarks and anti-quarks.

Gell-Mann defined a quark as a "very peculiar particle with an atomic mass number of $1/3$ and a charge of $+2/3$ or $-1/3$. He said, "There are three kinds of quarks: one with charge $+2/3$ and two with charge $-1/3$."

The term quark is another example of Gell-Mann's literary bent, which shows up in all the names he has given to his great theoretical contributions. The idea of "strangeness" comes from Francis Bacon's line: "There is no excellent beauty that hath not some strangeness in the proportion." The Eightfold Way appears in the Buddhist teaching: "This is the noble truth that leads to the cessation of pain. This is the noble eightfold way. . ."

With tongue in cheek Gell-Mann speculates on the derivation of quark. "One possible derivation of the name —scholars are already disputing this, some assuming it comes from the German word for rotten cheese—is from the heading of a page in *Finnegans Wake* where Humphrey Chimpden Earwicker rolls over in his sleep to hear a clock strike, and the text says, 'Three quarks for Muster Mark.' "

"Are quarks actually real objects?" Gell-Mann asks. "My experimental friends are making a search for them in all sorts of places—in high-energy cosmic ray reactions and elsewhere. A quark, being fractionally charged, cannot decay into anything but a fractionally charged object because of the conservation law of electric charge. Finally, you get to the lowest state that is fractionally charged, and it can't decay. So if real quarks exist, there is an absolutely stable quark. Therefore, if any were ever made, some are lying around the earth."

But since no one has yet found a quark, Gell-Mann concludes that we must face the likelihood that quarks are not real.

Without a trace of disappointment he says, "Actually that is just as well; mathematical quarks are even easier to work with than real ones, because certain restrictions imposed by the reality of the particles can be dispensed with. And, working with mathematical quarks, we can begin to make a fairly satisfactory theory of the detailed properties of meson and baryon levels."

Gell-Mann, who is Robert Andrews Millikan Professor of Theoretical Physics at Caltech, has earned more than his share of honors. He received the Dannie Heineman Prize of the American Institute of Physics in 1959; the Ernest Orlando Lawrence Award from the Atomic Energy Commission in 1966; the Franklin Medal of the Franklin Institute of Philadelphia in 1967; and last year he won the John J. Carty Medal of the National Academy of Sciences as well as the Research Corporation Award.

But with all the honors, including the Nobel Prize, Gell-Mann has not lost sight of his goal to uncover the secret of matter.

"I think particle physics is where atomic physics was in the early years of the century," he says. "We're getting an outline of an underlying structure, but there is still no complete theory of either strong or weak interactions which enables us to understand what is really happening at the bottom of everything."

Gell-Mann has also managed to keep his eyes on the world around him. He is an ardent conservationist who actively campaigns for the preservation of wildlife and the expansion of natural parks. On one recent vacation he flew to Africa with his wife, Margaret, for a photography safari by Land Rover.

Murray Gell-Mann is a humanist who happens to be a physicist. You can only speculate about what he would have discovered had he opted for archaeology instead of physics. Maybe even Atlantis, way down there at the bottom of everything.