K.C. COLE:

In the Mind's Eye

I am continually amazed at the confidence with which physicists claim to "see" particles that effervesce into existence for a mere billionth of a second, or quasars teetering 12 billion light-years away at the very brink of space and time. I know, for a fact, that they have seen no such thing. At best, they have seen a bump on a curve plotting the ratio of various kinds of particles produced in a nuclear collision; more often, their sightings are conclusions laboriously drawn from long hours of computer calculations and long chains of assumptions and inferences. Hardly the sort of thing to inspire an exultant "Eureka!" (or even "Land, ho!"). Sometimes the things scientists see are so far removed from actual quarks or quasars that one wonders if they (or we) should believe their eyes.

Of course, the way we go about seeing things in our everyday lives is scarcely more direct. I see my typewriter because rapidly oscillating electrons in the filament of the light bulb overhead are sending out streams of photons, some of which collide (as in an atom smasher) with the molecules on the surface of the typewriter and are rapidly re-emitted in the direction of my eyes. Those that penetrate the pupil are focused onto a light-sensitive screen (the retina), which passes along information about their energies, frequencies, and trajectories to the brain in the form of electrical signals. On the basis of laborious calculations and long chains of inferences and assumptions, the brain concludes that the light patterns represent something hard and cool and heavy and solid that translates passing thoughts into printed words.

That I could accurately assess even the visible world through this abstract process is unlikely enough. Far more humbling is a consideration of the world I *can't* see. The pupil is but a tiny porthole in a sea of radiation. In a universe alight with information, we are mostly in the dark. Human eyes respond to those electromagnetic vibrations with wavelengths between .00007 and .00004 centimeters. Yet, as I type, I am bombarded by other kinds of light, with wavelengths as small as atoms and as large as mountains, coming from the far reaches of space, from the inside of my own body, from the television transmitter 20 miles away. We walk through this dense web of radiant information every day without being the least aware of its existence.

"Science is *mainly* a way of extending our perceptual contact with the world," concluded physicist David Bohm in *The Special Theory of Relativity*. It fosters "an awareness and understanding of an ever growing segment of the world with which we are in contact." This it has done admirably: technology has unveiled vast new vistas, opening up untapped realms of time, space, and temperature. To modern telescopes and particle accelerators, the radio waves and gamma rays invisible to us are rich with images. By definition, these new-found senses are ever more removed from direct observation. The images "seen" with telescopes using Very Long Baseline Interferometry, for example, are really interference patterns resolved from information recorded separately at individual telescopes as much as 6,000 miles apart, synchronized by atomic clocks, and pieced together by computer.

In the same way, the particles produced in accelerators cannot be perceived unless you smash them against other particles with unimaginable energies and carefully analyze the resulting debris. But then, the blades of a rapidly spinning propeller cannot be perceived either "until you stop them or throw a rock at them," as MIT's Philip Morrison likes to point out. You cannot see the typewriter until you rn on the light.

Perception is a surprisingly active process. We are constantly deciding what to focus on, what to ignore; what is information and what is background noise. Recently, four people sat in my living room directly underneath a loud antique clock. At 3:05, I asked whether the clock had struck three. Two people insisted it had, and two insisted it hadn't. Physicists analyzing the data from particle accelerators must learn to ignore the background noise of cosmic rays just as everyone learns to "erase" such an extraneous but ever present image as the nose on his face. But the potential for mistakes is obvious. Perhaps this was the real brilliance behind the discovery of the faint radiation that pervades the universe, a probable remnant of the primal Big Bang. When Robert Wilson and Arno Penzias heard that funny "static" in their radio telescope, they somehow knew that it wasn't just noise.

Once the information is gathered and sorted, it must be interpreted. What does it mean? Sometimes the conclusions we reach are as far removed from the incoming information as physicists' visions of quarks and quasars. Sensations of "soft," "green," and "melodious" arrive at the brain as electrical signals. Taste is the detection of molecular structure on the tip of the tongue, warmth a calculated difference in the rate of chemical reactions. Even Galileo recognized that qualities like color and smell "can no more be ascribed to the external objects than can the tickling or the pain caused sometimes by touching such objects." All sensory experience occurs within the boundaries of our bodies, and yet we attribute those properties to objects "out there."

Sensory data, like scientific data, are always ambiguous. Then how do we answer the question "What is this?" The number of possible answers is infinite, writes Richard Gregory in *The Intelligent Eye*. And so when in doubt we fall back on what is familiar. "Perception is a matter of selecting the most likely object," he says. "This acceptance by the brain of the most probable answer implies a danger: it must be difficult, perhaps sometimes impossible, to see very unusual objects."

The Dutch scientist Christiaan Huygens drew detailed pictures of the planet Saturn as seen through his homemade telescopes. But he never recognized the unusual patterns as the now familiar rings. "We not only believe what we see," writes Gregory. "To some extent we see what we believe."

Curiously, even intellectual knowledge does not always affect what we see. We perceive the rising and setting of the sun, but not the turning of the earth. We perceive the moon as a disc about a foot across and a mile away, even though we know it to be a rocky sphere about 2,000 miles across and 240,000 miles away.

Does this mean that our senses and our sciences are hopelessly inadequate to perceive the real world? Is reality an arbitrary invention? Not at all. Perceptual hypotheses, like scientific ones, must stand up to the scrutiny of further testing. Each new link in the chain of connections adds confidence to the current version of reality. Physicists cannot directly observe the inside of an atom, for example, but if their view is fundamentally wrong, then "our interpretation of the wide field of atomic phenomena would be nothing but a web of errors," says MIT's Victor Weisskopf, "and its amazing success would be based upon accidental coincidence."

Science does, however, increasingly involve leaping beyond our perceptual limitations: Einstein—like Columbus—was out of his senses. After all, sensible people can clearly see that the sun rises, the world is flat. As Sir Arthur Eddington observed, any true law of nature is likely to seem irrational to rational man. In the end, all good science is based on an intimate knowledge of the capabilities and caprices of the equipment: the true key to knowing the universe will lie in knowing ourselves.