AMERICAN SCHOLAR volume 60, number 2, spring 1991

Thinking Otherwise

THE EMPEROR'S NEW MIND: CONCERNING COMPUTERS, MINDS AND THE LAWS OF PHYSICS. *By Roger Penrose. Oxford University Press. $24.95.*

Reviewed by JOEL E. COHEN

Can a computer have a mind? Some people think so. Fans of artificial intelligence argue that a machine has a mind if the machine performs a sufficiently complex algorithm. An algorithm is a set of rules for manipulating symbols. An algorithm does for letters what choreography does for dancers. Since computers execute algorithms, and those algorithms could in principle be as complex as the human mind, proponents claim, computers can have a mind.

Roger Penrose thinks otherwise, and not just because some computer regularly sends him a bill for $0.00. His reasons fill a long (450 pages), fascinating, and highly original book, *The Emperor's New Mind: Concerning Computers, Minds and the Laws of Physics.* Penrose, the Rouse Ball Professor of Mathematics at the University of Oxford, is a brilliant creator of mathematics and physical theories. His book has become a best-seller, but make no mistake: to grasp Penrose's argument is a real intellectual challenge.

Penrose's text bristles with equations, diagrams, and concepts from current research in logic, computer science, mathematics, physics, and neurophysiology. He treats in earnest detail electromagnetism, thermodynamics, relativity, quantum theory, black holes, the big bang, Turing machines, computability, Gödel's theorem, tilings, tessellations, and many other arcana. Given all this science, it comes as a shock that Penrose believes computers have no minds for reasons that are, at root, religious: a Platonic belief in an otherworldly reality of mathematical ideas.

Penrose's argument that minds are too complicated to be found in computers rests on a "reflection principle." "By 'reflecting' upon the meaning of the axiom system and rules of procedure," he explains, one may arrive at "further true mathematical statements that were not deducible from those very axioms and rules." Insight-filled pure thinking, he says, can arrive at conclusions that cannot be reached by formal, step-by-step calculations according to given rules. Thinking can beat algorithms. Therefore computers, which can only execute algorithms, can't have real minds, he claims.

Penrose's own experiences of mathematical insight, and similar reports by others, lead Penrose to affirmations of faith that can only be described as religious: " 'God-given' mathematical ideas should have some kind of timeless existence, independent of our earthly selves. . . ." "I imagine that whenever the mind perceives a mathematical idea, it makes contact with Plato's world of mathematical concepts. (Recall that according to the Platonic viewpoint, mathematical ideas have an existence of their own, and inhabit an ideal Platonic world, which is accessible via the intellect only. . .)." "I believe that (conscious) minds are *not* algorithmic entities. . . . I believe consciousness to be closely associated with the sensing of necessary truths—and thereby achieving a direct contact with Plato's world of mathematical concepts."

Evidently businessmen, journalists, mere empirical scientists (whose truths are all contingent), artists of every stripe, athletes, politicians, most teachers, factory workers, bus drivers, and lawyers have no conscious minds, if Penrose is right, because their lives do not lead to "the sensing of necessary truths." If ever there were a mathematics-centered view of the conscious mind, this is it. But Penrose's

JOEL E. COHEN is a professor at Rockefeller University, New York. He wrote this review as a Director's Visitor at the Institute for Advanced Study, Princeton, New Jersey.

Platonism is fortunately not universal among mathematicians.

Penrose concedes that brains are physical objects and governed by physical laws. If mathematical minds have access to truths that algorithms cannot attain, as Penrose claims, then there must be some shortcoming in algorithmic theories of physical objects. "It is our present lack of understanding of the fundamental laws of physics that prevents us from coming to grips with the concept of 'mind' in physical or logical terms," he writes.

A crucial gap in present physical theory, according to Penrose, is that there is no satisfactory explanation of the growth of certain crystalline-like substances called quasicrystals. In 1984, a quasicrystal was discovered that displays an icosahedral symmetry, a symmetry impossible for a strict crystal. These physical quasicrystals have their mathematical counterpart in Penrose's invention of mathematical shapes that could be used to tile a floor quasi-periodically with fivefold symmetry, a symmetry that is impossible for strictly periodic tilings.

"Now, a remarkable feature of the quasicrystalline tiling patterns . . . is that their assembly is necessarily *non-local,*" Penrose writes. "In assembling the patterns, it is necessary, from time to time, to examine the state of the pattern many, many 'atoms' away from the point of assembly. . . . Their assembly cannot reasonably be achieved by the local adding of atoms one at a time, in accordance with the *classical* picture of crystal growth, but instead there must be a *non-local* essentially quantum-mechanical ingredient to their assembly."

Penrose speculates that similar non-local processes may govern the way the brain changes over time. "The brain is not really quite like a computer, but it is more like a computer which is continually changing. These changes . . . could be governed by something like the processes involved in quasicrystal growth." The least mystical statement of Penrose's viewpoint is that the lack of a physics of non-local effects prevents a physical explanation of mind.

I think it is a mistake to ask, "Can a computer have a mind?" as a yes-or-no question. For, as Penrose grants, "consciousness is a matter of degree." In ancient Greece, calculating with ratios was considered so difficult that a person who could do so was called rational. Today, calculating a ratio takes only dancing your fingers over a pocket calculator. By the standards of the ancient Greeks, perhaps the calculator has now been imbued with a certain limited rationality.

As people get better at instructing a computer to carry out mental functions, a computer can gradually acquire more of a mind. Perhaps when quasicrystals are incorporated as computing elements in machines of a future generation, and the growth of those quasicrystals helps determine the output of computations, machines will be imbued with minds by the standards of Penrose. Will a computer ever attain the brilliant mathematical insight of a Roger Penrose? Will a machine ever reflect deeply on the origins of its own consciousness? Wait and see.