his eyes and hands during drawing were tracked by sensors (and video recorded) as he scanned and fixated on the model's face. The hand movements have been captured in a remarkable three-dimensional sculpture that makes one marvel how such a mapping could conceivably help to transform the face into a two-dimensional image. From research begun by Vernon Mountcastle and continued by many neuroscientists, we have known that the mechanisms for such apparently effortless transformations are likely to reside in the parietal cortex of the brain. Crucial to the analysis of Ocean's activities, however, are the periods of suspension of movement when the artist weighs the veracity of his perceptions; pauses and references to the model diminish as the construction of the representation gathers pace.

This special skill of artists is captured in a story of Picasso told by Françoise Gilot (an artist herself):

> Picasso stood off, three or four yards from me, looking tense and remote. His eyes didn't leave me for a second. He didn't touch his drawing pad; he wasn't even holding a pencil. It seemed a very long time. Finally he said, "I see what to do. You can dress now. You won't have to pose again." When I went to get my clothes I saw I had been standing there just over an hour (*2*).

Contrasts between artists (including Ocean) and nonartists in mental processing have been found by John Gabrieli and associates at Stanford University. They used functional magnetic resonance imaging to quantify differences between the two groups in regional brain activity during drawing. The artists showed differences in temporal and frontal areas of the brain, which contrasted with the nonartists' greater dependence on visual areas. The expert knowledge implemented by their neural networks had evidently refined the ultimate process of turning noisy sensation into aesthetic image.

The comments above focus on those elements that find the greatest resonance with my own interests in cognitive neuroscience and art. But the scope and ramifications of *n01se* could make someone reading several independent reviews incredulous that each has described one and the same thing. The exhibition and book both make us aware of exciting and creative cross-mappings among science, technology, and art.

References and Notes

1. One can follow or participate in the experiment online at http://talking-heads.csl.sony.fr.
2. F. Gilot and C. Lake, *Life With Picasso* (New York, McGraw Hill, 1964).
3. Thanks to R. Bush for advice on technical artistic matters.

BOOKS: PHYSICS

Professor Newton's Principles

Chris Quigg

An ant making its daily rounds was nearly run over by a centipede that streaked across its path. Awestruck by the larger arthropod's effortless grace and speedy motion on so many legs, the ant inquired, "Please tell me how you know when to move leg number 57 and when to move leg number 62." The centipede's face contorted in thought. Its mouth opened to speak, but no sound issued forth. Then its hundred legs began to convulse in chaotic motion; they became hopelessly entangled, and it fell in a confusion of twitching legs, never to walk again. Perhaps it is fear of the centipede's fate that discourages physicists from thinking too much about what they do.

Indiana University's eminent mathematical physicist Roger Newton harbors no such fears. On the contrary, he argues that time spent understanding "what lies behind the solutions to large problems tackled in the past" makes physicists better scientists—and better problem solvers. In *Thinking About Physics*, a fast-paced and challenging collection of essays, Newton appears as an opinionated yet approachable discussion leader. He exhorts the reader to "use my arguments as starting points for your own thinking." From the meaning of a theory to the nature of quantum-mechanical reality, Newton cuts a wide swath and sprinkles his analysis with provocations that make it hard to be a passive reader. Throughout the book, I found myself wanting to engage him in conversation—to ask, "Just what do you mean by that?" or to protest, "I don't see it quite that way."

Though he is an ardent believer in the power of mathematics as an instrument of thought, Newton takes issue with Galileo's contention that mathematics is the language of nature. "Nature," he writes, "just is; it speaks no language and follows no plan; language and plans are human additions." Mathematics is, however, "the only language capable of describing nature unambiguously." Newton opens a compact treatment of symmetries in physics with a clear statement of the modern view that symmetries "express themselves not in the world as we directly experience it, but in the underlying laws and theories." We seek, in other words, symmetries in the laws of nature and the equations that express them, not necessarily in the solutions.

Thoughtful discussions of the arrows of time and of the meaning of causality and probability in physical theory illuminate Newton's insightful assessment of the conflicts between quantum theory and everyday experience. "Many of the quantum paradoxes," he writes, "... have a linguistic nature, stemming from the use of the concepts of particles and waves, to which our everyday intuition and language seem to drive us, but the connotations of which, originating from the macroworld, are simply inappropriate to the microworld." He also provides a clear-headed analysis of recent experiments that rule in favor of the probabilistic predictions of quantum mechanics.

Newton argues forcefully that "at the most basic level, nature is best described in terms of the quantum field." He disagrees with those who think in terms of particles and Feynman diagrams, in part because the cartoon picture of particles interacting through the exchange of a few quanta may in some situations be uneconomical, incomplete, or even misleading. I am not sure that I recognize the battle lines here. Many of us slide effortlessly between particles and fields, according to the situation, without claiming that the dialect we choose more often is necessarily the more fundamental. A question of greater interest to me is where the essential information lies. I was disappointed that Newton chose not to explain the special nature of gauge invariance and the crucial role of the nonintegrable phase—not the potentials or the field strengths—in the gauge theories that govern the fundamental interactions.

Thinking About Physics
by Roger G. Newton

Princeton University Press, Princeton, NJ, 2000. 208 pp. $24.95, £15.95. ISBN 0-691-00920-1.

The range of topics and allusions make *Thinking About Physics* a difficult book for an advanced undergraduate to read without encouragement and supervision. Teachers of undergraduates, aided by the useful index, will find many small nuggets of insight with which to enrich their problem-solving lectures. It would be very interesting to organize a graduate seminar around the book for students completing their course work. Practicing physicists will find the book a perceptive colleague's scan on the foundations of the way we work. They may also catch themselves talking back to Professor Newton—which just might be his aim.

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