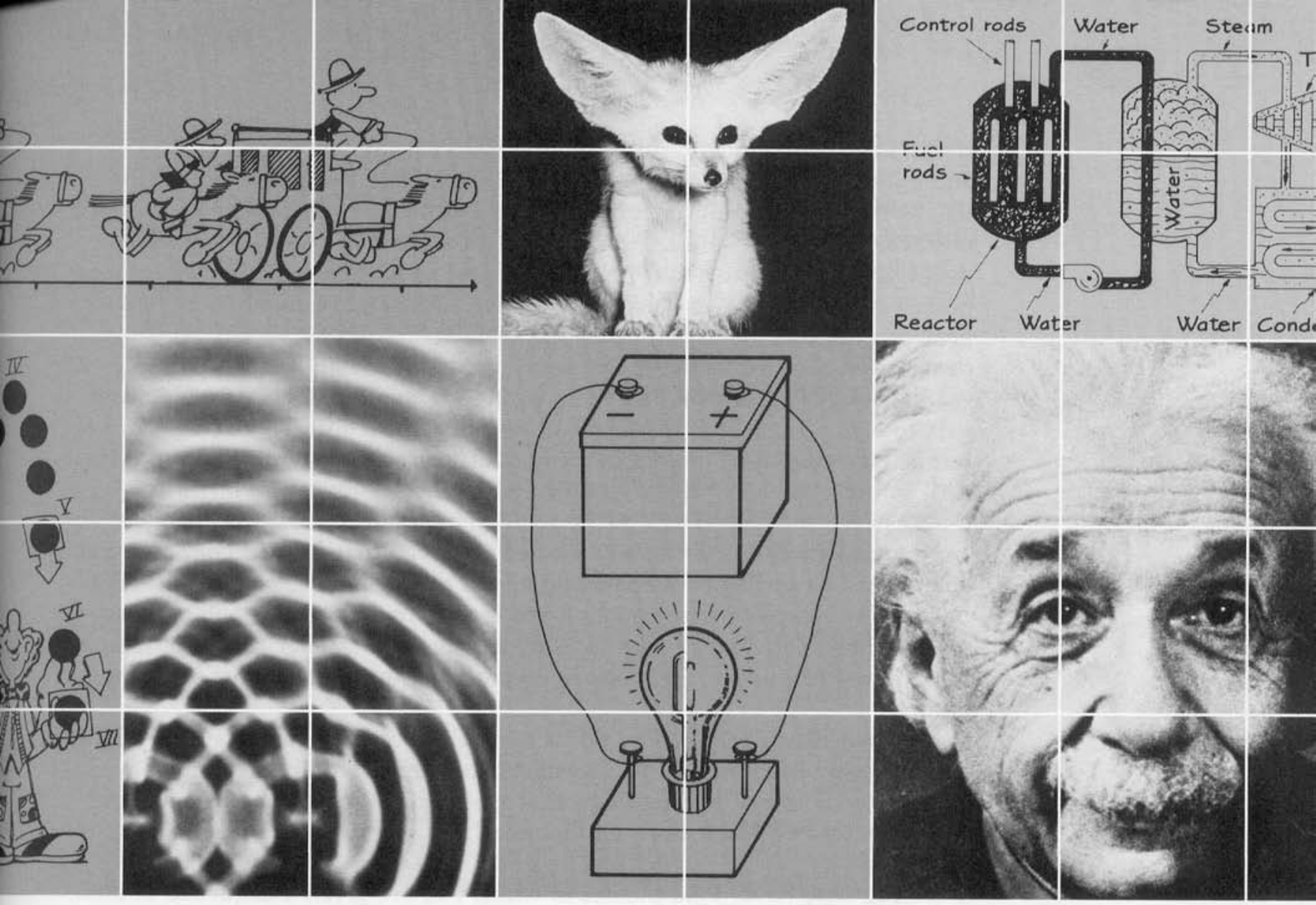

Introduction

Our children, Kevin and Kim, ask lots of questions:

Why do things fall down?
Why won't my sled work on the sidewalk?
What is a star?
Why did the cat scratch me?
Why aren't all people treated fairly?
How do we know about atoms?

You no doubt asked many of the same questions. In a lifetime, we ask literally thousands of questions—questions to gain information about ourselves and our world. Each question is an attempt to understand, to organize better the experiences we have had. They become the basis for the knowledge that we hand down from generation to generation.

Scientists ask only questions that have specific characteristics. First, the questions must deal with concepts upon which we can agree. Why aren't all people treated fairly? is not a scientific question because its answer depends on different definitions of *fair*—definitions that depend on the values and emotional response of the person asked. On the other hand, How do we know about atoms? is a scientific question. Knowledge accumulated during centuries of investigation has resulted in a definition of the atom upon which everyone agrees. A second characteristic of a scientific question is that it must be able to be answered by experimentation. Normally, Why did the cat scratch me? cannot be answered experimentally because we cannot duplicate the event. If we could, we could vary the circumstances and discover what combination motivates the cat to scratch. The requirement that we be able to answer a question by experimentation helps assure us that we can agree upon the answer, that the answers will become part of the knowledge base.

Asking questions that can be answered by experimentation allows scientists to agree upon the answers and describe their observations in common terms. However, the answers to many questions change over a span of centuries, sometimes even over a span of a few months. How, you might ask, can the answers change? Because the experiments we can perform change. As we develop more-sophisticated ways of observing nature, we gain new perspectives. Our concepts of space, time, and matter have changed as we have been able to explore the space beyond our earth, to observe objects moving at incredibly high speeds, and to "see" smaller and smaller pieces of matter. Each new perspective adds new answers, answers that modify our view of nature.

When Kevin asks, "Why doesn't my sled work on the sidewalk?" he is beginning to be a scientist. His question can be answered by experimentation. But he needs to ask and answer other questions—questions that enable him to see patterns: "Will it work on the lawn? On a wet lawn? On snow covered with dirt?"

You may have done puzzles in which you are given a sequence of numbers and asked to predict the next one: 2, 4, 6, ?. To solve such a puzzle, you look for a pattern. Once you find a pattern, you can use it to predict the next number. Kevin has to do much the same thing with his answers. He looks for a pattern as he tries the sled on various surfaces.

Were patterns all that concerned us, we could be content with a list of patterns—a list of observations, so to speak. But science tries to place a series of patterns within a broader pattern, several broader patterns within still broader patterns, and so forth. In short, scientists try to understand the patterns. In the process they build theories.

We can illustrate the increased power of theories with an everyday example. In a letter to Ann Landers, a woman complained about her mother-in-law, who would habitually arrive an hour ahead of the prescribed time for dinner. The daughter-in-law recognized the pattern and responded by inviting her an hour later than she really wished her to arrive. At this point she observed a single pattern. The immediate problem is solved but not really understood. What if the two women were to meet for a concert? Should the daughter-in-law add an hour to the starting time? Without understanding the overall problem—looking for broader patterns and developing a theory—the daughter-in-law cannot answer this question. Only when she looks at other situations can she build a theory of her mother-in-law's behavior. Is her mother-in-law habitually early for all invitations or only for the daughter-in-law's? Is she early for movie invitations as well as for dinner invitations? Broader and broader patterns lead to a theory that is ultimately more useful.

Asking questions, recognizing patterns, and building theories help define science. Physics is one of several disciplines that share this approach to knowing. As you study physics in the chapters that follow, you will share the knowledge accumulated by thousands of physicists over a span of the last 400 years. As you tackle the task of learning about the theories of intellectual giants like Galileo, Newton, Maxwell, Einstein, and Curie, please bear in mind the words of Didacus Stella, a Roman general:

> *Pygmies placed on the shoulders of giants can see more than the giants themselves.*

Compared to Newton and Einstein, we are all intellectual pygmies. Yet their knowledge can become ours, granting us an even broader and richer understanding of our world. This gift is, after all, what makes us human.