Making Connections

6. Select one of the elements listed in **Table 4**.
   (a) Where does it come from, how is it extracted, and what is it used for?
   (b) Does it pose any health or environmental hazards? How should it be handled?
   (c) Do the advantages of having this element available outweigh the drawbacks? To help you decide, separate your findings into two categories: advantages and drawbacks. Write a paragraph summarizing your findings and explaining your position.

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1.2 Developing a Model of the Atom

empirical knowledge: knowledge coming directly from observations

theoretical knowledge: knowledge based on ideas created to explain observations

model: a mental or physical representation of a theoretical concept

analogy: a comparison of a situation, object, or event with more familiar ideas, objects, or events

theory: a comprehensive set of ideas that explains a law or a large number of related observations

In all aspects of our lives, we can achieve understanding through observations (experience). The same is true in science: Understanding comes from observing the natural world and trying to make sense of those observations. All scientific knowledge can be classified as either empirical (observable) or theoretical (non-observable). Generally, **empirical knowledge** comes first, and can be as simple as a description or as complex as a powerful scientific law. For example, the physical and chemical properties of some elements were known empirically for thousands of years before we had a theory to explain these properties. This is a common occurrence: Empirical knowledge is usually well developed before any explanation is generally accepted within the scientific community. Although scientific laws are important statements summarizing considerable empirical knowledge, they contain no explanation. For an explanation—an answer to the question "Why?"—a theory is required.

So far in this chapter, you have encountered only empirical knowledge of elements, based on what has been observed. But why do the properties of elements vary across the periodic table? Why are groups of elements similar in their physical and chemical properties? Can we explain the chemical formulas of compounds formed from elements? An answer to these and other questions about elements requires a theory about what makes up elements.

Curiosity leads scientists to try to explain nature in terms of what cannot be observed. This step—formulating ideas to explain observations—is the essence of **theoretical knowledge** in science. Albert Einstein referred to theoretical knowledge as "free creations of the human mind."

It is more challenging to communicate theoretical knowledge than empirical knowledge because ideas are, by definition, abstract and cannot be seen. Theoretical knowledge can be communicated in a variety of ways such as words, symbols, **models**, and **analogies**. The difference between an analogy and a model is not always obvious. Models are representations (**Figure 1**). Analogies are comparisons. For example, some properties of a liquid can be explained using the analogy of a crowd of people in a confined space.

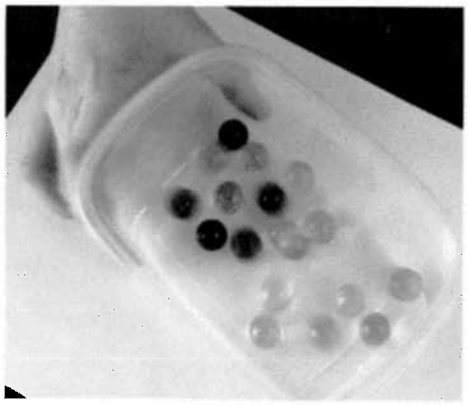

Figure 1
A physical model to represent the motion of particles described by the kinetic molecular theory of gases could be a vibrating box containing marbles. In what ways is this model useful in describing air in a sealed container? In what ways is it deficient?

Theories are dynamic; they continually undergo refinement and change. To be acceptable to the scientific community, theories must

- *describe* observations in terms of non-observable ideas;
- *explain* observations by means of ideas or models;
- successfully *predict* results of future experiments; and
- be as *simple* as possible in concept and application.