Models in Science

A large part of scientific inquiry is the building, testing, and revising of models. Scientists use models to represent nature in a way that they can visualize and manipulate. Models can be used to represent systems that are too small to be seen or are inaccessible for study—atoms for instance, or systems that are too large to see—such as our solar system or universe. They can also be used to visualize phenomena that might be invisible, such as electromagnetic waves or magnetic fields. Often models are simplified representations that allow scientists to focus on the features of an object or system that are important to their study. Models typically used in science include physical models, scale models, mental models, mathematical models, and computer models.

Physical models are physical representations of objects and systems that enable us to visualize and manipulate things we may not be able to otherwise. **Scale models** are a specific type of physical model in which the objects or other aspects of the system are sized in proportion to how they are found in nature. A globe is an example of a scale model, where Earth is represented on a much smaller scale, but the relative sizes among continents and surface features are kept in proportion to their actual sizes.

Mental models are conceptual representations we use to describe an object or phenomenon. For example, scientists have constructed many mental models to describe how electrons and protons are arranged in an atom. For decades, scientists were able to observe the effects of the structure of atoms by the atoms' behavior, but they did not have the technology to observe an atom directly, so they needed to construct mental models to explain atomic behavior.

Mathematical models are a type of manifestation of mental models, in which the system is explained by a set of mathematical equations. Weather forecasters use mathematical models to represent the interactions among various weather-related conditions, such as humidity, temperature, and wind speed. Meteorologists' mathematical models enable them to use existing conditions to forecast what the weather will be like in the near future. Scientists often program computers with the information and equations from their mathematical models in order to create **computer models** of scientific phenomena. Computer models predict and explain phenomena by making pictures of what would be if nature were to follow their mathematical rules.

Scientists use models to explain how things work in nature. A model can almost never represent all of the complexity found in the actual object or system, but scientists must develop a model that accurately represents the behavior or features that are important to their study. In some cases, the assumptions made in designing a model will introduce flaws that become apparent with further research. For example, when the wave model for electromagnetic radiation was first developed, it helped explain many properties of electromagnetic radiation, such as refraction and diffraction. However, when scientists also assumed that, as a wave, electromagnetic radiation requires a medium in which to travel like water and sound waves—the model became flawed and led to many failed experiments in which researchers tried to measure the "ether" through which they thought electromagnetic waves would travel. Ultimately, scientists learned that the wave model for electromagnetic radiation works very well in certain respects, but has its limitations. Understanding the strengths and limitations of any model is a foundation of good science.