

Section 2

Models in Science

Key Concept Models are ways of representing real objects or processes to make the natural world easier to understand.

What You Will Learn

- Physical models and mathematical models are two common types of scientific models.
- Theories and laws are models that describe how the universe works.

Why It Matters

Models allow scientists to study phenomena that may be impossible to investigate in the natural world.

A crash-test dummy, a mathematical equation, and a road map are all models that represent real things. A **model** is a representation of an object or a process that allows scientists to study something in greater detail. Models allow scientists to change variables without affecting or harming the subject that they are studying. For example, scientists use crash-test dummies to study the effects of car accidents on people.

Types of Models

Models can represent things that are too small to see, such as atoms. Models can also represent things that are too large to see entirely, such as Earth. Models can be used to explain the past and present and to predict the future. Two common kinds of scientific models are physical models and mathematical models.

Standards Check Why are different-sized models used to represent different things?



Physical Models

Physical models are models that you can touch. Physical models often look like the things they represent, but physical models have limitations. For example, because Earth is nearly a sphere, a globe most accurately represents Earth. But to make a map,

you make a flat model of Earth's surface. In the process of making a map, you change the distances between points, and the map becomes inaccurate, as shown in **Figure 1**.



Figure 1 This orange is a physical model of Earth. Notice how the shapes of the continents change when the orange peel is flattened.

Mathematical Models

A *mathematical model* is made up of mathematical equations and data. Some mathematical models are simple. These models allow you to calculate things such as how far a car will travel in an hour or how much you would weigh on the moon. Other models are so complex that computers are needed to process them. **Figure 2** shows a graph made by computer models of population growth. Because so many variables affect population changes, scientists use computers to create mathematical models of population growth.

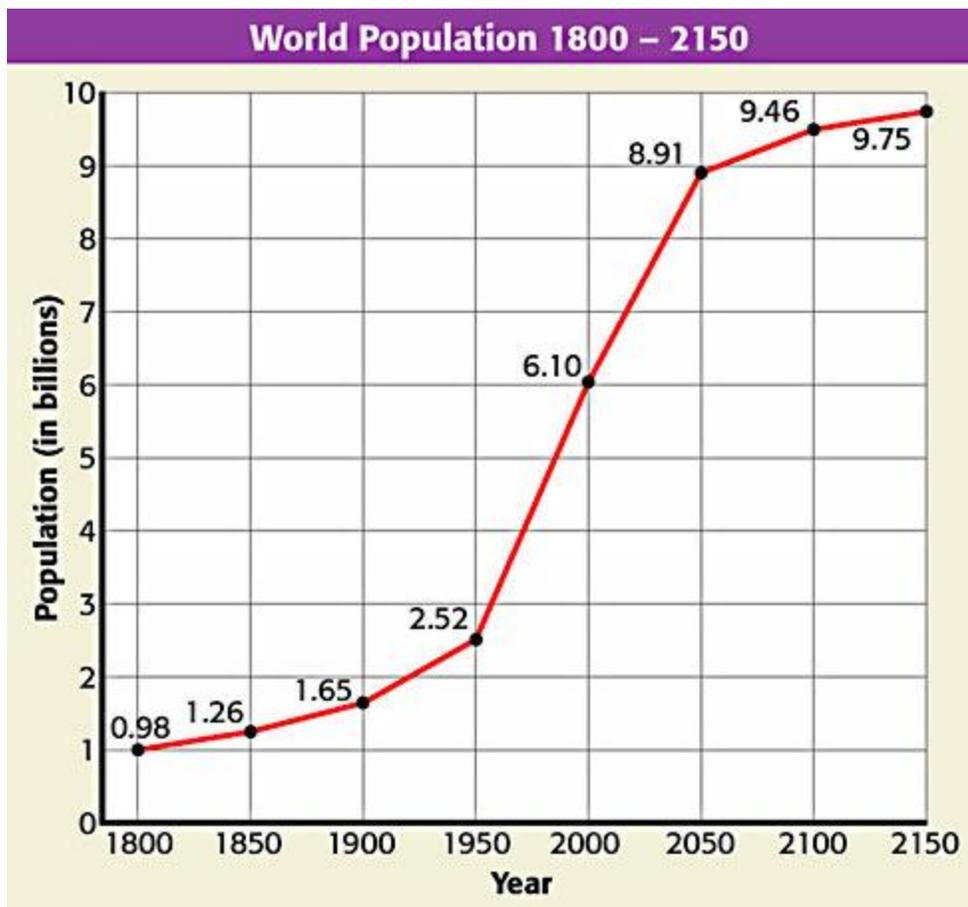


Figure 2 This graph was the product of mathematical models that were processed by a computer.



Computer Models

You may wonder how scientists build models that require large amounts of data. Powerful supercomputers that can make more than 30 trillion calculations every second help scientists process data. Computers are used to make these models because the models require many data sets. To calculate every variable by itself would take years. Some computers, however, can perform all of the calculations at the same time, almost instantly.

Standards Check Explain why computers are necessary to make complex mathematical models.

Combinations of Models

Scientists commonly use computers to build mathematical and physical models. For example, you can imagine how hard it is to predict the weather next week. So, how can scientists predict Earth's climate 100 years from now? Scientists use computers to run mathematical models that track the variables that affect Earth's climate. **Figure 3** shows one climate model that simulates climate change.

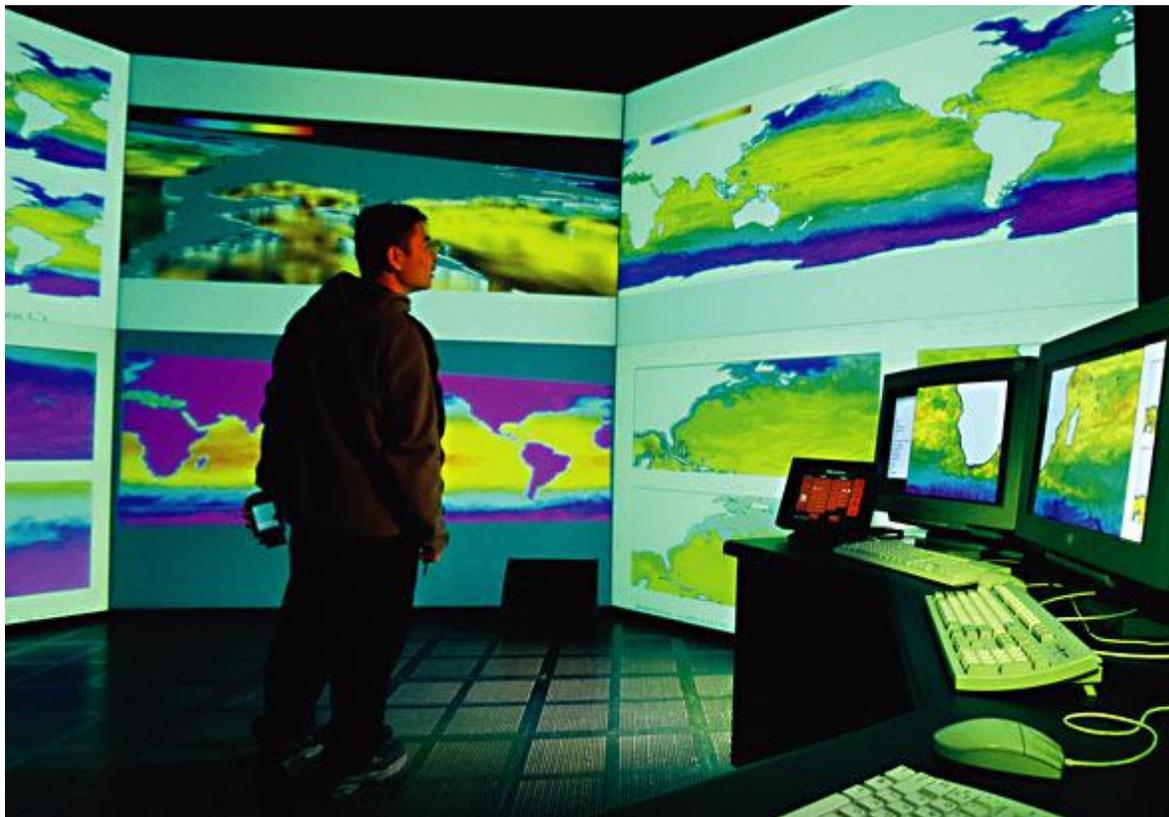


Figure 3 Supercomputers help scientists create very complex models that predict the results of climate change.

To model climate change, researchers use information about current and past land and ocean-water temperatures around Earth. They also use information about weather patterns, ocean currents, and carbon dioxide levels in the atmosphere. These models do not make exact predictions about future climates, but they estimate what might happen if variables change.

Patterns in Nature

It is possible for scientists to make models because events in nature often follow predictable patterns. For example, if you drop a ball from a certain height, you can predict how high it will bounce. Another pattern in nature is yearly migration of some animals. Observing patterns in nature is the basis of science. These observations lead to explanations about the way the world works. Although these explanations are supported by observations, they may not be accurate. For example, **Figure 4** shows that the sun appears to move across the sky. For thousands of years, people observed this pattern and incorrectly concluded that Earth was the center of our solar system.



Figure 4 For thousands of years, people watched the sun appear to move across the sky. From this pattern, they incorrectly developed a theory that Earth was the center of our solar system.

Theories and Laws

Observing patterns in the natural world can lead to the development of scientific theories and laws. The words *law* and *theory* have special

meanings to scientists. In science, a **law** is a statement or equation that reliably predicts events under certain conditions. A theory is not a guess, or hypothesis. A **theory** is a scientific explanation that encompasses many scientific observations and may include many hypotheses and laws.

You may think that scientific theories are less important or less useful than scientific laws. But theories are very powerful explanations of the way the world works. Theories do not eventually become laws. Instead, theories are fully formed scientific explanations that are supported by evidence and data from many scientific disciplines.



Theories and Scientific Observations

Like all scientific theories, the theory of an Earth-centered universe was supported by scientific evidence. But even if a theory is supported by most scientific evidence, the theory may not be correct.

Over time, scientists observed movements of planets across Earth's sky that did not fit the theory of an Earth-centered universe. Sometimes, planets appeared to be moving backward across Earth's sky. Four moons were seen traveling around Jupiter. The movement of Jupiter's moons showed that objects can revolve around objects other than Earth. Scientists developed a new theory to incorporate their new observations. They suggested that Earth and the other planets in our solar system travel around the sun, as shown in **Figure 5**.

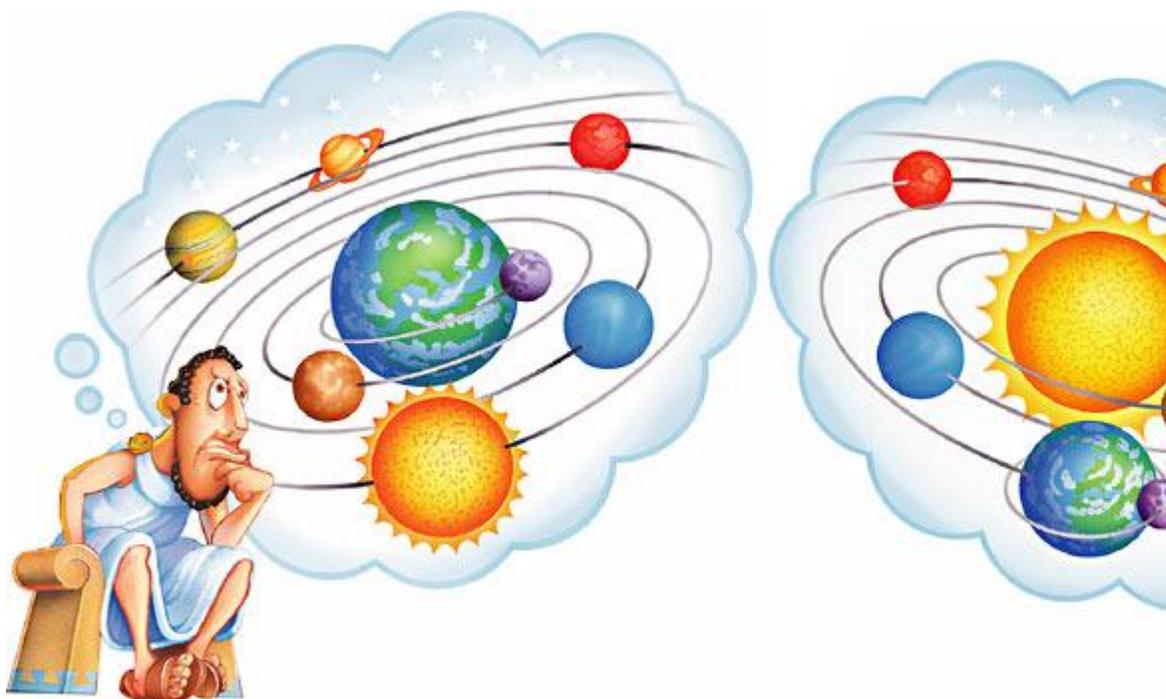


Figure 5 Early astronomical theories stated that Earth was the center of the solar system. This theory was challenged by evidence that Earth travels around the sun.

Laws and Theories

In 1665, Sir Isaac Newton discovered the *law of universal gravitation*. This law states that all objects in the universe, including the sun and planets, attract each other with a force called *gravity*. Scientists used this law to strengthen the theory of a sun-centered solar system. Gravity holds the planets in their orbits as they travel around the sun.

Standards Check What effect can new observations have on a scientific theory?





Limitations of Models

Although models are important scientific tools, all models are limited because they are simplified versions of the systems that they try to explain. Simplification makes a model easy to understand and use, but information is left out when a model is made.

All models can change. Models can change if a scientist finds new data or thinks about concepts in a new way. Scientists work to continually improve the models that we use to understand the world. Sometimes, new technology challenges existing models. Or, technology may help create new models that allow us to understand the world differently.

Section Summary

- Scientists must choose the right type of model to study a topic.
 - Physical models, mathematical models, and computer models are common types of scientific models.
 - Events in nature usually follow patterns. Scientists develop theories and laws by observing these patterns.
 - Theories and laws are models that describe how the universe works. Theories and laws can change as new information becomes available.
 - All models have limitations, and all models can change based on new data or new technology.
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