1.2 Paths to Discovery: Scientific Methods

Section Objectives

- **Identify the steps that make up scientific methods.**
- **Explain how the meteorite-impact hypothesis developed.**

Through research, scientists seek to explain natural phenomena and solve mysteries of the earth. Over the years, the scientific community has developed organized, logical approaches to scientific research, called **scientific methods.** Scientific methods are not a set of sequential steps that scientists invariably follow. Rather, they are guides to scientific problem solving.

State the Problem

Scientific inquiry often begins as a result of **observation.** Simply put, observation is using the senses of sight, touch, taste, hearing, and smell to gather information about the world. When you notice thunderclouds forming in the summer sky, that is an observation. So, too, is feeling the cool, smooth surface of polished marble or hearing the roar of rapids around the bend of a river.

Observations often lead to questioning. What causes tornadoes to form? Why is oil found only in certain locations and not in others? What causes a river to change its course? Asking questions like these is one way of stating the problem to be investigated through scientific methods.

One problem that has long puzzled scientists is the extinction of the dinosaurs. For more than 135 million years, these huge reptiles dominated the earth. Then, about 65 million years ago, the dinosaurs and three-fourths of all the other species on the earth died out. Scientists wondered what could have caused such a mass extinction.

Gather Information

To investigate a problem, such as the extinction of the dinosaurs, scientists gather information. An important means of gathering information is **measurement.** Measurement involves the comparison of

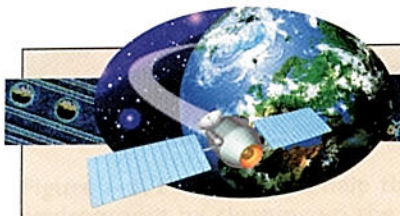
Figure 1-6. One means of gathering information is through careful measurement. In this photo, geologists are measuring a crack in the earth's surface caused by an earthquake.

Figure 1–7. Geologists found a clay layer with high-iridium content in Montana.

some aspect of an object or phenomenon with a standard unit, such as a meter, a Celsius degree, or a kilogram. For example, when you measure a rock and find that it is 20 cm long, you are comparing the length of the rock with a unit of measure—one centimeter. What other units of measure can you name?

Accuracy is important in scientific measurements. Inaccurate measurements can lead to an incorrect conclusion. Scientists often use special tools such as micrometers and calipers to help them make precise measurements.

In the case of the dinosaurs, scientists examined the fossil record for clues to what happened 65 million years ago. They studied rock layers throughout the world that date from the time when the dinosaurs disappeared. The scientists discovered that in certain locations these layers contain iridium, a substance that is uncommon in earth rocks, but common in meteorites. Scientists then measured the amount of iridium in the rock layers. They found that the rock layers in these particular locations contained nearly 160 times the amount of iridium normally found in earth rocks. The scientists searched for an explanation that would relate the iridium measurements to the disappearance of the dinosaurs.



SCIENCE & TECHNOLOGY

The Internet

Do you want to go for a spin on the information highway? Do you want to venture into cyberspace and "surf the Net"? Then take a trek on the Internet, a powerful information system that brings the electronic frontier to your doorstep.

The Internet began as an experimental computer network created by the United States Department of Defense during the Cold War. Its purpose was to safeguard scientific and military research in the event of a nuclear attack. If one or two computing centers were lost, the remaining sites in the network would continue to process and communicate vital data.

Today the backbone of the Internet consists of more than 2 million host computers in about 60 countries worldwide. At least 20 million computer users access these Internet computers using ordinary telephone lines. Once connected, they are able to send and retrieve information around the world with just a few keystrokes or mouse clicks.

Access to so much information makes the Internet an exciting place for scientific research. From on-line photographs of earthquake damage to space shuttle experiments displayed in real time, the information on the Internet is

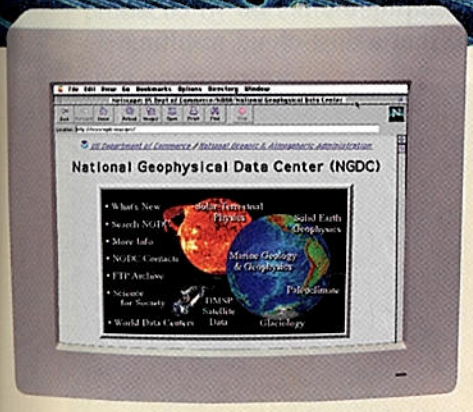
Form a Hypothesis

Once a problem has been stated and information gathered, a scientist may propose a **hypothesis,** (HIE-POTH-uh-sus, pl. hypotheses), a possible explanation or solution to the problem. A hypothesis is based on facts, which are often established through observation.

For example, the scientists who discovered the iridium-laden rock layers proposed the meteorite-impact hypothesis to explain the extinction of the dinosaurs. This hypothesis states that about 65 million years ago, a giant meteorite crashed into the earth. The impact of the collision raised enough dust to block the sun's rays for many years. The earth probably became colder, plant life began to die, and many animal species, including the dinosaurs, became extinct. As the dust settled over the earth, it formed a layer of iridium-laden rock.

Test the Hypothesis

Once a hypothesis has been proposed, it should be tested. A hypothesis will not be accepted by the scientific community unless there is evidence to support it.



This Web page is home to the National Geophysical Data Center (www.ngdc.noaa.gov).

extremely current. Much of this information is difficult or impossible to find elsewhere.

The Internet also makes scientific collaboration easier than ever before. For the cost of an Internet subscription, anyone can quickly share research with an international audience. Various discussion groups and electronic message (e-mail) services help scientists stay informed about new discoveries and make valuable contacts with other professionals in their field.

The best way to get to know the Internet is to explore it firsthand. One popular vehicle for doing this is the World Wide Web, which combines text with graphics such as video clips or photographs. The Web enables users to travel the Internet by simply clicking on highlighted text or icons.

For the new user, there is on-line help available as well as numerous books and magazines about the Internet. Throughout this textbook, you will find Web addresses directing you to Web sites known as home pages. These home pages relate to specific earth science topics and contain links to other useful Web sites.

How might the Internet enhance scientific methods?

On-line information about the Internet and the World Wide Web is available at many sites, including the University of Maryland at **www.cs.umd.edu** and Pacific Lutheran University at **www.plu.edu.** Please note that the standard **http://** prefix has been omitted from all Web addresses in this textbook.

A hypothesis is tested by **experimentation.** An experiment is a scientific procedure carried out according to certain guidelines. An experiment enables scientists to test each **variable** that might prove or disprove the hypothesis. A variable is a factor in an experiment that can be changed. An experiment set up to test a variable is called a *controlled experiment*.

To ensure that only one variable is tested in an experiment, scientists will also run a control. The control will have the same conditions as the experiment except for the variable being tested. For example, to test the effects of sunlight on a green plant, a scientist would grow two identical plants. To control the experiment, the scientist would vary the amount of sunlight reaching one plant, while keeping the amount of sunlight constant on the other plant. The scientist would then observe both plants and record the observations. What is the variable in this experiment?

In the study of earth science, setting up controlled experiments to test a hypothesis is often difficult, and sometimes impossible. The scientists studying the disappearance of the dinosaurs, for instance, cannot bombard the earth with a giant meteorite to see if it produces life-threatening conditions.

Recently, however, scientists have developed computer models that enable them to test hypotheses by simulating certain conditions. For example, scientists have entered information into a computer about the possible climatic conditions during the period when the dinosaurs became extinct. They found that a dust cloud resulting

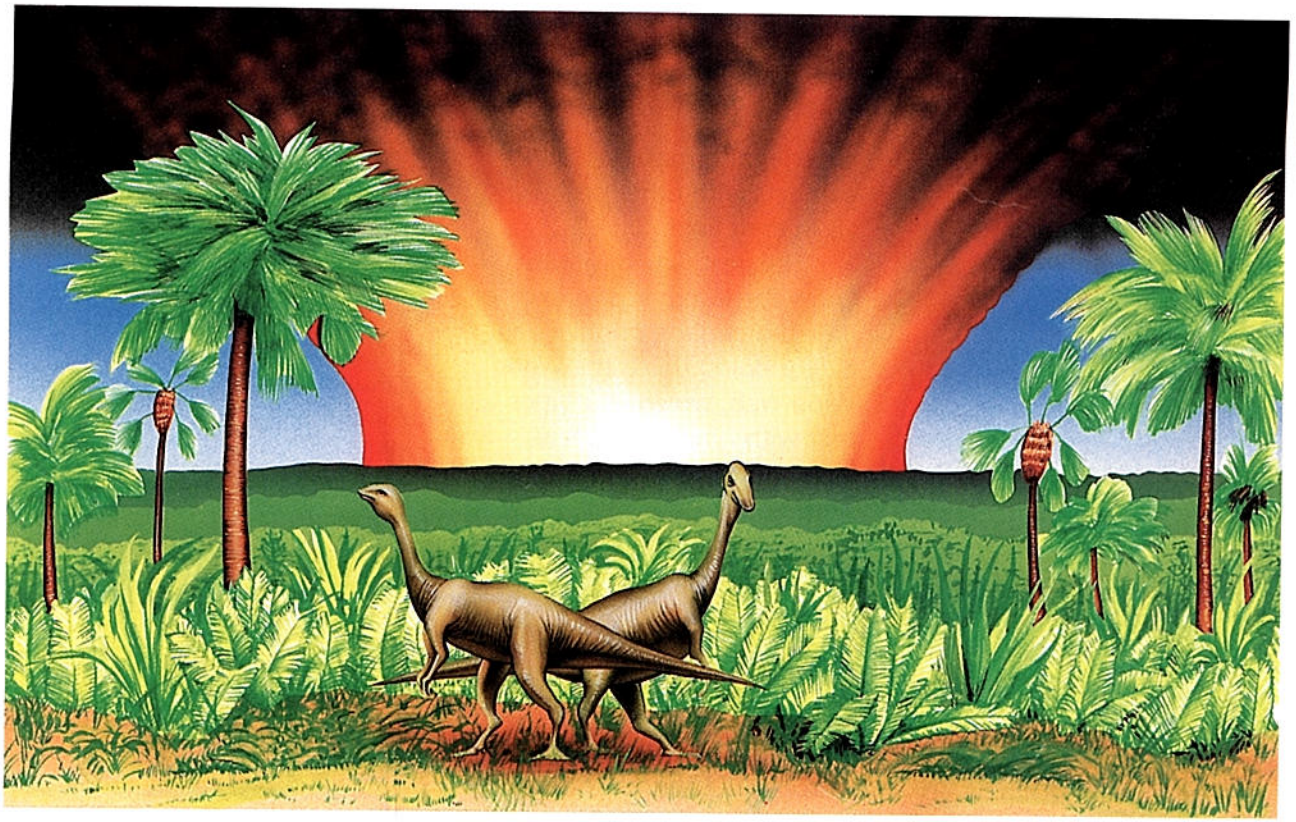


Figure 1-8. According to the meteorite-impact hypothesis, a huge meteorite crashed into the earth 65 million years ago. Dust from the impact blocked out the sun and led to the extinction of the dinosaurs.

Figure 1–9. Meteor Crater, in the northern Arizona desert, is 1,300 m in diameter and nearly 200 m deep. The crater is visible proof of the explosive power of a meteorite hitting the earth.

from the collision of a meteorite 10 km in diameter would have been sufficient to lower the earth's temperature considerably.

When experimentation is impossible, scientists often make more observations to gather evidence that will either support or discredit the hypothesis. The hypothesis is then tested by examining how well it fits or explains all the known observations.

To test the meteorite-impact hypothesis further, scientists had to find additional evidence that the iridium in the rock layers on earth had once come from meteorites. Scientists again examined the rock layers and this time they found strangely deformed particles of the mineral quartz. Previously this type of quartz had been found only near meteorite craters, at nuclear-testing sites, and in moon rocks. Scientists concluded that such quartz particles could only have been produced by an extremely powerful explosion. The collision of the earth with a huge meteorite, they reasoned, could have produced such an explosion.

INVESTIGATE!

To learn more about scientific methods, try the In-Depth Investigation on pages 20–21.

State a Conclusion

After many experiments and observations, scientists generally reach conclusions regarding the correctness of the hypothesis being considered. Depending on how well the hypothesis fits the known facts, it may be accepted as stated, altered slightly, or discarded altogether.

The fossil evidence for the meteorite-impact hypothesis does not prove that a meteorite was responsible for the extinction of the dinosaurs. The evidence does show, however, that an abnormally high amount of meteorite dust reached the earth at that time. Thus, until new evidence is found or a better hypothesis is proposed, the meteorite-impact hypothesis serves as one possible explanation of why the dinosaurs disappeared.

Section 1.2 Review

1. What are scientific methods?
2. Define *hypothesis*.
3. How do scientists test hypotheses?
4. Summarize the evidence scientists found to support the meteorite-impact hypothesis.
5. How have scientific methods contributed to the development of modern science?