## Section 2
# Scientific Methods in Earth Science

**Key Concept** Scientists conduct careful investigations by following standard methods that allow them to collect data and communicate results.

### What You Will Learn
- Scientific methods are a series of steps followed to solve problems.
- A scientist must be open to new ideas and must present investigations that can be replicated.
- Scientific investigations often lead to new questions and further investigation.

### Why It Matters
Following a series of steps will help you investigate and solve problems.

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Imagine that you are standing in a thick forest on the bank of a river. Suddenly, you hear a booming noise, and you feel the ground begin to shake. You notice a creature's head looming over the treetops. The creature's head is so high that its neck must be 20 m long! Then, the whole animal comes into view. You now understand why the ground is shaking. The giant animal is *Seismosaurus hallorum* (SIEZ moh SAWR uhs hah LOHR uhm), the "earth shaker," shown in **Figure 1.**

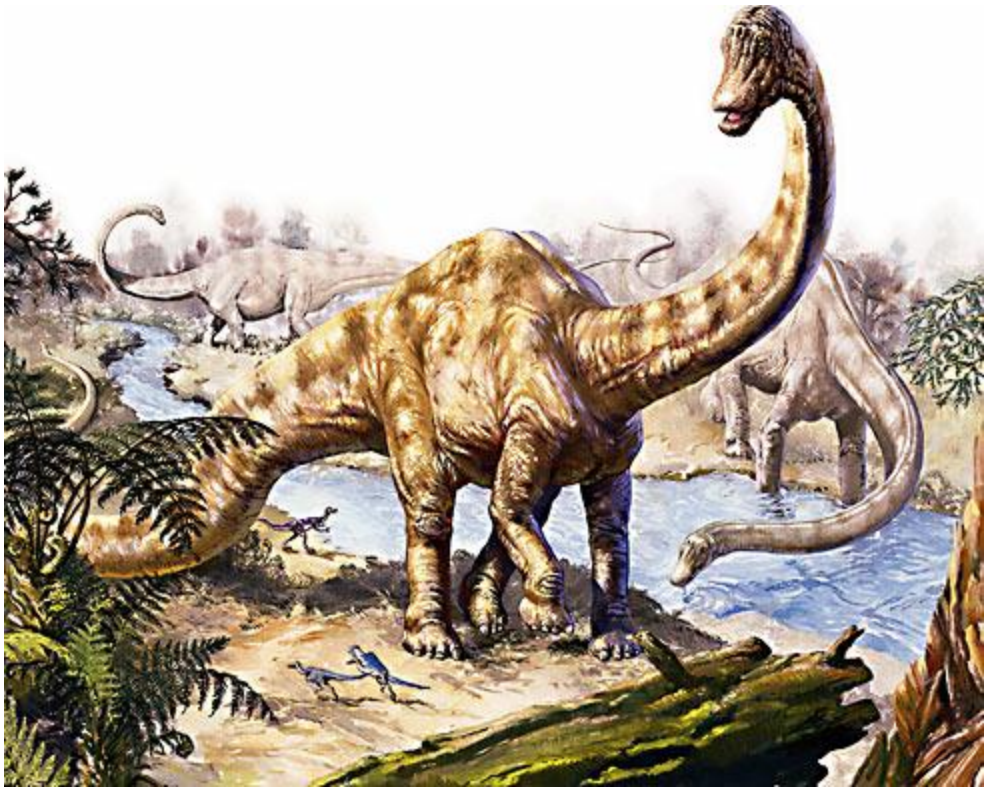

**Figure 1** Seismosaurus hallorum is one of the largest dinosaurs known to have existed.

## Learning About the Natural World

The description of the *Seismosaurus hallorum* is not based on imagination alone. Scientists have been studying dinosaurs since the 1800s. Scientists gather bits and pieces of information about dinosaurs and their environment. Then, scientists recreate what dinosaurs might have been like hundreds of millions of years ago. But how do scientists put all of the pieces together? How do they know if they have discovered a new kind of dinosaur? Asking such questions is the beginning of a process that scientists use to learn more about the natural world.

## Forming a Hypothesis

When scientists want to investigate a question, they form a hypothesis. A **hypothesis** (plural, *hypotheses*) is a possible explanation or answer to a question. It is sometimes called an *educated guess.* The hypothesis is a scientist's best answer to the question. But a hypothesis can't be just any answer. Someone must be able to test the hypothesis to see if it is true.

From his observations and previous knowledge about dinosaurs, Gillette formed a hypothesis about the bones. He said that the bones, shown being excavated in **Figure 3,** came from a kind of dinosaur not yet known to scientists. This hypothesis was Gillette's best testable explanation. To test it, Gillette would have to do a lot of research.

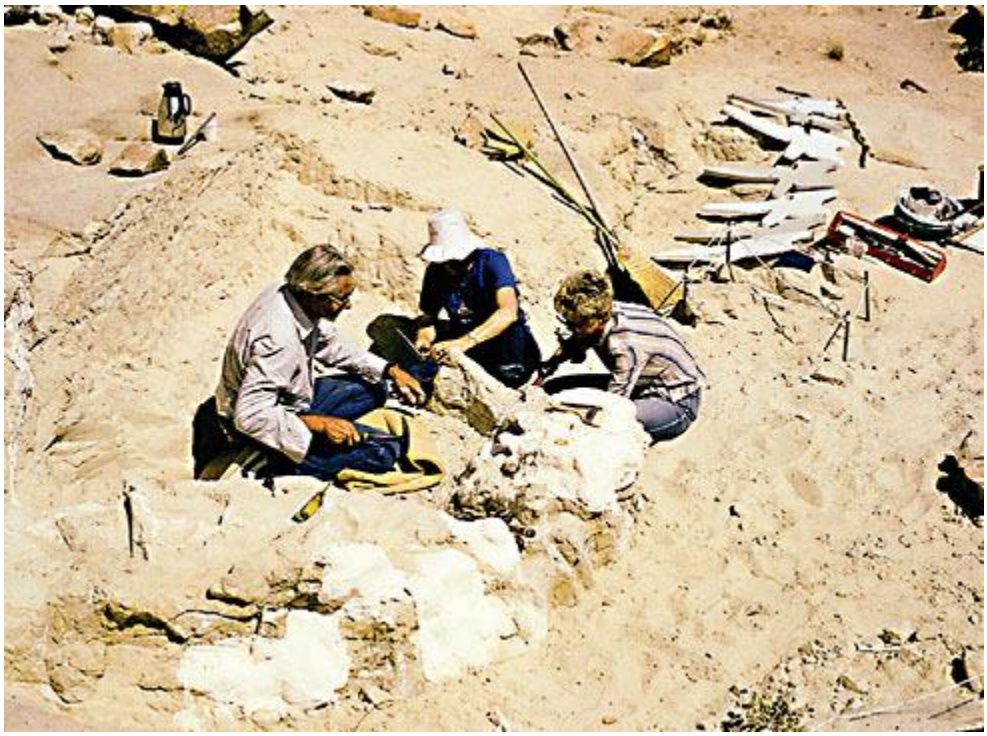

**Figure 3** Gillette and his team had to dig the bones out of the rock carefully before studying them.

### Making Predictions

Before scientists test a hypothesis, they make predictions. To make a prediction, you say what you think will happen in your experiment or investigation. Predictions are commonly stated in an if-then form. For example, Gillette could make the following prediction: "*If* the bones are from a dinosaur not yet known to scientists, *then* at least some of the

bones will not match any dinosaur bones that have been studied before." Sometimes, scientists make many predictions about one experiment. After predictions are made, scientists can do experiments to see which predictions, if any, support the hypothesis.

## Testing the Hypothesis

To learn if an idea can be supported scientifically, scientists must test the hypothesis. They do so by gathering data. **Data** are any pieces of information gathered through observations or experimentation. The data can help scientists tell if the hypothesis is correct. To test his hypothesis, Gillette took measurements of the bones, as **Figure 4** shows. He compared his measurements with the measurements of bones from known dinosaurs. He also visited museums and talked with other scientists.

**Figure 4** To test his hypothesis, Gillette took hundreds of measurements of the bones.

**Standards Check** Why do scientists need to test their hypotheses?

### Testing with Experiments

To test a hypothesis, a scientist may conduct a controlled experiment. A **controlled experiment** tests only one factor, or

*variable,* at a time. All other variables remain constant. By changing only one variable, scientists can see the results of just that one change.

During experiments, scientists must keep accurate records of everything that they do and observe. Accurate record keeping is important for maintaining a scientist's credibility with other scientists and society.

### Testing without Experiments

Not all investigations are made by doing controlled experiments. Sometimes, it is not possible to use a controlled experiment to test something. Also, some scientists depend on observations more than they depend on experiments to test their hypotheses. By observing nature, scientists can often collect large amounts of data about their hypotheses. When large amounts of data support a hypothesis, the hypothesis is probably correct.

## Analyzing the Results

After they finish their tests, scientists must analyze the results. Analyzing the results helps scientists form explanations based on the evidence that they have collected. To arrange their data, scientists often make tables and graphs. **Table 1** shows how Gillette organized his data. When Gillette analyzed his results, he found that the bones of the unknown dinosaur did not match the bones of any known dinosaur.

**Table 1 Comparison of Hip Region Bones**

| | *Diplodocus* | *Apatosaurus* | *Unknown dinosaur* |
|---|---|---|---|
| Top View | | | |

| | | | |
|---|---|---|---|
| |  |  |  |
| Side view |  |  |  |

## Drawing Conclusions

After analyzing the results of their tests, scientists must decide if the results support the hypothesis. Discovering that a hypothesis is not true can be as valuable as finding out that it is true. If the hypothesis is not supported, scientists may repeat the investigation to check for mistakes. Or they may look at the original question in a new way, ask new questions, and form new hypotheses. New questions and hypotheses can lead to new investigations and discoveries.

From all of his work, Gillette concluded that the bones found in New Mexico, shown in the model in **Figure 5,** were from an unknown dinosaur. He concluded that the dinosaur was about 35 m (110 ft) long and had a mass of 30 to 70 metric tons. The dinosaur certainly fit the name that Gillette gave it— *Seismosaurus hallorum,* or the "earth shaker."

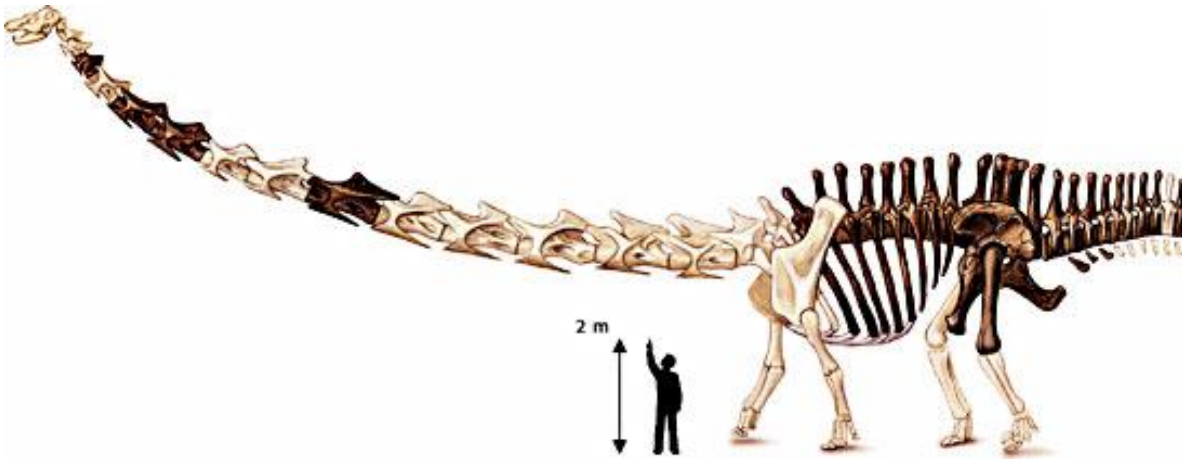


**Figure 5** This model of the skeleton of Seismosaurus hallorum is based on Gillette's research. The bones shown in the darker color are the bones that have been found so far.

## Communicating Results

After finishing an investigation, scientists communicate their results. By doing so, they share what they have learned. Scientists communicate by writing reports and by giving talks. They can also put their results on the Internet.

Science depends on sharing information. Sharing allows other scientists to repeat experiments to see if they get the same results. Openness and replication of experiments maintain a scientist's believability with other scientists and society.

Sharing information also helps scientists compare hypotheses and form consistent explanations. When sharing information, scientists sometimes learn that similar investigations gave different results. When different results are found, scientists do more studies to find out if the differences are significant.

**Standards Check** What are two reasons that scientists share the results of their investigations?

## Is the Case Closed?

Often, the results of an investigation are reviewed year after year as new evidence is found. Sometimes, the new evidence supports the original hypothesis even more. Other times, the hypothesis is questioned. For example, scientists are debating whether *Seismosaurus* is a new genus. Some scientists argue that Gillette's dinosaur belongs to the genus *Diplodocus,* an already known genus. The best way to solve this argument would be to discover at least one more skeleton of the dinosaur. If such a discovery does not support the hypothesis, a new hypothesis may be formed. Either way, Gillete continues the investigation, as shown in **Figure 6.**

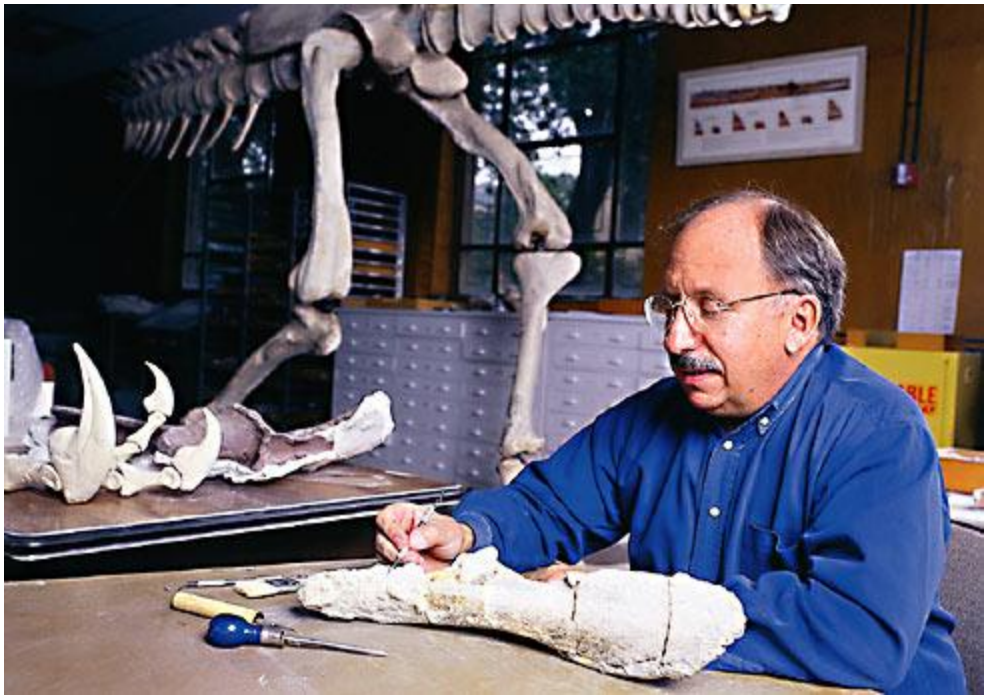

**Figure 6** David Gillette continues to study the bones of Seismosaurus hallorum for new views into the past.

## Section Summary

- Scientific methods are the ways in which scientists follow steps to answer questions and solve problems.
- The steps used in scientific methods are to ask a question, form a hypothesis, test the hypothesis, analyze the results, draw conclusions, and communicate results.
- A controlled experiment tests only one factor at a time so that scientists can determine the effects of changes to just that one factor.
- Accurate record keeping, openness, and replication of results are essential to maintaining a scientist's credibility.
- When similar investigations give different results, the scientific challenge is to verify by further study whether the differences are significant.