Name _____ Class _____ Date _____

CHAPTER 1 The World of Physical Science

SECTION 2

Scientific Methods

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the steps in scientific methods?
- How do scientists form a hypothesis?
- What do scientists do before telling others about their experimental results?

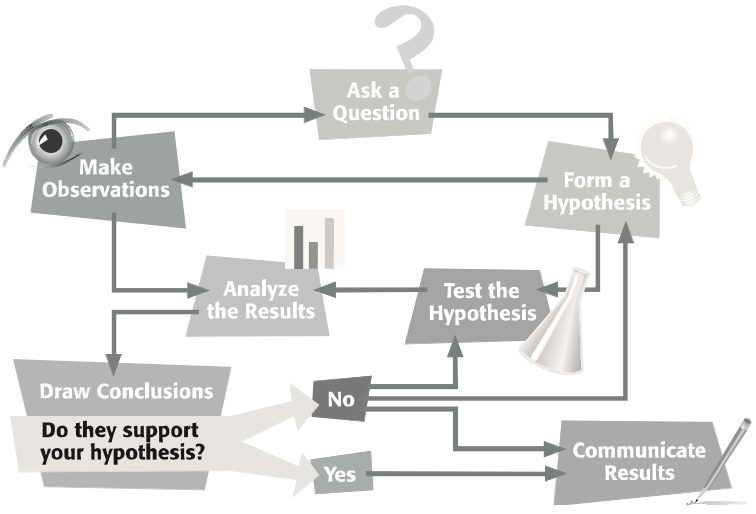
What Are Scientific Methods?

Two scientists wanted to find a better way to move ships through the water. They thought that studying the way penguins swim might give them some ideas about how to improve ships. In this section, you will learn how these scientists used scientific methods to answer their questions.

Scientific methods are the ways in which scientists answer questions and solve problems. As scientists look for answers, they often use the same steps. However, there is more than one way to use the steps. Look at the figure below. ☑

This figure shows six steps that are part of most scientific methods. Scientists may use all of the steps or just a few steps during an investigation. They may repeat some of the steps or do the steps in a different order.

Steps of Scientific Methods



STUDY TIP

Outline As you read this section, make a chart showing how two scientists used the steps in scientific methods to improve ships.

READING CHECK

1. Describe What are scientific methods?

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TAKE A LOOK

2. Identify What is the usual next step after analyzing results?

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Why Do Scientists Ask Questions?

Asking questions helps scientists focus on the reason for an investigation. Questions arise at every step of scientific methods. However, the question that becomes the focus of an investigation often comes from observation. **Observation** is the process of using your senses to collect information.

REAL-WORLD EXAMPLE

Two engineers, James Czarnowski and Michael Triantafyllou, wanted to improve the way ships moved through the water. An *engineer* is a scientist who builds things using scientific knowledge. Czarnowski and Triantafyllou used scientific methods to improve how ships move. ☑

READING CHECK

3. Describe What is an engineer?

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The two engineers studied how the propellers on ships work. They found that ships use a lot of fuel to push themselves through the water. They asked the question, "How can we make ships move faster with less fuel?" That is, they wanted to improve the efficiency of ships. A ship that is *efficient* does not use as much fuel as other ships to travel the same distance.

The engineers looked to nature to find a way to make ships more efficient. They observed sea animals to learn how some of them swim faster than others. The engineers observed that penguins are very efficient swimmers. Penguins have stiff bodies, just like ships. However, they are able to push themselves through the water with ease.

Now, the scientists had a new question. They wanted to know, "How can we make a ship that moves through the water more easily?"

Penguins use their wings as flippers to "fly" underwater. As their wings are pulled inward, they push against the water. This movement pushes the penguins forward.

TAKE A LOOK

4. Identify How do penguins use their wings?

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How Do Scientists Form a Hypothesis?

Once a scientist has made observations and asked a question, he or she is ready to predict an answer. This is called forming a hypothesis. A **hypothesis** (plural, *hypotheses*) is a possible explanation for, or guess at, an answer to a question. ☑

READING CHECK

5. Describe What is a hypothesis?

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A POSSIBLE ANSWER FROM NATURE

The ship engineers had observed the slow movements of ships and the fast swimming of penguins. Their observations led them to form a hypothesis. They guessed, "A propulsion system that imitates the way a penguin swims is more efficient than a system that uses propellers."

ANOTHER WAY TO WORD PREDICTIONS

Scientists often state their predictions as *if-then statements*. For example, the engineers' prediction might have been: "If we use flippers instead of a propeller to move a boat, then it will be more efficient." An if-then statement makes it easier to determine whether your prediction is true.

The table below gives some examples of if-then statements.

Critical Thinking

6. Explain How does an if-then statement make it easier to determine whether a prediction is true?

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"If" statement	"Then" statement
If car A uses less gasoline than car B during the same trip . . .	. . . then car A is more efficient than car B.
If more force is needed to stop an object with a large mass than an object with a small mass . . .	. . . then _____ force is needed to stop a large truck than a compact car.
If a grape and an orange fall at the same rate . . .	. . . then, when dropped from the same height, they will hit the ground at _____ time.

TAKE A LOOK

7. Complete In the table, complete the "then" statements.

Why Do Scientists Test a Hypothesis?

All hypotheses must be testable. A scientist tests a hypothesis by gathering more information or by doing an experiment. Scientists test a hypothesis to find out if it answers their question correctly.

CONTROLLED EXPERIMENTS

One way to test a hypothesis is to do a controlled experiment. Suppose you want to know how much air will make a basketball bounce highest. You gather 15 basketballs that are all made by the same company. All the basketballs are the same size and are made of the same material. You divide the basketballs into three groups.

You inflate the balls in the first group with the amount of air that the maker recommends. You put more air in the balls in the second group. You put less air in the balls in the third group. Then, you drop each ball from the same height and measure how high it bounces. This is a controlled experiment.

A *controlled experiment* is an experiment in which only one factor changes at a time. The factor that changes is called the *variable*. In your experiment, the variable was the amount of air in the balls. Everything else about the balls was the same. ☑

READING CHECK

8. Define What is a variable?

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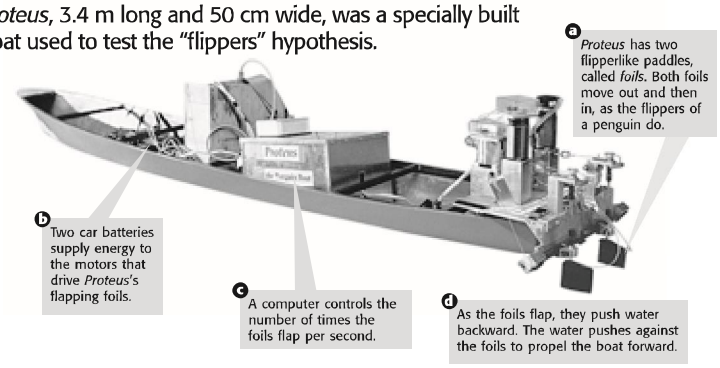
Doing a controlled experiment allows a scientist to determine the effects of a variable more easily. Suppose you had used basketballs that were not all made of the same material. It would have been harder to determine whether the air or the material caused some to bounce higher than others.

Sometimes, it is not possible to do a controlled experiment. In these cases, scientists test their hypotheses by making observations or doing research.

BUILDING A TEST BOAT

The engineers who were trying to design an efficient boat thought they should test their hypothesis by building one. They built *Proteus*, the penguin boat. It had flippers like a penguin so that the scientists could test their hypothesis about propulsion through the water.

Proteus, 3.4 m long and 50 cm wide, was a specially built boat used to test the "flippers" hypothesis.



TAKE A LOOK

9. Identify What does *Proteus* use instead of a propeller to move through the water?

_____

How Did the Scientists Test *Proteus*?

Instead of using many groups, you can do a controlled experiment by repeating the test several times. For each test, you change one factor. That's what the engineers did with *Proteus*.

The engineers took *Proteus* to the Charles River in Boston. For each test, they paddled the boat across the river for the same distance with the same weather. The variable was the flapping rate of the flippers. ☑

Proteus, the "penguin boat," was tested in the Charles River in Boston.

The engineers collected data on the speed of the boat and the amount of energy used to move its flippers. **Data** (singular, *datum*) are pieces of information collected from experiments. The data recorded for the first trip were considered the control data. The control data were compared with the data from all of the other trips. ☑

The experimental part of the test began with the second trip. The engineers changed the variable by increasing the flapping rate of the flippers. Then, they recorded the speed and the energy used during the trip. The engineers made several more experimental trips. Each time, they set a different flapping rate and collected data on the energy used and the speed.

When all the data were collected, the engineers compared the results of the trips. They interpreted their results to find out which flapping speed used the least energy. That is, they learned which was the most efficient.

READING CHECK

10. Identify What two factors stayed the same when *Proteus* was paddled across the river?

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_____

11. Identify What was the variable for each trip?

_____

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READING CHECK

12. Define What are data?

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How Do Scientists Analyze Results?

After scientists collect data, they must analyze it. To *analyze* data means to interpret what the data mean. One way to analyze data is to organize them into tables and graphs. Tables and graphs make the patterns in the data easier to see. ☑

READING CHECK

13. Describe What does it mean to analyze data?

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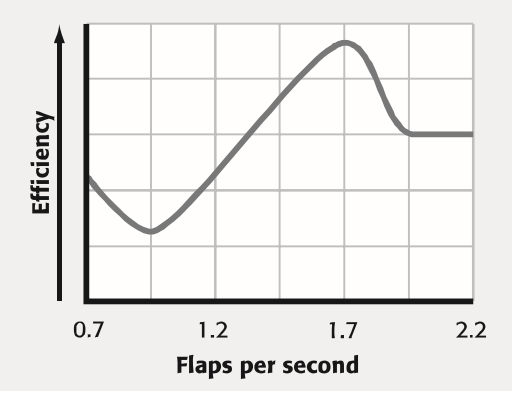
It's always a good idea to perform your experiment several times. Repeated tests can tell you whether your data are accurate. If you get similar results every time, then you can be more sure that the results are accurate. If the results support your hypothesis, you know that your hypothesis is probably correct.

ANALYZING *PROTEUS*

The engineers collected data about the energy used and the speed of each trip. They used the data to calculate *Proteus*'s efficiency. Then, they made a graph of their data, shown below.



This graph shows the efficiency of *Proteus* when the flippers are moving at different rates.

Math Focus

14. Analyze Which flapping rate gave *Proteus* the highest efficiency?

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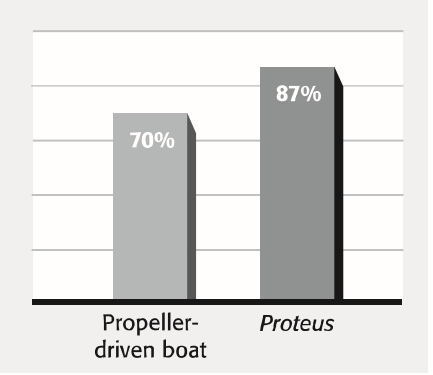
The scientists also used the data to compare the efficiency of *Proteus* with the efficiency of a regular boat. That analysis is shown in the bar graph below.



This graph shows the efficiency of *Proteus* compared with the efficiency of a propeller-driven boat.

Math Focus

15. Compare Which boat was more efficient? How much more efficient was it?

_____

_____

What Are Conclusions?

At the end of the investigation, you must draw a conclusion. You do this by looking at your analysis. The results tell you whether your hypothesis was correct. If it was, then you can say that your results support your hypothesis. That is your conclusion.

It's also possible that you will come to a different conclusion. You may decide that your results do not support your hypothesis. If so, you can change the procedure, gather more information, or ask new questions. Whether your hypothesis is supported or not, the results are always important.

PROTEUS CONCLUSION

The engineers found that penguin propulsion was more efficient than propeller propulsion. They concluded that the results supported their hypothesis. ☑

The scientists were able to reach this conclusion because they did many tests. They were careful to control all the factors except the variable. They measured everything accurately. This showed that their results were not accidental. Their data showed the same relationship many times. Therefore, their results were probably accurate.

Drawing a conclusion to support your hypothesis usually leads to more questions. More questions lead to more investigations. This is how scientific progress continues.

READING CHECK

16. Explain Why did the engineers think that their hypothesis was correct?

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How Do Scientists Share Results?

Other scientists will want to know your results. Some will want to conduct their own tests based on your results. There are three ways to communicate the results of your investigation to them. You can use any or all of them. ☑

Method of communicating results	Audience
Write a paper for a scientific journal.	scientists and others who read the journal
Give a talk.	scientists and others who attend the talk
Create a Web site.	anyone interested in the work

READING CHECK

17. Identify What are three ways scientists communicate the results of their investigations?

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Sharing your results allows other scientists to continue your work. Sharing also makes it possible for others to do your experiments and support your results.

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Section 2 Review

SECTION VOCABULARY

data any pieces of information acquired through observation or experimentation	**observation** the process of obtaining information by using the senses
hypothesis a testable idea or explanation that leads to scientific investigation	**scientific methods** a series of steps used to solve problems

1. Identify Fill in the missing steps in the table.

Steps in Scientific Methods
Form a hypothesis.
Test the hypothesis.

2. Infer A *synonym* is a word that has the same meaning as another word. What are two synonyms for *hypothesis*?

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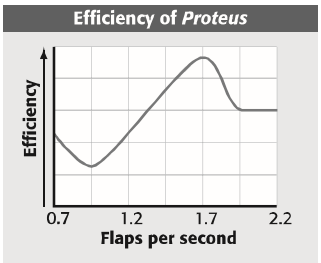
_____

3. Interpret a Graph According to the graph, at what flapping rate was *Proteus* least efficient?



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4. Define What is a controlled experiment?

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5. Describe How can a scientist do a controlled experiment if it is not possible to use several different groups?

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6. Explain How can a scientist test a hypothesis if it is not possible to do a controlled experiment? Give two ways.

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