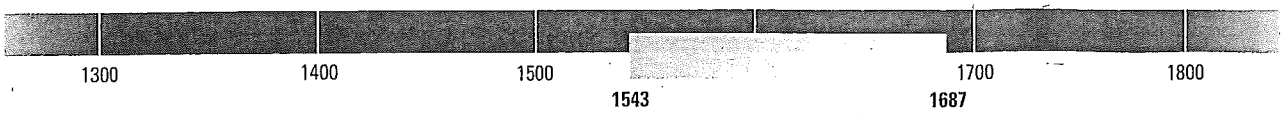


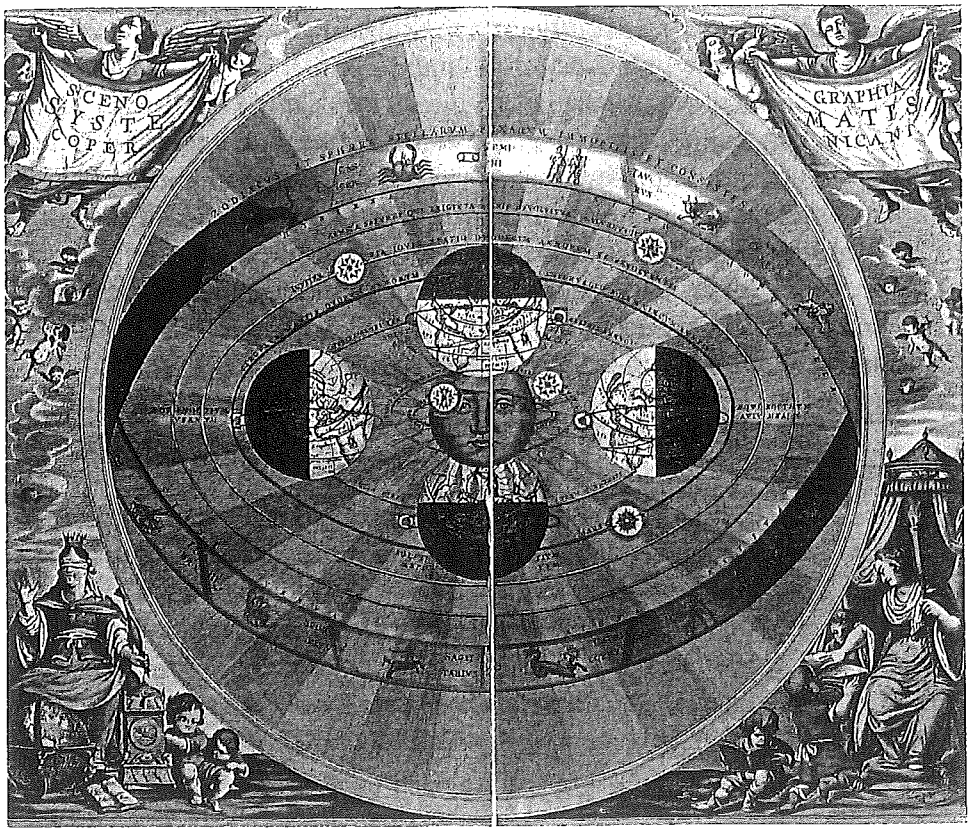
LESSON 4

Scientific Revolution

Clearly, by 1543, Nicolaus Copernicus, the Polish physician and astronomer, did not have much longer to live. For years, Georg Joachim, his young assistant, had begged Copernicus to publish his revolutionary theories on planetary motion. Copernicus theorized that the sun, not the earth, was the center of the universe. Copernicus claimed he needed more time to provide mathematical and factual support for these theories. But, on his deathbed, he agreed to publish.

Copernicus died later that year. But on the day he died, Joachim brought him the first copy of his work, *On the Revolution of the Celestial Spheres*.

The publication of Copernicus's theory began a movement that would change people's view of the world. Theories that had been accepted for hundreds of years would be challenged by scientific experiment and observation.



◄ *In Ptolemy's system, the earth is circled by water, air, fire, and seven planets—including the moon and sun. The plan shown here illustrates Copernicus's sun-centered theory.*

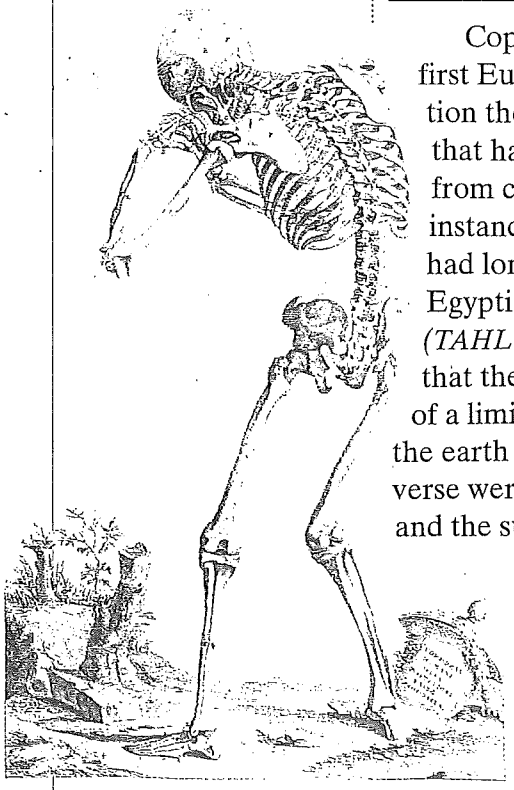
THINKING FOCUS

What was the Scientific Revolution?

Key Terms

- Scientific Revolution
- scientific method
- hypothesis

New Visions of the Natural World



▲ *In order to carry out his experiments and make drawings such as this, Vesalius sometimes stole the bodies of people who had been hanged.*

■ *How did the scientific discoveries of Copernicus offer a new view on the world?*

Copernicus was one of the first European scientists to question theories about the universe that had been handed down from classical philosophers. For instance, educated Europeans had long accepted the theory of Egyptian astronomer Ptolemy *(TAHL uh mee),* which stated that the earth was at the center of a limited universe. Between the earth and the limits of the universe were the moon, the planets, and the sun.

The Universe

After years of observation and mathematical research, Copernicus concluded that the universe was sun-centered. Drawings demonstrating Copernicus's theory appear on the preceding page and on page 516 of the Minipedia. According to this theory, the planets, including earth, revolve around the sun in circular orbits. The German astronomer Johannes Kepler later proved that the planets' orbits were oval.

Protestant and Catholic leaders alike opposed Copernicus's theory. The Protestants claimed that the Bible said the earth stood still. The Catholics claimed that the earth and its human beings—not the sun—held the central place in the universe. In 1610, the Catholic church declared that all followers of Copernicus were heretics.

The Human Body

While Copernicus and Kepler explored the universe, Flemish physician Andreas Vesalius explored the human body. His observations challenged the works of Galen, a second-century physician whose theories based on the dissection of animals were widely accepted. Vesalius's thorough dissection of the human body enabled him to write a much more accurate description of human anatomy. Vesalius's book stimulated new research in the field of anatomy. Some results stemming from continued research are discussed in Making Decisions on pages 358 and 359.

Vesalius and Copernicus both dared to question and reevaluate accepted theories. Their emphasis on careful observation of the natural world marked a new era in scientific thinking, a period that became known as the **Scientific Revolution.** ■

Galileo and the Church

The Italian astronomer and physicist Galileo continued the work of Copernicus. He greatly admired the Polish astronomer's genius. Like Copernicus and Vesalius, Galileo recognized the importance of relying on observation rather than blindly trusting classical authorities.

Through observation and experimentation, Galileo tested the theory of falling bodies. This theory, which held that heavy objects fall faster than lighter objects, had been accepted since about 300 B.C. Galileo made his own observations by dropping objects of various weights and shapes from differen

heights. He then developed a mathematical formula showing that all bodies—no matter what their shape or weight—would fall at the same speed.

Galileo also applied his method of observation to astronomy. In 1609, he developed a telescope that was larger and more powerful than any made before. Galileo was the first person to observe sunspots, Jupiter's moons, and Saturn's rings. He also provided new information about the rough, crater-marked surface of our moon, which had previously been considered smooth.

Galileo's observations of one planet, Venus, provided strong support for Copernicus's theory. But when Galileo argued the point in his *Dialogue Concerning the Two Chief World Systems,* the Catholic church reacted. Because the idea of a sun-centered universe went against Catholic beliefs, the publication was placed on the *Index of Prohibited Books*. The inquisition in Rome condemned Galileo in 1616. Threatened with torture, Galileo, now an old man, denied his belief in Copernicus's ideas.

But his spirit was not broken. Upon leaving his trial, he is believed to have said of the earth, "but still it moves." Galileo spent the remaining eight years of his life under house arrest on his estate near Florence, where he continued his scientific activities.

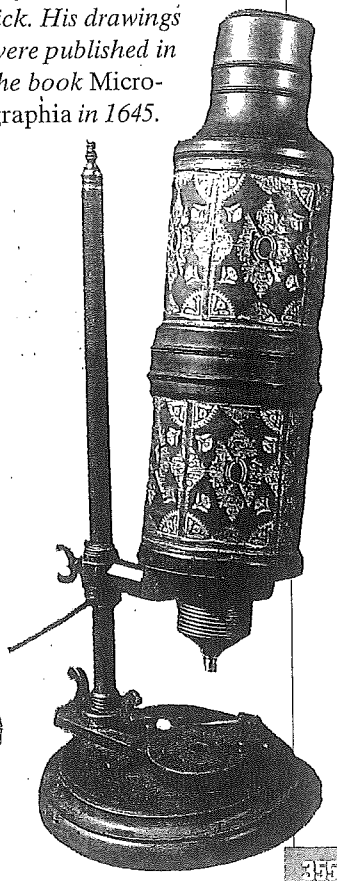
The church's victory was short-lived. By the late 1630s, the theory of the sun-centered universe was well established, and the age of science was under way. ■

How Do We Know?

HISTORY *Church officials banned books whose ideas threatened the church's power and authority. By reading the books listed in the* Index of Prohibited Books, *modern scholars have determined which ideas the church considered to be most dangerous.*

■ *Why was the Catholic church threatened by Galileo's ideas?*

▼ *Using this compound microscope, Robert Hooke examined cork, snowflakes, and tiny organisms, such as the tick. His drawings were published in the book* Micrographia *in 1665.*



The Scientific Method

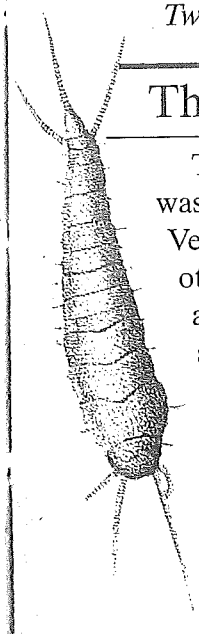
The Scientific Revolution was pioneered by Copernicus, Vesalius, and Galileo. Many other thinkers and writers also contributed to its success.

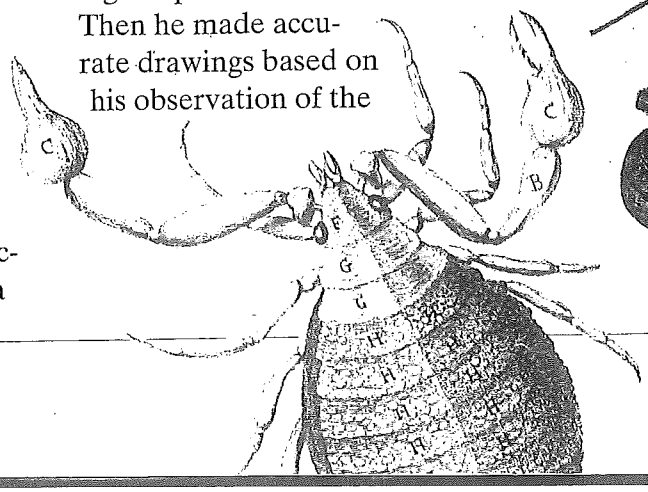
Francis Bacon

One such thinker was Francis Bacon, an English philosopher. In his book *Novum Organum,* published in 1620, Bacon stressed the importance of observation and experimentation leading to the statement of general principles about the natural world. This way of doing scientific research is now known as the **scientific method.**

A key part of this process, according to Bacon, was forming a hypothesis. A **hypothesis** is an assumption that can be tested by investigation. For example, Robert Hooke, an Englishman who developed the compound microscope in 1665, hypothesized that a microscope with two lenses could produce a clearer image of a magnified object.

This hypothesis was then tested by an experiment, and the results were recorded. Hooke experimented by adjusting and readjusting the placement of the lenses. Then he made accurate drawings based on his observation of the





Isaac Newton was praised by the English poet Alexander Pope in the following rhyme: "Nature, and nature's laws lay hid in night/ God said, 'Let Newton be!' and all was light."

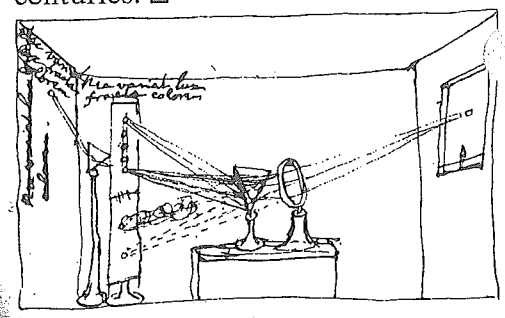
magnified objects. Finally, the collected data were analyzed and a conclusion was drawn. Hooke's data indeed revealed that objects could be more closely observed using a microscope with two lenses.

Bacon's method helped others in the Scientific Revolution organize and formulate their research. The scientific method is still at the core of scientific research.

Isaac Newton

Sir Isaac Newton, English scientist, astronomer, and mathematician, also used the scientific method. Many scientists before Newton made observations and recorded data. However, Newton's biggest contribution was in providing an explanation for the universe that was very large in scope. His great ability lay in interpreting data and drawing accurate conclusions about the nature of the universe.

Newton's studies of how light passes through a prism helped explain how rainbows are formed.



Born in 1642, the year Galileo died, Newton expanded and perfected many of Galileo's theories. Like Galileo, Newton was fascinated by falling objects. According to the story, while in the country one day, Newton saw an apple fall from a tree branch. He hypothesized that there must be some force pulling the apple to the ground. He further hypothesized that the same force that pulls an object to earth keeps the moon and planets in orbit around the sun. After much observation and many experiments, Newton announced that a force called gravity holds the universe together. He described this theory and many others in the *Mathematical Principles of Natural Philosophy* published in 1687.

■ *What was revolutionary about the scientific method?*

During the Reformation and the Scientific Revolution, people began to reexamine their spiritual and physical worlds. Freed from having to rely on accepted theories and beliefs, they sought new answers to old questions. This searching set the stage for further reformation in the 18th and 19th centuries. ■

REVIEW

1. **FOCUS** What was the Scientific Revolution?
2. **CONNECT** What did the new scientific thinkers and the leaders of the Reformation have in common?
3. **BELIEF SYSTEMS** Why was the publication of Vesalius's findings considered revolutionary?
4. **SCIENCE** How did Newton use the scientific method?
5. **CRITICAL THINKING** Which scientific achievements do you think were more important, those of Copernicus or those of Galileo? Explain.
6. **ACTIVITY** Use Bacon's scientific method to answer the following question: Which weighs more, a pound of apples or a pound of lettuce?

Making Hypotheses

Here's Why

You know that a hypothesis is an explanation, based on known facts, that can be tested as more facts become available. To develop a hypothesis, you gather all the information you can about a question or a problem. The hypothesis then becomes the basis of any further testing. You can test a scientific hypothesis through observation or experimentation, as discussed in Lesson 4.

Other subjects, such as history, also invite hypotheses. Some hypotheses about history can never be proved or disproved because of lack of evidence. However, you can continue to test a hypothesis when you find new information.

Suppose you want to explain why the church lost so much of the power it once had. You have read many facts about this in the chapter. You could use these facts to form a hypothesis.

Here's How

Look at the diagram below. It shows the steps involved in making a hypothesis. The arrows indicate that each step leads to the next. To formulate a hypothesis of your own, follow these steps in order:

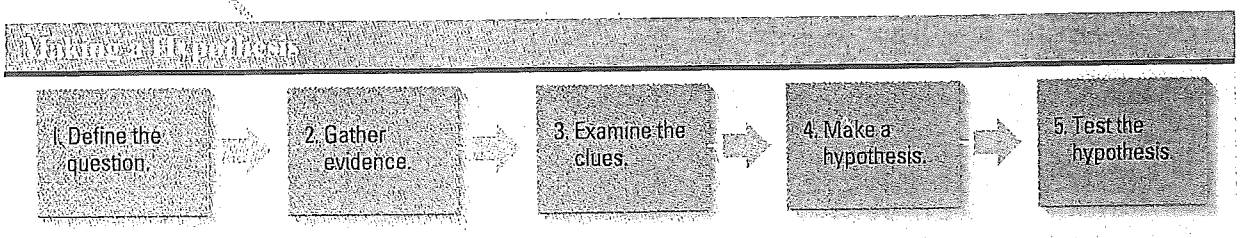
1. **Define the question.** You could ask, for example: What was the primary cause of the decline in church authority between 1300 and 1500?
2. **Gather evidence.** Read through the chapter and list events that caused the church's authority to decline. Your list may look something like this:
   - Secular rulers gained power.
   - The Great Schism caused confusion.
   - Corruption existed within the church.
   - Many groups were asking for reform in the church.
3. **Examine the clues.** Analyze the list. Can the clues be placed under a particular heading? How might the ideas be summarized?
4. **Make a hypothesis.** One example of a hypothesis that shows the primary cause of the decline in church authority between 1300 and 1500 is this: The church did not use its power wisely.
5. **Test the hypothesis.** You can test your hypothesis by reading more about the topic, either in your textbook or in outside sources.

Try It

Now form a hypothesis of your own that answers this question: Why did the Calvinists have such a strict code of behavior? Use what you have learned about the Calvinists in Lesson 3 to complete steps 2–4.

Apply It

Formulate a hypothesis which answers this question: Why do some seventh grade students. make excuses about late homework assignments? Use the five-step process to work out your hypothesis. Write down the facts you used to develop your hypothesis. When you learn new facts about the question, examine them and be prepared to alter your hypothesis to account for the new information.

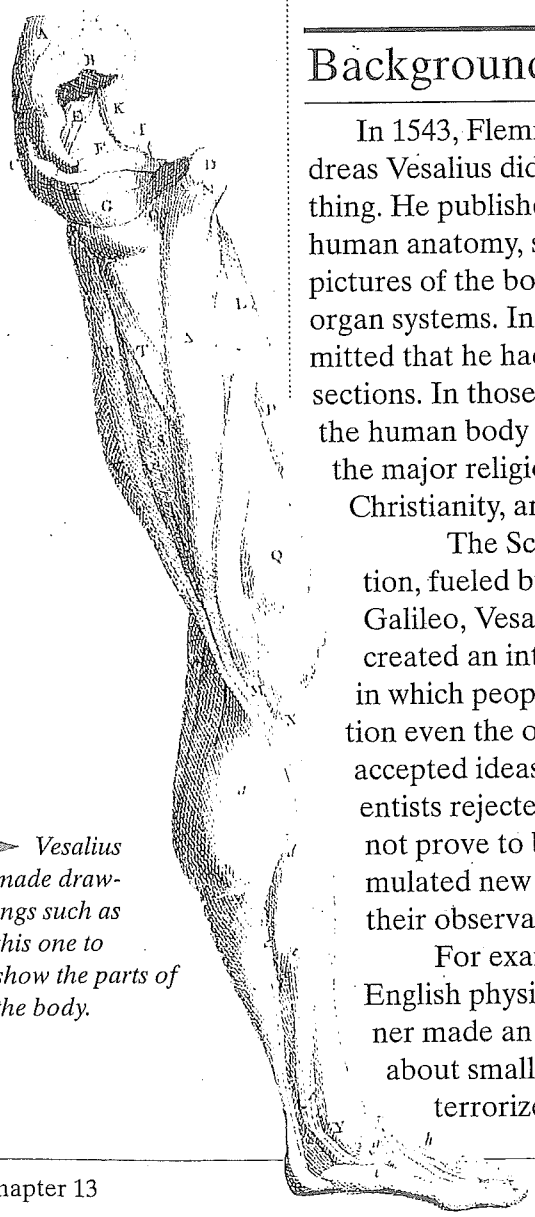


MAKING DECISIONS

Scientific Discoveries

In all corners of the world, I sought for the true and experienced arts of medicine. Not alone with doctors; but with barbers, surgeons, learned physicians, women, magicians, alchemists . . . , with the wise and the simple, I [gathered information] for a foundation of medicine which should be unspotted by fables or babble.

Paracelsus, a Swiss physician, 1493–1541



➢ *Vesalius made drawings such as this one to show the parts of the body.*

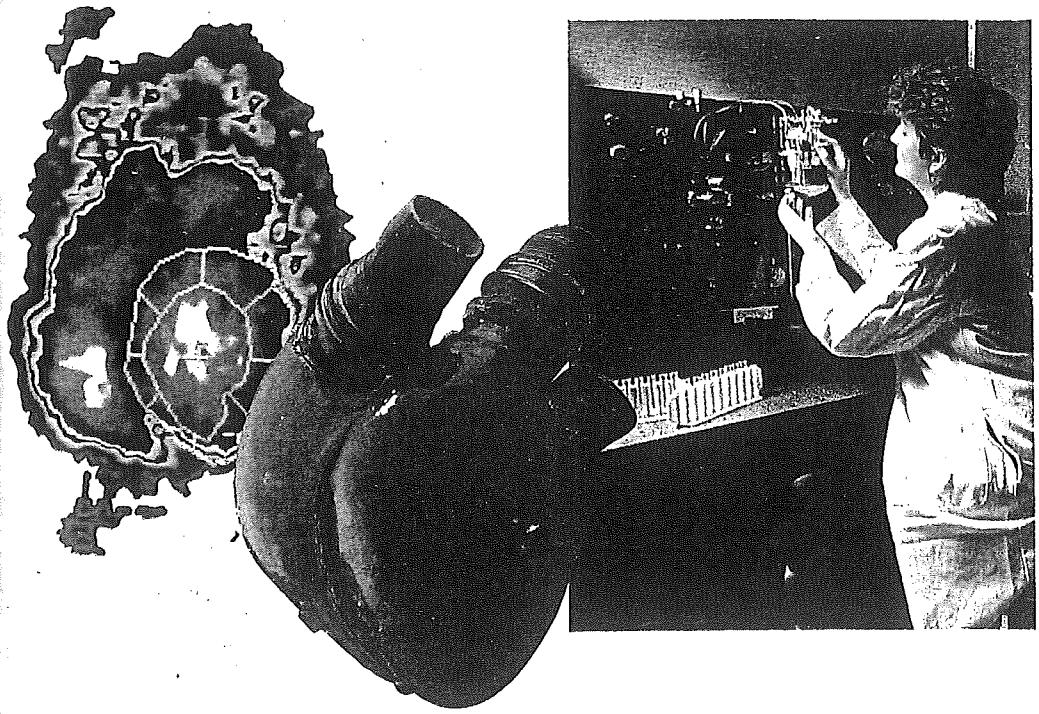
Background

In 1543, Flemish scientist Andreas Vesalius did a shocking thing. He published a book about human anatomy, showing detailed pictures of the bones, muscles, and organ systems. In doing so, he admitted that he had performed dissections. In those days, dissecting the human body was forbidden by the major religions—Judaism, Christianity, and Islam.

The Scientific Revolution, fueled by the courage of Galileo, Vesalius, and others, created an intellectual climate in which people began to question even the oldest and most accepted ideas. Doctors and scientists rejected what they could not prove to be true and formulated new theories based on their observations of the world.

For example, in 1796, English physician Edward Jenner made an observation about smallpox, a disease that terrorized Europe. Milkmaids— young girls who milked cows—rarely contracted the disease. Jenner found that these girls had previously suffered from cowpox, a disease similar to smallpox, but much milder. Victims of both diseases developed infected sores on their skin.

Jenner did an experiment to find out if injecting a person with fluid from a cowpox sore prevented the person from contracting smallpox. A young boy volunteered to be the guinea pig. Several weeks after injecting the boy with fluid from a cowpox sore, Jenner injected the boy with material from smallpox sores. Jenner, the boy, and the boy's mother waited anxiously to see if the boy would come down with smallpox, but the boy remained healthy. By recognizing that cowpox and smallpox were related and conducting a daring experiment, Jenner had found a way to protect people from smallpox.



Magnetic resonance imaging produces pictures of the human body that enable doctors to pinpoint problems before surgery. Today, doctors are also able to use artificial hearts and cell-separation techniques to save lives.

Knowledge and Responsibility

Jenner's discovery was not easy for people to accept at first. Even physicians found it unsettling to think of injecting people with material from infected sores. Was Jenner taking too many risks? Was he sure that injections could do no harm? Should people wait for more proof before submitting themselves to Jenner's procedure?

Decision Point

1. What were the risks and benefits of Jenner's treatment for smallpox? Do you think Jenner was right to test his procedure the way he did? Why?
2. If you had been alive in Jenner's day, would you have wanted to undergo Jenner's treatment? What would you want to ask him before you agreed to the procedure? List the questions you would ask before making this decision.
3. Suppose a researcher discovers a drug that helps cure heart disease. Its side effects are not yet fully known or understood. What information could help you decide whether this new drug should be given to patients? How could you find this information?