# The Process of Science



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# CONCEPT 1 The Process of Science

## Lesson Objectives

The student will:

- describe the scientific method of problem solving.
- list some values of the scientific method of problem solving.
- describe the difference between hypothesis, theory, and scientific law as scientific terms.
- explain the necessity for experimental controls.
- identify components in an experiment that represent experimental controls.
- explain the concept of a model and why scientists use models.
- explain the limitations of models as scientific representations of reality.

## Vocabulary

- controlled experiment
- experiment
- hypothesis
- model
- problem
- scientific law
- scientific method
- theory

## Introduction

Socrates (469 BC - 399 BC), Plato (427 BC - 347 BC), and Aristotle (384 BC - 322 BC) are among the most famous of the Greek philosophers. Plato was a student of Socrates, and Aristotle was a student of Plato. These three were probably the greatest thinkers of their time. Aristotle's views on physical science were, in particular, highly influential and widely accepted until well into the 1300s.

Unfortunately, many of Aristotle's opinions were wrong. Aristotle was a brilliant man without doubt, but he was using a method unsuitable for determining the nature of the physical world. The philosopher's method depended on logical thinking and not on observing the natural world. This led to many errors in Aristotle's views on nature. Let's consider two of Aristotle's ideas as examples.

In Aristotle's opinion, men were bigger and stronger than women, so it was logical to him that men would have more teeth than women do. Thus, Aristotle concluded this as a fact without actually counting the number of teeth in any mouths. Had he done so, he would have found that men and women have exactly the same number of teeth. As another example, Aristotle considered what would happen if he were to drop two balls identical in all ways but mass. In his mind, it was clear that the heavier ball would fall faster than a lighter one would, and he concluded that this must be a law of nature. Once again, he did not consider doing an experiment to see which ball would fall faster.

This conclusion, however, was also incorrect. Eighteen centuries later, Galileo tried this experiment by dropping two balls of different masses off a building (the Leaning Tower of Pisa, according to legend). Galileo discovered, by experimental observation, that the two balls hit the ground at exactly the same time. Aristotle's logical conclusion was again wrong.

## The Scientific Method of Problem Solving

In the 16th and 17th centuries, innovative thinkers were developing a new way to understand the nature of the world around them. They were developing a method that relied upon making observations of phenomena and drawing conclusions that corresponded to their observations.

The **scientific method** is a method of investigation involving experimentation and observation to acquire new knowledge, solve problems, and answer questions. Scientists frequently list the scientific method as a series of steps. Some scientists oppose this listing of steps because not all steps occur in every case, nor do they always occur in the same order. The scientific method is listed here as a series of steps, but you should remember that you are not required to rigidly follow this list. Instead, the scientific method is a valuable tool that provides a basic and adaptable strategy for tackling scientific questions.

**The Steps in the Scientific Method**

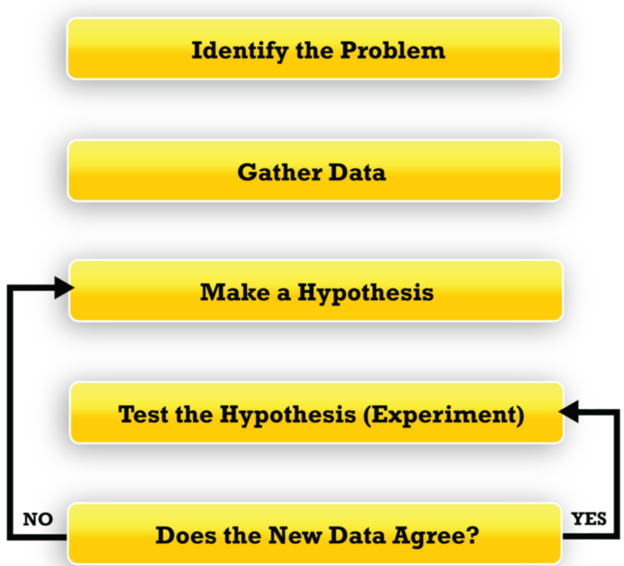
Step 1: Identify the **problem** or phenomenon that needs to be investigated. This is sometimes referred to as "defining the problem."

Step 2: Gather and organize data on the problem. This step is also known as "making observations."

Step 3: Suggest a possible solution or explanation. A suggested solution is called a **hypothesis**.

Step 4: Test the hypothesis by making new observations.

Step 5: If the new observations support the hypothesis, you accept the hypothesis for further testing. If the new observations do not agree with your hypothesis, add the new observations to your observation list and return to Step 3.




Suppose you are required to maintain a large campfire, but you are completely unfamiliar with the property that makes objects combustible (able to burn). The first step in the scientific method is to define the problem. The problem statement for this investigation is: What property makes objects combustible?

The next step is to gather data on the problem. At the beginning, you may be collecting objects at random to put into the fire. It is important to keep good records of what objects were tried and whether or not they burned. A list of organized data (observations) is shown in **Table** 1.1.

**TABLE 1.1: List of Items Tried in the Fire**

| Will Burn | Won't Burn |
|---|---|
| tree limbs | rocks |
| chair legs | bricks |
| pencils | marbles |
| baseball bat | hubcaps |

The list of organized observations helps because now you can focus on only collecting items on the "will burn" list and not waste any effort by dragging items that won't burn to the fire. However, you would soon use up all the items on the "will burn" list, making it necessary to guess what property the "will burn" objects have that allow them to burn. If you had that answer, you could keep the fire going by bringing objects that may not be on the "will burn" list but have the "will burn" property.

The third step in the scientific method is to suggest a hypothesis. A hypothesis is a tentative explanation that can be tested by further investigation. Your guess about what property makes the "will burn" objects combustible is a hypothesis. Suppose you notice that all the items on the "will burn" list are cylindrical in shape, so you hypothesize that "cylindrical objects burn."

The fourth step in the scientific method is to test your hypothesis. To test the hypothesis that cylindrical objects burn, you go out and collect a group of objects that are cylindrical, including iron pipes, soda bottles, broom handles, and tin cans. When these cylindrical objects are placed in the fire and most of them do not burn, you realize your hypothesis is not supported by these new observations. The new observations are the test, but your hypothesis has failed the test.

When the new observations fail to support your hypothesis, you reject your original hypothesis, add your new data to the table, and make a new hypothesis based on the updated observations list. A new updated table is seen in **Table** 1.2.

**TABLE 1.2: List of Items Tried in the Fire**

| Will Burn | Won't Burn |
|---|---|
| tree limbs | rocks |
| chair legs | bricks |
| pencils | marbles |
| baseball bat | hubcaps |

**TABLE 1.2:** (continued)

| **Will Burn** | **Won't Burn** |
| --- | --- |
| broom handle | iron pipes |
| | soda bottles |
| | tin cans |

According to the schematic diagram of the scientific method, if the new data does not support the hypothesis, the scientist returns to Step 3 and makes a new hypothesis. When the hypothesis is supported by the the results of several experiments, you might think that the work is finished. For a hypothesis to be useful, however, it must withstand repeated testing. Other scientists must be able to repeat the experiments using the same materials and conditions and get the same results. Scientists submit reports of research to other scientists, usually by publishing an article in a scientific journal, so that the work can be verified.

## Scientific Hypotheses, Theories, and Laws

Hypotheses that have passed many supportive tests are often called theories. A **theory** is an explanation that summarizes a hypothesis or a set of hypotheses and has been supported with repeated testing. Theories have a great deal more supportive testing behind them than do hypotheses. Suppose your new hypothesis is "wooden objects burn." You will find this hypothesis more satisfactory since all of the wooden objects you try will burn. You can see from this example that the hypothesis does not become what we think of as a "fact" but rather a tentatively accepted theory, which must undergo continuous testing and possible adjustments. Even if your theory seems successful, you might be ignoring other types of combustible materials, such as a large stack of old car tires, objects made of fabric or paper, or perhaps containers of petroleum. You can see that even though you are quite satisfied with your theory because it does the job you want it to do, you actually do not have a complete statement on all the properties that make objects burn.

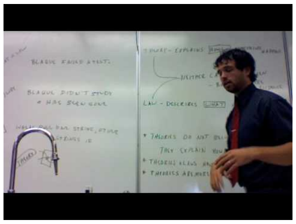
In science, theories can either be descriptive (qualitative) or mathematical (quantitative). However, a scientific theory must be falsifiable, or capable of being proved false, in order to be accepted as a theory. A theory is never proven true and is never a "fact." As long as a theory is consistent with all observations, scientists will continue to use it. When a theory is contradicted by observations, it is discarded and replaced.

A theory is also a possible explanation for a law. A **scientific law** is a statement that summarizes the results of many observations and experiments. A law describes an observed pattern in data that occurs without any known exception. A law that has withstood the test of time is incorporated into the field of knowledge. Because they explain the patterns described in laws, theories can be used to predict future events.

One example of a scientific law was discovered around the 1800s by a group of scientists who were working with gases to, among other reasons, improve the design of the hot air balloon. After many tests, Jacques Charles and other scientists discovered that patterns and regularities existed in their observations of gas behavior. They found that if the temperature of the gas increased, the volume of the gas also increased. This relationship has held true over time and is now a scientific law. Any scientific theory that describes gas behavior would need to reflect this law and predict that the volume of a gas increases whenever the temperature increases.

Around the same time, another scientist named J. W. Henry was trying to find a pattern between the pressure of a gas and the amount of the gas dissolved in water. Henry found that when one of these variables increased, the other variable increased in the same proportion. If you have ever gone scuba diving, you may already be familiar with this observation. During training, scuba divers learn about a problem known as "the bends." As scuba divers dive deeper, the increased pressure of the air they breathe causes more nitrogen to be dissolved in the diver's blood. Coming up too quickly from a dive causes the pressure to decrease rapidly and the nitrogen to leave the blood quickly, which could lead to joint pains known as "the bends." Henry's Law is a scientific law because it indicates a repeatedly observed relationship (regularity) between gas pressure and the amount of dissolved gas.

In this video a teacher discusses the difference between a theory and a law **(1f - IE Stand.)**: http://www.youtube.com/watch?v=eDED5fCY86s (4:18).



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## Experimentation

The scientific method requires that observations be made. Sometimes the phenomenon we wish to observe does not occur in nature or is inconvenient for us to observe. If we can arrange for the phenomenon to occur at our convenience, we can control other variables and have all of our measuring instruments on hand to help us make observations. An **experiment** is a controlled method of testing a hypothesis under the conditions we want at a time and place of our choosing. When scientists conduct experiments, they are usually seeking new information or trying to verify someone else's data. In comparison, classroom experiments often demonstrate and verify information that is already known to scientists but may be new to students.

Suppose a scientist observed two pools of water in bowl-shaped rocks that are located near each other while walking along the beach on a very cold day following a rainstorm. One of the pools was partially covered with ice, while the other pool had no ice on it. The unfrozen pool seemed to contain seawater that splashed up on the rock from the surf, but the other pool was too high up for seawater to splash in and was most likely filled with only rainwater.

Since both pools were at the same temperature, the scientist wondered why one pool was partially frozen and the other was not. By tasting the water (not a good idea), the scientist determined that the unfrozen pool tasted saltier than the partially frozen one. The scientist thought perhaps salt water had a lower freezing point than fresh water, so she decided to go home to test her hypothesis. In order to test this hypothesis, the scientist will conduct an experiment during which she can make accurate observations. So far, the scientist has identified a question, gathered a small amount of data, and suggested a hypothesis.

For the experiment, the scientist prepared two identical containers of fresh water and added some salt to one of them. A thermometer was placed in each container, and both containers were placed in a freezer. The scientist then observed the conditions and temperatures of the two liquids at regular intervals (see the tables below).

**Temperature and Conditions of Fresh Water**

**Temperature and Conditions of Salt Water**

| time (min) | temperature (°C) | condition | time (min) | temperature (°C) | condition |
|---|---|---|---|---|---|
| 0 | 25 | liquid | 0 | 25 | liquid |
| 5 | 20 | liquid | 5 | 20 | liquid |
| 10 | 15 | liquid | 10 | 15 | liquid |
| 15 | 10 | liquid | 15 | 10 | liquid |
| 20 | 5 | liquid | 20 | 5 | liquid |
| 25 | 0 | frozen | 25 | 0 | liquid |
| 30 | -5 | frozen | 30 | -5 | frozen |

The scientist found support for her hypothesis from this experiment: fresh water freezes at a higher temperature than salt water. Much more support would be needed before the scientist is confident in this hypothesis. She would perhaps ask other scientists to verify the work.

In the scientist's experiment, it was necessary that she freeze the salt water and fresh water under exactly the same conditions. Why? The scientist was testing whether or not the presence of salt in water would alter its freezing point. It is known that even changing the air pressure will alter the freezing point of water. In order to conclude that the presence of the salt was what caused the change in freezing point, all other conditions had to be identical. When doing an experiment, it is important to set up the experiment so that relationships can be seen clearly. A **controlled experiment** is one that compares the results of an experimental sample to a control sample. The control sample is identical to the experimental sample in all ways except for the one variable being tested. The fresh water sample is the control sample, while the sample containing salt is the experimental sample. The presence of salt is the only thing allowed to change in the two samples and is the effect being tested. In an experiment, there may be only one variable, and the purpose of the control is to guarantee that there is only one variable. Unless experiments are controlled, the results are not valid.

Suppose you wish to determine which brand of microwave popcorn leaves the fewest unpopped kernels. You will need a supply of various brands of microwave popcorn to test, and you will need a microwave oven. If you used different brands of microwave ovens with different brands of popcorn, the percentage of unpopped kernels could be caused by the different brands of popcorn or by the different brands of ovens. Under such circumstances, the experimenter would be unable to conclude confidently whether the popcorn or the oven caused the difference. To eliminate this problem, you must use the same microwave oven for every test. In order to reasonably conclude that the change in one variable was caused by the change in another specific variable, there must be no other variables in the experiment. By using the same microwave oven, you control the number of variables in the experiment.

This video presents both how errors can occur and how to avoid them when conducting experiments in the laboratory **(1b, 1c, 1j IE Stand.)**: http://www.youtube.com/watch?v=RU1DZeqY4To (3:57).


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## Scientific Models

Chemists rely on both careful observation and well-known physical laws. By putting observations and laws together, chemists develop models. A **model** is a descriptive, graphic, or three-dimensional representation of a hypothesis or theory used to help enhance understanding. Scientists often use models when they need a way to communicate their understanding of what might be very small (such as an atom or molecule) or very large (such as the universe).

A model is any simulation, substitute, or stand-in for what you are actually studying and provide a way of predicting what will happen given a certain set of circumstances. A good model contains the essential variables that you are concerned with in the real system, explains all the observations on the real system, and is as simple as possible. A model may be as uncomplicated as a sphere representing the earth or billiard balls representing gaseous molecules, but it may also be as complex as mathematical equations representing light.

If you were asked to determine the contents of a box that cannot be opened, you could do a variety of experiments in order to develop an idea (or a model) of what the box contains. You would probably shake the box, perhaps put magnets near it, and possibly determine its mass. When you completed your experiments, you would develop an idea of what is inside; that is, you would propose a model of what is inside the box that cannot be opened. With your model, you could predict how the unopened box would behave under a different set of conditions.

However, even though your model may be capable of accurately predicting some behavior of the unopened box, you would find that the model does not always agree with new experimental results and observations. The model is only be as good as the data you have collected. Because you would never be able to open the box to see what is inside, you also would never be able to create a perfectly accurate model of the box. The model can only be modified and refined with further experimentation.

Chemists have created models about what happens when different chemicals are mixed together, heated up, cooled down, or compressed by using many observations from past experiments. They use these models to predict what might happen during future experiments. Once chemists have models that predict the outcome of experiments reasonably well, those working models can be applied for practical purposes, such as producing an especially strong plastic or detecting potential toxins in your food.

A good example of how a model is useful to scientists is to examine how models were used to develop the atomic theory. As you will learn in the chapter "The Atomic Theory," the concept of an atom has changed over many years. In order to understand the different theories of atomic structure proposed by various scientists, models were drawn to make the concepts easier to understand.

## Lesson Summary

- The scientific method is a method of investigation involving experimentation and observation to acquire new knowledge, solve problems, and answer questions.
- The steps in the scientific method are:
  1. Identify the problem.
  2. Gather data (make observations).
  3. Suggest a hypothesis.
  4. Test the hypothesis (experiment).
  5. Accept the hypothesis for further testing, or reject the hypothesis and make a new one.
- A hypothesis is a tentative explanation that can be tested by further investigation.
- A theory is an explanation that summarizes a hypothesis or a set of hypotheses and has been supported with repeated testing.
- A scientific law is a statement that summarizes the results of many observations and experiments.
- An experiment is a controlled method of testing a hypothesis.
- A controlled experiment is one that compares the results of an experimental sample to a control sample.
- The control sample is identical to the experimental sample in all ways except for the one variable whose effect is being tested.
- A model is a descriptive, graphic, or three-dimensional representation of a hypothesis or theory used to help enhance understanding.
- Scientists often use models when they need a way to communicate their understanding of what might be very small (such as an atom or molecule) or very large (such as the universe).

## Further Reading / Supplemental Links

The *learner.org* website allows users to view the Annenberg series of chemistry videos. You are required to register before you can watch the videos, but there is no charge to register. The website has two videos that apply to this lesson. One video called “Thinking Like Scientists” relates to the scientific method. The other video is called “Modeling the Unseen.”

- http://learner.org/resources/series61.html

This website has a video that explores the history of the scientific method.

- http://videos.howstuffworks.com/hsw/5881-scientific-method-history-video.htm

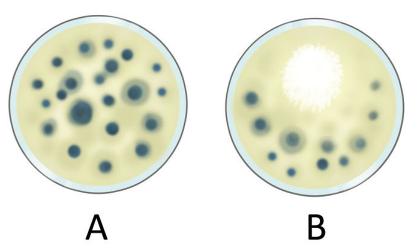
This video is a ChemStudy film called “High Temperature Research.” The film is somewhat dated but the information is accurate.

- http://www.youtube.com/watch?v=Tt2JEwbOtq8

## Review Questions

*Use the following paragraph to answer questions 1 and 2.*

In 1928, Sir Alexander Fleming was studying *Staphylococcus* bacteria growing in culture dishes. He noticed that a mold called *Penicillium* was also growing in some of the dishes. As shown in the illustration below, Petri dish A represents a dish containing only *Staphylococcus* bacteria. In dishes containing the *Penicillium* mold, represented by Petri dish B below, Fleming noticed that a clear area existed around the mold because all the bacteria in this area had died. In the culture dishes without the mold, no clear areas were present. Fleming suggested that the mold was producing a chemical that killed the bacteria. He decided to isolate this substance and test it to see if it would kill bacteria. Fleming grew some *Penicillium* mold in a nutrient broth. After the mold grew in the broth, he removed all the mold from the broth and added the broth to a culture of bacteria. All the bacteria died.




1. Which of the following statements is a reasonable expression of Fleming’s hypothesis?
   a. Nutrient broth kills bacteria.
   b. There are clear areas around the *Penicillium* mold where *Staphylococcus* doesn’t grow.
   c. Mold kills bacteria.
   d. *Penicillium* mold produces a substance that kills *Staphylococcus*.
   e. Without mold in the culture dish, there were no clear areas in the bacteria.
2. Fleming grew *Penicillium* in broth, removed the *Penicillium*, and poured the broth into culture dishes containing bacteria to see if the broth would kill the bacteria. What step in the scientific method does this represent?

a. Collecting and organizing data
b. Making a hypothesis
c. Testing a hypothesis by experiment
d. Rejecting the old hypothesis and making a new one
e. None of these

3. A scientific investigation is *not* valid unless every step in the scientific method is present and carried out in the exact order listed in this chapter.
    a. True
    b. False
4. Which of the following is closest in meaning to the word "hypothesis"?
    a. Fact
    b. Law
    c. Formula
    d. Suggested explanation
    e. Conclusion
5. Why do scientists sometimes discard theories?
    a. The steps in the scientific method were not followed in order.
    b. Public opinion disagrees with the theory.
    c. The theory is opposed by the church.
    d. Contradictory observations are found.
    e. Congress voted against it.

*Use the following paragraph to answer questions 6 through 10.*

Gary noticed that two plants of the same type were different in size after three weeks, even though they were initially the same size when his mother planted them on the same day. Since the larger plant was in the full sun all day and the smaller plant was in the shade of a tree for most of the day, Gary believed that the sunshine was responsible for the difference in plant size. In order to test this, Gary bought ten small plants of the same size and type. He also made sure they have the same amount and type of soil. Gary then built a frame to hold a canvas roof over five of the plants, while the other five were nearby but out in the sun. Gary was careful to make sure that each plant received exactly the same amount of water and plant food every day.

6. Which of the following is a reasonable statement of Gary's hypothesis?
    a. Different plants have different characteristics.
    b. Plants that get more sunshine grow larger than plants that get less sunshine.
    c. Plants that grow in the shade grow larger.
    d. Plants that don't receive water will die.
    e. Plants that receive the same amount of water and plant food will grow the same amount.
7. What scientific reason might Gary have for insisting that the container size for the all plants be the same?
    a. Gary wanted to determine if the size of the container would affect the plant growth.
    b. Gary wanted to make sure the size of the container did not affect differential plant growth in his experiment.
    c. Gary wanted to control how much plant food his plants received.
    d. Gary wanted his garden to look organized.
    e. There is no possible scientific reason for having the same-sized containers.
8. What scientific reason might Gary have for insisting that all plants receive the same amount of water every day?
    a. Gary wanted to test the effect of shade on plant growth, and therefore he wanted to have no variables other than the amount of sunshine on the plants.

b. Gary wanted to test the effect of the amount of water on plant growth.
c. Gary's hypothesis was that water quality was affecting plant growth.
d. Gary was conserving water.
e. There is no possible scientific reason for having the same amount of water for each plant every day.

9. What was the variable being tested in Gary's experiment?

   a. The amount of water
   b. The amount of plant food
   c. The amount of soil
   d. The amount of sunshine
   e. The type of soil

10. Which of the following factors did Gary not control in his experimental setup that may be varying?

    a. Individual plant variation
    b. Soil temperature due to the different colors of the containers
    c. Water loss due to evaporation from the soil
    d. The effect of insects, which may attack one set of plants but not the other
    e. All of the above are possible factors that Gary did not control

11. When a mosquito sucks blood from its host, it penetrates the skin with its sharp beak and injects an anti-coagulant so that the blood will not clot. It then sucks some blood and removes its beak. If the mosquito carries disease-causing microorganisms, it injects these into its host along with the anti-coagulant. It was assumed for a long time that the typhus virus was injected by the louse (singular for lice) when sucking blood in a manner similar to the mosquito. This turned out not to be true. The infection is not in the saliva of the louse but in the feces. The disease is thought to be spread when louse feces come in contact with scratches or bite wounds on the host's skin. A test of this was carried out in 1922 when two workers fed infected lice on a monkey, taking great care that no louse feces came into contact with the monkey. After two weeks, the monkey had *not* become ill with typhus. The workers then injected the monkey with typhus, and the monkey became ill within a few days. Why did the workers inject the monkey with typhus near the end of the experiment?

    a. To prove that the lice carried the typhus virus
    b. To prove the monkey was similar to man
    c. To prove that the monkey was not immune to typhus
    d. To prove that mosquitoes were not carriers of typhus
    e. To demonstrate that the workers were mean

12. When a theory has been known for a long time, it becomes a law.

    a. True
    b. False

13. During Pasteur's time, anthrax was a widespread and disastrous disease for livestock. Many people whose livelihood was raising livestock lost large portions of their herds to this disease. Around 1876, a horse doctor in eastern France named Louvrier claimed to have invented a cure for anthrax. The influential men of the community supported Louvrier's claim of having cured hundreds of cows of anthrax. Pasteur went to Louvrier's hometown to evaluate the cure. The cure was explained to Pasteur as a multi-step process during which: 1) the cow was rubbed vigorously to make her as hot as possible; 2) long gashes were cut into the cows skin; 3) turpentine was poured into the cuts; 4) an inch-thick coating of cow manure mixed with hot vinegar was plastered onto the cow; and 5) the cow was completely wrapped in a cloth. Since some cows recover from anthrax with no treatment, performing the cure on a single cow would not be conclusive, so Pasteur proposed an experiment to test Louvrier's cure. Four healthy cows were to be injected with anthrax microbes. After the cows became ill, Louvrier would pick two of the cows (A and B) and perform his cure on them, while the other two cows (C and D) would be left untreated. The experiment was performed, and after a few days, one of the untreated cows died and the other got better. Of the cows treated by Louvrier's cure, one cow died and the other got better. In this experiment, what was the purpose of infecting cows C and D?

a. To give Louvrier more than two cows to choose from
b. To make sure the injection actually contained anthrax
c. To serve as experimental controls (a comparison of treated to untreated cows)
d. To kill as many cows as possible

14. A hypothesis is:

a. a description of a consistent pattern in observations.
b. an observation that remains constant.
c. a theory that has been proven.
d. a tentative explanation for a phenomenon.

15. A scientific law is:

a. a description of a consistent pattern in observations.
b. an observation that remains constant.
c. a theory that has been proven.
d. a tentative explanation for a phenomenon.

16. A number of people became ill after eating oysters in a restaurant. Which of the following statements is a hypothesis about this occurrence?

a. Everyone who ate oysters got sick.
b. People got sick whether the oysters they ate were raw or cooked.
c. Symptoms included nausea and dizziness.
d. The cook felt really bad about it.
e. Bacteria in the oysters may have caused the illness.

17. Which statement best describes the reason for using experimental controls?

a. Experimental controls eliminate the need for large sample sizes.
b. Experimental controls eliminate the need for statistical tests.
c. Experimental controls reduce the number of measurements needed.
d. Experimental controls allow comparison between groups that are different in only one variable.

18. A student decides to set up an experiment to determine the relationship between the growth rate of plants and the presence of detergent in the soil. He sets up ten seed pots. In five of the seed pots, he mixes a precise amount of detergent with the soil. The other five seed pots have no detergent in the soil. The five seed pots with detergent are placed in the sun, and the five seed pots with no detergent are placed in the shade. All ten seed pots receive the same amount of water as well as the same number and type of seeds. He grows the plants for two months and charts the growth every two days. What is wrong with his experiment?

a. The student has too few pots.
b. The student has two variables different between the groups.
c. The student did not add detergent to all ten pots.
d. The student has no experimental control on the soil.

19. A scientist plants two rows of corn for experimentation. She puts fertilizer on row 1 but does not put fertilizer on row 2. Both rows receive the same amount of sun and water. She checks the growth of the corn over the course of five months. What is acting as the control in this experiment?

a. The corn without fertilizer
b. The corn with fertilizer
c. The amount of water
d. The height of the corn plants

20. If you have a control group for your experiment, which of the following is true?

a. There can be more than one difference between the control group and the test group but no more than three differences, or else the experiment is invalid.
b. The control group and the test group may have many differences between them.

c. The control group must be identical to the test group except for one variable.
d. None of these are true.

21. If the hypothesis is rejected by the experiment, then:
    a. the experiment may have been a success.
    b. the experiment was a failure.
    c. the experiment must be poorly designed.
    d. the experiment didn't follow the scientific method.
22. A well-substantiated explanation of an aspect of the natural world is a:
    a. theory.
    b. law.
    c. hypothesis.
    d. none of the above.