Have you ever wondered why on a cool, dry day you often can receive an electric shock after walking on a carpet and touching a metal object? Why plants facing a sunny window grow toward the window? Why your leg muscles ache the day or two after you run around the track at school? Scientists explore these and other questions so that we have a greater understanding about our world. In this section, we will explore the methods that scientists use to discover and develop these explanations.

What Is Science?
Science is both a body of knowledge and a way of understanding how the world works. Science involves the application of human intelligence and creativity to explore, discover, and explain how the natural and physical world works. Scientific explanations are developed when people make observations and then describe them based on what they already know about the world. An observation is a careful inspection of an object or an event in which the observer uses his or her senses. This leads to asking questions, which can lead to experimenting, collecting and organizing data, and drawing valid conclusions. Scientific explanations are subject to change whenever new observations challenge existing explanations. By exploring the historical development of scientific concepts and the individuals who contributed to scientific knowledge, you can better understand scientific inquiry and the relationship between science and society.

Early Science
At one time, scientific discovery and knowledge was based on opinions and ideas that attempted to explain observations. An example of this is the account of Jean Baptiste van Helmont, a sixteenth-century Dutch physician. He supported the theory of spontaneous generation—that nonliving material could produce living organisms. A theory is an explanation of natural phenomena supported by a large body of scientific evidence obtained from many different investigations and observations. Van Helmont devised an experiment similar to the one in Figure 1.1, to demonstrate the spontaneous generation of mice. The procedure involved throwing some grains of wheat and a soiled shirt into an open container, and then placing it in a damp cellar for about 21 days.

Figure 1.1 Van Helmont's experiment was designed to prove the theory of spontaneous generation.
After the 21 days, van Helmont discovered that there were mice in the container. Also, the amount of wheat was less, so van Helmont concluded that the wheat, not the soiled shirt, spontaneously became mice.

The experiment that van Helmont conducted failed to recognize the origins of living matter. If van Helmont had conducted his experiment in a location other than a damp basement, his results probably would have been different. It might seem silly to believe that wheat combined with an old soiled shirt would produce baby mice in a damp cellar. However, the theory of spontaneous generation seemed reasonable at that time based on van Helmont's observations and those of others, existing ideas on the origins of life, and available scientific tools. In the modern view, a scientific explanation is accepted when it is consistent with experimental and observational evidence, and when it leads to accurate conclusions.

CHECK FOR UNDERSTANDING What experiment did van Helmont devise to prove the spontaneous generation of mice?

Scientific Inquiry

Scientific investigations are used to answer questions and explain how things operate in the natural and physical world. Scientific investigations generally use scientific methods that involve the following:

- Observing
- Developing questions based on observations
- Developing a hypothesis—a testable explanation or possible answer to a question
- Developing an experiment—a set of procedures that lead to testing a hypothesis
- Collecting and organizing data from the experiment
- Developing inferences—explanations based on the observable results of an experiment
- Publishing results for peer review

The Scientific View of the World

The scientific view is founded upon direct observation of the world around us. To think scientifically one must critically examine events and explanations and attempt to avoid all sources of bias. Keep in mind that scientific explanations are subject to change. No matter how well one explains a set of observations, it is possible that another explanation will fit just as well or better. In science, this testing and improving of explanations occurs continually.

The scientific view involves many individuals doing many different kinds of work, such as those in Figure 1.2. These people include scientists, engineers, mathematicians, physicians, technicians, computer programmers, librarians, and others. They contribute to the scientific view with data gathering, the building of science tools and instruments, and/or communicating. It is appropriate in science to turn to knowledgeable sources of information by seeking people who specialize in different disciplines. Well-accepted scientific explanations have been supported by the process of scientific testing and involve the contributions of many different individuals.

CHECK FOR UNDERSTANDING Why does a scientific discovery involve the assistance of many people besides scientists?
Testing Proposed Explanations

Suppose your teacher brought in several brands of paper towels and asked the class the following question: Which brand of paper towel is most absorbent? This is the beginning of a scientific inquiry. Your teacher then instructed the class to think about ways to answer this question. The teacher also brought in magnifiers, rulers, beakers, cylinders, plastic tubs, eyedroppers, and balance scales. Applied thinking skills will be used to design a plan to test the absorbencies of the different brands of paper towels.

Scientific Inquiry and Testing

Inquiry involves asking questions. These questions should lead to forming a plan or plans to test the paper towel samples. Among the questions the class might consider before developing a testing plan are:

- What is absorbency?
- What aspects of paper towel absorbency can be investigated using the available materials?
- What factors need to be controlled in order to compare testing results?
- Will you buy the most absorbent brand of paper towel after you complete your tests?

Inquiry involves examining the questions used to formulate a good experimental design. The class might consider testing the various brands of paper towels to determine which paper towel absorbs the greatest volume of water, or absorbs the most water in a given period of time, or has the greatest change in mass when immersed in a specific amount of water. Solutions to each of these investigative possibilities can be explored through a research plan and the development of a hypothesis to test methods being considered.

Development of a Research Plan

When a scientist defines a problem for investigation, such as exploring the absorbency of several brands of paper towels, it usually is followed by a search for information about the topic to be investigated. It is important to know what other people have learned about the topic before beginning research. This involves the development of a research plan in which background information can be obtained that will assist in developing a hypothesis and devising an experimental design. Most research plans begin with a thorough library search that can include a review of the literature contained in scientific journals, and a search of library databases and the Internet, as shown in Figure 1.3. Research in the classroom on the topic of paper towel absorbency can even include contacting the various companies that manufacture each of the brands being tested. In addition, it can include a careful review of the tests and results that each company has conducted on their brand of paper towel. Familiarity with the existing research on a topic allows a scientist to avoid repeating investigations already done and to plan the best approach for investigating the problem. In the course of their research, scientists must make judgments about the reliability of and relevance of the information they uncover.

✔ CHECK FOR UNDERSTANDING Why is it important to develop a research plan before fully investigating a problem?

Developing a Hypothesis

Next, a scientist will formulate an explanation for the question or problem that can be tested. This explanation is known as a hypothesis. In a cause-and-effect relationship, such as the paper towel absorbency problem, the hypothesis is an educated guess about the outcome of the investigation about which paper towel will absorb the most liquid. Experiments that follow either will or will not support the hypothesis. A hypothesis can never be proven or confirmed with absolute certainty.
In formulating a hypothesis, a scientist should know what is involved in solving the problem based on his or her previous observations and research. The hypothesis is often written as an “if-then” statement or as a statement where you can add, “I think that” to the beginning. If we were to investigate the problem of paper towel absorbency based on the amount or volume of water that a paper towel sample can absorb, a possible hypothesis would be: If you soak several brands of paper towels in a specific volume of water, then the brand that is most absorbent will soak up the largest volume of water. This statement is testable and can lead to designing an experiment that will either support or fail to support the hypothesis.

CHECK FOR UNDERSTANDING Why is the statement of a hypothesis so critical to the experiment that will follow?

For the paper towel problem, the proposed hypothesis will not prove which paper towel is most absorbent. Additional hypotheses based on surface area absorption and rate of absorption could lead to other experiments, which might indicate another brand of paper towels as being the most absorbent. A hypothesis sets the groundwork for designing an experiment to support or not support it. The following are examples of hypotheses.

- If you exercise strenuously for 10 minutes, then your heart rate will increase.
- If you place a plant near a window, it will grow toward the window because a plant responds to light.
- Wheat and a damp shirt in a cellar do not create mice in 21 days. Only mice can reproduce to make more mice.
- Rotten meat does not turn into flies. Only flies can reproduce to make more flies.

**Experimenting**

Once a scientist has completed background research on a problem and has developed a hypothesis, he or she designs an experiment to test the hypothesis. An experiment is an investigation consisting of procedures that test a hypothesis by collecting information under controlled conditions.

**Controls and Variables**

Science experiments usually have a control component. A **control** is the standard in which all conditions are kept the same. This is in contrast to an experimental, or test group. In an experimental group, all conditions are kept the same as the control except for the condition being tested. The condition that is tested in an experiment is known as the **independent variable**, because it is the only variable that affects the outcome of the experiment. When changing the independent variable, the scientist observes or measures a second condition that results from the change.
This condition is known as the dependent variable because it “depends” on the changes made to the independent variable.

If we were to continue our paper towel exploration to determine which of several brands would soak up the largest volume of water, we also would have to control several factors in designing an experiment. Variables to control might include:

- testing each brand with the same volume of water and in the same size beaker or tub;
- testing the same size of toweling;
- soaking each towel for the same amount of time;
- allowing each soaked towel to drip water back into the beaker for the same amount of time.

The brand of towel that leaves the least amount of water remaining in the beaker or tub would be rated the most absorbent. In this case, the independent variable would be the various brands used, while the dependent variable would be how much water each towel absorbed.

If we were to investigate the hypothesis of plant stems growing toward the source of light, we would set up a controlled experiment, such as the one in Figure 1.4. The controls in this type of experiment would include plants of the same species and size, planted in the same type of soil, maintained under the same temperature and soil conditions, and subjected to these conditions for the same length of time. Both groups of plants would be placed in opaque containers of moist soil. The independent variable, or factor that would vary, would be that one group would receive light only from one direction. We would then compare this group to the control group that received the same total intensity of light, but evenly distributed around the plant. If after a set period of time, the plants receiving directed light demonstrated growth toward the light, while the control plants did not exhibit any measurable change, we have supported the hypothesis. Remember that there should be only one variable tested at a time.

CHECK FOR UNDERSTANDING What is the dependent variable in the experiment where we investigated the effect of directed light on plant stems? Explain your answer.

Carrying Out an Investigation
When carrying out an investigation, scientists need tools that enable them to record information as accurately as possible. Selecting scientific equipment and considering the safety precautions required to use it, and planning how to maintain the accuracy of the results are important parts of carrying out an investigation.

The safe and proper use of scientific tools is a key factor in determining accurate results in any investigation. In addition, the number of samples and trials conducted also help determine the accuracy of an investigation.

Consider the plant study described previously.
Would the information from testing a plant from the control and a plant from the experimental group provide accurate results? Proper testing would include using multiple plant samples. In addition, several trials should be conducted to determine if your results are consistent. The same factors apply to paper towel testing. Multiple samples and trials involving each brand would have to be tested to see if the results of the testing were consistent. Repeated trials with large sample sizes provide information that is more accurate and reduce the probability that errors are due to chance.

### Observing, Analyzing, and Concluding

During experiments, scientists collect data based on the observations they make. Data are all of the information obtained from an experiment, and sometimes are referred to as experimental results.

#### Gathering and Organizing Data

Scientists organize and analyze data. Scientists make decisions based on their analysis of data. Data can be organized into diagrams, charts, graphs, equations, matrices, and tables, such as Table 1.1 shown below. Sometimes data are expressed in verbal or written form that describe observations. Often, data are expressed in numerical form based on measurements such as time, temperature, length, mass, area, volume, or numerical counts of matter.

To collect the quantitative data from the plant experiment, a scientist would have to measure the length and angle of the stems of the control plant group and the experimental group. These measurements will be taken at the beginning and end of the experiment for comparison. These results can then be recorded. A data table is one way to record and organize the results of testing the volume of water absorbed by several different brands of paper toweling. Data tables also can help scientists examine information collected while doing an experiment.

Another way that scientists examine data is to construct a graph. A graph allows the scientist to represent data visually, often making it easier to make comparisons of the data collected. It also can allow scientists to see patterns in data such as those shown in Figure 1.5.

![Graph](image)

**Figure 1.5** Graphs permit scientists to interpret data. This line graph shows an inverse relationship between the distance of food and the number of turns in worker bees’ waggle dances.

#### Table 1.1 • Water Absorbency in Different Brands of Paper Towels

<table>
<thead>
<tr>
<th>Brand</th>
<th>Amount of Water in Container Before Soaking</th>
<th>Amount of Water in Container After Soaking (60 s)</th>
<th>Amount of Water Absorbed by the Paper Towel</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>150 mL</td>
<td>126 mL</td>
<td>24 mL</td>
</tr>
<tr>
<td>B</td>
<td>150 mL</td>
<td>118 mL</td>
<td>32 mL</td>
</tr>
<tr>
<td>C</td>
<td>150 mL</td>
<td>132 mL</td>
<td>18 mL</td>
</tr>
</tbody>
</table>

☑ **CHECK FOR UNDERSTANDING** Describe three ways in which a scientist can collect and organize data.

There are three basic forms of graphs: circle graphs, bar graphs, and line graphs. A scientist must decide which type of graph will be the most effective means of presenting data.
When constructing a graph, there are several rules that should be followed.

- Create a title for your graph.
- The independent variable is plotted on the horizontal or x-axis. This is the factor you altered or varied.
- The dependent variable is plotted on the vertical or y-axis. This variable is what you discover or measure because of the experiment.
- Create a scale on each axis by marking off equal spaces on each axis. Make sure that each scale covers the range of data collected for each variable. Label the units on each side.
- Make sure your x-axis and y-axis are titled and units are labeled.
- Data points in a line graph are connected and the lines should not go beyond the data points plotted.

The data collected from the paper towel absorbency testing also can be represented in the form of a bar graph like the one in Figure 1.6. A careful examination of the experimental results represented in the bar graph would indicate that Brand B is the most absorbent brand when absorbing a specific volume of water.

**Developing Valid Conclusions**

Careful analysis of data collected in an experiment allows a scientist to make decisions about the outcome of the experiment. Those decisions often are referred to collectively as a conclusion.

A scientist will need to determine if the stated hypothesis was supported by the actual results of the experiment. Scientists usually consider data from an experiment valid after that experiment has been repeated several times and yielded similar results. Statistical analysis techniques are often used by scientists to determine if their results were affected by errors in measurement, differences among test samples, or by chance. Once a pattern or relationship can be supported through repeated testing, a scientist then tries to explain these results.

**Reporting Results**

Because of the nature of science, it is possible that other individuals could have conducted similar experiments and arrived at similar conclusions. Experiments that cannot be repeated, or do not yield similar results, cannot be considered valid.

Research among scientists must be reported clearly and in detail so that other scientists can repeat the investigation and duplicate the results. The results of investigations are reported in scientific journals or are shared with colleagues during professional meetings. A report describes the hypothesis, including a literature review of previous studies and how the experiment was performed. It also describes data and states the scientist’s conclusions. Public discussion and review of an experiment may result in a scientist revising his or her explanation and thinking about additional research.

Peer review is a process in which scientists evaluate the results of scientific investigations and the explanations proposed by other scientists. A peer review can be a presentation, as shown in Figure 1.7 on page 8. It generally includes analysis of experimental procedures, careful examination of evidence, identification of faulty reasoning and statements that go beyond the evidence, and suggestions for alternative explanations for the same observations. Peer review serves as a system of checks and balances for scientific research.

Evidence is a collection of facts offered to support the validity of an idea. Scientific claims must be supported by a large collection of evidence before they are considered valid. Scientific claims that are based on small data samples, biased or inadequately controlled data, and misleading use of numbers, usually come under question.

In science, a hypothesis that is supported by many separate observations and investigations over a long period of time becomes a theory.
A theory results from a continuing process of verification and refinement of many related hypotheses. A valid theory often raises more questions. Theories can change or be refuted as new information and data are derived from experimentation. The theory of evolution began with the observations of naturalists. Over the years, many scientists and others have researched the many aspects of evolution to form one general theory.

**Quick Review**

Base your answers to questions 1 through 3 on the information below and on your knowledge of biology. Use one or more complete sentences to answer each question.

When a drug manufacturer develops a new drug to treat some form of disease, the drug should be tested to ensure that it does what it is supposed to do. Usually, the drug is tested on animals and, if these tests are successful, it is then tested on humans.

A drug called Lowervil was developed by a drug company to lower blood pressure. Lowervil has been tested successfully on animals, and the drug company is now ready to test it on humans. The drug company claims that one dose of Lowervil per day will decrease blood pressure in individuals experiencing high blood pressure.

A researcher has been hired to determine whether or not Lowervil lowers blood pressure. Answer the following questions related to the experimental testing of the new drug Lowervil.

1. How should the experimental group and control group be treated differently?
2. Why would it be important to use a large number of people in this experiment?
3. How could the researcher determine if the drug is effective in reducing blood pressure?

Base your answers to questions 4 through 6 on the information and data tables below and on your knowledge of biology. Use one or more complete sentences to answer each question.

Drinking alcohol during pregnancy can cause the class of birth defect known as fetal alcohol syndrome (FAS). Scientists do not yet understand the process by which alcohol causes damage to the fetus. There is evidence, however, that the more the pregnant woman drinks, the greater the chances that the child will be affected and the birth defects will be intellectual and behavioral problems.

<table>
<thead>
<tr>
<th>Infant Characteristics</th>
<th>Alcohol Use During Pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics (Average)</td>
<td>Drinker</td>
</tr>
<tr>
<td>Weeks of development before birth</td>
<td>38.9</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>2555</td>
</tr>
<tr>
<td>Birth length (cm)</td>
<td>46.8</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>32.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Abnormalities Detected in Infants at Birth</th>
<th>Alcohol Use During Pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Abnormality</td>
<td>Drinker (% of 40 infants)</td>
</tr>
<tr>
<td>Low birth weight</td>
<td>73</td>
</tr>
<tr>
<td>Small brain</td>
<td>33</td>
</tr>
<tr>
<td>Flattened nasal bridge</td>
<td>8</td>
</tr>
<tr>
<td>Abnormal facial features</td>
<td>15</td>
</tr>
<tr>
<td>Spinal defects</td>
<td>8</td>
</tr>
<tr>
<td>Heart defects</td>
<td>8</td>
</tr>
</tbody>
</table>

4. Do the data in the tables justify scientists' conclusions that alcohol causes physical abnormalities at birth by interfering with the normal development of the fetus? Defend your position with supporting data.

5. What additional data would be needed to better support the scientists' conclusions?

6. Explain why alcohol consumption by the mother is especially harmful during the early stages of pregnancy.
1 A scientist tested a hypothesis that white-tailed deer would prefer apples over corn as a primary food source. The findings of the test, in which the scientist claimed that the deer preferred apples, were published. Which research technique, if used by the scientist, might result in this claim being questioned?
   (1) The scientist observed four deer in different locations at various times of the day.
   (2) The scientist observed a total of 500 deer in 20 different locations at various times of the day.
   (3) The scientist observed 200 deer in various natural settings, but none in captivity.
   (4) The scientist observed 300 deer in various locations in captivity, but none in natural settings.

2 An experimental design included references from prior experiments, materials and equipment, and step-by-step procedures. What else should be included before the experiment can be started?
   (1) a set of data
   (2) a conclusion based on data
   (3) safety precautions to be used
   (4) an inference based on results

3 The current knowledge concerning cells is the result of the investigations and observations of many scientists. The work of these scientists forms a well-accepted body of knowledge about cells. This body of knowledge is an example of a
   (1) hypothesis
   (2) controlled experiment
   (3) theory
   (4) research plan

4 In his theory, Lamarck suggested that organisms will develop and pass on to offspring variations that they need in order to survive in a particular environment. In a later theory, Darwin proposed that changing environmental conditions favor certain variations that promote the survival of organisms. Which statement is best illustrated by this information?
   (1) Scientific theories that have been changed are the only ones supported by scientists.
   (2) All scientific theories are subject to change and improvement.
   (3) Most scientific theories are the outcome of a single hypothesis.
   (4) Scientific theories are not subject to change.

5 The data table below summarizes the results of an investigation in which seeds from the same plant were grown under different conditions of temperature and relative humidity.

<table>
<thead>
<tr>
<th>Temperature: 20°C</th>
<th>Temperature: 31°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Humidity: 20%</td>
<td>Relative Humidity: 95%</td>
</tr>
<tr>
<td>Genes Present in Cells of Organism</td>
<td>Appearance of Organism</td>
</tr>
<tr>
<td>AA</td>
<td>red</td>
</tr>
<tr>
<td>Aa</td>
<td>red</td>
</tr>
<tr>
<td>aa</td>
<td>white</td>
</tr>
</tbody>
</table>

Which conclusion can be drawn from the information in the data table?
   (1) Color in this species is determined by genes, only.
   (2) Many characteristics are not inherited.
   (3) Mutations occur only when plants are grown at low temperatures.
   (4) There is an interaction between environment and heredity.

6 Diagrams, tables, and graphs are used by scientists mainly to
   (1) design a research plan for an experiment
   (2) test a hypothesis
   (3) organize data
   (4) predict the independent variable

Content Questions for Regents Exam Practice • 9
7 The use of technology often alters the equilibrium in ecosystems. With which of the following statements would most scientists agree?

(1) Humans should develop new technology to expand the influence of humans' natural communities.

(2) Humans should learn how to control every aspect of the environment so that damage due to technology can be spread evenly.

(3) Humans should use their knowledge of ecology to consider the needs of future generations of humans and other species.

(4) Humans should develop the uninhabited parts of Earth for human population expansion.

8 Scientific studies have indicated that there is a higher percentage of allergies in babies fed formula containing cow’s milk than in breast-fed babies. Which statement represents a valid inference made from these studies?

(1) Milk from cows causes allergic reactions in all infants.

(2) Breast feeding prevents all allergies from occurring.

(3) There is no relationship between drinking cow’s milk and having allergies.

(4) Breast milk most likely contains fewer substances that trigger allergies.

9 An experiment was performed to determine the effect of different mineral salts on plant growth. Forty pots containing genetically identical plants were divided into four equal groups and placed in a well-lighted greenhouse. Each pot contained an equal amount of nonmineral potting soil and one plant. Minerals were then added in equal amounts to each experimental group of pots as shown below.

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Plant" /></td>
<td><img src="image" alt="Plant" /></td>
</tr>
<tr>
<td>Water + Nitrogen salts</td>
<td>Water + Potassium salts</td>
</tr>
</tbody>
</table>

For the experiment to be valid, what should be added to the control group of pots?

(1) water

(2) nitrogen salts

(3) potassium salts

(4) potassium and phosphorus salts

---

**Part B**

10 What is the dependent variable in the experiment summarized in the graph below?

![Graph](image)
Base your answers to questions 11 through 14 on the data table and information below and on your knowledge of biology. The data table shows water temperatures at various depths in an ocean.

<table>
<thead>
<tr>
<th>Water Temperatures at Various Depths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Depth (meters)</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>75</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>

*Directions (11–14):* Using the information in the data table, construct a line graph on the grid following the directions below.

11. Mark an appropriate scale on the axis labeled “Water Depth (m).”

12. Plot the data on the grid. Surround each point with a small circle and connect the points.

   Example: [Diagram of a line graph with data points connected]

13. State the general relationship between temperature and water depth.

14. The approximate water temperature at a depth of 125 meters would be closest to
   (1) 15°C       (3) 8°C
   (2) 13°C       (4) 3°C
A student designed an investigation to determine the effect of temperature on the rate of seed germination. The student placed moist filter paper in each of four culture dishes. Ten bean seeds were placed on the filter paper in each dish. The four dishes were numbered and placed in the dark at different temperatures as follows: Dish 1: 10°C, Dish 2: 15°C, Dish 3: 20°C, Dish 4: 25°C. The total number of germinated seeds in each culture dish was counted each day for two weeks. Which data table is best for recording the results of this investigation?

<table>
<thead>
<tr>
<th>Petri Dish</th>
<th>Day</th>
<th>Temperature</th>
<th>Amount of Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part C

Base your answer to question 16 on the information below and on your knowledge of biology.

You are the head of the research division of the Leafy Lettuce Company. Your company is experimenting with growing lettuce using hydroponic technology. Hydroponic technology involves growing plants in containers of growth solution in a greenhouse. No soil is used. The growth solution that the company uses contains water, nitrogen, and phosphorus. The company wants to know if adding iron to this formula will improve lettuce growth.

16 Briefly describe how to test the effect of the formula with iron added. In your description, be sure to:
   - state a hypothesis to be tested in the new experiment
   - state how the control group will be treated differently from the experimental group
   - identify two factors that must be kept the same in both the experimental and control groups
   - state what type of data should be collected to support or refute the hypothesis

17 With only the materials list supplied below and common laboratory equipment, design an investigation that would show how a change in pH would affect the activity of enzyme X. Your design need only include detailed procedure and a data table.

Materials
- Enzyme X
- Sugar C solution
- Indicators
- Substances of various pH values—
  - vinegar (acidic)
  - water (neutral)
  - baking soda (basic)

Procedure:

Data Table:
Part D

Answer all questions in this part.

Directions (18–20): Base your answers on the information and data table below and on your knowledge of biology.

You are going to devise an experiment to determine if a person can squeeze a clothespin more times in a 1-minute period by exercising first or by NOT exercising first.

18 State a hypothesis for your experiment.

19 Complete the data table below with the correct column name.

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Pulse Count at Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td></td>
</tr>
<tr>
<td>Student 2</td>
<td></td>
</tr>
<tr>
<td>Student 3</td>
<td></td>
</tr>
</tbody>
</table>

20 Identify a tool or tools needed to collect these data.

Directions (21): Base your answer on your knowledge of biology.

The diagram below shows a partial setup of a laboratory activity used by a student during an investigation of diffusion. The U-shaped tube contains sugar solutions separated by a membrane. The concentrations of the sugar solutions are not equal. Water can pass through the membrane, but sugar cannot. The first drawing shows the tube at the beginning of the activity. The second tube shows the tube after time has lapsed.

21 Which statement best explains why the liquid levels are not equal on each side of the U-shaped tube after a period of time has lapsed?

(1) Water molecules diffused to the side with the greater sugar concentration.
(2) Pressure was applied to the surface of the liquid on the right side of the tube.
(3) Water molecules diffused to the side with the smaller sugar concentration.
(4) The U-shaped tube was submerged into a hot-water bath.
Directions (22–26): Base your answers on the information and data table below and on your knowledge of biology.

A biology class wanted to conduct an experiment to determine if exercise affects their ability to think. They planned to divide the class into two groups. In Group 1, the students would use a stop watch to calculate the time required to complete a page of simple math problems. In Group 2, the students would run in place for a 2-minute period and rest for a 1-minute period. Then, the students would use a stop watch to determine the length of time required to complete the same page of simple math problems. The data collected are shown below:

<table>
<thead>
<tr>
<th>Student</th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>4.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Student 2</td>
<td>5.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Student 3</td>
<td>5.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Student 4</td>
<td>3.7</td>
<td>4.5</td>
</tr>
<tr>
<td>Student 5</td>
<td>4.3</td>
<td>3.0</td>
</tr>
</tbody>
</table>

22 What is the independent variable in this activity?

23 What is the dependent variable in this activity?

24 Which group is the control?

25 Describe a method that could be used to compare the two sets of data.

26 Describe a method that can be used to make sure that the computational skills in each group are approximately the same.