

Introduction to Science and the Scientific Method

I. What is Science?

- A. The goal of science is to investigate and understand the natural world, to explain events in the natural world, and to use those explanations to make useful predictions.
- B. Science:
 - 1. Science deals only with the natural world.
 - 2. Scientists collect and organize information in a careful, orderly way, looking for patterns and connections between events.
 - 3. Scientists propose explanations that can be tested by examining evidence.
 - 4. Science is an organized way of using evidence to learn about the natural world.
- C. How is science done?
 - 1. Science begins with an observation. This is the process of gathering information about events or processes in a careful, orderly way.
 - 2. Data is the information gathered from making observations.
 - 3. There are two types of data:
 - a) Quantitative data are numbers and are obtained by counting or measuring.
 - b) Qualitative data are descriptions and involve characteristics that cannot be counted.
 - 4. Hypothesis
 - a) A hypothesis is a scientific explanation for a set of observations.
 - b) A hypothesis must be stated in a way that makes it “testable”. The hypothesis is just a possible answer to a question, and it must be thoroughly tested.

II. Scientific Methods

- A. The scientific method is a series of steps used by scientists to solve a problem or answer a question.
- B. The Steps to the Scientific Method

Step 1: Observation / Asking a Question

- 1. A problem or a question must first be identified.
- 2. Examples: How much water can a root hair absorb? Why does a plant stem bend toward the light? What effect does temperature have on heart rate?

Step 2: Form a Hypothesis

- 1. Hypothesis: A possible explanation to the question or problem. It is simply a prediction and has not yet been proven or disproven.
- 2. It must be stated in a way that is testable. A statement is considered “testable” if evidence can be collected that either does or does not support it.

Step 3: Designing a Controlled Experiment

- 1. The factors in an experiment that can be changed are called variables. Some example of variables would be: changing the temperature, the amount of light present, time, concentration of solutions used.
- 2. A controlled experiment works with one variable at a time. If several variables were changed at the same time, the scientist would not know which variable was responsible for the observed results.
- 3. In a “controlled experiment” only one variable is changed at a time. All other variables should be unchanged or “controlled”.

4. An experiment is based on the comparison between a “control group” with an “experimental group”.
 - a) These two groups are identical except for one factor.
 - b) The control group serves as the comparison. It is the same as the experiment group, except that the one variable that is being tested is removed.
 - c) The experimental group shows the effect of the variable that is being tested.
5. Example: In order to test the effectiveness of a new vaccine, 50 volunteers are selected and divided into two groups. One group will be the control group and the other will be the experimental group. Both groups are given a pill to take that is identical in size, shape, color and texture.

Describe the control group: Even though they are given identical looking pills, the control group will not actually receive the vaccine.

Describe the experimental group: This group is receiving the vaccine.

What variables are kept constant? The size, shape, color, and texture of the pill.

What variable is being changed? Whether or not the pill contains any vaccine.

6. There are two variables in an experiment:
 - a) The independent variable is the variable that is deliberately changed by the scientist.
 - b) The dependent variable is the one observed during the experiment. The dependent variable is the data we collect during the experiment. This data is collected as a result of changing the independent variable.
 - c) In the above example, what is the independent variable? The addition of the vaccine to the pills that were given to the volunteers.
 - d) In the above example, what is the dependent variable? The observed health of the people receiving the pills.

Step 4: Recording and Analyzing Results

1. The data that has been collected must be organized and analyzed to determine whether the data are reliable.
2. Does the data support or not support the hypothesis?

Step 5: Drawing Conclusions

1. The evidence from the experiment is used to determine if the hypothesis is proven or disproven.
2. Experiments must be repeated over and over. When repeated, the results should always be the same before a valid conclusion can be reached.

III. Forming a Theory

- A. A theory may be formed after the hypothesis has been tested many times and is supported by much evidence.
- B. Theory: A broad and comprehensive statement of what is thought to be true.
- C. A theory is supported by considerable evidence.

IV. Practice Problem

You want to determine the effects of a certain fertilizer on the growth of orchids grown in a greenhouse. Materials that are available to you include: greenhouse, 100 orchid plants, water, fertilizer, and soil. You want to know if the orchids will grow best with a weak concentration of fertilizer, a medium concentration of fertilizer, or a high concentration of fertilizer. How will you design an experiment to test different concentrations of this fertilizer?

- A. State your hypothesis: (Possible answer: I predict that the orchids will grow best with a medium concentration of fertilizer.)
- B. How will you set up a controlled experiment?
1. The 100 plants will be divided into 4 groups as follows:
Group 1: 25 plants will receive plain water
Group 2: 25 plants will receive a weak concentration of fertilizer
Group 3: 25 plants will receive a medium concentration of fertilizer
Group 4: 25 plants will receive a high concentration of fertilizer
 2. The plants will be watered daily. Over a period of a month, the plants will be measured to see which ones grew the tallest.
- C. What is the control group in this experiment? (The control group consists of the 25 plants that are receiving plain water.)
- D. What is the experimental group in this experiment? (The experimental group consists of the 75 plants that are receiving various concentrations of fertilizer.)
- E. What variables must be kept constant in this experiment? (All plants receive the same amount of fluid each day. All plants are grown in pots of equal size. All plants are grown at the same temperature. All plants receive the same amount of sunlight.)
- F. What variable is being changed in this experiment? (The variable being changed is the amount of fertilizer.)
- G. After one month of measuring the orchids, the following data is obtained:
- Group 1 (Control Group): Grew to an average height of 15 cm.
Group 2 (Weak concentration): Grew to an average height of 35 cm.
Group 3 (Medium concentration): Grew to an average height of 28 cm.
Group 4 (High concentration): Grew to an average height of 10 cm.

Is your hypothesis supported or disproved by these results? (We hypothesized that the orchids would grow best with a medium concentration of fertilizer. The results do not support this. The results disprove our hypothesis.)

What is your conclusion based on these results? (Orchids grow best with a weak concentration of fertilizer. At medium to high concentrations, plant growth is inhibited.)

V. Analysis Questions:

- A. Why is it important to have a large sample size in any experiment?

It is important to test a large sample in order to get a true picture of the results of the experiment. If the sample size is too small, an inaccurate conclusion may be reached. Results obtained by testing a large number of individuals would be much more accurate than if only a few individuals had been tested.

- B. Why is it important to repeat the experiment many times?

Experiments should be repeated to see if the same results are obtained each time. This gives validity to the test results.

- C. What is the importance of the control?

The control shows what will happen when the experimental factor is omitted. Without the control, there would be no basis for comparison and you would not know how the experimental factor affected the results.

- D. How is a theory different than a hypothesis?

A hypothesis is an “educated guess” that is testable through observations and experimentation. A theory is a broad statement of what is believed to be true based on many experiments and considerable amounts of data.

- E. Why is it so important that a scientist accurately describes the procedure used in the experiment?

It allows other scientists to repeat the experiment and verify the results.

- F. What is the difference between the independent and the dependent variables in an experiment?

The independent variable is the variable that is deliberately changed by the scientist. The dependent variable is the one observed during the experiment. The dependent variable is the data we collect during the experiment.

- G. In a “controlled experiment”, why must all of the variables, except one, be kept constant throughout the experiment?

If several variables were changed at the same time, the scientist would not know which variable was responsible for the observed results.