DOING SCIENCE

Science is not simply a set of facts. It is really a kind of process—a way of learning about and understanding nature. Scientists know that their ideas about the universe are not fixed and certain. This uncertainty is not a sign that something is wrong with their work or their thinking. It comes partly from the fact that many of the things scientists study cannot be observed directly.

However, scientific uncertainty goes beyond that fact. It is built into science itself and is actually one of the great things about it. Science does not deal in absolute facts and absolute laws. No one is forced to accept scientific ideas just because a scientist has put them forth. Such ideas must be tested, challenged, and questioned. If these ideas turn out to be successful in describing the way the world works, they are accepted and used. Even then, however, scientists do not consider these ideas to be certainties. The process of science will continue, and the ideas will eventually develop or be replaced by other ideas that work even better.

There are many different methods and techniques that can be used in science. However, all truly scientific methods have certain things in common. They all involve an open-minded approach to nature and systematic ways of gathering and processing information, and of coming to conclusions. There is no single, correct step-by-step order in which scientific investigation must be carried out. However, the description below will give you a good idea of how the approach works in general.

OBSERVING

A scientist usually begins by noticing something about the world—perhaps the fact that a certain kind of plant (say, a bean plant) does not seem to grow equally well under all conditions. The initial observation is often followed up with more careful observations, perhaps involving measuring instruments. The scientist will wonder why the thing that is observed behaves the way it does, or perhaps wonder what factors affect its behavior. In the case of the plants, for example, he or she might wonder what factors cause bean plants to grow rapidly and remain healthy.

HYPOTHESIZING

Such observing and wondering often leads to an educated guess about what has been observed. Such an attempt to explain observations in terms of their causes is called a *hypothesis*. In the case of the bean plants, the scientist might make the hypothesis that rapid and healthy growth depends upon the plants' receiving light. A statement of the hypothesis might be that bean plants that are exposed to light grow better than those that are not exposed to light.

DESIGNING AN EXPERIMENT

A non-scientist might be content to stop with an educated guess and simply assume that it is correct. A good scientist assumes nothing, however. Instead, he or she plans a way to test hypotheses to see whether they will hold up and apply to actual new situations. A way of testing hypotheses and gathering more information is called an *experiment*. Although experiments are sometimes used simply to gather background information before any hypothesis is made, they generally follow the hypothesis step and serve as a check on the soundness of the hypothesis.

Experiments must be designed carefully if they are to be of use in answering questions. A good experiment permits observation of one particular factor that is a suspected cause of something observed. This factor whose effects are to be studied is called the variable. For example, the amount of light to which bean plants are exposed can serve as the variable in the experiment.

It is not enough simply to expose a plant to light and to observe what happens. The variable factor, light, must, as its name implies, be *varied*. For example, two bean plants might be observed. Plant A will be exposed to light. Because it contains the variable, the setup involving plant A will serve as the experimental setup. A different bean plant, B, will not be exposed to light. The B setup is called the control setup. It lacks the variable, light.

It would not make sense to treat the two plants differently in any respect other than the amount of light they are given. For example, if one plant were watered and the other were not, the effects observed could not be interpreted clearly. You would not know which effect, the amount of water or light, was responsible , or whether both were. Therefore, all factors other than the variable one are controlled, or kept the same, for the two setups.

COLLECTING AND ORGANIZING DATA

The experiment that has been designed is then carried out. Observations and measurements are carefully made and recorded. For example, data on the heights of the two plants over the following several weeks might be graphed, to permit easy comparison.

INTERPRETING DATA AND COMING TO A CONCLUSION

The organized data are then studied. For example, it might be found that plant A grew 8 centimeters per week, whereas plant B grew only 1 centimeter. Then a conclusion is drawn on this basis as to the correctness of the original hypothesis. In the example of our bean experiment, the conclusion might be that light does have a positive effect on the growth rate of bean plants.

COMMUNICATING RESULTS

Scientific findings are not of much use unless others are informed of them. Scientists thus communicate their findings to others. This can be done informally, but is usually done by means of written reports that are published in scientific journals. Such reports provide complete information on the experiments that were done. Thus, other scientists need not take the results on faith. They can analyze the design and conclusions of the experiment, or repeat the experiment themselves. This repeatability is a good check on the correctness of scientific conclusions.

In carrying out the procedures described in this manual, think carefully about what you are doing and why you are doing it. Keep in mind the hypothesis you have formulated and how the data you will gather will help to confirm or reject it. Work carefully and systematically and collect data accurately on the things you observe and measure. Take care analyzing the data and think about what the findings reveal. Finally, make conclusions based upon your findings. If you do all these things, you can congratulate yourself on acting as a real scientist does and you will learn a great deal in the process.