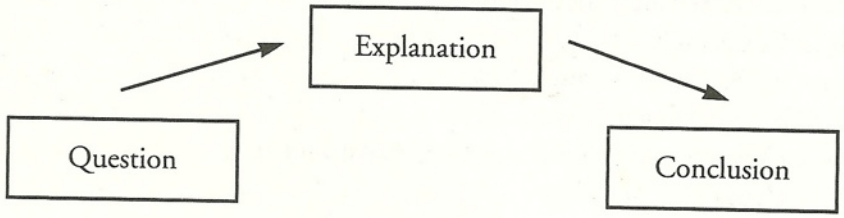
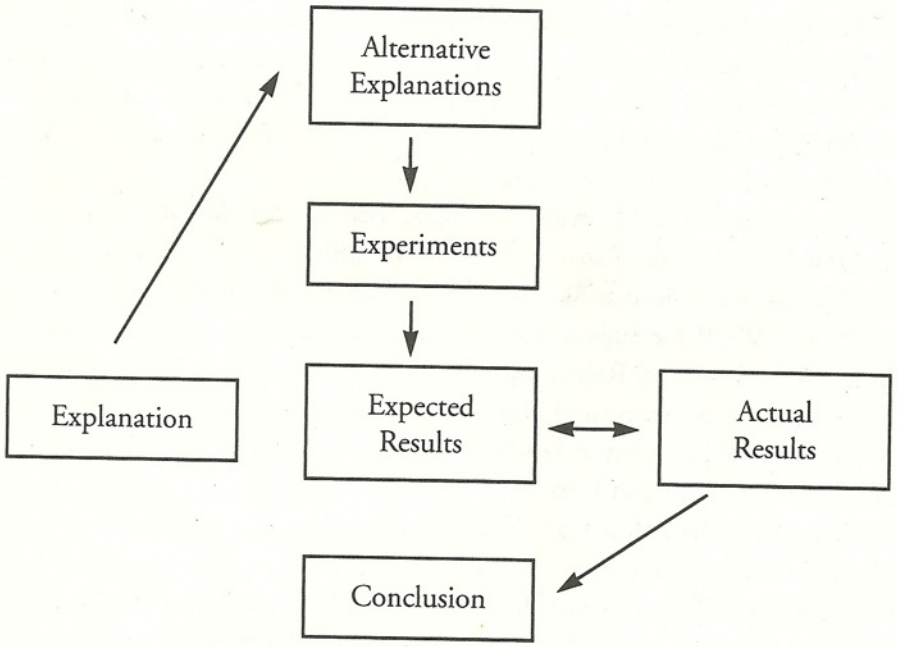
This course has been designed to improve your ability to think scientifically by investigating living things and their surroundings. Biological investigations have two key questions. The first is, *What is happening?* The second is, *What caused it to happen?* The first question calls for an adequate description of objects, events, and situations, while the second, more difficult question calls for an explanation.

Unfortunately, many high-school students reach conclusions about explanations in the way diagrammed below:



A question is raised, a single explanation (answer) pops into their heads, and they immediately conclude that it is correct without generating and attempting to test any alternatives. This course will help you think more scientifically, like this:



In other words, many possible explanations are proposed and conclusions are not drawn until all the possibilities have been tested thoroughly by comparing expected results of experiments with actual results of those experiments.

Keep in mind that doing science means you must do two things. You must keep alert to discover what is happening, and you must always ask why it is happening. Not *why — What is the purpose?* — but *why — What is the cause?* In brief, your job is to do the following:

- make observations and look for patterns
- raise questions about causes
- create a number of possible explanations (referred to as alternative hypotheses)
- design and conduct experiments to test possible explanations
- collect, organize, and analyze data
- draw reasonable conclusions from the evidence
- reflect back on what you have done and heard and what it means

By the end of the year, you should be quite good at doing these things. You should know quite a lot more about the nature of life on Earth, and you should also be a lot better at thinking like a scientist. The scientific thinking patterns you learn here will serve you well in any future occupation you choose.

Lab Report Guidelines

During the year, you will be doing a number of investigations. For some of these, you may be required to submit a detailed lab report based on your investigation. Following is information to help you with the format of the lab report.

Causal Question

In this section, you should state the causal question you are addressing. You should include an introduction consisting of any background information your reader might need and a discussion of why the question is important or interesting biologically. Essentially, the question you address has been supplied to you in the titles of the investigations, but you probably will find it necessary to include additional questions. For example, in addition to asking the causal question, *What causes molecules to pass into and out of cells?,* you might also want to ask a descriptive question such as, *How does the concentration of molecules affect their movement into and out of cells?*

Alternative Hypotheses (Explanations)

In this section, you will present the alternative hypotheses (at least two) that you will be testing. Be sure your proposed explanations can be tested with the facilities at your disposal. For example, suppose you hypothesize that water rises in plants because little pumps are in the roots, and/or because one-way valves are in the stems. These are reasonable hypotheses. To test them, you must be able to imagine and conduct an experiment that yields expected results (predictions) and actual results (your data). Your hypotheses must be ones that are testable.

Experimental Procedure

This section will describe what you did to test your proposed explanations. You should include a diagram of your setup and enough verbal description so that someone unfamiliar with your experiment could repeat it. State your independent variable (the factor that you manipulate) and your dependent variable (what you are measuring) for each experimental design. Be sure that you have designed controlled experiments and that you have enough data to differentiate random variations from "real" variations. You may need to repeat your experiment several times.

Expected Results (Predictions)

Your expected results (predictions) are derived from your proposed explanations and your experimental design. To generate a prediction, one assumes for the purpose of investigation that the explanation is correct. The prediction may be stated as part of an *If-then* statement. The *if* portion is essentially a restatement of your proposed explanation. An explicit *and* portion represents your experiment, and a *then* portion states the results you expect to find if your proposed explanation is correct.

Example: *If* pumps that allow water to rise are in the roots of plants (proposed explanation) and you cut off the roots of a group of experimental plants while not cutting off the roots of a second group of plants (experiment), *then* you would expect that those plants with intact roots would show a greater water rise than those plants without roots (prediction).

Important Note: The *If-then* statement is simply a convenient way to illustrate the relationship among a proposed explanation, an experiment, and the expected results. A hypothesis does not have to include the word *if,* and a prediction does not have to start with *then.* You cannot differentiate hypotheses from predictions just by looking for these cue words because they are frequently omitted. You must understand the difference between them.

Actual Results

In this section, you will present the actual results of your experiment. Your data should be quantitative and should be presented in tables and/or graphs. Be very careful to label clearly the axes on graphs and the columns and rows on tables.

Discussion and Conclusion

In this section, you will identify trends in your data and discuss whether these trends agree or disagree with predictions derived from your proposed explanations. You may discuss any qualitative observations, explain any irregular or abnormal results, and suggest possible improvements in your experimental design. In your conclusion, you should decide whether to accept or reject your hypotheses based on the results of your experiments. Do your actual results agree with your expected results? If so, then the hypotheses have been supported. If you decide to reject your proposed explanations, you may be able to suggest additional explanations at this time. Do your results suggest any further investigations of interest? If so, briefly discuss them.