A hypothesis must be testable to ensure that it is valid. For example, a hypothesis that depends on what a bear thinks is not testable, because it can never be known what a bear thinks. To test a hypothesis, a researcher will conduct one or more experiments designed to eliminate one or more of the hypotheses. This is important. A hypothesis can be shown to be false or eliminated, but it can never be proven true. Science does not deal with proof, like mathematics. If an experiment supports the hypothesis, this is not to say that down the road, a better explanation will not be found, which is why the word "prove" is not used when a hypothesis is supported.

Each experiment will have variables, controls, and experimental groups. A variable is any part of the experiment that can vary or change during the experiment. There are typically three kinds of variables: independent, dependent, and standardized. The **independent variable** is the variable that is being altered or changed by the researcher. It is the variable whose effect is being tested. The **dependent variable** is the variable that may change when the independent variable is applied. This is what the researcher will observe, measure, and record during the experiment. The **standardized variables** are variables that must be kept consistent among all test groups; otherwise, they can affect the outcome or results of the experiment. The **experimental groups** in an experiment receive varying types or amounts of the independent variable. A control group is usually included as a basis of comparison for the experimental groups. For the **control group** the independent variable is absent or set to some predetermined standard. Look for the variables, controls, and experimental group(s) in the following example.

An experiment is conducted to test the hypothesis that phosphate availability limits the growth of algae in freshwater ponds. A series of artificial ponds are filled with water, and half of them are treated by adding phosphate each week, while the other half is treated by adding salt. Salt is a known substance that is not used by algae. The independent variable here is the phosphate. The experimental groups are the ponds to which phosphate was added, and the control group is the ponds to which the salt was added. Adding the salt is a control against the possibility that adding extra matter to the pond influences algae growth. Some factors must be standardized in both the control and experimental ponds. For example, both the temperature and pH of the water should be standardized. If the water in the control ponds has a significantly higher temperature or pH compared to the water used in the experimental ponds, this could influence the growth of algae. These factors need to be measured and kept relatively constant between the two groups. These are examples of standardized variables. If the ponds treated with phosphate show more algae growth than the control ponds, then we have found support for our hypothesis. If they do not, then we reject our hypothesis. Be aware that rejecting a hypothesis does not determine whether or not the other hypotheses can be accepted; it simply eliminates one hypothesis that is not valid (Figure 1.21).

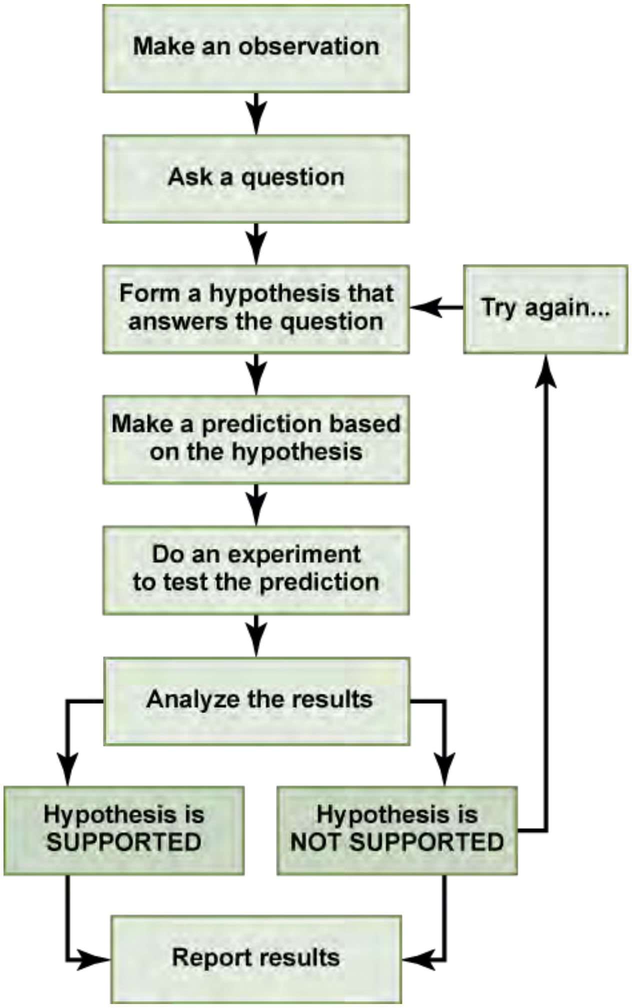

Figure 1.21 The scientific method is a series of defined steps that include experiments and careful observation. (credit: Fowler et al. / Concepts of Biology OpenStax)

In the example below, the scientific method is used to solve an everyday problem.

Check your knowledge

Which option below is the hypothesis? Which is the prediction?
Based on the results of the experiment, is the hypothesis supported?
If it is not supported, propose some alternative hypotheses.

1. My toaster doesn't toast my bread.
2. Why doesn't my toaster work?
3. There is something wrong with the electrical outlet.
4. If something is wrong with the outlet, then my coffeemaker also won't work when plugged in.
5. I plug my coffeemaker into the outlet.
6. My coffeemaker works.

Answers: (3) hypothesis; (4) prediction; The hypothesis would be rejected. Hypothesis 2: The toaster has a loose wire and is broken.

The scientific method is not as rigid and structured as it might first appear. Sometimes an experiment leads to conclusions that favor a change in approach. Often, experiments bring about entirely new scientific questions. Many times, science does not operate linearly; instead, scientists continually draw inferences and make generalizations, finding patterns as their research proceeds. Scientific reasoning is more complex than the scientific method alone suggests.

Basic and Applied Science

The scientific community has been debating for the last few decades about the value of different types of science. Is it valuable to pursue science for the sake of simply gaining knowledge, or does scientific knowledge only have worth if we can apply it to solving a specific problem or bettering our lives? This question focuses on the differences between two types of science: basic science and applied science.

Basic science or "pure" science seeks to expand knowledge regardless of the short-term application of that knowledge. It is not focused on developing a product or a service of immediate public or commercial value. The immediate goal of basic science is knowledge for knowledge's sake, though this does not mean that in the end, it may not result in an application.

In contrast, applied science or "technology," aims to use science to solve real-world problems, making it possible, for example, to improve crop yield, find a cure for a particular disease, or save animals threatened by a natural disaster. In applied science, the problem is usually defined by the researcher.

One example of how basic and applied science can work together occurred with the discovery of the DNA structure. This discovery then led to the understanding of the molecular mechanisms that control DNA replication. Every human has unique chromosomes, strands of DNA wrapped around proteins, found in their cells. DNA provides the instructions necessary for life. During cell division, new copies of DNA must be made before a cell divides to form two new cells (Figure 1.22). Understanding the mechanisms of DNA replication enabled scientists to develop laboratory techniques that are now used to identify genetic diseases, pinpoint individuals who were at a crime scene, and determine paternity. Without basic science, it is unlikely that applied science would exist.

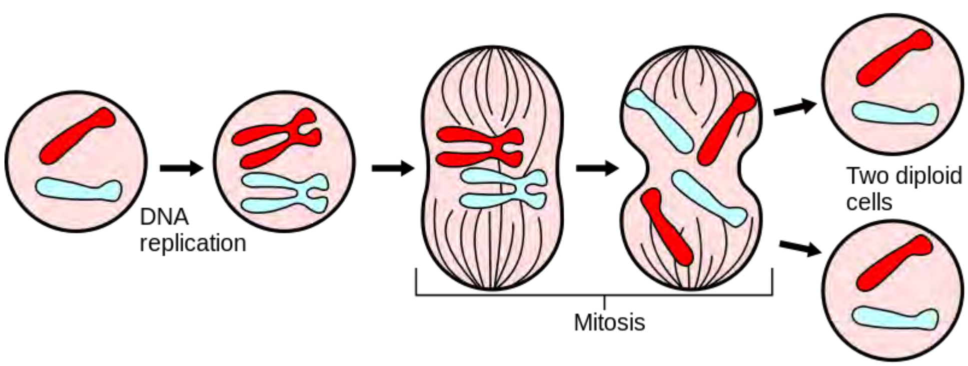

Figure 1.22 Shows DNA replication and cell division by the process of mitosis. Note: diploid means each cell has pairs of chromosomes. (credit: Mysid / Wikimedia Commons)