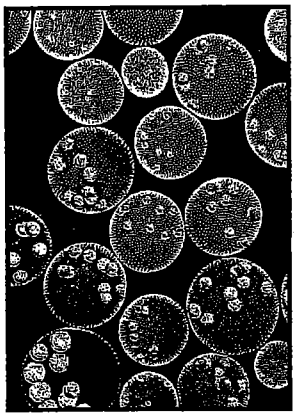
CHAPTER 1

Origins of Living Things



IMPORTANCE OF THE CELL THEORY

The cell is the basis of life. It has been estimated that the human body is made up of about one hundred trillion cells. Different cells in the body are specialized to perform various tasks. Muscle cells, for example, are capable of rapid contraction. If they did not function properly, movement would not be possible. Nerve cells transmit electrochemical messages. If they did not work properly, a person would not be aware of his or her environment, or be able to respond to changes in it. Vision, hearing, taste, smell, and touch all depend on nerves. The transport of oxygen, defense against disease, and communication all depend on specialized body cells. Cells are not exclusive to humans; they are also found in plants, bread mold, and pond scum. In fact, all life forms are composed of at least one cell.

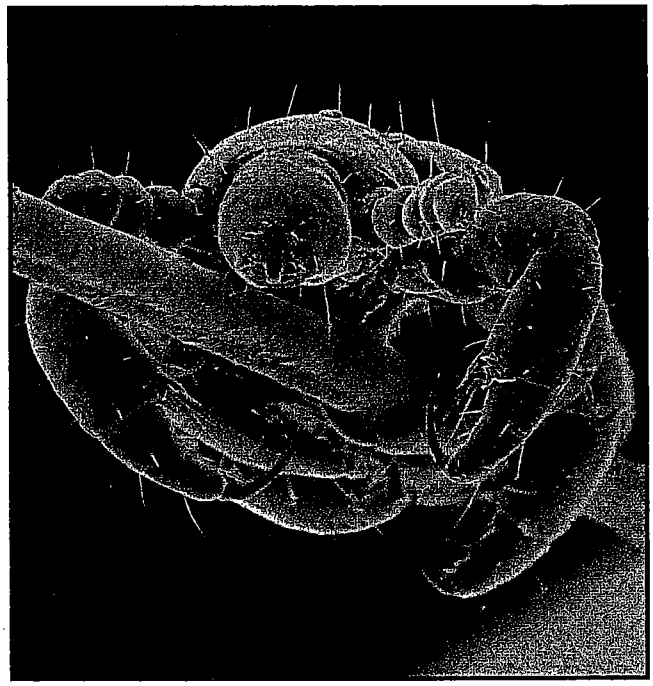


Figure 1.1

A head louse clings to a human hair. The head louse inhabits the hair of the head, gluing its eggs to the individual hairs.

Most of the cells that you encounter every day are invisible to the naked eye. The idea that you are not alone becomes evident if you examine the cells that coexist with you. A small, rod-shaped bacterium, called *Escherichia coli*, lives in your gut. This microbe, or its

descendants, supplies you with important vitamins and will likely be with you until the end of your life. A survey of your skin may reveal different types of fungi. Athlete's foot is an example of a fungus. Your skin also harbors a sphere-shaped bacterium called *Staphylococcus epidermis*. You might also see tiny mites in your eyebrows, plant spores and pollen that have found their way into your lungs, and a host of microbes and microscopic animal eggs that enter your body with the food you consume. Your body is a walking ecosystem.

Cells outside your body also play an important role in your life. The yogurt that you ate for lunch is a living community of bacteria. A bacterium called *Lactobacillus bulgaricus* causes the milk in the yogurt to sour, while a second bacterium, *Streptococcus lactis*, enhances the taste. The processing of cheese, beer, and wine depends on cells. Even the tanning of leather could not be accomplished if it were not for cells. Is it any wonder that an introduction to biology can begin with a study of the cell?

In spite of their varied size, shape, and appearance, cells have several things in common. All cells digest nutrients, excrete wastes, synthesize needed chemicals, and reproduce. Cells define both life and death.

ABIOGENESIS

Biology, like other forms of science, progresses by observation. Unfortunately, observations of nature are often flawed by interpretations that attempt to explain what was observed. This is due, in part, to the fact that the observer is actually part of nature. Therefore, the observer is subject to many of the same factors as the objects being observed. In an attempt to interpret natural events, scientists often propose explanations. An explanation is also called a **hypothesis**. The hypotheses proposed by early scientists were almost never tested by experiment. Often one unsubstantiated hypothesis became the basis for another, and scientists moved further and further from the truth.

A **hypothesis** *is a possible solution to a problem or an explanation of an observed phenomenon.*

Early scientists noticed that ponds dried up during a long period of drought and that no living fish were found in the mud. When rain began to fall in the spring and the pond filled with water, observers noticed that the pond was teeming with frogs and fish. Some concluded that the frogs and fish must have fallen to earth during the rainstorm. Incredible as this explanation may seem now, it seemed logical to many people in earlier times. The fact that nobody had ever been hit by a frog or a fish during a rainstorm did not seem to have occurred to anyone!

Figure 1.2

Some early scientists believed that frogs fell from the sky during rainstorms.

Aristotle, the great philosopher of ancient Greece, did not accept the hypothesis of fish and frogs falling from the sky. He proposed that fish and frogs came from the mud. He also believed that flies came from rotting meat, because he had always observed flies on decayed meat. Aristotle was so persuasive in his arguments that scientists accepted his theory of **abiogenesis** for nearly 2000 years. Abiogenesis is the theory that proposes that nonliving things can be transformed into living things spontaneously. The theory is sometimes referred to as "spontaneous generation." A mere 300 years ago, a Belgian doctor, Jean van Helmont, concluded that mice could be created from grains of wheat and a dirty shirt. Van Helmont had placed grains of wheat and a dirty shirt in a container, and within 21 days mice appeared. According to van Helmont, the sweat in the shirt caused the wheat to ferment. The fermenting wheat bubbled and was eventually transformed into mice.

Abiogenesis *is a theory that states that nonliving things can be transformed into living things.*

Experimental *variables are designed to test a hypothesis. Experimental groups test a single variable at a time.*

Controls *are standards used to verify a scientific experiment. Controls are often conducted as parallel experiments.*

In 1668, Francesco Redi, an Italian physician, conducted an experiment to test the hypothesis that rotting meat can be transformed into flies. Prior to Redi's work, science was based on logical analysis rather than on experimentation. Redi placed bits of snake, eel, fish, and veal in four different jars. He repeated the same steps in four other jars, but sealed the second set of jars. The open set of jars was designated the **experimental** group, while the closed set was designated the **control** group. What do you think happened next? After a period of time, Redi noticed that maggots were crawling all over the meat in the open jars. Apparently, flies had been attracted to the meat and began laying eggs on the food supply. The eggs hatched into maggots, which began feeding on the meat. The maggots then became flies and the cycle continued. Redi concluded that flies come from other flies, not from rotting meat. However, Redi's critics replied that the sealed jars were different from the control set, because no fresh air circulated around the meat. Air, claimed the critics, is the "active ingredient" that causes spontaneous generation. Fresh air must circulate around the meat in order for flies to appear.

Once again, Redi turned to experimentation for his answer. He repeated the experiment, but this time placed fine, meshed wire over the opening of the experimental set of jars. As Redi had predicted, flies were not found inside the experimental jars, despite the fact that air circulated around the meat. Once again, Redi proved that rotting meat cannot be transformed into flies.

CHARACTERISTICS OF LIVING THINGS

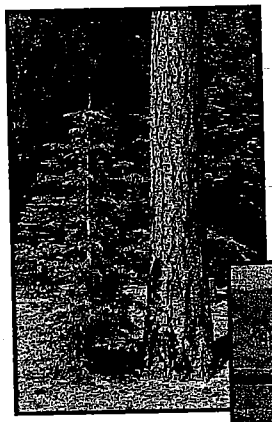
Living things share a number of observable traits. Some of the characteristics are described in these pictures. What other characteristics would you add?

Living things require energy.

Energy is transferred from plants to animals.

Some animals rely on other animals for their source of energy.

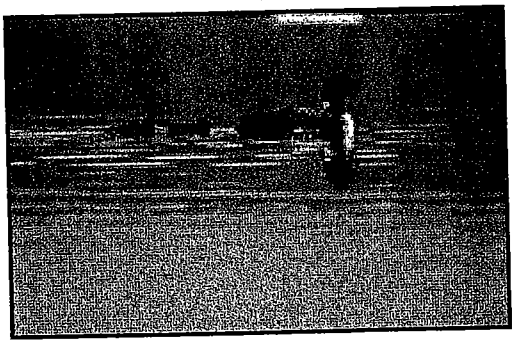
Living things grow and reproduce.



Some trees continue to grow for hundreds of years.

Adult animals tend to be larger than juveniles.

Living things produce similar offspring.



Offspring inherit traits from their parents.

ABIOGENESIS AND MICROBES

Even as the invention and refinement of the light microscope revolutionized the study of biology, scientists continued to make mistakes as they sought to interpret their observations. Such was the case of the English biologist John Needham (1713–1781) when he set out to re-examine the theory of abiogenesis. Needham observed that meat broth left unsealed soon changed color and gave off a putrid smell. Mold and bacteria were found growing in the rich nutrient, but it was unclear where these microbes came from. Unlike the early supporters of abiogenesis who used logical analysis, John Needham tested his hypothesis through experimentation. Experimentation had become an essential component of science.

Needham boiled flasks containing nutrient meat broth in loosely sealed flasks for a few minutes in order to kill the microbes. The solutions appeared clear after boiling. The flasks were then left for a few days and the murky contents were examined under a microscope. The broth was teeming with microorganisms. Could this mean that the broth had spontaneously created microbes? Needham rushed to retest the experiment, using different nutrient solutions. Despite the boiling, the microbes reappeared a few days later. Needham concluded that the microbes had come from nonliving things in the nutrient broth.

Needham's conclusions sent many scientists down the wrong pathway. Let us re-examine his experiment to understand why. One of the difficulties arose from the fact that the flasks were not sealed properly—the tiny microbes could have entered the flasks after boiling. Another difficulty resulted from the design of his experiment. The fact that the flasks appeared clear immediately after boiling did not mean that all the microorganisms were destroyed. If only a few of the tiny microbes had survived, they would be able to multiply to millions within a few days. Needham did not check the flasks for microbes immediately after boiling. Even if he had checked the flasks, it is unlikely that he would have found any of the remaining microbes. Each drop of the nutrient would have to be examined, and such an examination might even infect the flask.

Needham's conclusions were upheld for nearly 25 years. Lazzaro Spallanzani (1729–1799) repeated Needham's experiment, but boiled the flasks longer. Spallanzani also took special care to seal the flasks completely. No microorganisms were found; abiogenesis did not occur. Needham's supporters were cautious about Spallanzani's experiments. They suggested that because Spallanzani had completely sealed the jars, the active principle had been destroyed. You will recall that the active principle objection had been used to oppose the work of Francesco Redi about 100 years earlier. Others claimed that the boiling had destroyed the nutrients. Although Spallanzani did not believe that an active principle existed, he was unable to overcome the objections that centered on the active-principle hypothesis.

The final blow to the theory of abiogenesis was delivered by the great French scientist Louis Pasteur (1822–1895). In 1864, Pasteur had a glassworker develop a special swan-necked flask. Broth was placed in the flask and subsequently boiled to destroy the microbes. Air passed from the flask during boiling. Fresh air entered the flask as the flask cooled. However, the microbes were trapped in the curve of the flask and were not carried into the broth from the surrounding air. Because the broth remained clear, Pasteur predicted that microbes were not present.

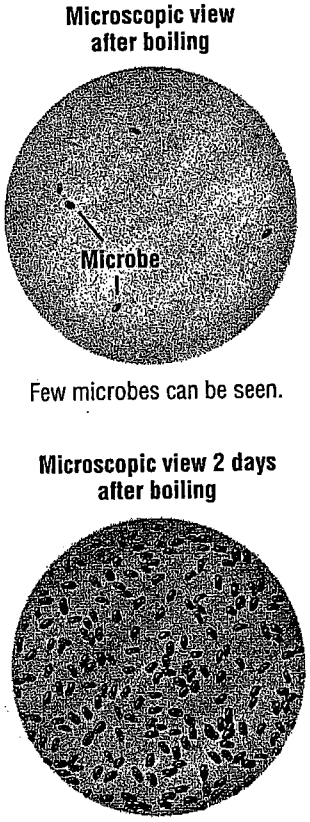


Figure 1.6

Supplied with enough nutrients, microbes reproduce quickly.

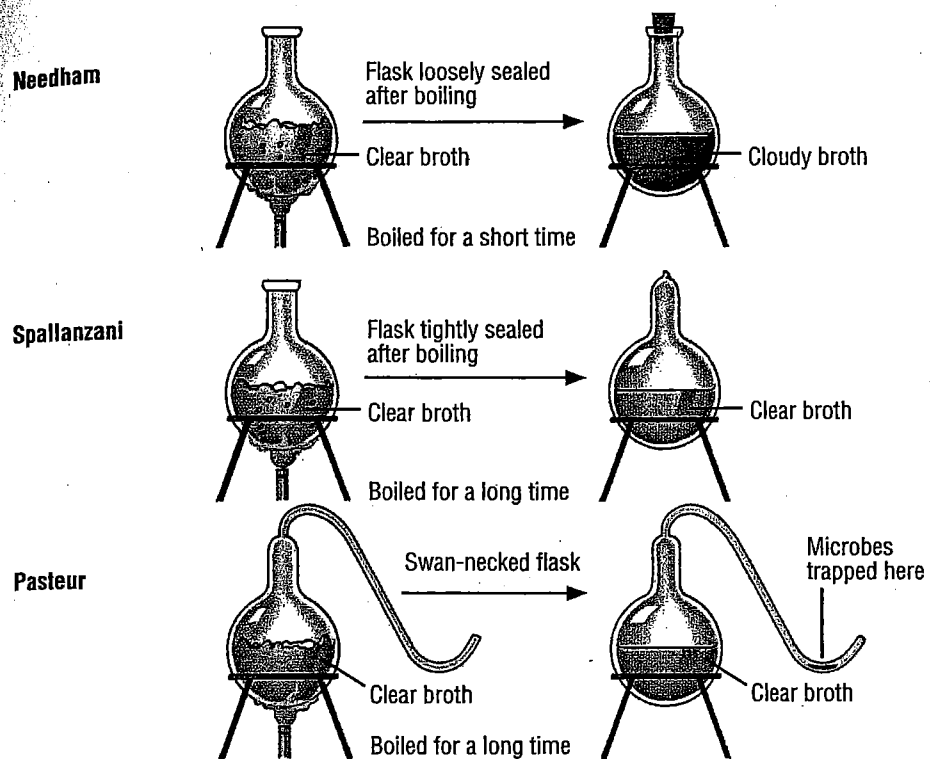


Figure 1.7

Pasteur's improvements to Needham's and Spallanzani's experiments dealt the final blow to the theory of abiogenesis.

A microscopic examination of the nutrient broth confirmed his prediction. Microbes could not be created from nonliving broth. As a finale, Pasteur tipped the broth in one of the flasks, allowing it to run into the curve of the swan-necked flask. As Pasteur had predicted, the broth became contaminated by the microorganisms trapped there. In a few days, the flask became cloudy.

EMERGENCE OF THE CELL THEORY

No one scientist developed the cell theory. Cells were probably first described in 1665, when the English scientist, Robert Hooke, noticed many repeating honeycomb-shaped structures while viewing a thin slice of cork under his primitive microscope. In his book, *Micrographia*, Hooke used the word "cell" to describe these structures. However, cork, the spongy tissue from cork trees, has few living cells. What Hooke observed were the rigid cell walls that surrounded the once-living plant cells.

A few years later, Anton van Leeuwenhoek observed living blood cells, bacteria, and single-cell organisms in a drop of water. As microscopes improved, more structures were described. Around 1820, Robert Brown described the appearance of a tiny sphere in plant cells. He called the structure the *nucleus* (plural: "nuclei"). Nuclei were soon discovered in animal cells. A zoologist, Theodor Schwann, and a botanist, Mathias Schleiden, concluded that plant and animal tissues are composed of cells. Schwann and Schleiden prepared the foundations for the modern *cell theory*. The modern cell theory states:

- All living things are composed of cells. The cell is the basic living unit of organization.
- All cells arise from pre-existing cells. Cells do not come from nonliving things.

Figure 1.8

Cork cells seen through a microscope. The visible objects are the cell walls that surrounded the living cells.