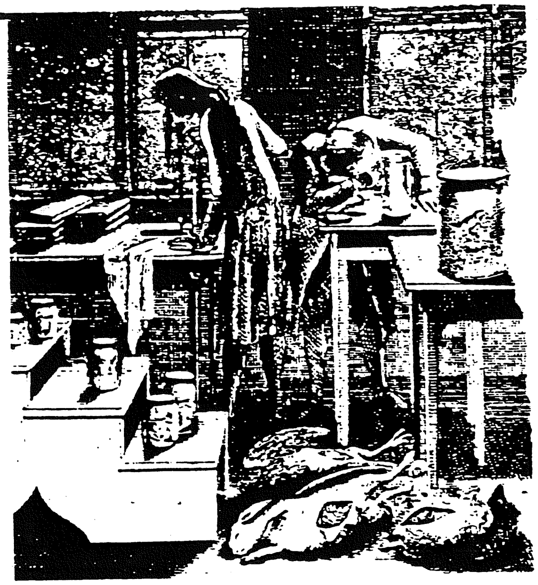
BIOLOGICAL THEME

The History of Biological Ideas



Early biologists like these eighteenth-century scientists studied the structure of organisms.

Ideas are man-made, and their history is the story of men. The development of biological concepts has followed the pattern of the other sciences. Man started by observing the variety of organisms and processes in the living world. Only after a long period of organizing data and classifying objects and observations did theoretical concepts begin to be developed. Great scientists could see patterns in the information collected for years and centuries. From these patterns they formed the concepts of modern biology.

Concepts of biology depend on both the men who invented them and the times in which these men worked. An idea cannot exist alone; it must relate to the science as a whole. The history of biology makes it clear that science does not proceed in a straight line to success. A great deal of careful work and observation took place between Hooke's observation of "little boxes" in cork and the modern cell theory put forward by Schleiden and Schwann. Recently, the biochemical studies of DNA and RNA have added a great deal to our understanding of cell division. Many men must work and much data must be accumulated before old and new evidence can be made meaningful by a unifying concept.

The Development of the Cell Theory

11–7 The cell is the basic unit of life.

The similar method of division in all kinds of cells may be a clue to evolutionary relationships between all organisms. This similarity between the structure and reproduction of all cells is part of an important biological generalization: the **cell theory** This theory proposed that all animals and plants are built of cells, structural and functional units which act somewhat independently. The life of the organism depends on proper function and control of all its cells.

The major assumptions of the modern cell theory are: (1) *the cell is the basic unit of structure and function of a multicellular organism;* and (2) *cell division brings about genetic continuity between parent cells and their cell offspring.* The cell theory provides a logical explanation of the way in which multicellular organisms may have evolved from unicellular forms. It has been emphasized in previous chapters that the basic processes of fermentation, respiration, photosynthesis, and chromosome duplication are activities that take place within cells. According to the cell theory, these processes always occur within the cells of organisms whether the organisms are single-celled or multicellular. In other words, the *life* of a multicellular organism resides in its *cells*.

These generalizations may seem obvious to you. The cellular structure of animals and plants seems almost like "common sense" when you look at certain tissues under the microscope. But like many other "obvious" generalizations, the cell theory was developed only after new methods for observation of tissues were invented.

11–8 The microscope leads to new observations.

The ancient Greeks, in particular Aristotle and Theophrastus, knew quite a bit about the organs that make up living things. But they did not know about the smaller units, the cells, that make up thes organs, because they did not have micro scopes.

The first compound microscopes were prob-ably made by Dutch spectacle-makers. One of these people, Jansen, is generally given credit for its invention in 1590. A compound microscope consists of two or more lenses. If the lenses are accurately ground, the magnification and clarity of detail (resolution) are far superior to that obtained by a single lense. But for a long time the lenses were poor, producing images that were blurred and distorted. It was not until about 35 years after the invention of the compound microscope that anyone made use of it to look at living things.

Improvements in the compound microscope were made by Robert Hooke, a seventeenth-century English scientist. Figure 11-11 shows Hooke's microscope. 1665

Using an ordinary penknife, Hooke sliced a very thin piece of cork and placed it under his microscope for examination. He very carefully described what he saw:

> I could exceedingly plainly perceive it to be all perforated and porous, much like a Honeycomb . . . these pores, or cells, were not very deep, but consisted of a great many little Boxes . . .[1]

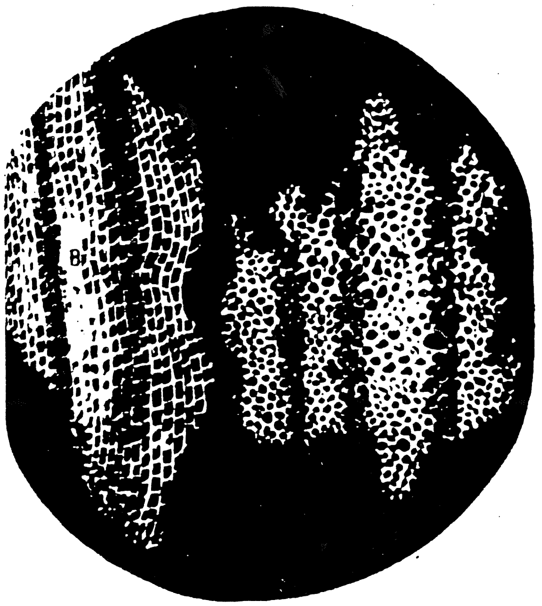


Figure 11–12 *Robert Hooke's drawing of cork cells. Hooke was describing what we would call the cell wall for the term "cells" meant little cubicles or rows of small rooms.*

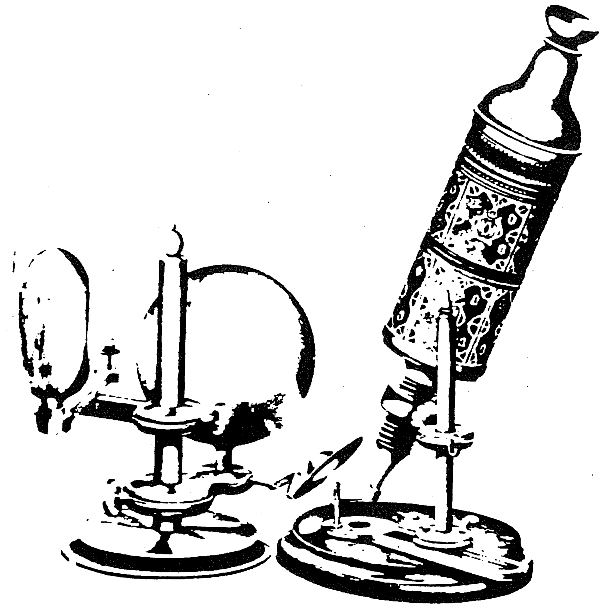


Figure 11–11 *A drawing of Robert Hooke's microscope. The main tube was about six inches long with a smaller sliding tube inside it. The microscope was focused by changing the distance between the two lenses.*

Note that Hooke used the word *cells* to describe the tiny "pores" that he saw in the thin pieces of cork. Figure 11–12 shows Hooke's drawing of a piece of cork. He pictured the cells as "little rooms" or "boxes." Hooke was looking at the cell walls of dead tissue. He certainly did not see "cells" as we think of them today. Nor did he originate the cell theory. He did, however, use the compound microscope as a biological tool. His discovery of small structures within living things encouraged other scientists to use this new tool.

Anton van Leewenhoek used a single polished lens to look at pond water. He observed nuclei & unicellular organisms. He saw bacteria and described them as 'animalcules'

11–9 Knowledge of cells gradually accumulates.

By the beginning of the nineteenth century it was known that the organs of the body are made up of parts called *tissues.* A combination of different kinds of tissues make up such organs as the heart, brain, and stomach. Some of the fundamental tissues of a vertebrate's body are blood, bone, muscle, cartilage, fat, and nerve. Tissues also make up plant organs such as stems, roots, and leaves. An example of a plant tissue is wood. Scientists of the nineteenth century knew about tissues, but they did not know what tissues themselves were made of.

Although many scientists had made carefull observations during the 150 years after the time of Robert Hooke, no one had stated a general theory concerning cells. Then in France in 1824, R. J. H. Dutrochet (doo-troh-SHAY) began comparing plant and animal tissues. He was a careful observer and came very close to a statement of the cell theory when he wrote that:

> . . . all the organic tissues of animals [are] really globular cells of an extreme smallness, which are united only by cohesion [clinging together]. Thus, all the tissues, all the organs of animals and plants are really only a cellular tissue diversely modified.[2]

Dutrochet believed that living tissues were really tiny cells held together by some kind of glue-like force and that organs were made up of different kinds of tissues.

An important observation and generalization resulted a few years later from the research of the Scottish botanist Robert Brown. He observed the leaf cells of orchids. Within each cell he detected a darker, circular portion, which he called a *nucleus*. From these observations he went on to generalize that nuclei were also found in the cells of other flowering plants. However, he did not detect the role of the nucleus in cell division.

11–10 The cell theory is proposed.

The stage was now set for the modern cell theory. The theory came about through the work of two nineteenth-century German biologists, Theodor Schwann and Matthias Schleiden. Schleiden published a paper in 1838 that dealt with the way cells originate. In this paper he set forth the hypothesis that the nucleus plays a major role in the development of the cell. Then he said that each cell leads a kind of double life. One part of its life is independent, pertaining to its own development alone. The other part of the life of the cell is its action as a part of plant tissue. In other words, every cell that one sees under a microscope, whether from stem, leaf, or root of a plant, acts as though it were a tiny independent organism. But it also contributes to the life of the larger organism of which it is a part.

While Schleiden was working with plant cells, Schwann was observing those of animals. He found that some of his observations on frog cells could easily apply to Schleiden's idea of the plant cell. (See Figure 11–13.) Schwann tested this hypothesis by examining a variety of animal structures, from bird's eggs to muscle fibers. His observations led him to make the following generalization:

> . . . the elementary parts of all tissues are formed of cells . . . it may be asserted that there is one universal principle of development for the elementary parts of organisms, however different, and that this principle is the formation of cells.[3]

Schleiden and Schwann cannot be said to have discovered the cell or even to have named it. But they did state the basic idea that *cells make up all living things,* and that these cells act independently and yet function together. This basic idea, that cells make up all living things from single-celled organisms to oak trees to men, is now called the cell theory. It explained many of the observations that had been made since the time of Hooke. This new way of considering the structure of plants and animals gave a new spirit to biological research, opening the door to new ideas in many areas of biology.

Working at the same time as Schleiden and Schwann, Purkinje named the living contents of cells protoplasm. This word comes from root words meaning 'first or primary fluid'.

11–11 The cell theory illustrates the interaction of facts and ideas.

Improved microscopes and staining methods soon led to further discoveries. New facts about the nature of cell division were uncovered. These discoveries helped to correct some of the mistaken ideas of Schleiden and Schwann, especially those which dealt with the nature of cell division. They had thought that cells solidified from fluid, or that tiny new cells formed inside of older ones in a simple process.

These new discoveries were made when scientists observed that cells of developing organisms duplicated themselves by means of cell division. Sperm and eggs, essential for sexual reproduction, had not been recognized as cells up to this time. New observations, however, showed that sperms are male reproductive cells and that eggs are female reproductive cells. In 1842 it was shown that the pollen grains of plants are formed by cell division. In such cell divisions it was found that the nucleus is always involved.

Finally in 1855 Rudolf Virchow (FIR-koh), a German physician and biologist, generalized that cells always multiply by cell division. Virchow's statement in Latin was: *omnis cellula e cellula,* which means that every cell comes from another cell. This generalization contradicted the spontaneous generation arguments. (See Section 4–5.) The statement also helped to provide a basis for the idea of evolution as presented by Darwin a few years later.

By 1879, new stains and improved lenses were available. The German biologist Walther Flemming was thus able to follow the nuclear events of cell division. He described the events of cell division very much as you have already studied them. Because of the threadlike chromosomes, Flemming named the process "mitosis," after the Greek word meaning "thread." Figure 11–14 is a drawing from his book, showing the various stages of mitosis that he observed.

Little was added to the picture of the fine structure of cells for eighty years after the work of Flemming. His knowledge of the cell was about the same as that in 1922, presented in Figure 11–1. Since 1930 there has been a tremendous advance in knowledge of the cell. Why? What happened?

An important new instrument, the electron microscope, was developed in the 1930's and it was soon used in the study of cells. This microscope uses electron waves rather than light rays as its "light" source. One does not look directly at an object through the electron microscope. (See Figure 11–15.) Instead, a beam of electrons is directed through an object onto a viewing screen or photographic plate. The photographic plate is then developed, enlarged, and examined. The electron microscope is capable of magnifying parts of cells approximately 100,000 times. Such magnification has revealed unimagined detail inside cellular particles. Figure 11–16 shows how much more detail can be seen through the electron microscope as compared with the light microscope.

New techniques and instruments such as the electron microscope have enabled scientists to continue their exploration of the cell. New facts and new ideas bring new advances. New instruments have provided an important link in this chain of scientific progress.

The history of the cell theory is a good illustration of the relationship between ideas and observation in science. When men attempted to speculate too far beyond their observations, they sometimes went wrong. Still, even wrong ideas may be better than none at all. At least they may serve to stimulate others to think about the same problem and may lead to further experiments. The cell theory and the theory of evolution provide two of the fundamental generalizations in biology. The third main theory is the gene theory, which was introduced in Chapter 9 and will be developed further in a later chapter. These three theories merge into one broad structure of related ideas, each theory lending support to the others. In the chapters that follow you will see how these three theories are used to account for many characteristics of higher plants and animals.

• • • Refinement of the cell theory has been going on since the time of Schleiden and Schwann. As new tools have been invented, more and more about the structure of the cell has been learned. The process of mitosis, by which the nucleus divides, could be more easily observed because of new dyes and better lenses. The functioning of an organism depends upon its individual cells, yet each cell maintains its own independent life. The continuity of life is assured by the specialized reproductive cells. The electron microscope has enabled biologists, chemists, and physicists to examine parts of cells never before imagined by man.