MODERN BIOLOGICAL PRINCIPLES

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PREFACE

THE PRESENT GENERATION has witnessed an explosive increase in biological knowledge, especially in the fields of molecular and cell biology. New techniques of study, such as the use of the electron microscope and of radioactive tracers, have made discoveries possible which have surpassed even the most optimistic expectations of a few years ago. At the same time the ever expanding curriculum of the colleges and universities has brought about a contraction in the amount of time allowed for biology courses in the general curriculum. Courses of one quarter, one semester, or abbreviated year courses have become more and more common.

This book has been written to satisfy the need for a text covering the great principles of biology in the light of modern discoveries, yet with sufficient descriptive biology to make these principles meaningful. The material to be included has been carefully selected so that the size of the book is such that it can serve for shortened courses, although it can easily be adapted to longer courses by supplemental library assignments.

Introductory chapters at the beginning of the book orient the student in the field of biology. These are followed by chapters on the molecular basis of life presented in conjunction with the theoretical origin of life on the earth. This topic leads logically into the cellular, then the organismic, and finally the ecological organization of living matter, with the principle of homeostasis as a unifying theme throughout. Considerable emphasis is placed on radiation biology and genetics in each of these topics. Chapters on the plant and animal kingdoms are included in the introductory section. These chapters can be omitted without interrupting the continuity of the study by teachers who would prefer that their students not take the time to study them in detail. Nevertheless, this section of the book can serve as a valuable reference when the students run across the names of unfamiliar organisms or taxonomic groups in other sections of their study.

The extensive use of photographs and diagrams as illustrations serves both to stimulate student interest and to aid in the understanding of the subject matter. Most of these illustrations have been made by the author; those which are the work of others are acknowledged in the captions. A laboratory manual to accompany this text is available from the William C. Brown Company, Publishers, of Dubuque, Iowa.

The author is deeply grateful to all of those who have assisted in the prepara-

tion of this book. In particular, the author wishes to acknowledge the invaluable assistance given by the critic readers who carefully read and made detailed suggestions for revision of the original manuscript. These are Dr. Gerald Nisbet, of Ball State College, Muncie, Indiana, and Dr. Herbert Treuting, of Trenton State College, Trenton, New Jersey. Some others who have been very helpful in specific sections of the book are Dr. Daniel Arnon, of the University of California, for his suggestions on the process of photosynthesis; Dr. William Shull, of the University of Michigan, for suggestions and illustrations on human genetics; Dr. C. M. Pomerat of the Pasadena Foundation for Medical Research, for valuable suggestions and photographs on cell biology. In addition, my colleagues at Colorado State College have always been helpful in answering questions and making suggestions on topics in their specialties. These include Dr. John Gapter, Dr. Arthur Moinat, Dr. Gerald Schmidt, Dr. Maynard Stamper, Dr. Robert Sund, and Dr. Bert Thomas. The author would appreciate criticisms, comments, and suggestions for improvement of the book by those who use it as a text.

A. M. WINCHESTER

Greeley, Colorado
January 1965

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Chapter 1

BIOLOGY—THE STUDY OF LIFE

BIOLOGY is a study of things that exhibit the properties of life. Life has intrigued man since the beginning of recorded history. Some ancient cultures thought of life as a mysterious force, somehow associated with supernatural deities. Even today, after all our scientific advances, there is much to be learned about it. It is very difficult to pinpoint the moment when a plant or animal ceases to be alive. When a human being no longer breathes and the heart stops beating, we commonly say that he is dead, yet most of the cells of the body may still be alive. Some such so-called dead people have been brought back to life by means which restore the breathing and circulation before the brain cells die.

In spite of our incomplete knowledge, modern biology has done much to fathom the many secrets associated with life. New techniques of studying the nature of the cells and what takes place within them have contributed much to this knowledge. As it is in the cells that the living processes take place, most of the answers to the questions of life ultimately must be found by studies on the cellular level. Since cells are very small, we must be prepared to deal with matter on a minute scale: molecules, atoms, and even the subatomic particles become integral parts of modern research in biology. In this book we shall become acquainted with some of the studies that are being made and learn of some findings that have resulted from these studies.

To some students a study of biology is a necessary part of their preparation for a vocation. Biology is fundamental for many of the professions. To all, biology has much to offer; many problems arise in everyday life which can be solved better with a background of biology. No person today can consider himself well-informed without some basic knowledge of life science. Newspapers, popular magazines, radio and television programs, as well as public speakers and discussion groups, all assume at least an elementary understanding of this great field of learning on the part of their audiences. Since it is such a basic subject, almost all college programs include a requirement for a study of biology in the curriculum.

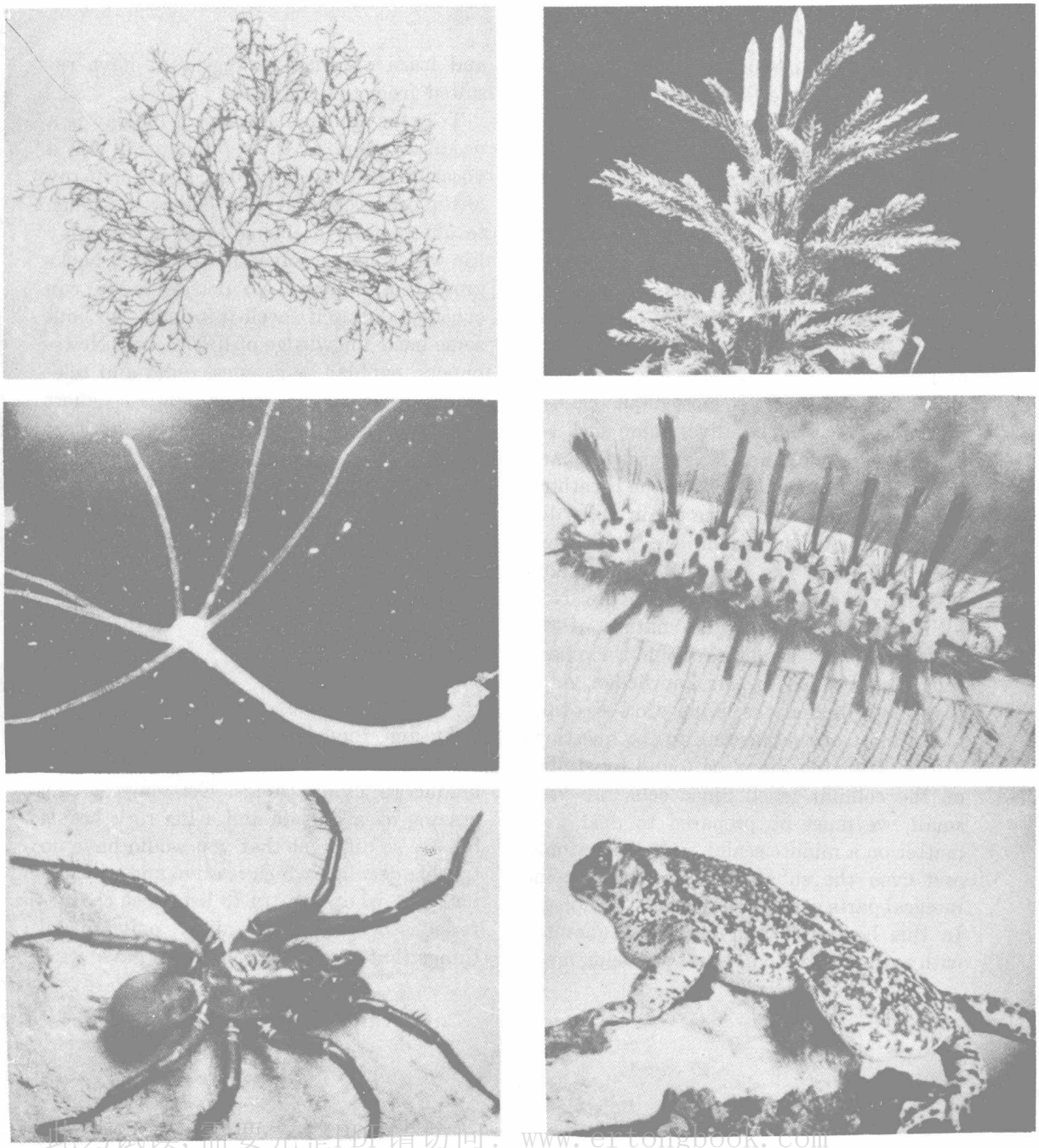
DISTINCTIVE FEATURES OF LIVING MATTER

At first thought you might feel that it would be easy enough to list the features unique to living things. Certainly a cow grazing on a hillside and a big rock beside her are so different that you would have no trouble deciding which is alive and which is not. Yet, when you try to list those characteristics which would apply only to all things that are alive, you might have some

difficulty. Remember that plants are alive as well as animals. We know there is a difference between living and nonliving things, but just what is it? There are several important differences. Let us try to list some characteristics that will apply only to living things.

1. Made of Protoplasm. Living matter is made of a distinctive material, known as

Fig. 1.1 *The variety of life. All of the organisms pictured here have characteristics in common which lead us to classify them as living, even though they exhibit extreme diversity in appearance. From left to right and top to bottom: a red alga; ground pine;* Hydra, *a small water animal; the caterpillar of a moth; a tarantula spider; a toad.*



protoplasm, which is not duplicated in any nonliving matter. All protoplasm has certain distinctive characteristics, whether it be in a cell in a leaf of a tree, a cell in a flea sucking blood from a dog, or a cell in the skin on your hand. The chemical make-up of protoplasm includes **proteins, carbohydrates, lipids** (fatty materials), **water** and **nucleic acid** (the material of which genes are made). Nowhere outside of living matter can this particular combination of materials to be found occurring naturally.

This is not to imply that all protoplasm is exactly alike; it exists in an infinite variety of forms. The various materials can be put together in different ways and even

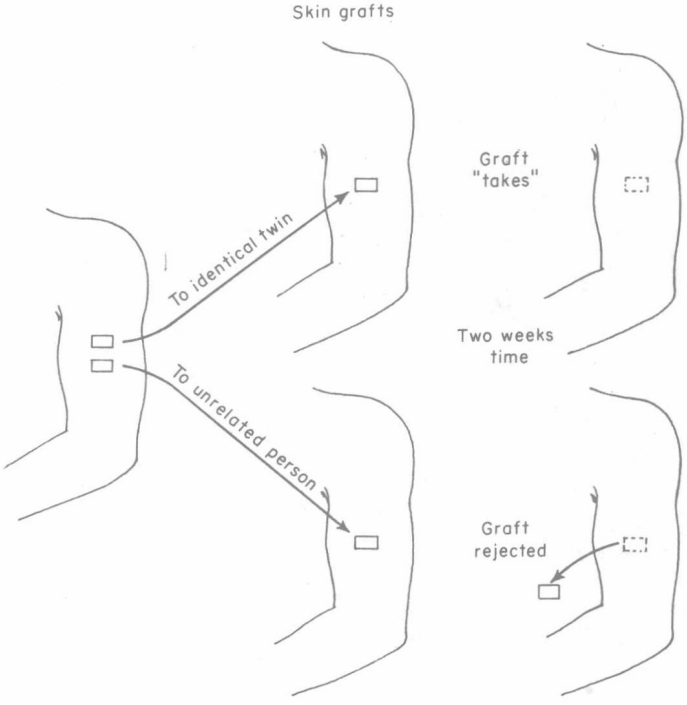


Fig. 1.2 *Skin grafts demonstrate the difference in protoplasm even within the same species. The only grafts that a human being will accept are grafts from another human being who is his identical twin and so has an identical heredity.*

members of the same species may show distinctive differences. The protoplasm of your skin, for instance, is different from that of your classmates. We see the proof of this when we try to transplant skin from one person to another. The grafted skin will be rejected by the recipient because of subtle differences in the makeup of its protoplasm. We shall learn more about this in Chapter 8.

The basic components of protoplasm, however, remain the same; they can just be put together in a great variety of ways.

2. Exhibits Growth. Living things exhibit a certain type of growth that sets them apart from all nonliving things. Food is taken into a living organism and converted into more protoplasm and the organism becomes larger; it grows. When you see a huge fullback come crashing through the

opponent's line to score a touchdown at a football game, you may find it hard to realize that this great hulk of a man was once a gurgling baby in a lace-trimmed dress playing with his toes in his crib. Where did all this bone and muscle come from that makes him what he is today? It resulted from growth—the ability of the cells to convert some of the food that was eaten into human flesh.

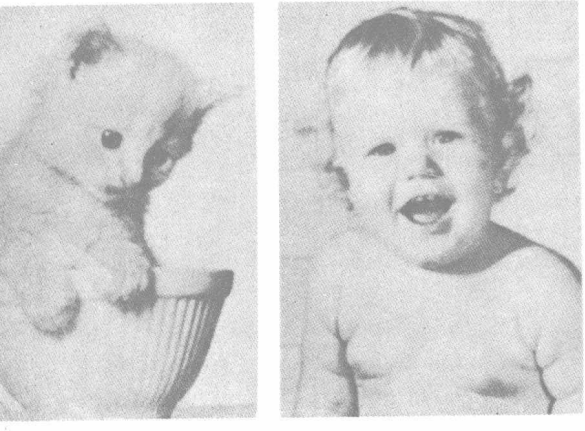


Fig. 1.3 *Growth of living matter. Although the kitten in the bowl and the human baby were formed from about the same food elements, they are quite different because they have inherited genes which put the food elements together in particular ways. This is directed growth, characteristic of living matter.*

Such growth is directed growth. An expectant female cat and an expectant human mother may eat exactly the same kind of food, yet in one case this food is converted into kitten flesh and kittens are born. In the other, it is converted into human flesh and a human baby is born. Within the cells are tiny bodies known as **genes,** which direct this growth in such a way that bodies resembling the parents are built in each case.

There are cases of growth of nonliving matter, but it is an entirely different kind of growth. In large underground caves you may see beautiful stalactites hanging from above and stalagmites protruding up from the floor. These grow larger with the passage of time. Water seeping down contains minerals in solution and some of the minerals are deposited as the water evaporates. This type of growth involves the addition of material to the surface. We find such growth above ground in regions where there are hot springs boiling up out of the ground. These springs may be rich in minerals, which are deposited as the water cools. It is easy to see that growth of this nature is quite different from the growth of living matter.

3. Has Cellular Organization. Living things are generally composed of small units known as **cells.** Some organisms are composed of single cells but the larger forms are multicellular. The human body, for instance, is composed of literally billions of cells. Each cell is a self-contained unit within which many complicated reactions take place.

There is one exception to this cellular organization. The smallest known forms exhibiting the properties of life are known as **viruses.** You have certainly heard of these, because they cause many serious human diseases. Polio, flu, measles and the common head cold are some of the diseases that result when certain viruses invade the human body. Viruses can be seen with high-powered electron microscopes as tiny units that are not complete cells. They have some of the parts found in cells, but certain other parts are missing. For this reason, the viruses must gain entrance to live cells before they can exhibit the properties of life. We shall learn more about viruses as we continue our study, for through investigations on these "incomplete cells" we have learned much about the function of the parts of complete cells.

4. Obtains Energy from Food. Not all of the food that an animal eats is used for

growth. Some of it is used to provide the energy needed to sustain all forms of life. Life cannot continue without the expenditure of energy. Everything you do requires energy—walking, running, thinking or even sitting still—there is a continuous conversion of food into the energy required for all the processes of living.

Plants, likewise, use a part of their food for energy, although this is generally not released at so great a rate of speed as in animals because of the lesser activity of plants.

Most forms of life obtain energy by combining food with oxygen from the air. You must breathe constantly from the moment of birth until death to supply the oxygen needed for this method of energy release. A few small forms of life, such as some of the bacteria, have the power to release some of the energy from their food without oxygen. Much less energy is obtained, however, when oxygen is not used.

5. Shows Favorable Response to Environment. Do you remember the times

Fig. 1.4 *"Growth" of nonliving matter. This beautiful terrace in Yellowstone Park increases its size at the rate of several inches each year. The hot water boiling out of the ground contains much calcium carbonate dissolved from the rocks it has passed through. As the water cools, the calcium carbonate is deposited in the patterns shown here. Contrast this with the growth of living things.*

when you have gone into a movie theater on a bright, sunny day? Remember how dark it seemed as you stumbled around and perhaps tried to sit in someone's lap? Within a few minutes, however, the theater appeared light and you could see clearly. This is a good example of how living things can adapt to their environment. Your eyes have the power to make adjustments so that you can see clearly on a bright beach or in a darkened room, where the light may be less than one-thousandth as bright. Some animals can make the adjustment much more quickly than others. The owl, for instance, which must chase its prey from bright moonlight into dark forests and back again can adjust its eyes almost instantly. If you move a flashlight back and forth across the eyes of an owl, you can see the pupils open and close as fast as the light moves.

Fig. 1.5 *This owl appears to have become confused in the adaptation of its eyes since one pupil is larger than the other. Actually, the picture shows the rapidity of adaptation of the owl's eyes to changing light intensity. The picture was made by flash while a small beam of light was shining into the eye shown on the left. This is a good example of short-term adaptation to environment.*

Some adaptations to the environment take place more slowly, but last longer. The human skin becomes darker after exposure to sunlight, but this does not take place in one day. Many fair-skinned people have learned that they cannot get a coat of tan in one afternoon at the beach; instead they may get a bad sunburn. Moderate exposure of the skin of such persons over a period of days will bring about a tanning that protects from sunburn.

Plant responses are generally rather slow in developing, but they are just as definite as those of animals. A plant placed near a window will turn its leaves in such a manner as to receive the best exposure to light. No matter which way seeds are planted, the roots will turn down and the stem will turn up. All living things are constantly making these adjustments to the conditions in which they live.

Nonliving things can show some response to the environment. A piece of steel placed in the sunlight will expand because of the effect of the heat, but this is purely a mechanical response and certainly is of no advantage to the steel.

6. Adapts to Environment through Natural Selection. All species achieve inherited adaptations to their environment. These differ from the individual adaptations in that they are passed on from generation to generation through the units of

heredity. These inherited adaptations are necessary because the environment is constantly changing and life must accommodate itself to the fluid conditions or it will no longer continue to exist. Today we find the fossil remains of many plants and animals that once were abundant upon the earth but which became extinct because they did not change fast enough to adapt themselves to the changing environment.

Such adaptations are brought about through natural selection. There will be some variation among individuals within all species, and some of these individuals will be better adapted for survival in a particular environment than others. These will tend

Fig. 1.6 *Adaptation in root growth. A farmer does not have to plant his seeds in any particular position; the roots will always grow downward, no matter in what position the seeds happen to fall.*

to live, while those less well adapted will perish. Consequently, the traits which favor survival in a given environment tend to be perpetuated by means of the units of heredity. We shall study this topic more fully in Chapter 6.

7. Reproduces. No living thing can live forever; so there must be some way for it to leave offspring that can continue its kind on the earth. This process is known as **reproduction.** In some of the simpler forms of life, reproduction is very simple: after a period of growth each organism splits itself in two, and each half becomes a complete organism; these grow and split in turn, and the species continues. Many plants and some simple animals produce buds or simi-

lar outgrowths, which can break off and produce entire new plants or animals. The great majority of living things produce sex cells or **gametes;** these unite with gametes produced by individuals of the opposite sex of the same species and initiate the life of new organisms.

During the Middle Ages it was believed that living organisms could appear from nonliving matter; this process was called **spontaneous generation.** Maggots were thought to be generated within decaying meat; mice and rats were thought to originate from neglected garbage; and frogs

Fig. 1.7 *Adaptation through natural selection. The whippoorwill in this picture is not easy to see at first glance because it blends so well with its surroundings. Only living things have the power to become thus adapted through natural selection.*

were believed to appear from mud in ponds formed by spring rains. One may read some old books and find pictures and descriptions of the various stages of generation of eels from mud in a river bottom or a formula for making mice by mixing stale cheese, dirty shirts and other such ingredients. These ideas were accepted because there was insufficient information about the methods of reproduction of the forms of life involved. As scientists learned more about the continuity of life, it became apparent that living things can arise only through some pre-existing living things, under conditions