

TEXT BOOK PREPARED FOR F.S.

BIOLOGICAL SCIENCE

AN INQUIRY INTO LIFE



BIOLOGICAL SCIENCES CURRICULUM STUDY

PUBLISHERS
KUTAB KHANA ANJUMAN HIMAYAT

FOR
PUNJAB TEXT BOOK BOARD, LAHORE

Contents

Foreword

Preface

vii

PART 1 UNITY

The earth is populated by millions of different types of living creatures. Each has its own way of living, but all share *the only known kind* of structural and chemical organization that means *being alive*. Whatever their dissimilarities, plants, animals, and other creatures solve their big problems—those of being alive—in much the same way. The study of these unifying features will be one theme in Part 1. We will also learn how biologists acquire knowledge of living creatures.

CHAPTER

Biology—What Is It About?

1

1

Biology is the sum of man's knowledge about life—his own life and that of all other creatures. This knowledge consists not only of a collection of facts, but more importantly, of the way these facts are associated and interpreted in general theories. An example of a biological investigation is the theme of this chapter. The cause of mankind's most serious disease, malaria, is used as a case history in showing how man attempts to answer his biological questions.

CHAPTER

Life from Life

19

2

Less than a century ago scientists debated furiously the question of whether life could arise spontaneously from nonliving substances. The far-reaching implications of this biological question are not necessarily the same for life today and life in its most distant past. But they *are* the same for all kinds of living things, as investigation of this biological problem in terms of life today has abundantly illustrated.

CHAPTER

Basic Structure

38

3

Unifying theories relate isolated facts. Science is at its best when it seeks a new theory to organize an accumulation of poorly understood facts. One of the greatest unifying theories of biology is that all, or nearly all, forms of life have a common basic structure. That this is true is not at all obvious: a fish and a tree really do not seem to resemble one another. Yet both are alike in being composed of cells. Cells were first discovered almost 200 years before their nature was understood well enough to lead to the cell theory.

CHAPTER**4****Basic Functions**

If nearly all forms of life have a common basic structure — cells — do they also have common functions? Does life as a fish have anything in common with life as a tree? This biological question is closely connected with the history of chemistry — especially with the argument that life can be understood in terms of the same general laws that apply to all matter.

54

CHAPTER**5****Living Chemistry**

Even though all forms of life — all living organisms — exist in full conformity with natural patterns that we recognize as the laws of chemistry and physics, the patterns of life involve *complex* chemistry and *complex* physics. Living organisms are composed of atoms that are common in the nonliving world, but these atoms are much more complexly organized than in nonliving matter. Only in living structures are atoms found organized into large molecules of nucleic acids, proteins, carbohydrates, and fats. The cells of all living creatures are composed chiefly of these same classes of chemical substances.

80

CHAPTER**6****The Physiology of Cells**

A living cell, with its huge number of complex substances, exhibits ceaseless chemical activity. Substances are entering and leaving the cell at all times, as molecules are built up and broken down within the cell. Transfers of energy for all the cell's activities are occurring constantly. These ceaseless processes of chemical and energy change are

10

CHAPTER**7****Reproduction — of Cells — of Individuals**

The most basic characteristic of life is reproduction; that is, the production of new structures and individuals similar to the existing structures and individuals. Reproduction occurs at different levels of organization. Parts of the cell, such as the chromosomes, produce new chromosomes. Cells then produce new cells; and individuals, offspring themselves. In this chapter, reproduction by cells and by individuals is discussed in terms of a fundamental feature — the replication and distribution of chromosomes in mitosis and meiosis.

CHAPTER**8****The Hereditary Materials**

The physical basis of genetic continuity can be traced from cell to nucleus to chromosome. In this chapter you will list the requirements for a hereditary material, then look for molecules that fulfill these requirements. The observations and experiments that led to the belief that DNA is the hereditary material are used as an inquiry into the procedures. Finally, the manner in which the hereditary instructions of DNA are carried out by specific proteins of the cell is described.

x

PART 2 DIVERSITY

Diversity among the earth's microorganisms, plants, and animals is more obvious in many ways than the fundamental unity in life. Historically, diversity emerged as modifications upon a common pattern. Unity continues to be shown in the recognition that different organisms are similar chemically, have a common structural basis in cells, reproduce, evolve, respond to stimuli, and constitute parts of an interrelated whole. Yet diversity in life is seen in the millions of different types of living organisms—the three principal groups being microorganisms, plants, and animals. This section of the book will be concerned with the many variations upon the fundamental theme.

PART 2a MICROORGANISMS

CHAPTER

9

Beginnings—Viruses—Time

177

Several billion years ago the earth was vastly different from what it is today. The primeval seas may have become rich mixtures of organic molecules. Probably a chance combination of molecules produced a larger molecule (possibly similar to the DNA of today) that had a chemical structure giving it a pattern for exact duplication. Slowly, the duplicating molecules became parts of more complex systems, until they could be called "organisms." From these humble beginnings life spread over the earth and evolved into its innumerable species—each an experiment in living in a particular way. The viruses of today may represent a level of complexity similar to that of some of the earliest forms of life. They cannot live independently but require a living cell for their life and reproduction. This may be analogous to the requirements of the hypothetical first organisms for an environment rich in organic compounds.

CHAPTER

10

Bacteria—Pioneers of Cellular Organization

198

The bacteria, more complex than the viruses, are the simplest organisms that can be called cells. They also are the smallest organisms that can be studied with the compound microscope. Their activities are basically those of every living organism. Life in the simplest cells can be very complex—even to reproduction by sexual means.

CHAPTER

11

Small Organisms of Great Importance

214

Because of their small size, bacteria were discovered only after the invention of the microscope. Their importance became rapidly recognized, for they are organisms that cause spoilage, decay, and disease, but that have many useful activities. The discovery that bacteria cause disease is one of the most interesting examples of the methods of science. Bacteria are beneficial in industry, food preparation, and vitamin production, mostly because of their ability to carry on fermentations that result in valuable byproducts.

PART 2b PLANTS

CHAPTER

12

Molds, Yeasts, and Mushrooms

230

Collectively known as fungi, the molds, yeasts, and mushrooms are more complex than bacteria. They represent distinctive lines in the evolution of organisms that cannot carry on photosynthesis. They, like the animals, are dependent ultimately upon the green plants. Together with the bacteria they are the chief decomposers—they break down the bodies of dead animals and plants and release substances that are used by the living. In their decomposition activities, fungi may do great damage to timber, stored foods, and other products. In another role, as producers of plant diseases, they have affected the distribution of the world's population.

CHAPTER

13

The Trend Toward Complexity

241

The most successful line of plant evolution gave rise to the green plants, of which the simplest are the green algae. From their origin in the sea, green algae provided the ancestors of the green land plants. Although this happened long ago, the evolutionary steps are still plainly seen by the study of present-day algae.

CHAPTER

14

The Land Turns Green

254

More than 400 million years ago, some species of green algae evolved into plants that could live on land. Until then, the land had been barren and lifeless. Slowly the earth grew a mantle of green—the life-supporting green of photosynthetic organisms. Special structures and processes, primarily for obtaining water, carbon dioxide, and nitrogen compounds—and for preventing subsequent loss of water—became necessary for plant life on land. The liverworts and mosses of today are reminders of some of the early experiments in the evolution of green land plants.

CHAPTER

15

Photosynthesis—The Link Between Two Worlds

279

Life is the child of light. Green plants capture the energy of sunlight and use it to synthesize energy-rich compounds. These compounds are the sole source of energy for nearly all other organisms. The essential substance in green plants that makes photosynthesis possible is chlorophyll, which in most land plants is concentrated in leaves. In the living leaves, H_2O and CO_2 are used in the manufacture of sugars and amino acids.

CHAPTER

16

Stems and Roots—A Study of Complementarity of Structure and Function

296

Stems and roots support the leaves in elevated positions in which maximum light can be received. The water used in photosynthesis is absorbed by roots and transported to leaves.

through the tissues of the roots and the stem. The rapid movement of materials and the support of leaves are aided by the complex conducting systems that have evolved in the vascular plants.

CHAPTER

17

Reproduction and Development in Flowering Plants

309

The pinnacle of evolutionary development of the green plants is the large group characterized by flowers. Most of the familiar plants of the world are flower-producing species. It is this group that provides, directly or indirectly, for nearly all of man's needs — his food, his shelter, and most of his clothes and fuels.

PART 2C ANIMALS

CHAPTER

18

The World of Animals

329

Green plants are producers; animals are consumers. Given a proper temperature and the necessary inorganic substances, green plants can live wherever there is light. Animals can live only where there are green plants or products derived from green plants. This basic dependence defines the boundaries of the world of animals. The animal way of life — whether of a single-celled organism such as *Amoeba* or of large and complex animals — makes a series of demands on the world of life. These demands can be understood from the study of one kind of animal and its dependence upon other organisms and upon the nonliving environment.

CHAPTER

19

The Diversity Among Animals — Variations on a Theme

348

There are probably two million species of animals living today. Fundamentally, all live the same way, but in detail they vary tremendously. The many animal species can be classified into major groups known as phyla. Ten of these phyla include at least 98 percent of all known animals. The known history of animals begins more than a half billion years ago, when all their ancestors lived in water. Much later, some of the animals evolved modifications permitting them to colonize the land.

CHAPTER

20

Digestion in Multicellular Animals

388

In animals that have many cells, some degree of specialization, or division of labor, occurs among the cells. Some of the cells may be specialized in capturing food, others in digesting it, still others in coordinating these activities and additional ones. Digestion is carried out in a simple sac (in *Hydra*) or a complex sac (in planarians), a simple tube (in some worms) or a complex tube (in grasshoppers and many other animals, including man). This chapter is a study of one essential aspect of this division of labor — the enzyme-controlled breakdown of food substances.

CHAPTER**21****Transportation Within Multicellular Animals**

404

Multicellular animals require a mechanism for transporting materials throughout the body. Sometimes simple diffusion will suffice, as in *Hydra*, but diffusion can supply the requirements of only very small bodies. Animals of larger size and complexity have transport systems. How these systems are constructed and how they function is the subject of this chapter.

CHAPTER**22****Respiration in Multicellular Animals**

419

In animal cells, carbon dioxide is a major product of energy-liberating reactions. Oxygen is often required in these reactions. Respiration involves the exchange of oxygen and carbon dioxide by the animal with its environment, as well as energy-liberating reactions within the cells.

CHAPTER**23****Excretion and Homeostasis in Multicellular Animals**

429

Excretion is the removal from the body of chemical substances present in excess. In addition to water and carbon dioxide, major waste products in animals include one or more nitrogen compounds such as urea. Respiratory processes eliminate carbon dioxide, while nitrogen-containing wastes in larger animals usually are removed by specialized excretory organs such as kidneys. Heat released in metabolism also poses a problem, and special homeostatic mechanisms may regulate body temperature, apart from the mechanisms that regulate body chemical makeup.

CHAPTER**24****Coordination in Multicellular Animals**

438

Multicellular animals, with their many types of specialized cells, have special means of coordinating the activities of all the parts. Coordination is brought about in two general ways: control by nerves and control by chemical substances known as hormones. Information and "orders" are carried from one part of the body to another by both the nerves and the hormones.

CHAPTER**25****Animal Support and Locomotion**

458

One of the most obvious characteristics of the animal way of life is movement. Single-celled animals may move by cilia, flagella, or by a flowing motion of the cell itself. More complex animals move by means of tentacles, wings, feet, fins, and sometimes even by cilia. In many instances the movement is dependent upon the contraction of muscle cells—contraction made possible by special chemical reactions and the energy of ATP. Among the more complex animals, body movement usually involves supporting structures for the body—a skeleton on the inside, as in man, or on the outside, as in the insects.