BIOLOGICAL SCIENCE
AN INQUIRY INTO LIFE

STUDENT LABORATORY GUIDE

SOLE TEXT BOOK PRESCRIBED FOR F.Sc.

BIOLOGICAL SCIENCE

AN INQUIRY INTO LIFE

BIOLOGICAL SCIENCES CURRICULUM STUDY

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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 1 **Biology—What Is It About?** 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 2 **Life from Life** 19

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.

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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, common functions? Does life as a fish have anything in common with life as a biological question is closely connected with the theme of evolution. The argument that life can be understood in terms of the same principles applying to all matter.

CHAPTER 5

Living Chemistry

Even though all forms of life—all living organisms—exist in full conformity with patterns that we recognize as the laws of chemistry and physics, the behavior of living matter involves complex chemistry and complex physics. Living organisms are composed of atoms that are common in the nonliving world, but these atoms are much more highly organized than in nonliving matter. Only in living structures are atoms found in the 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.

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 being 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

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 like 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.

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

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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.

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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 [illegible]

PART 2b PLANTS

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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.

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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.

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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.

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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.

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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.

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CHAPTER 18 **The World of Animals**

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

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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.

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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 chapte is a study of one essential aspect of this division of labor—the enzyme-controlled bre down of food substances.

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CHAPTER 26 **Reproduction in Animals**

Reproduction is a prime attribute of life. It may be asexual, as when a single-celled animal divides into two, or it may be sexual, involving the production and union of an egg and a sperm. Sexual reproduction – so widespread in the living world that we must assume it to be the most successful type so far evolved – provides for great variety in the hereditary makeup of organisms. The reproduction of most animals, including man, is sexual.

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CHAPTER 27 **The Development of Animals**

In sexual reproduction, the union of a sperm and an egg produces a fertilized egg. The fertilized egg is only a single cell and, hence, is vastly different from the multicellular adult. The events that occur during the gradual growth and change from fertilized egg to adult are known as development. Basically, development consists of an increase in the number of cells, the differentiation of cells into different types, growth, and the organization of cells into the structures of the adult.

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CHAPTER 28 **The Analysis of Development**

For centuries man has speculated on the underlying factors that control development. How can the fertilized egg, itself a single cell, develop into a complex adult with its many forms of cells, tissues, and organs? One hypothesis was that the adult body was preformed in miniature in the sperm or in the egg. When microscopes were available, it was possible to make the observation that disproved this hypothesis. Biologists of today believe that the complexity of the adult is a slow development from the simplicity of the embryo, and they are performing experiments to learn how this comes about.

PART 3 CONTINUITY

Living organisms of today are the passing manifestations of a lineage of life that extends backward in time for several billion years. Individuals die, but life continues in their offspring. Two aspects of the continuity of life by reproduction must be considered. First is the short-term continuity based on transmission of hereditary instructions from one generation to the next. Second is the long-term continuity – evolution – based on mutation, recombination of alleles, and changes in frequency of alleles because of natural selection.

CHAPTER **Patterns of Heredity**

a full-grown organism. Heredity is the process by which this information is transmitted from one generation to another, in exact and predictable ways, as set forth in the laws discovered by Gregor Mendel, and by others in the century since Mendel's work.

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CHAPTER 30

The Chromosome Theory of Heredity

The exact and predictable nature of inheritance suggests that it has a physical basis in the cell. During the first quarter of the twentieth century, biologists discovered this physical basis: the information of inheritance is carried by genes, which are parts of chromosomes. The arrangement and distribution of chromosomes during the formation of eggs and sperms, and the particular combinations of chromosomes that occur at fertilization, determine the pattern of heredity. As a part of this pattern, there is even a basis for recombination of genes located on the same chromosome. Specificity of hereditary instructions appears to be due to a specific sequence of nucleotides in the DNA of the chromosomes.

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APTER 31

Darwinian Evolution

More than a century ago, Charles Darwin announced his hypothesis of evolution—one of the most profound intellectual insights of all time. He offered a rational explanation for the innumerable different species that live on the earth, and for the changes that occur in them with the passage of time. The fossil evidence of life long ago, and the evidence derived from the study of life today, have substantiated the correctness of Darwin's hypothesis, which has become a major part of the theory of evolution.

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The Mechanisms of Evolution

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In Darwin's time the available biological data were not sufficient to prove the correctness of the hypothesis of evolution. More than half a century later, the careful study of inheritance did provide the necessary theoretical basis. We now understand the nature of hereditary differences among organisms. From among genetically different individuals, those whose inherited characteristics best fit them to their environment are selected by nature; that is, the "better" gene combinations survive in the succeeding generations, whereas the "inferior" gene combinations do not. Isolation—in terms of geographic barriers to mixing, and gradually emerging genetic barriers to interbreeding—helps complete the separation of closely related populations into new species.

R

The Evolution of Man

The biological processes that affect all or
evolved—and has done so
Within the last

CHAPTER 34 **The Cultural Evolution of Man** 627

In the last 25,000 years man has changed little in his structure, but tremendously in his way of life. He has domesticated plants and animals and has solved, in increasing ways, a biological problem that he cannot escape—the need for food. He has built villages and cities and developed the science and technology that is the basis of our civilization. His mind and hands have produced science, art, and literature. He has the information necessary to provide the individuals of his species with a secure and rewarding life.

PART 4 INTERACTION

At all levels of biological organization there is unity, diversity, continuity, and interaction. We come now to the last of these. No individual is complete in itself. Its behavior, and life itself, is a consequence of interactions with other individuals of the same species, with the individuals of different species, and with the entirety of the living and nonliving environments.

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Organisms are constantly active, responding to processes within themselves, to the presence of other organisms, and to the nonliving environment. Such activities and interdependence among organisms are particularly obvious in animals. Biologists analyze the entire pattern of animal activities in the study of animal behavior.

CHAPTER 36 **Checks and Balances in Nature**

All organisms are the products of their genetic makeup and their environments. Under the influence of the environment, evolution occurs, for the environment selects organisms genetically best suited to survive in certain habitats. In each habitat, green plants are the primary producers, and other forms of life are the consumers. The stockpile of materials in dead organisms is decomposed and returned to living circulation by bacteria, fungi, and other decomposers. All organisms on earth are part of a great cycle that ultimately depends on the energy of sunlight.

APPENDIX

CHAPTER 37 **A World of Ecosystems**

Plants, animals, and microorganisms, together with the environments in which they live, make up interdependent units or ecosystems. An ecosystem may be in the open ocean or in the shallow sea along the shore. On land it may be in a forest, or on mountains, plains, lands, tundra, or desert. Each of these, because of physical and biological factors, supports a different set of living things.

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Among the biological problems that man cannot escape is his own effect on his ecosystem. Primitive man generally lived in balance with nature. He was an integrated part of the biological community. Civilized man, especially in recent centuries, has approached nature with an arrogance that could be his own undoing. He has destroyed vast areas of productive soil by poor agricultural practices; he has devastated forests, only to find his water supply diminishing and his soil supply eroding; he has fouled rivers and streams, thereby making their water unsuitable to his needs. But today he is beginning to behave as he must — as a living creature who depends on other life for his existence.

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Man and all other living species are products of the past, associating in the present. We are linked not only to the creatures around us but to those no longer living — and to an earth before life began. In this final chapter the diversity of organisms, extinct and living, is portrayed against the background of the evolution of the earth itself.

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