PRINCIPLES OF CELL BIOLOGY

Lewis J. Kleinsmith

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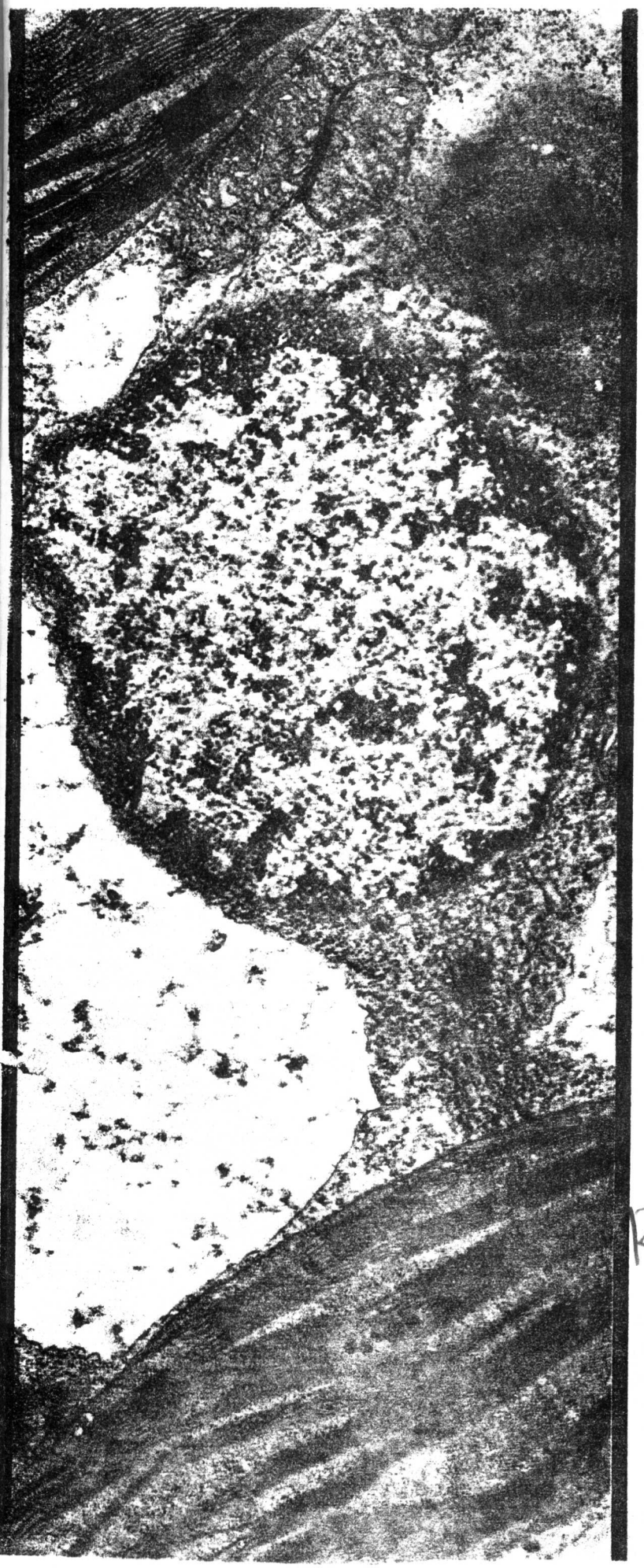

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Preface

In the last two decades the field of cell biology has undergone a veritable revolution, leading to major advances in our understanding of cell structure and function. The convergence of cytological, genetic, and biochemical approaches has generated a rich panorama of detail, the significance of which we are still attempting to unravel. *Principles of Cell Biology* is written as an introduction to this rapidly growing field. Our goal is to acquaint the undergraduate student who is encountering the subject for the first time with the fundamental principles that characterize cellular organization and function. This textbook has been drawn from our collective teaching experiences, both at a large university and at a small liberal-arts college. Our primary concern has been to write a book that is readable.

PLAN OF THE BOOK

Principles of Cell Biology is organized into three sections, with the first two sections making up the core, involving organelle structure and function. The remaining section allows the student to see how these general principles of cellular organization apply to various differentiated cell types. Because of this arrangement the book can easily serve a full year course, one that is a semester in length, or courses of shorter duration.

In Part 1, we present background information essential to the understanding of concepts discussed later in the book. Although some students may be able to use this section as a review of material already learned, we have assumed only a basic understanding of biological and chemical principles and have included these first three chapters as a means of introducing certain elements fundamental to the subject matter. Chapter 1 presents an overview of the various organelles found in eukaryotic and prokaryotic cells and discusses in detail the structure of important cellular molecules. The chapter concludes with a short discussion of the origin of cells and a description of how cells differ from viruses. This chapter sets the stage for the rest of the book and should be read as a prelude to the remaining material. Because enzymes are critically involved in many, if not most, cellular events, we have devoted an entire chapter to a discussion of their properties. Chapter 2 focuses on enzymes as biological catalysts, discussing thermodynamic and kinetic features of these important cellular proteins. The last chapter in Part 1 serves as a repository for the discussion of experimental tech-

niques commonly used in the study of cells. Chapter 3 should be used as a reference that the student can consult when necessary. The single exception to this approach involves the discussion of techniques used to dissect and study genetic systems. Because of the difficult vocabulary and necessity for having a well-developed understanding of genetics, we have placed the discussion of these techniques within the chapter to which they apply (Chapter 10). After reading Chapters 1 and 2, and becoming familiar with Chapter 3 as a reference, students should be prepared to begin a study of the core material presented in Part 2.

There are many ways to organize a discussion of cellular organelles. We have chosen to begin by concentrating on the architecture and function of membranes, since this organelle plays such an important role in a diverse spectrum of cellular processes. Chapters 4 and 5 deal with the plasma membrane, cell walls, and the extracellular material covering the cell surface, with Chapter 4 devoted to structural considerations and Chapter 5 concerned primarily with function. The cytoplasmic membrane system is the subject of Chapter 6. Following a discussion of the membranes of the endoplasmic reticulum and Golgi complex, coverage is expanded to include the biology of lysosomes, since they are involved in membrane recycling events. Theories of how membranes are formed and cycled throughout the cell are also a part of this material. Finally, we discuss the biogenesis and function of microbodies such as peroxisomes and glyoxysomes.

The next major subject to be introduced is cellular energetics. The mitochondrion has historically served as a model system illustrating the essential ingredients of structure-function relationships, revealing to cell biologists some fundamental principles of subcellular organization. Following a description of how the cell is able to transform energy in preformed organic molecules into a usable form (involving a study of glycolysis and mitochondrial respiration pathways), we turn to the chloroplast in Chapter 8. Using Chapter 7 as a framework, we build on that knowledge, showing why the evolution of cells that could make their own organic molecules from inorganic precursors was such an important event in the history of living things. The study of photosynthesis illustrates the complexities involved in transducing radiant energy into energy of the chemical bond, and provides the student with a solid basis on which to evaluate the relationship between organelle architecture and function.

The study of the cytoskeleton is a rapidly expanding area in cell biology. We have included an overview of the principles of cytoskeletal organization in Chapter 9, focusing on the structural and functional differences encountered in comparing microtubules, microfilaments, and intermediate filaments. The rate at which experimental data are accumulating in this area has often exceeded our abilities to formulate conceptual models about the array of functions the cytoskeleton provides the cell. Nevertheless we have tried to present the basic principles that ultimately may lead to a fuller understanding of the diverse roles of the cytoskeletal framework.

Chapters 10 through 13 are devoted to an analysis of the flow of information from nucleus to cytoplasm. We begin this section with Chapter 10, which provides the conceptual groundwork concerning genetic principles of information transfer. Chapter 11 describes how RNA synthesis is achieved and regulated, and relates this information to the morphology of the nucleus. Chapter 12 is devoted to a discussion of the biogenesis and structure of the ribosome, as well as to its role in protein synthesis. Chapter 13 concludes this sequence with an analysis of cell division. The final chapter in Part 2, Chapter 14, focuses on the biogenesis of mitochondria and chloroplasts; in it topics such as cytoplasmic inheritance, the genetics of these organelles, and their evolutionary origins are considered. These topics are more typically discussed in units on mitochondria and chloroplasts, but because they require an understanding of the principles of genetic information flow, we chose to offset the material from its usual location. This eliminates any interruption in the flow of dialog between Chapters 7 and 8, and allows a direct comparison of the biogenesis of mitochondria and chloroplasts within the same chapter.

Whereas Chapters 1 through 14 present principles of organelle structure and function in the "typical" cell, very often it is easy to lose sight of the fact that many cells of multicellular organisms are programmed to perform a limited array of highly specialized functions. This differentiation is revealed by unique shapes, sizes, and molecular functions of the cells involved. In Part 3 we show how specific cells have modified their basic architectural plans in order to achieve these specialized functions. Chapter 15 introduces this section with a brief overview of developmental processes. In Chapter 16 the molecular events set in motion by hormones acting at the levels of the plasma membrane and nucleus are brought into focus. Chapter 17 deals with the cells of the immune system, some of which are responsible for antibody synthesis, while others are involved in cell-mediated immune reactions. The role of the neuron as the functional unit of the nervous system is the topic of Chapter 18. In this chapter the unique electrical properties of this cell type are highlighted. The unusual molecular composition of muscle cells is the subject of Chapter 19. Here we discuss the biochemistry of contractile proteins and the way in which these proteins must work together to achieve contraction. In the final chapter of the book we introduce the cancer cell, which can be considered a specialized cell in the sense that it represents a unique, though aberrant, phenotype. Chapter 20 examines the causes of cancer, discusses

some properties of cancer cells, and, finally, offers prospects for the control of this disease.

AIDS TO THE STUDENT

One of the major concerns of this book is to provide students with a basic understanding of what a cell is and why the cell is the fundamental unit of life. Our approach throughout has been to focus on the major questions involved and the experimental approaches utilized in addressing these questions. This emphasis on experimental design should allow students to understand not only current theories and models regarding cell biology, but also the complex thought processes required to arrive at these ideas. To aid students in identifying key terms, we have highlighted those that we feel most relevant to the ideas presented by placing them in boldface type. Other, somewhat less important words appear in italics. The illustrations in this text are of a variety of types. Some are composites of data drawn from the literature, while others are original illustrations that interpret new findings that have appeared. Others are taken directly from published sources. We have also included a large number of micrographs that help to round out discussions of morphology and also aid in tying together biochemical data with structural observations. As an added feature, the magnification of each micrograph has been transposed to a bar with the length noted above it, thereby allowing size comparisons to be made more easily. Each illustration or micrograph is cited in a special credits section at the end of the book. Finally, each chapter is concluded by a substantial summary, which can be used as a general introduction to the chapter as well as a review when study of the material is completed.

Because the principles of cell biology are constantly being reevaluated in the light of current scientific information, the scientific literature is the place to search for the most up-to-date information on a given subject. We have included as suggested readings a representative listing of recent books and articles that can be used by students as a bridge to the literature. Because of space constraints, we have decided not to include all of the classical papers and other references used in preparing the text. Some information along these lines is available in the credits section at the end of the book. Finally, a word about the index. A properly designed index is absolutely essential for the efficient use of a text. We have compiled the index with the following features in mind: It should be pertinent, detailed without being cumbersome, and easily read. As an added feature, pages on which key terms are defined appear in boldface type. We believe that such an approach is more useful than a simple glossary, since it allows the meanings of terms to be looked up within their appropriate context. We have also included an appendix that serves as an easy guide to symbols, prefixes, and abbreviations in common usage.

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