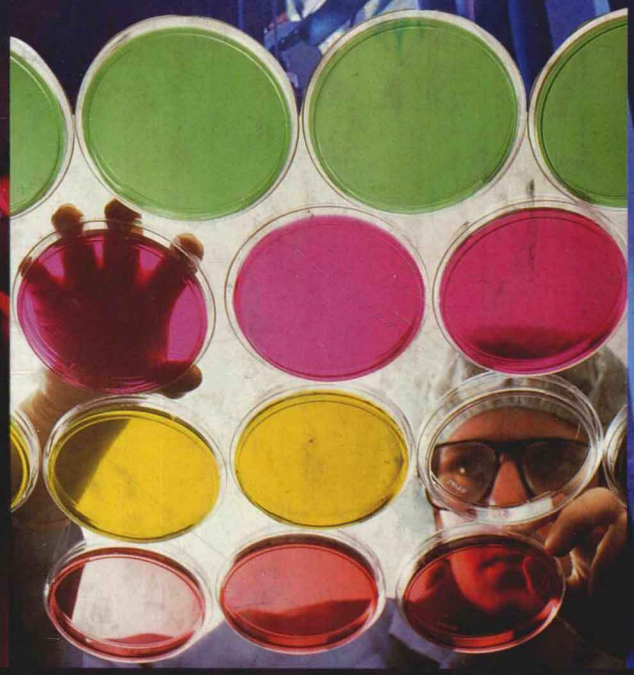
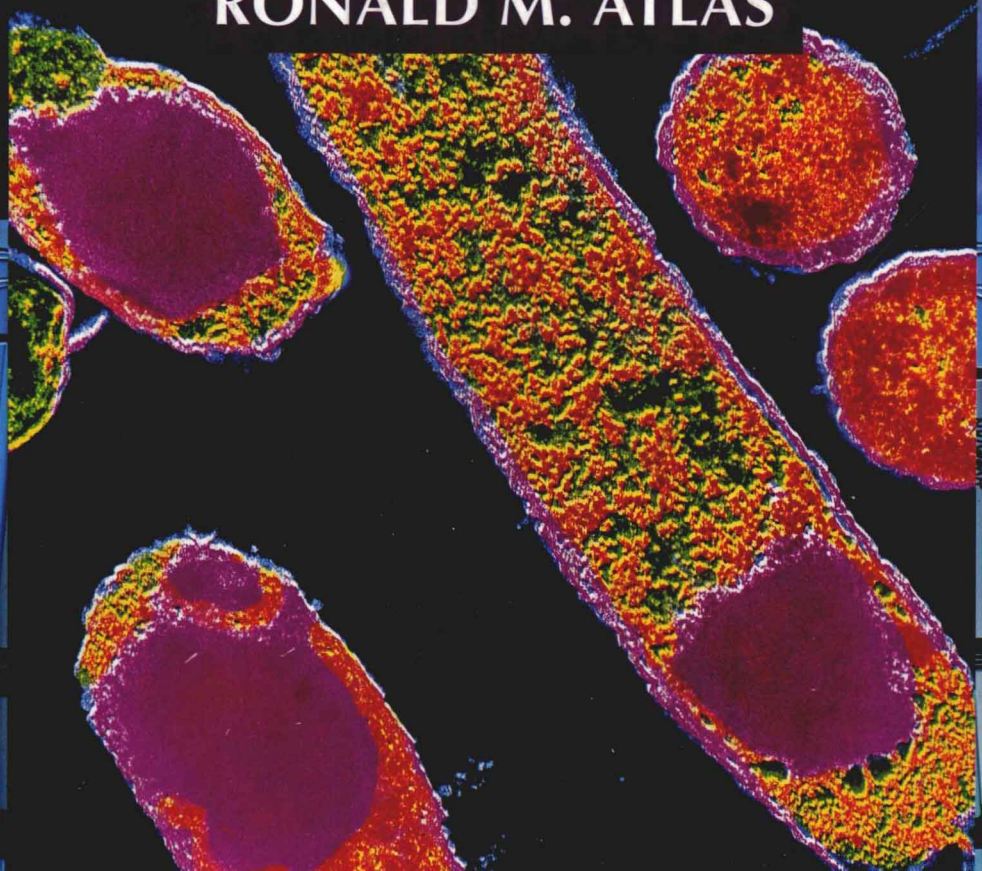
PRINCIPLES OF MICROBIOLOGY



RONALD M. ATLAS



PRINCIPLES OF MICROBIOLOGY

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PRINCIPLES OF MICROBIOLOGY

PREFACE

The study of microorganisms has had a major impact on all the biological sciences and on the quality of life for humankind. Great strides have been made using microorganisms to understand the principles that govern life. Many of the discoveries made by microbiologists have spawned new fields of science, such as molecular biology and biotechnology. The discovery of DNA as the molecular basis of heredity was made using microorganisms, laying the foundation of genetic engineering and its application in biotechnology. Controlling microorganisms has become a fundamental part of modern health practices. The maintenance of environmental quality depends largely on the metabolic activities of microorganisms. Microorganisms have become the mainstays of many technologies. The seemingly overwhelming and ever expanding state of knowledge about microorganisms—their diversity, activities and uses—makes it difficult to define the appropriate scope of microbiology. The successes of microbiology have created a dilemma for teaching microbiology. What are the central themes of microbiology? What are the basics that students should learn about microorganisms?

Principles of Microbiology presents an insightful discussion of modern microbiology. It brings together over 100 years of discoveries that place the scientific discipline of microbiology at its current state of the art. It focuses on the microorganisms—the unifying theme of this field of science. It captures the excitement of this contemporary and dynamic science, bringing forth the latest information available about microorganisms—their activities and relevance. It shows how microorganisms have evolved numerous strategies for carrying out essential life functions and how the activities of microorganisms contribute to the overall health and welfare of humans and the environment. It explains why some of the diverse and ubiquitous microorganisms are beneficial to humankind—describing the essential role of microorganisms for the maintenance of life on Earth, and why others are harmful, causing diseases of plants and animals—with a major impact on human health.

This book is about the scientific study of microorganisms. It is intended to provide the foundation for understanding and learning microbiology as a biological science. A major goal of the book is to extend the principles of biology to cover the microorganisms. It is designed to provide comprehensive, although not encyclopedic, coverage of microbiology. It provides an in-depth view of microbiology, giving sufficient detail to grasp concepts, yet not so much detail that the unifying principles of microbiology are obscured. The subjects covered and the detailed discussion on those topics reveal the breadth of microbiology and how far this science has developed—microbiology is at the cutting edge of scientific exploration leading into the twenty-first century.

Contents and Organization of the Book

Principles of Microbiology is designed to help instructors teach microbiology and to help students learn about microorganisms. The textbook is designed to be flexible; the order of chapters and topics can be subject to the instructor's creativity. Topics may be selected from the various chapters to meet individual course needs. Students can supplement their coursework by reading topics of interest that are omitted by the instructor from the formal class presentation.

Each chapter has the following general structure:

- Overview
  The overview sets out the scope of information that will be covered in the chapter.
- Text of chapter
  To develop an understanding of a topic, the text is designed to reveal the principles related to the topic of each chapter. Key terms are shown in boldface or italics. Boxes within each chapter cover current topics of special interest, topics of historical interest, and methodologies used in the study of microbiology. Elaborate illustrations supplement the written text.
- Suggested supplementary readings
  The suggested readings are meant to supplement the text for more advanced courses and to sustain interest in a particular topic relevant to the student's purpose for having enrolled in an introductory microbiology course.
- Study questions
  The set of review questions is intended to allow students to test their comprehension of the material they have just examined.
- Situational problems
  The situational problems are intended to challenge a student's creativity, to challenge him or her to think, and to aid in the development of an in-depth understanding of microbiology.

The book is organized into major parts arranged from the subcellular to the entire organism, from the fundamental to the pragmatic. Each part contains an essay written by a prominent microbiologist describing his or her view of that field of microbiology and

his or her contribution to the scientific development of that field. The essays provide unique insights into why some of us chose careers as microbiologists and how we pursued our career goals.

Part One

This section reviews the scientific study of microorganisms. It introduces the microorganisms and the methods and methodologies used for their study. It presents a brief overview of the microbial world, exploring the realm of studies on microorganisms. Students reading this section gain a perspective on microbiology with its many vistas.

Chapter 1 This chapter provides an overview of the microorganisms that are the focus of the textbook. It traces the development of microbiology as a scientific discipline, showing how scientists think and how they use the scientific method for studies on microorganisms. It gives a historical perspective to microbiology, highlighting the contributions of noteworthy microbiologists such as Louis Pasteur and Robert Koch.

Chapter 2 This chapter reviews methodologies used by microbiologists. The science of microbiology depends on the ability to make observations. The chapter discusses the various forms of microscopy that are used to view microorganisms, the culture methods employed for studying microorganisms, and the development of molecular methodologies that have contributed to the understanding of microorganisms.

Part Two

This section on microbial physiology and cell biology examines the structure and function of cells of microorganisms. It explores many of the fundamental properties of living systems, showing how microorganisms have developed diverse solutions for meeting essential requirements for life.

Chapter 3 This chapter covers the organization of prokaryotic and eukaryotic cells of eubacteria, archaebacteria, and eukaryotic microorganisms. The emphasis is on prokaryotic cells, which are often only covered cursorily in general biology classes. The chapter compares structures that have evolved in different organisms to serve similar functions, emphasizing the differences between prokaryotic and eukaryotic cells, many of which have important practical implications. It highlights the design of cellular structure and reveals how cells meet the essential requirements for life.

Chapter 4 This chapter treats the bioenergetics of cellular metabolism, indicating how the principles of chemistry apply to biological systems. It focuses on the flow of energy through cellular metabolism and diverse strategies that occur among microorganisms for generating ATP.

Chapter 5 This chapter covers the metabolic reactions involved in forming cell biomass by autotrophic and heterotrophic metabolisms. It treats the transformations of materials that are necessary for the formation of new cells and shows how cells can use simple starting substrates to make complex cell structures.

Part Three

This section about microbial genetics and molecular biology covers topics of great contemporary interest. It focuses on the structure and functioning of DNA, showing that the basic revelations of the structure of DNA have led to recombinant DNA technology.

Chapter 6 This chapter examines the role of DNA in heredity and control of cellular functions. It demonstrates the discovery of the structure of DNA and the revolution in our understanding of the functioning of cells. It examines the molecular basis of heredity and how DNA controls protein synthesis, relating genetics to the functioning of the cell.

Chapter 7 This chapter discusses the genetic changes that alter hereditary information. It shows the molecular events involved in recombination. It establishes the principles underlying the development of recombinant DNA technology, giving the basis for genetic engineering and its practical importance.

Part Four

This section examines microbial growth and replication, shows that microorganisms have enormous potentials for population growth, and examines the factors that control the rates of microbial reproduction.

Chapter 8 This chapter is about viruses. It covers the replication of viruses, distinguishes viruses from living organisms, and shows why viruses depend on host cells for their replication. It describes the stages of viral replication and the strategies employed for the replication of different viruses.

Chapter 9 This chapter discusses bacterial growth and reproduction; examines the consequences of bacterial reproduction by binary fission, showing that exponential increases of bacterial cell numbers occur due to reproduction by binary fission; and discusses the influences of various environmental factors, such as temperature, on bacterial growth rates.

Chapter 10 This chapter deals with the basis for control of microbial growth and the abilities of physical and chemical factors to kill or prevent the growth of microorganisms. It relates the modes of action of various antimicrobial agents to fundamental properties of microbial physiology.

Part Five

This section about microorganisms and human disease covers topics of importance related to human health. It emphasizes relationships between the defenses of the human body and virulence factors of pathogenic microorganisms. It describes how diseases are spread and how the transmission of pathogens can be controlled.

Chapter 11 This chapter introduces immunology and the defenses of the body against infections and diseases. It discusses the innate and specific defense systems that protect the human body from infection, highlighting the complex nature of the body's lines of defense against disease. It shows the underlying molecular basis for the body's resistance to invasion by foreign substances. It also describes the consequences of failures of the immune system.

Chapter 12 This chapter gives an epidemiological perspective to selected human diseases caused by microorganisms. It examines the underlying principles of disease transmission and how understanding the basis of infectious disease can be used to block disease transmission. It includes a discussion of how vaccines are used to control and to eliminate specific diseases.

Chapter 13 This chapter covers the basis of pathogenesis of infectious diseases. It examines properties of pathogenic microorganisms that contribute to their abilities to cause disease and physiological changes that occur as a result of microbial infections. It also examines the basis for diagnosing various diseases.

Part Six

This section examines applied and environmental microbiology, emphasizing some of the practical aspects of microbiology. It shows the essential functions of microorganisms in ecology and the practical uses of microorganisms in biotechnology.

Chapter 14 This chapter examines interactions among microorganisms and the roles of microorganisms in global biogeochemical cycling. It also discusses the importance of microorganisms for maintenance of environmental quality, including essential uses of microorganisms for degrading wastes and pollutants.

Chapter 15 This chapter is about biotechnology, including the economic uses of microorganisms for producing foods, antibiotics, and numerous other products; recombinant DNA technology; and traditional practices employed in industrial microbiology.

Part Seven

This section is a survey of microorganisms that describes their great diversity.

Chapter 16 This chapter provides a survey of the prokaryotic bacteria and archaebacteria. It explains microbial systematics and the approaches used in taxonomy. It also characterizes the diverse groups that comprise the eubacteria and archaebacteria.

Chapter 17 This chapter gives a brief overview of eukaryotic microorganisms, including fungi, algae, and protozoa.

Part Eight

Additional material provides a framework for review and study.

Study Outlines The detailed study outlines for each chapter are included to aid in learning the material covered in each chapter. The outlines should be especially helpful in preparing for examinations.

Appendix: Chemistry for the Microbiologist The appendix provides an overview of organic chemistry and biochemistry as it relates to biological systems.

Glossary of Microbiological Terms An extensive glossary has been included to help understand the terminology used by microbiologists.

Illustration Program

The figures included in this text were carefully selected to enhance student understanding of key information. A color coding scheme was used throughout the text whereby specific chemicals and structures are a specific color. This will enable students to readily identify the identical structures in different organisms. The key to the color coding is presented below.

KEY TO COLOR CODE OF CHEMICALS AND STRUCTURES

Color	Chemical	Structure	Microorganism
	Protein, lipoprotein	Viral capsid, bacterial pili, flagella	Virus
	Peptidoglycan	Bacterial cell wall	Bacteria
	Carbohydrate glycoprotein, lipopolysaccharide	Bacterial outer membrane, glycocalyx, capsule	
	DNA	Bacterial chromosome, plasmas, chloroplasts	
	RNA, ATP	Ribosomes, nucleus	
	Lipid, phospholipid	Membranes, mitochondria	Eukaryotes

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Ronald M. Atlas

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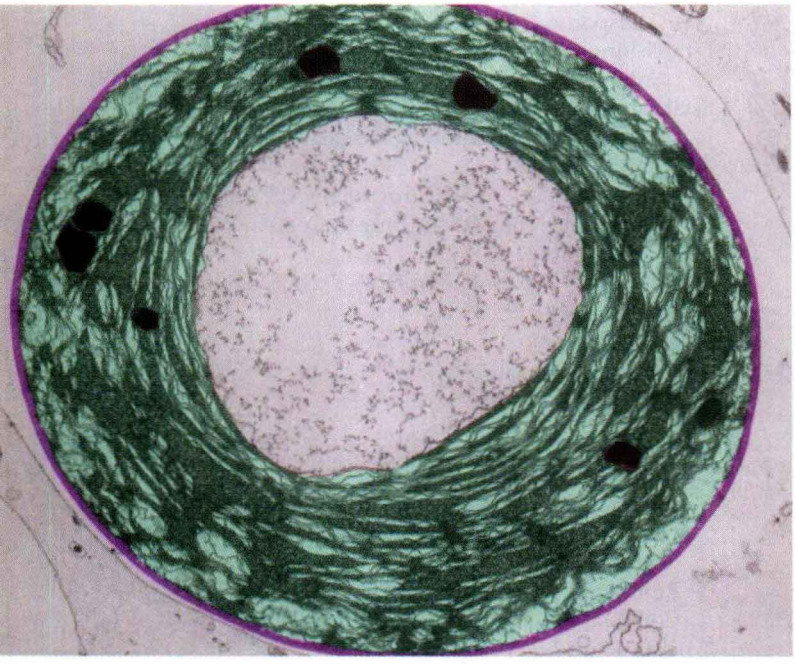

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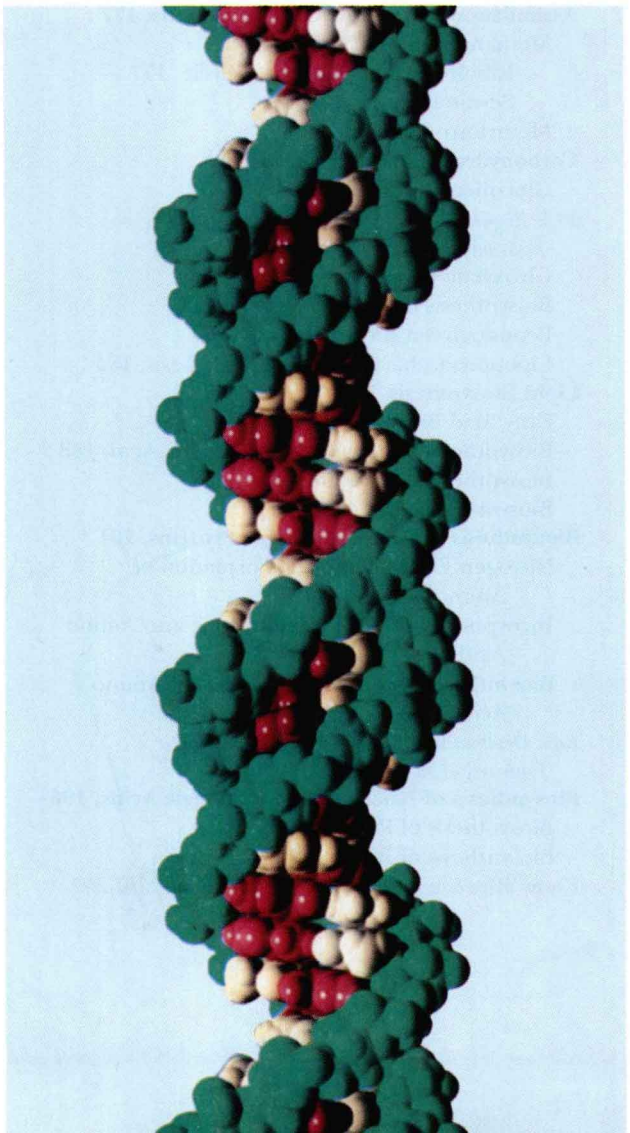

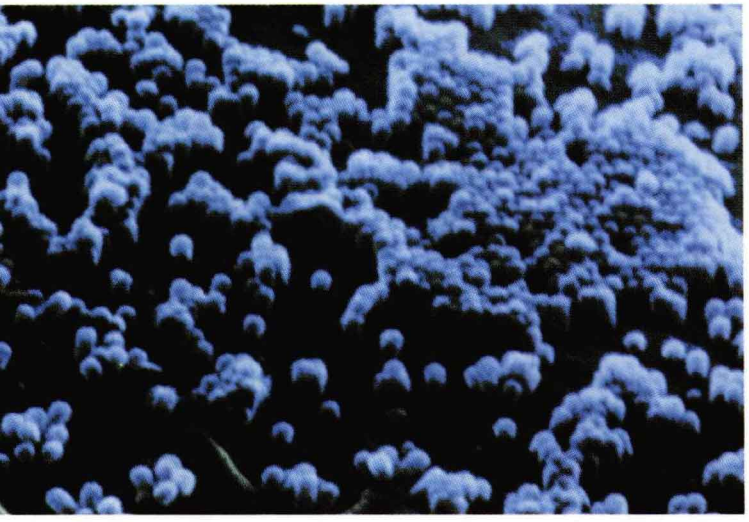

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