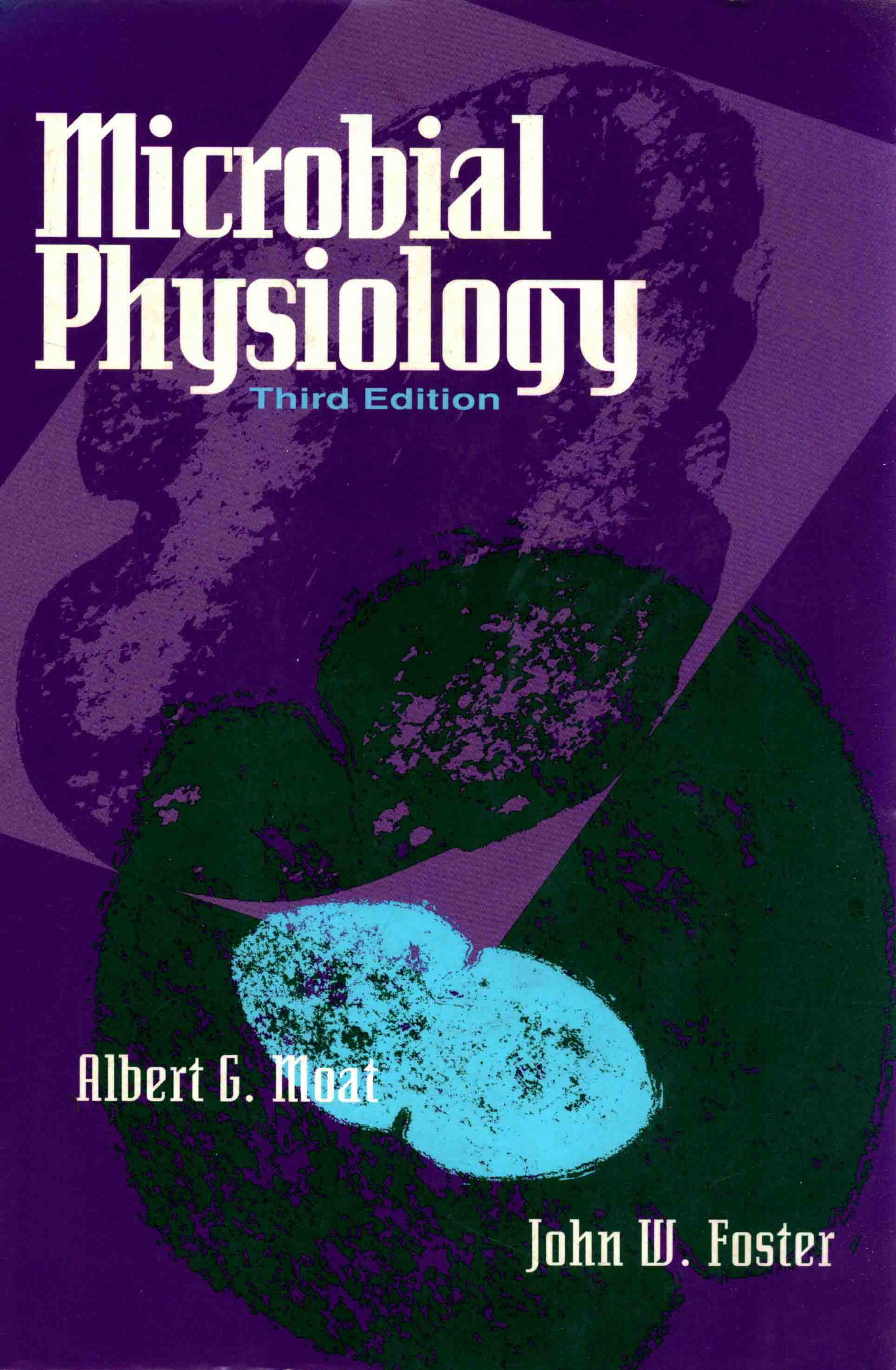
Microbial Physiology

Third Edition



Albert G. Moat

John W. Foster

MICROBIAL PHYSIOLOGY

Third Edition

ALBERT G. MOAT
Marshall University School of Medicine
Huntington, West Virginia

JOHN W. FOSTER
University of South Alabama School of Medicine
Mobile, Alabama

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MICROBIAL PHYSIOLOGY

To
Irene and Zari

PREFACE

The field of microbial physiology continues to develop at a rapid pace, thanks to the introduction of more and more sophisticated genetic and molecular approaches to the subject. Consequently, we have found it necessary not only to write a new edition to this text but to reorder the text material to present the physiological aspects in their true light. The concepts of microbial genetics and molecular biology have been presented first so the reader might have a thorough grounding in these disciplines before delving into the main aspects of microbial cell structure, intermediary metabolism, and growth. We felt that this order of presentation would help the reader to fully appreciate the current level of our understanding of microbial physiology.

We would like to thank all of those who have provided us with help and encouragement in this undertaking. We especially wish to thank those who granted us permission to use illustrations and/or provided us with original materials for this purpose.

ALBERT G. MOAT
JOHN W. FOSTER

Huntington, West Virginia
Mobile, Alabama

MICROBIAL
PHYSIOLOGY

CONTENTS

CHAPTER 1

INTRODUCTION TO MICROBIAL PHYSIOLOGY

THE *ESCHERICHIA COLI* PARADIGM

Microbial physiology is an enormous discipline encompassing knowledge culled from the study of thousands of different microorganisms. It is, of course, impossible to convey all that is known within the confines of one book. However, one can build a solid foundation using a limited number of organisms to illustrate key concepts of the field. The goal of this text is to help set the foundation for further inquiry into microbial physiology and genetics. To accomplish this we have taken the gram-negative organism *Escherichia coli* as the paradigm. We will include other organisms that provide significant counterexamples to the paradigm or use alternative strategies to accomplish a similar biochemical goal. In this introductory chapter we would like to paint a broad portrait of the microbial cell with special focus on *E. coli*. Each topic will be covered in depth in a later chapter but this chapter should serve as a point of convergence where the student can see how one aspect of physiology relates to another.

CELL STRUCTURE

As any beginning student of microbiology knows, bacteria come in three basic models; spherical (coccus), rod (bacillus), and spiral (spirillum). Bacteria do not possess a membrane-bound nucleus as do eukaryotic microorganisms and are, therefore, termed prokaryotic. in addition to these basic types of bacteria, there are other more specialized forms described as budding, sheathed, and mycelial bacteria. Figure 1-1 presents a schematic representation of a typical (meaning *E. coli*) bacterial cell. We will briefly tour this cell starting from the exterior.

The Cell Surface

The interface between the microbial cell and its external environment is by definition the cell surface. It is what protects the cell interior from external hazards and maintains the

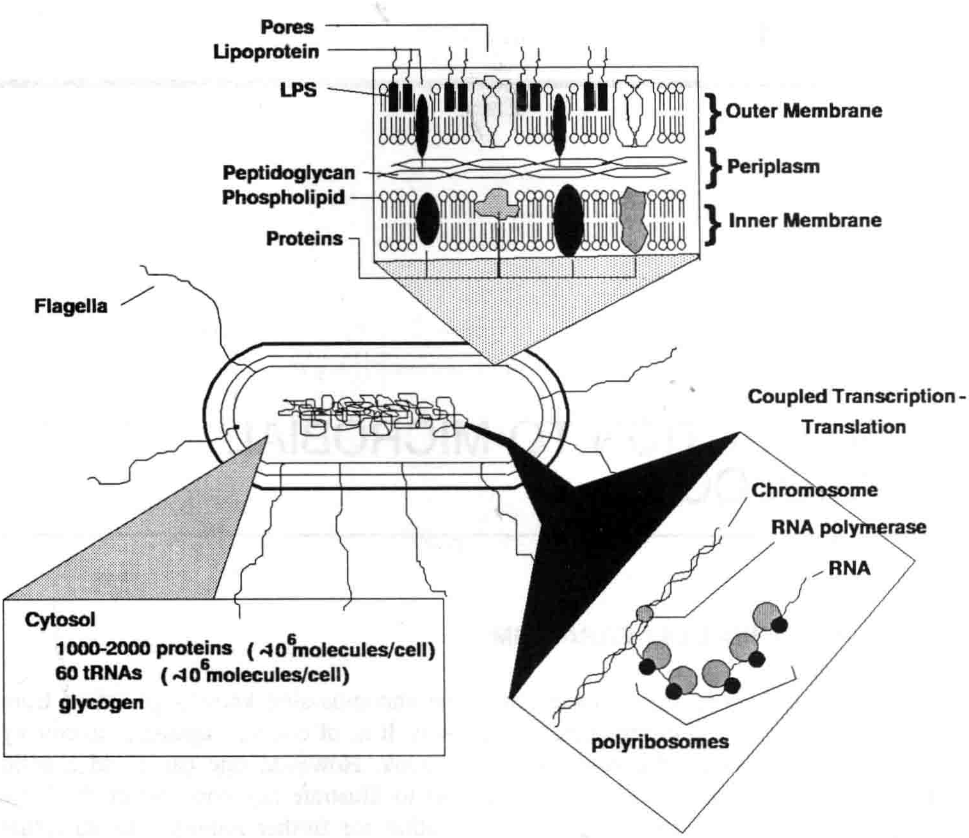

Fig. 1-1. Diagrammatic representation of a "typical" bacterial cell. Portions of the cell are enlarged to show further details.

integrity of the cell as a discrete entity. Although it must be steadfast in fulfilling these functions, it must also enable transport of large molecules into and out of the cell. These large molecules include carbohydrates (e.g., glucose), vitamins (e.g., vitamin B_{12}), amino acids, and nucleosides, as well as proteins exported to the exterior to the cell. The structure of the cell surface can vary considerably in its complexity depending on the organism.

Cell Wall. In 1884 the Danish investigator Christian Gram devised a differential stain based on the ability of certain bacterial cells to retain the dye crystal violet after decoloration with 95% ethanol. Those cells that retained the stain were called **gram positive.** Subsequent studies have shown that this fortuitous discovery distinguished two fundamentally different types of bacterial cells. The surface of gram-negative cells is much more complex than that of gram-positive cells. As shown in the schematic drawings in Figure 1-2, the gram-positive cell surface has two major structures: the cell wall and the cell membrane. The cell wall of gram-positive cells is composed of multiple layers of peptidoglycan. Peptidoglycan is a linear polymer of alternating units of *N*-acetylglucosamine (NAG) and *N*-acetylmuramic acid (NAM). A short peptide chain is attached to muramic acid. A common feature in bacterial cell walls is cross-bridging between the peptide