MICROBIOLOGY

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MICROBIOLOGY

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PREFACE

Soon after we set out to prepare a comprehensive textbook of microbiology we realized that the subject matter was too vast for a few authors to handle. We decided instead to call upon leading experts throughout the world to write individual chapters on subjects that belong to their areas of acknowledged authority. This international approach allowed us to go beyond the limitations imposed by the usual institutional, regional, or even national boundaries that most textbooks must observe in their authorship and to produce the first multi-authored international textbook of microbiology. Seventy-one authors have contributed 88 chapters to this new systematic textbook.

In addition to striving for authenticity, we have tried to give students a cohesive account of all aspects of microbiology. This was done by presenting the information in three sections that would give a logical progression from general principles to specific information. Because the contributors are both scientists and teachers, they have presented their material in a way that lets even the beginning student understand this complicated subject. Students concerned primarily with the basic aspects of microbiology will find complete presentations of microbial genetics, biochemistry, morphogenesis, physiology, latency, and taxonomy. These fundamental topics are covered not only with respect to bacteria and viruses but to mycology and parasitology as well. Students with a special interest in fungi or parasites should find this textbook valuable because it satisfies their need for information in their own fields and also allows them to refer to closely related information dealing with the other microbial agents. It should be noted that the parasitology in this book is not restricted to invasive agents but presents extensive coverage of ectoparasites and other arthropods important to entomologists.

The chapters on specific microbial agents will meet the needs of the special areas of microbiology. For the medical technologist there are complete diagnostic data on every organism of medical importance; for the experimental pathologist and immunologist there is an extensive analysis of the pathogenic properties and immune reactions for each pathogenic agent; for the pharmacist and pharmacologist there are the essentials of antimicrobial chemotherapy; and for the epidemiologist there are sections in each chapter dealing with the prevalence, mode of spread, and protection against each specific microbial agent.

This textbook plus a larger section on specific infectious diseases is also published under the title of *Medical Microbiology and Infectious Diseases* by the same publisher.

For all this we thank our many distinguished authors who gave generously of their time, expert knowledge, and teaching skills. We hope this book will justify their valuable efforts by helping students learn microbiology throughout the world.

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I Microbiology

A. GENERAL MICROBIOLOGY

Bacteriology

1 THE STRUCTURE OF THE BACTERIAL CELL

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and David L. Ringo, Ph.D.

The structure of bacteria can be best understood by contrasting their cellular organization to that of the higher biologic forms — animals, plants, protozoa, algae, and fungi. In these life forms the cells are divided into internal compartments by membrane systems. These compartments (cellular *organelles)* have specific activities for the maintenance of the life functions of the cell. The nuclear compartment *(nucleus)* contains the cell's hereditary material, *deoxyribonucleic acid* (DNA). The nucleus is separated by a nuclear membrane from the rest of the cell, the *cytoplasm*. The DNA of higher cells is organized in two or more chromosomes.

Bacterial cells are not compartmentalized and therefore are considered to lack organelles. The hereditary material of bacteria consists of a single chromosome. This bacterial *nucleoid* is a single, tightly bundled, long strand of DNA that lies within the cytoplasm not surrounded by a nuclear membrane. For this reason bacteria are referred to as *prokaryotic,* that is, having a primitive nuclear structure; and higher cells are designated as *eukaryotic,* literally, having a true nucleus. All bacteria (as well as the blue-green algae) possess the prokaryotic form of organization.

In a broad sense, all types of cells function in the same manner. The information stored in the DNA is transcribed as *messenger ribonucleic acid* (mRNA), which moves from the nucleus into the cytoplasm. Here the messenger RNA attaches to ribosomes, where the genetic information is translated into specific proteins by the polymerization of amino acids. The synthesis of proteins is one of the most basic of cell processes, since virtually every metabolic activity of the cell is mediated by enzymes, the proteins that catalyze specific chemical reactions.

The basic function of a bacterial cell is to assimilate chemicals from its environment in order to grow and divide. Some bacteria perform these functions by using the simplest inorganic chemicals (carbon dioxide and minerals), and are termed *autotrophs.* Certain members of this group, photosynthetic bacteria and blue-green algae, rely on light as a source of energy and thus resemble plants in their photoautotrophic metabolism. Another and larger group of bacteria, the *heterotrophs,* use simple organic molecules from their environment as a source of energy and as building blocks for cellular material. Many of this latter group have adapted to growth within the animal body. Some are harmless symbionts, such as *Escherichia coli,* which normally inhabits the mammalian gut. Others are harmful and may cause human disease. These bacteria are termed *pathogens,* and their infection of body tissues results in a characteristic illness. Many of the features of bacterial cell structure are related, in one way or another, to their role as disease organisms and to the ways in which these diseases are treated and controlled.

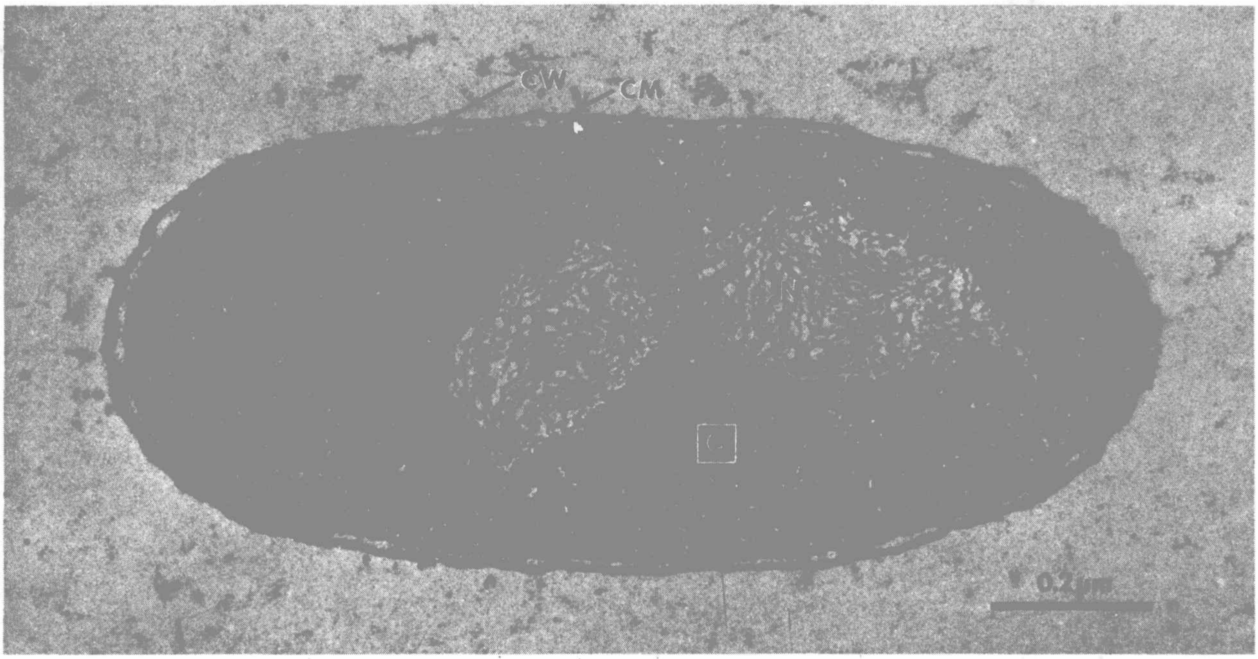

FIGURE 1. *This electron micrograph outlines the organization that is common to all bacterial cells. The nucleoid (N) occupies the central area of the cell; the cytoplasm (C) contains many ribosomes (individual dark granules); a cytoplasmic membrane (CM) and cell wall (CW) surround the cell. This bacterium,* Alteromonas espejiana, *is a marine pseudomonad that possesses a very simple wall structure.*

The generalized structure of a typical bacterial cell is shown in Figure 1. The prokaryotic cell consists of a cell wall, a cytoplasmic membrane surrounding a cytoplasm packed with ribosomes, and a more or less central nucleoid. The figure is an example of the image produced by the electron microscope of a very thin section cut through a chemically preserved (fixed) bacterium. It is possible to determine the overall shape and size of such a bacterial cell with the light microscope, but details that are smaller than about 0.2 μm cannot be resolved (Table 1). Thus, the internal structure of the bacterium can be deduced only through the use of the higher resolving power of the electron microscope, and all such detailed knowledge has been obtained only within the past 25 years.

TABLE 1. Units Used to Describe Bacteria and their Structures, and the Useful Limits of Resolution of the Human Eye, the Light Microscope, and the Electron Microscope

Units:
- $1\ m \times 10^{-3} = 1$ mm (millimeter)
- $1\ mm \times 10^{-3} = 1\ \mu m$ (micrometer or micron)
- $1\ \mu m \times 10^{-3} = 1$ nm (nanometer)

Limits of Resolving Power:
- Unaided human eye: 0.2 mm
- Compound light microscope: 0.2 μm
- Transmission electron microscope: 2 nm to 0.2 nm

NUCLEOID

Embedded in the ribosome-rich cytoplasm is the bacterial genetic apparatus, the nucleoid. No boundary separates it from the rest of the cytoplasm; the nucleoid's physical segregation is maintained by the very nature of the DNA that is its make up. The DNA consists of one very long and narrow molecule — a double helix — which if stretched to its full length would measure more than 1.0 mm long and only 0.000002 mm (2 nm) wide. Genetic analysis has shown that most of the bacterial genes are linked to one another in an orderly fashion, and, moreover, that the linkage is continuous and circular. We therefore describe the bacterial nucleoid as a single, circular chromosome. Physical studies also demonstrate that the DNA strand of the chromosome is a circle that is tightly coiled into a bundle to produce the nucleoid image shown with the electron microscope. The chromosome replicates in the growing cell in preparation for cell division. Bacterial cells divide by binary fission into two daughter cells, each of which retains a copy of the chromosome. A small percentage of the cell's genetic information is present as much smaller DNA molecules, *plasmids*, which may be present in many copies and replicate independently. Bacterial plasmids often carry the genes involved in resistance to chemotherapeutic drugs. Plasmids cannot be observed