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CELLULAR FORMS OF LIFE. PROKARYOTIC CELLS

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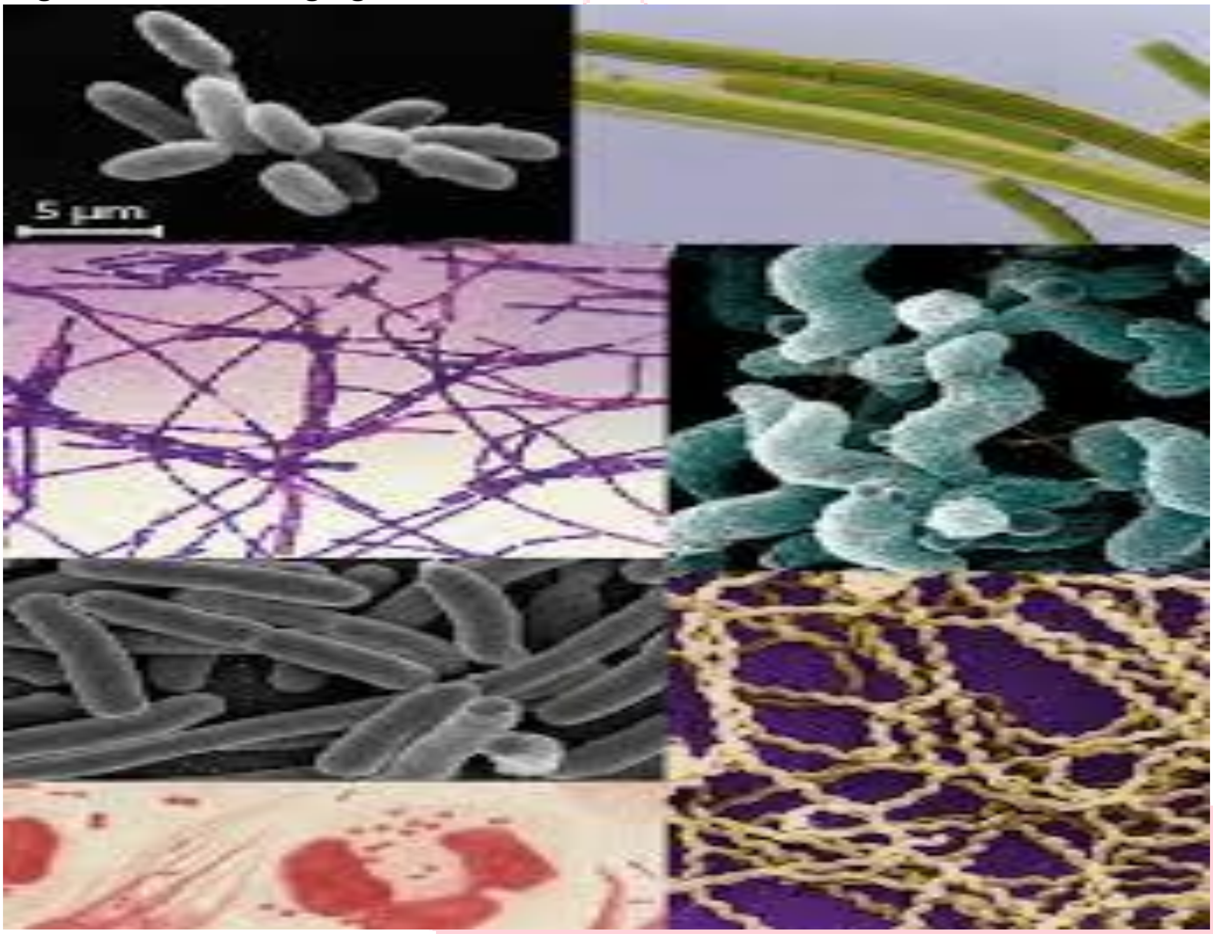
Abstract: This article presents a scientific review of the structure, biological characteristics, and medical significance of prokaryotic cells as one of the cellular forms of life. Although prokaryotes are defined as cells lacking a true nucleus and membrane-bound organelles, their internal organization is shown to be highly functional and evolutionarily refined. The article consistently explains the general features of bacteria and archaea, as well as the structure and functions of the nucleoid, plasma membrane, ribosomes, cell wall, capsule, plasmids, pili, and flagella. It also discusses the major differences between prokaryotic and eukaryotic cells, reproduction by binary fission, horizontal gene transfer, and the cellular basis of antibiotic sensitivity and resistance. The analysis demonstrates that prokaryotic cells are distinguished not by simplicity, but by compact and efficient organization. Their membranes are responsible for energy metabolism, whereas the cell wall provides mechanical protection and preserves cellular shape. A deep understanding of this topic helps students of dentistry and medicine gain an integrated view of microbiology, infectious processes, antisepsis, antibiotic therapy, and biotechnological processes.

Keywords: prokaryotic cell, bacteria, archaea, nucleoid, plasmid, ribosome, cell wall, capsule, flagella, antibiotic resistance

Introduction

The cell is the structural, functional, and genetic unit of living organisms. In modern biology, all cells are generally divided into two broad groups: prokaryotic and eukaryotic cells. Prokaryotes are described as mainly unicellular organisms whose genetic material is not enclosed within a clearly defined membrane-bound nucleus and which lack membrane-bound organelles. This group includes organisms belonging to the domains Bacteria and Archaea.



Prokaryotic cells are often labeled as “simple,” yet such a view is superficial. In reality, their morphological compactness is combined with high adaptability, rapid reproduction, genetic exchange, and resistance to extreme environments. For that reason, it is scientifically more accurate to interpret the prokaryotic cell not as a simplified structure, but as a highly optimized biological system. In medicine, especially, bacterial infections, biofilm formation, antibiotic-resistant strains, the microbiota of the oral cavity, and the role of opportunistic pathogens all require a thorough understanding of prokaryotic organization.

The study of prokaryotic cells is important both for theoretical biology and for practical medicine. The bacterial cell wall serves as the target of many antibiotics, while ribosomes are the molecular target of agents that inhibit protein synthesis. Plasmids, in turn, play a leading role in the spread of resistance genes. Thus, every structural element of the prokaryotic cell is directly connected with clinical microbiology.

From this perspective, the aim of the article is to describe the main structures of prokaryotic cells in a systematic manner, to highlight the differences between bacteria and archaea, and to explain the medical significance of this knowledge on a scientific basis.

Materials and Methods

The study employed the methods of analytical literature review, comparative biological analysis, morphological description, and functional interpretation. Open scientific and educational sources, microbiological explanations, and conceptual information taken from biology textbooks dealing with the description of prokaryotic cells were selected for analysis. Priority was given to materials that comprehensively reflected the fundamental structures of the prokaryotic cell and their medical significance.

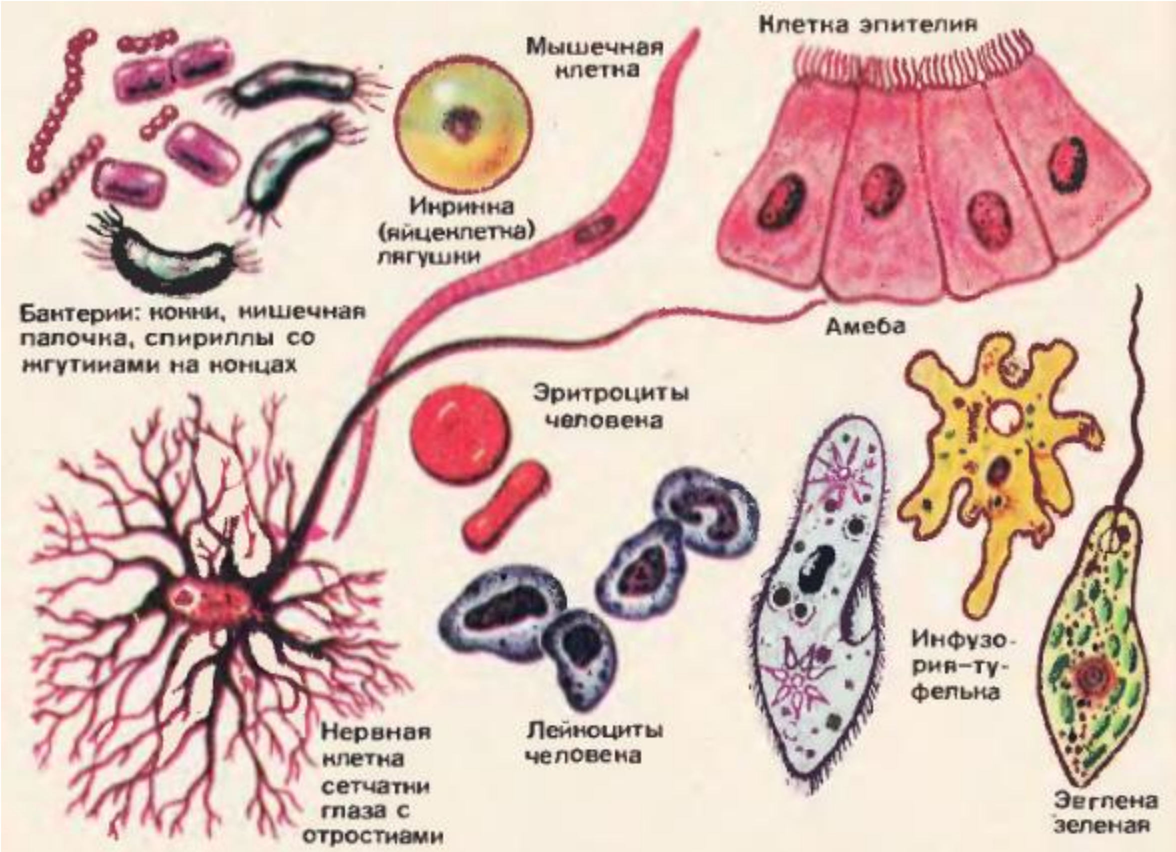
The collected information was grouped into three directions: first, identifying the general characteristics of the prokaryotic cell; second, describing its internal and external structural components; and third, evaluating the practical significance of these components for medicine and microbiology. Within this framework, prokaryotic and eukaryotic cells, as well as bacteria and archaea, were compared by means of a comparative approach.

Because the article is a review-type study, no experimental samples or laboratory observations were conducted. The results were generated by conceptually synthesizing confirmed morphological and functional information from scientific sources.

Results

The analysis showed that all cells contain four common components: a plasma membrane, cytoplasm, genetic material, and ribosomes. In prokaryotic cells, however, these components are organized in a specific way. Their DNA is located not inside a nuclear envelope, but in a cytoplasmic region called the nucleoid. The main chromosome is most often circular, and additional genetic elements may occur in the form of plasmids.

The plasma membrane of the prokaryotic cell is not merely a barrier; it is also a multifunctional metabolic platform. Several functions that are performed in eukaryotes by mitochondria or the endoplasmic reticulum are carried out in prokaryotes by enzyme systems associated directly with the membrane. Energy metabolism, transport, certain biosynthetic stages, and the formation of the proton gradient all take place here. Thus, the membrane is the central link in prokaryotic cell viability.



The cell wall is one of the most important protective and supporting structures of prokaryotes. In bacteria, it is usually composed of peptidoglycan, which gives the cell its shape, protects it from osmotic pressure, and increases its mechanical stability against external influences. In Gram-positive bacteria, the peptidoglycan layer is thick, whereas in Gram-negative bacteria it is thinner and, together with the outer membrane, forms a more complex cell envelope. This difference is reflected in staining properties, virulence, and sensitivity to antibiotics.

The surface of a prokaryotic cell may bear a capsule, slime layer, pili, or flagella. The capsule partially protects the cell from phagocytosis, enhances adhesion to surfaces, and participates in biofilm formation. Pili are involved in the exchange of genetic material, especially during conjugation. Flagella provide motility. Their structure differs fundamentally from that of eukaryotic flagella and functions through a rotary mechanism driven by proton motive force.

Ribosomes are the principal apparatus for protein synthesis in prokaryotic cells and differ from eukaryotic ribosomes in size and sedimentation coefficient. This difference forms the molecular basis for the selective action of many antibiotics. Tetracyclines, macrolides, aminoglycosides, and several other drugs act on bacterial ribosomal subunits and thereby inhibit the growth and reproduction of microorganisms.

Archaea also belong to the prokaryotes, but they differ from bacteria in a number of molecular features. The absence of typical peptidoglycan in their cell walls, the unique structure of their membrane lipids, and the fact that some of their mechanisms of genetic information processing resemble those of eukaryotes are all of major evolutionary significance. Therefore, the concept of the prokaryote is not homogeneous; it includes at least two large phylogenetic lineages.

During reproduction, prokaryotes usually increase rapidly in number through binary fission. Yet their adaptability is not limited to rapid multiplication. Mechanisms of horizontal gene transfer such as transformation, transduction, and conjugation create conditions for the spread of new metabolic capacities, virulence factors, and antibiotic-resistance genes. From a clinical point of view, this is highly important because the emergence of resistant strains reduces treatment effectiveness.

Table 1. Main components of the prokaryotic cell and their functions

Component	Structural feature	Main function
Nucleoid	Membrane-free DNA region	Storage of genetic information
Plasmid	Additional circular DNA	Carries resistance and adaptation genes
Ribosome	70S protein-synthesis apparatus	Protein biosynthesis
Plasma membrane	Phospholipid and protein layer	Transport and energy metabolism
Cell wall	Peptidoglycan or another envelope	Shape and mechanical protection
Capsule	Outer polysaccharide layer	Adhesion and evasion of immune defense
Pili/flagella	Surface protein	Motility and gene exchange

Component	Structural feature	Main function
	structures	

Discussion

The results show that the study of prokaryotic cells requires the integration of morphological and molecular approaches. If a student limits understanding to the definition of a "cell without a nucleus," the real biological potential of prokaryotes remains obscure. In fact, the cell wall, membrane, plasmids, and surface accessory structures form the basis of their viability, virulence, and ecological adaptation.

When considered in relation to medical practice, the importance of prokaryotic cell structure becomes even clearer. Many bacteria living in the oral cavity participate in dental caries, gingivitis, periodontitis, and endodontic infections. The capsules and adhesins of biofilm-forming bacteria complicate clinical treatment. In selecting antibiotics, the differences between Gram-positive and Gram-negative cell envelopes, ribosomal sensitivity, the presence of beta-lactamases, and the transmission of resistance through plasmids must all be taken into account.

Comparative study of prokaryotic and eukaryotic cells also develops biological thinking. The student learns to distinguish evolutionary continuity from cellular specificity, and to identify both universal and distinctive cellular features. The existence of archaea demonstrates that different molecular mechanisms may be hidden under the general term "prokaryote." Therefore, this topic is not only an introductory part of cytology, but also a foundational point for microbiology, genetics, pharmacology, and the theory of clinical infections.

In addition, in contemporary biology prokaryotes have become central objects of biotechnology, genetic engineering, and microbiome research. Plasmids are used as vectors in recombinant DNA technology, and certain bacteria are employed in the production of enzymes, antibiotics, and metabolites. This shows that the prokaryotic cell should be assessed not only as a source of pathogenicity, but also as a useful biological platform for science and industry.

Conclusion

In conclusion, prokaryotic cells are among the most ancient forms of life, yet they are also highly adapted from an evolutionary standpoint. The absence of a true nucleus and membrane-bound organelles does not signify simplicity, but rather a compact and efficient biological organization. The nucleoid, plasma membrane, peptidoglycan wall, ribosomes, plasmids, capsule, and locomotory structures of the prokaryotic cell all ensure survival, reproduction, and adaptation to the environment.

From a medical perspective, this topic is essential for understanding the mechanisms of antibiotic action, explaining the cellular basis of infectious processes, evaluating the spread of resistance, and understanding dental microbiology. Thus, the study of prokaryotic cells serves as an important bridge between fundamental biology and practical medicine.

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