Course: Medical Microbiology, PAMB 650/720 2009/2010 Lecture 32: Bacterial Cell

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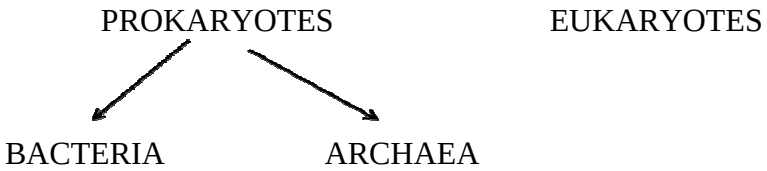
Suggested reading: Murray, 6th Edition, Chapter 2

KEY WORDS

Prokaryotic
Eubacteria (*Bacteria*)
Archaebacteria (*Archaea*)
Eukaryotic (*Eukarya*)
Plasmid
Chromosome
Ribosome
Peptidoglycan (murein, mucopeptide)
Gram stain
Gram negative
Gram positive
Cell envelope
Cell membrane
Cell wall
Outer membrane
Periplasmic space
Oxidative phosphorylation
Spheroplast/protoplast
Flagella
Chemotaxis
Axial filament
Periplasmic binding protein
Permeases
Storage Granules
Pili (fimbriae)
Capsule (slime layer, glycocalyx)
Endospore (spore)

Differences between prokaryotic and eukaryotic cells

"True" bacteria (which include all bacteria that infect man) are included in one kingdom (the eubacteria, *Bacteria).* Eubacteria are also common in the environment. A second group of environmental bacteria constitute a second kingdom (archaebacteria, *Archaea*); these organisms do not infect man. Morphologically the two kingdoms of organisms appear similar and thus are lumped together as prokaryotes. However, they have major molecular and biochemical differences. All other cellular forms of life (including plants, animals, man, and fungi) are referred to as eukaryotes.

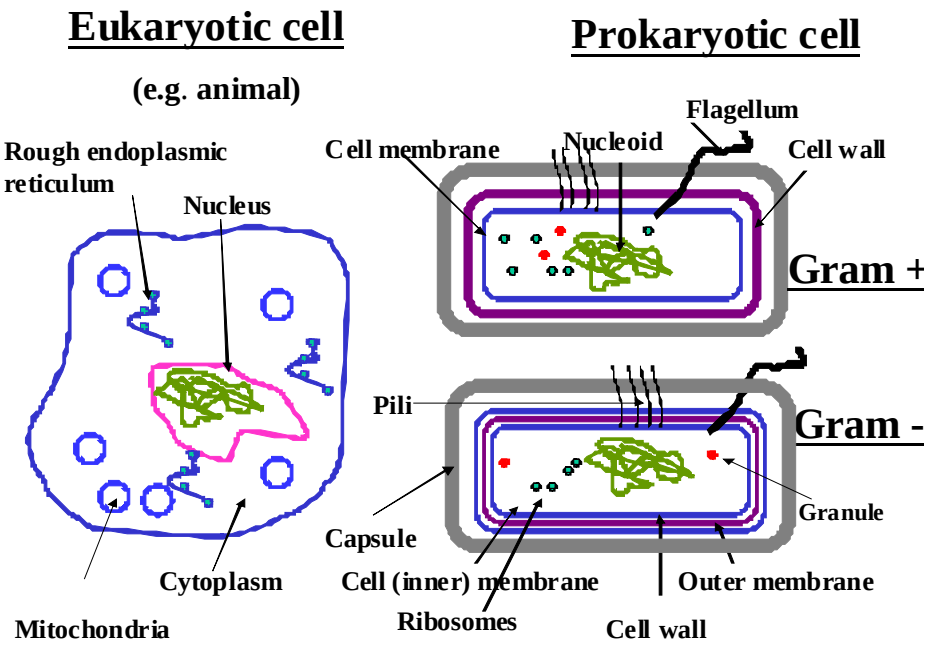


Differences between prokaryotes/eukaryotes:

1. The prokaryotic cell, in contrast to the eukaryotic cell, is not compartmentalized. A nuclear membrane, mitochondria, endoplasmic reticulum, golgi bodies, phagosomes and lysosomes are not present.

2. Prokaryotes generally possess only a single circular chromosome. Since there is no nuclear membrane the chromosome is bound to a specific site on the cell membrane - the mesosome.

Eukaryotes versus "eubacterial" prokaryotes



3. Prokaryotic ribosomes are 70S (S stands for Svedberg unit, a measure of size), whereas eukaryotic ribosomes (other than those found in mitochondria) are larger (80S). Prokaryotic ribosomal subunits are 30S and 50S (eukaryotic are larger). The 30S ribosome has 16S RNA, whilst the 50S ribosome contains 23S and 5S. Ribosomal RNA is also larger in eukaryotes (e.g. 18S versus 16S rRNA). Mitochondria of eukaryotes also have 70S ribosomes and were once free-living bacteria.

4. Bacterial membranes generally do not contain sterols (e.g. cholesterol).

Differences between bacteria and archaebacteria:

1. Eubacteria (with the exception of the genera *Mycoplasma* and *Chlamydia*) possess peptidoglycan (synonyms; murein, mucopeptide, cell wall skeleton). Peptidoglycan contains a unique sugar, muramic acid, not found elsewhere in nature. Archaebacteria contain a pseudomurein that is different in structure to eubacterial murein.

2. The 16S rRNA of the two bacterial kingdoms is distinct in sequence.

Members of the *Archaea* are not human pathogens and will not be discussed further. The following sections refer to eubacteria:

Plasmids: extra-chromosomal DNA, usually present in multiple-copy number, which often code for pathogenesis factors and antibiotic resistance factors. Some forms are also involved in bacterial replication.

The cell envelope: Bacteria can be divided into two groups on the basis of staining with the Gram stain; Gram positive bacteria remain stained by crystal violet on washing, Gram negative do not. All bacteria have a cell membrane where oxidative phosphorylation occurs (since there are no mitochondria). Outside the cell membrane is the cell wall that is rigid and protects the cell from osmotic lysis. In Gram positive bacteria the cell wall peptidoglycan layer is a much thicker layer than in Gram negative bacteria. Gram negative bacteria have an additional outer membrane. The outer membrane is the major permeability barrier in Gram negative bacteria. The space between the inner and outer membranes is known as the periplasmic space. Gram negative bacteria store degradative enzymes in the periplasmic space. Gram positive bacteria lack a periplasmic space and thus can not store degradative enzymes. In both cases digestive enzymes perform extra-cellular digestion. Digestion is needed since large molecules do not readily pass across the outer membrane (if present) or cell membrane.

Flagella: Some bacterial species are mobile and possess locomotory organelles- flagella. Those that do are able to taste their environment and respond to specific chemical foodstuffs or toxic materials and move towards or away from them (chemotaxis). Flagella are embedded in the cell membrane, extend through the cell envelope and project as a long strand. Flagella consist of a number of proteins including flagellin. They move the cell by rotating with a propeller like action. Axial filaments in spirochetes have a similar function to flagella. Binding proteins in the periplasmic space or cell membrane bind food sources (such as sugars and amino acids) causing methylation of other cell membrane proteins that in turn affect the movement of the cell by flagella. Permeases are proteins that then transport these foodstuffs through the cell membrane. Energy and carbon sources can then be stored when necessary in cytoplasmic "storage granules" which consist of glycogen, polyhydroxybutyrate or polyphosphate.

Wall-less forms of Bacteria. When bacteria are treated with: 1) enzymes that are lytic for the cell wall e.g. lysozyme or 2) antibiotics that interfere with biosynthesis of peptidoglycan wall-less bacteria are often produced. Usually these treatments generate non-viable organisms. Wall-less bacteria that do not replicate are referred to as spheroplasts (when an outer membrane is present) or protoplasts (if an outer membrane is not present). Occasionally wall-less bacteria that can replicate are generated by these treatments (L forms).

Pili (synonym; fimbriae): The types of pili (or whether they are produced at all) vary both among and between species. Pili are hair-like projections of the cell. Some are involved in sexual conjugation and others allow adhesion to host epithelial surfaces in infection.

Capsules and slime layers: These are structures surrounding the outside of the cell envelope; when more defined referred to as a capsule when less defined as a slime layer or glycocalyx. Usually consist of polysaccharide; however the capsule of *Bacillus anthracis* is composed of a polypeptide (D-polyglutamic acid). Capsules are not essential to cell viability and some strains (of certain species) may produce a capsule, whilst others may not. Capsules of pathogenic bacteria inhibit ingestion and killing by phagocytes. Capsules are often lost during *in vitro* culture.

Endospores: (spores) are a dormant form of bacterial cell produced by certain bacteria when starved; the actively growing form of the cell is referred to as vegetative. The spore is resistant to adverse conditions (including high temperatures and organic solvents). The spore cytoplasm is dehydrated and contains calcium dipicolinate (dipicolinic acid) which is involved in the heat resistance of the spore. Spores are commonly found in the genera *Bacillus* and *Clostridium* (both Gram positive).