BACTERIA CELL: STRUCTURE AND FUNCTION

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Bacteria Structure

- Chromosome
- Pilus (fimbria)
- Ribosomes
- Inclusion
- Flagellum
- Plasmid
- Capsule or slime layer
- Cell wall
- Cell membrane
Introduction

• Bacteria are classified as Prokaryotes
• They are unicellular organisms that lack nuclear membrane and true nucleus
• They also lack some cell structures such as mitochondria, endoplasmic reticulum and Golgi bodies
• The prokaryotic cell is simpler than eukaryotic cell but has a more complex cell envelope which protects against hostile environment
Characteristics of Bacteria

• All bacteria, both pathogenic and saprophytic, are unicellular organisms that reproduce by binary fission

• Most bacteria are capable of independent metabolic existence and growth

Exceptions: *Chlamydia* and *Rickettsia* are obligate intracellular organisms

• Bacterial cells are extremely small and are most conveniently measured in microns.
Shapes of Bacteria

- Coccus
  - Chain = Streptococcus
  - Cluster = Staphylococcus
- Bacillus
  - Rod
- Coccobacillus
- Vibrio - curved
- Spirillum
- Spirochete
(d) Staphylococcci
Bacterial Structures

- Cell envelope structures
  - Flagella
  - Pili
- Capsule
- Plasma Membrane
- Cell Wall
  - Lipopolysaccharides
  - Teichoic Acids
- Cytoplasmic structures
- Inclusions
- Spores
Surface Appendages

• Flagella: organs of locomotion
  – Flagella occur on both Gram-positive and Gram-negative bacteria, and their presence can be useful in identification
  – They are found on many species of bacilli but rarely on cocci

• Pili: occur almost exclusively on Gram-negative bacteria and are found on only a few Gram-positive organisms (e.g., *Corynebacterium renale*).
<table>
<thead>
<tr>
<th>Structure</th>
<th>Flagella Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monotrichous</td>
<td><em>Vibrio cholerae</em></td>
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<tr>
<td></td>
<td>Lophotrichous</td>
<td><em>Bartonella bacilliformis</em></td>
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<tr>
<td></td>
<td>Amphitrichous</td>
<td><em>Spirillum serpens</em></td>
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<tr>
<td></td>
<td>Peritrichous</td>
<td><em>Escherichia coli</em></td>
</tr>
</tbody>
</table>
Flagella

• Flagella can be sheared from the cell surface without affecting the viability of the cell
• The cell then becomes temporarily non-motile
• In time it synthesizes new flagella and regains motility

# The protein synthesis inhibitor chloramphenicol blocks regeneration of flagella.
Pili

- Thin, hair-like appendages on the surface of many Gram-negative bacteria
- Proteins of pili are referred to as pilins
- More rigid in appearance than flagella
- *Shigella* species and *E. coli*- pili are distributed profusely over the cell surface, with as many as 200 per cell.
- Pili can come in two types: short, abundant common pili, and a small number (one to six) of very long pili known as sex pili
Sex Pilus
Pili - Adhesins

- Pili in many enteric bacteria confer adhesive properties on the bacterial cells, enabling them to adhere to various epithelial surfaces
- To red blood cells (causing hemagglutination)
- To surfaces of yeast and fungal cells
- These adhesive properties of piliated cells play an important role in bacterial colonization of epithelial surfaces and are therefore referred to as colonization factors
Capsule and Loose slime

- Some bacteria form capsules, which constitute the outermost layer of the bacterial cell and surround it with a relatively thick layer of viscous gel.
- Capsules may be up to 10 µm thick, usually made of polysaccharides and rarely polypeptides.
- Capsules of encapsulated pathogens are often important determinants of virulence.
Capsule

- Encapsulated species are found among both Gram-positive and Gram-negative bacteria
- Mutational loss of enzymes involved in the biosynthesis of the capsular polysaccharides can result in the smooth-to-rough variation seen in the pneumococci
- Confer resistance to phagocytosis and hence provide the bacterial cell with protection against host defenses to invasion
<table>
<thead>
<tr>
<th>Genus and Species</th>
<th>Capsular Substances</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gram-positive bacteria</strong></td>
<td></td>
</tr>
<tr>
<td><em>S. pneumoniae</em></td>
<td>Polysaccharides: e.g., type 111, glucose, glucoronic acid (cellubiose), other types, various sugars and amino sugars.</td>
</tr>
<tr>
<td><em>Streptococcus spp</em></td>
<td>Polysaccharides: e.g., hyaluronic acid (group A), others containing amino sugars, uronic acids.</td>
</tr>
<tr>
<td><em>B. anthracis</em></td>
<td>γ-Glutamyl polypeptide</td>
</tr>
<tr>
<td><strong>Gram-negative bacteria</strong></td>
<td></td>
</tr>
<tr>
<td><em>H. influenzae</em></td>
<td>Polynucleoprotein.</td>
</tr>
<tr>
<td><em>Klebsiella spp</em></td>
<td>Polysaccharides: sugars such as hexoses, fucose, uronic acids.</td>
</tr>
<tr>
<td><em>N. meningitidis</em></td>
<td>Polysaccharides: N-acetylmannosamine phosphate polymer (group A); sialic acid polymers (groups B and C).</td>
</tr>
</tbody>
</table>
Cell Envelope Structures

• Consists of the membrane and the structures surrounding the cytoplasm

1. Plasma/ Cell Membrane- phospholipid bilayer with embedded proteins that envelop the cytoplasms

Lacks sterols except *Mycoplasma*.
Acts as osmotic barrier and site of electron trasnsport chain for energy generation
Plasma membranes - Functions

• Are the site of active transport
• Respiratory chain components
• Energy-transducing systems
• Site for the H+-ATPase of the proton pump
• Membrane stages in the biosynthesis of phospholipids, peptidoglycan, LPS, and capsular polysaccharides.
Cell Envelope Structures

2. Cell Wall - a rigid structure that maintains the shape of the cell and prevents the bursting of the cell from intracellular high osmotic pressure

- Two major types are

  - Gram positive cell wall
  - Gram negative cell wall

Mycobacteria have a modified Gram positive cell wall called Acid-fast cell wall.

Mycoplasmas have no cell wall, contains sterols in their cell membrane.
Gram Stain

Gram stain invented by Hans Christian Gram

Divides Eubacteria into two main groups based on stain.

Correlates with two types of cell wall architecture.
Gram Stain
Cell Wall

- Peptidoglycan Polymer (amino acids + sugars)
- Unique to bacteria
- Sugars; NAG & NAM
  - N-acetylglucosamine
  - N-acetylmuramic acid
- D form of Amino acids used
  - D form is hard to break down
- Amino acids cross link NAG & NAM
Gram Positive Cell-Wall

- Wall associated protein
- Teichoic acid
- Lipoteichoic acid
- Peptidoglycan
- Cytoplasmic membrane
Teichoic Acids

- A polysaccharide present only in Gram positive cell wall
- Teichoic acid is anchored to the peptidoglycan
- Lipoteichoic acid is anchored to the plasma membrane
- It acts as antigenic determinants
- Used in serologic identification of many species
- Attachment for Phages
Gram Negative Cell-Wall

- O-polysaccharide
- Core polysaccharide
- Protein
- Porin
- Lipid A
- Lipopolysaccharide (LPS)

Outer membrane:
- Gram-negative outer membrane

Periplasm:
- Lipoprotein

Cytoplasmic membrane:
- Peptidoglycan

Inside
- Inside

8 nm
Lipopolysaccharides

• Characteristic feature of Gram-negative bacteria

• A Gram-positive organism, *Listeria monocytogenes*, has been found to contain an authentic LPS

• Also called endotoxin, thereby distinguishing these cell-bound, heat-stable toxins from heat-labile, protein exotoxins secreted into culture media
Lipopolysaccharide (LPS)

- Endotoxin or Pyrogen
  - Fever causing
  - Toxin nomenclature
    - Endo- part of bacteria
    - Exo- excreted into environment

- Structure
  - Lipid A
  - Polysaccharide
  - O Antigen

- G-ve bacteria only
  - Removed by alcohol/acetone
Lipopolysaccharides

- Causes endotoxic shock,
- Pyrogenic
- Activates macrophages and complement
- Mitogenic for B lymphocytes
- Induces interferon production
- The endotoxic properties of LPS reside largely in the lipid A components
Periplasmic Space

- The periplasmic space is the region between the outer surface of the inner (plasma) membrane and the inner surface of the outer membrane.

- In addition to the hydrolytic enzymes, the periplasmic space holds binding proteins (proteins that specifically bind sugars, amino acids, and inorganic ions) involved in membrane transport and chemotactic receptor activities.
Mesosomes

• Thin sections of Gram-positive bacteria reveal the presence of vesicular or tubular-vesicular membrane structures called mesosomes.
• Are apparently formed by an invagination of the plasma membrane.
• More prominent in Gram-positive than in Gram-negative organisms.
Cytoplasm

- 80% Water {20% Salts-Proteins)
  - Osmotic Shock important
- DNA is circular, Haploid
  - More efficient; grows quicker
  - Mutations allow adaptation to environment quicker
- Plasmids; extra circular DNA
  - Antibiotic Resistance
- No organelles (Mitochondria, Golgi, etc.)
Nucleoid

- The bacterial nucleoid is a structure containing a single chromosome.
- The number of copies of the chromosome in a cell depends on the stage of the cell cycle (chromosome replication, cell enlargement, chromosome segregation, etc).
- Bacterial chromatin does not contain basic histone proteins, instead low-molecular-weight polyamines and magnesium ions may fulfill a function similar to that of eukaryotic histones.
Nucleoid

- Prokaryotic and eukaryotic cells are distinguished on the basis of structure
- Bacterial nucleoid, which contains the DNA fibrils, lacks a limiting membrane
- Under the light microscope, the nucleoid of the bacterial cell can be visualized with the aid of Feulgen staining, which stains DNA
- The DNA is then seen to be a single, continuous, "giant" circular molecule with a molecular weight of approximately $3 \times 10^9$
Other Intracellular Components

- Ribosomes of the 70S type
  - not arranged on a membranous rough endoplasmic reticulum as they are in eukaryotic cells
- Metabolic reserve particles such as poly-β-hydroxybutyrate (PHB), polysaccharide and glycogen-like granules, and polymetaphosphate or metachromatic granules
- Endospores are highly heat-resistant, dormant, dehydrated resting cells formed intracellularly in members of the genera *Bacillus* and *Clostridium*
Endospores

• Resistant structure
  – Heat, irradiation, cold, chemicals, dessication
  – Boiling >1 hr still viable
• Takes time and energy to make spores
• Location important in classification
  – Central, Subterminal, Terminal
• *Bacillus stearothermophilus* - spores
  – Used for quality control of heat sterilization equipment
• *Bacillus anthracis* - spores
  – Used in biological warfare
QUESTIONS ?
THANK YOU