Prokaryote Form and Function

Lecture 5

Learning Outcomes

• Cell morphology
• Extracellular Structures
  - Biofilms
• Cell wall structure
  - Gram +
  - Gram -
• Cellular processes
  - Diffusion
  - Osmosis
• Sporulation
**cocci**

- Spherical
- Smaller surface area:volume ratio
  - More tolerant of dehydration
- Diplococci
- Streptococci - chain
- Tetrad
  - Divide in horizontal planes
- Sarcine
  - Divide horizontally and vertically
- Staphylococci
  - Divide in any plane

**bacilli**

- Rods
- Larger surface area:volume ratio
  - More rapid exchange of nutrients with environment
- Only divide at end
  - Bacillus
- Diploracilli
- Streptobacilli
- Cocacobacilli
  - Short, rounded rod
Spiral Bacteria

- Vibrios
  - banana shaped
- Spirillum -
  - helical shape, inflexible, true flagella
- Spirochete -
  - helical flexible, axial filaments
  - Long but thin difficult to visualize with compound light microscope
  - Borrelia, Treponema

Prokaryote Form

- Capsule
- Cytoplast
- Cell wall
- Membrane
- Inclusion
- Plasmid
- Flagella
Extracellular Structures

- Glycocalyx
  - Polysaccharide, polypeptide or both
  - Excreted
- Slime layer
  - Not attached firmly to cell wall
  - *Streptococcus mutans*
- Capsule
  - More firmly attached
  - *Streptococcus pneumoniae*
  - Bacillus anthracis
- Functions
  - Attachment to substrate
  - Teeth
  - Prevent dehydration
  - Nutrient reserve
  - Protect against phagocytosis

Biofilms

- Complex mix of bacterial cells and matrix of polymers
- Decreases effectiveness of disinfectants
- *Staphylococcus aureus* biofilm on a catheter
- Plaque on teeth
- Quorum Sensing
Flagella

- Filament - helical
- Hook
- Basal Body - rotates clockwise or counterclockwise
- Motility
- Propel bacterium forwards
  - Chemotaxis
  - Phototaxis

Arrangement of Bacterial Flagella

- Peritrichous
  - Flagella over entire surface
- Polar
  - At one or both ends of cell
    - Monotrichous
      - One flagellum at one end
    - Lophotrichous
      - A tuft of flagella at one end
- Amphitrichous
  - Flagella at both ends
Axial Filaments

- Spirochetes only
- Endoflagella
- Fibrils attached at end
  - Wind around cell
- Outer sheath
- Rotation of filaments
  - Spin whole spirochete
- Corkscrew motion
  - Burrows through tissues

Fimbriae and Pili

- Both composed of pilin protein
- (Mostly on Gram-negative bacteria)
- Fimbriae
  - Numerous
  - Attachment
  - Neisseria gonorrhoeae
- Pili
  - Longer than fimbriae
  - Only 1-2 per cell
  - Used to transfer DNA in conjugation
  - Escherichia coli
Prokaryote Cell Wall

- Complex
- Semi-rigid
- Functions:
  - Determines cell shape
  - Protects plasma membrane from adverse conditions
  - Prevents bacteria from exploding (lysis)
- Almost all prokaryotes
- Clinically site of action of some antibiotics

Peptidoglycan

- Repeating disaccharide of N-acetylglicosamine (NAG)
- N-acetylmuramic acid (NAM)
- Alternating NAG-NAM chains
  - "Carbohydrate backbone"
  - "Glycan" of peptidoglycan
Peptidoglycan

- Parallel NAG-NAM chains cross-linked by tetrapeptide chains
- "Peptido" portion

Gram Positives

- Thick cell wall
  - Many layers of peptidoglycan
- Teichoic acids
  - Alcohol + phosphate
- Lipoteichoic acids
  - Span cell wall attach to plasma membrane
- Antigen specificity
• Outer membrane
• Strong negative charge
• Lipopolysaccharides
  - Lipid A
  - Endotoxin
  - O polysaccharides
  - Antigens
• Periplasm
  - Fluid filled space
  - One or very few layers of peptidoglycan
• Porins
  - Selective protein channels
  - Can inhibit or pump out antibiotics

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• Crystal Violet enters cytoplasm of both → purple
• Iodine mordant forms large crystals
• Alcohol - Gram +ve
  - Dehydrates peptidoglycan cell wall of → less permeable
• Alcohol - Gram -ve
  - Dissolves outer membrane
  - Crystal violet diffuses out → no color
• Safranin counterstain stains Gram -ve pink
• Dead gram +ve = pink cell wall degraded
Gram + v Gram -

<table>
<thead>
<tr>
<th>Trait</th>
<th>Gram Positive</th>
<th>Gram Negative</th>
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</thead>
<tbody>
<tr>
<td>Cell Wall</td>
<td>Thick</td>
<td>Thin</td>
</tr>
<tr>
<td>Presence of Peptidoglycan</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Presence of Lipopolysaccharide</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sensitivity to Gram-Inducing Dyes</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Sensitivity to Lysozyme</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Cell Walls and Antibiotics

- **Gram positive**
  - Penicillin
    - Inhibits function of bacterial enzyme DD-transpeptidase
    - Prevents peptide crosslinks
  - Lysozyme
    - Catalyzes hydrolysis of disaccharide bonds
- **Gram negative**
  - Not susceptible to penicillin
  - Less susceptible to Lysozyme
Prokaryote Plasma Membrane Structure

- Phospholipid bilayer
  - Polar head
  - Nonpolar tails
- Proteins
  - Integral proteins
  - Peripheral proteins
- Lack
  - Sterols
  - Carbohydrates
- Fluid Mosaic Model

Plasma Membrane Function

- Selective Permeability
  - Dissolved $O_2$, $CO_2$
- Protein Channels
  - Larger molecules
  - $H_2O$ and charged ions $Na^+$
- Membrane bound Enzymes
  - Breakdown nutrients
  - Produce ATP
- Chromatophores
  - Infoldings
    - Increase surface area
  - Photosynthetic pigments
    - E.g. Rhodospirillum rubrum
      - (Thylakoids of chloroplasts)
Movement Across Membranes

- Simple Diffusion
  - [high] \rightarrow [low]
  - Across plasma membrane
  - Small uncharged molecules
    - \(O_2, CO_2\)
- Facilitated Diffusion
  - Via transporter proteins
  - Ions
- Active Transport
  - Expends ATP energy
  - Glucose
- Group Translocation
  - Substrate chemically altered during transport

Osmosis

- Movement of water
  - [high \(H_2O\)] \rightarrow [low \(H_2O\)]
  - Aquaporins
- Isotonic Solution
  - \([\text{solute}] = \text{relative to cell}\)
- Hypotonic
  - \(< [\text{solute}]\) relative to cell
    - Lysis
- Hypertonic
  - \(> [\text{solute}]\) relative to cell
    - Plasmolysis
Cytoplasm and Ribosomes

- **Cytoplasm**
  - 80% water
- **Ribosomes**
  - site of protein synthesis
- **Prokaryote** smaller than Eukaryote
  - 70s v 80s
  - 'S' = Svedberg units
- 2 subunits
  - 30s = small
  - 50s = large
- **Antibiotic action**
  - streptomycin

Chromosome and Plasmids

- **Nucleoid**
- One double stranded DNA ring
  - NO HISTONES
- **Attached to plasma membrane**
- **Bacterial genome**
  - ~4000 genes
- **Plasmid**
  - Small circular DNA molecule
  - 5-100 genes
  - Replicates independently
  - Can be transferred
Endospores

- Resistant Resting Bodies
- Formed by Gram +ve
  - Bacillus
  - central
  - terminal
- Formed when:
  - Nutrient reserves low
  - Dehydrated
  - No metabolism
  - Dormant
- Survive stressful environmental conditions
  - Extreme heat
  - Lack of water
  - Toxic chemicals
  - Radiation
  - midterms
  - Break-ups

Sporulation

(a) Sporulation, the process of endospores formation
  - Spore mother cell divides to form two identical daughter cells.  
  - A wall is laid down around each daughter cell. 
  - The outer wall and inner wall must be removed to allow the spores to germinate. 
  - Spore is released from cell.

(b) An endospore is a resting cell.