Structure and Function of Bacterial Cells

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Size of Bacteria

- Average bacteria 0.5 - 2.0 um in diam.
  - RBC is 7.5 um in diam.
- Surface Area ~12 um^2
- Volume is ~4 um
- Surface Area to Volume is 3:1
- Typical Eukaryote Cell SA/Vol is 0.3:1
- Food enters through SA, quickly reaches all parts of bacteria
- Eukaroytes need structures & organelles
Shapes of Bacteria

- **Coccus**
  - Chain = *Streptococcus*
  - Cluster = *Staphylococcus*
- **Bacillus**
  - Chain = *Streptobacillus*
- **Coccobacillus**
- **Vibrio** = curved
- **Spirillum**
- **Spirochete**
- **Square**
- **Star**
Bacterial Structures

- Flagella,
- Pili or Fimbriae
- Capsule or Slime Layer
- Cell Membrane
  - Lipopolysaccharides
  - Teichoic Acids
- Cell Wall
- Cytoplasm
- DNA,
  - chromosome and plasmids
- Ribosomes
- Inclusions
- Spores
Chapter 4

Key Concept

Prokaryotic cells lack membrane-enclosed organelles. All bacteria contain cytoplasm, ribosomes, a plasma membrane, and a nucleoid. Almost all bacteria have cell walls.
Flagella

• Motility - movement

• Swarming occurs with some bacteria
  – Spread across Petri Dish
  – Proteus species most evident

• Arrangement basis for classification
  – Monotrichous; 1 flagella
  – Lophotrichous; tuft at one end
  – Amphitrichous; both ends
  – Peritrichous; all around bacteria

• Observe Picture in Micro Lab.
Mono- or Lophotrichorus

**Peritrichous**
- Bundled flagella (CCW rotation)
- Tumble flagella pushed apart (CW rotation)
- Flagella bundled (CCW rotation)

**Polar**
- CCW rotation
- CW rotation
- CCW rotation
GRAM+ or GRAM-?
WHICH ONE IS GRAM+?  WHICH IS GRAM-?
Basic Characteristics of Bacteria

- **Storage “granules”** - cytoplasm
- **When important nutrient sources are in “excess”**
- **Carbon often stored as lipid (Poly-β-hydroxybuteric acid)**
- **Inorganics (e.g., sulfur, iron) - most appear granular under light microscope**
Basic Characteristics of Bacteria

- Fimbriae (plural, fimbria is singular)
- Important in attachment to eukaryotic cell surfaces
- Can contribute to pathogenesis if attachment is needed to initiate tissue damage
Basic Characteristics of Bacteria

- Flagella (plural, singular is flagellum)
- Polar and peritrichous locations
- Enable flagellated bacteria to move (motility) – HOW??
Pili

• Short protein appendages
  – smaller than flagella

• Adhere bacteria to surfaces
  – E. coli has numerous types
  – Antibodies to pili block adherence

• F-pilus; used in conjugation
  – Exchange of genetic information

• Flotation; increase boyancy
  – Pellicle (scum on water)
  – More oxygen on surface
F-Pilus for Conjugation
Capsule or Slime Layer

- Capsule – tightly bound to cell
- Slime Layer – loosely bound to cell
- Glycocalyx - Polysaccharide on external surface
- Adhere bacteria to surface
  - S. mutans and enamel of teeth
- Prevents Phagocytosis
  - Complement can’t penetrate sugars
Cell Wall

• Peptidoglycan Polymer (amino acids + sugars)
• Unique to bacteria
• Sugars: NAG & NAM
  – N-acetylglucosamine
  – N-acetymuramic acid
• Amino acids cross link NAG & NAM
• D form of amino acids and L amino acids
  – Hard to break down D form
Basic structural unit of peptidoglycan
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N-Acetylglucosamine (G)  N-Acetylmuramic acid (M)

β(1,4) β(1,4) β(1,4)

Peptide bonds

L-Alanine

d-Glutamic acid

Meso-diaminopimelic acid

Lysozyme-sensitive bond
Simplified schematic of cell wall in a gram-positive bacterium
(showing plasma membrane; teichoic acids not shown)
Structure and Function

- **Cell Wall**
- peptidoglycan - imparts some rigidity
- Sugar backbone - NAG & NAM
- (Human lysozyme cleaves β(1,4) bond)
- Amino acid cross links – adds more rigidity
- Peptidoglycan layer thickness

![Diagram of peptidoglycan structure](image-url)
Cell Wall

- Gram positive – thicker peptidoglycan layer (includes teichoic acids)
- Gram negative – thinner peptidoglycan layer (has an outer “membrane-like” layer)
Gram-negative cell wall

- Lipopolysaccharide (LPS) component of outer membrane
- Can be involved in certain pathologies
Gram-negative cell wall lipopolysaccharide (LPS)

- **Phagocytes** normally engulf and destroy pathogens, **dead** body cells and tissues
- LPS stimulates phagocytes to **overproduce** inflammatory cytokines
  - Phagocytes indiscriminately destroy **healthy** cells and tissues
  - Severe inflammation & tissue damage (disease)
- LPS is called an “**endotoxin**” when it has this affect
Cell Wall Summary

- Determine shape of bacteria
- Strength prevents osmotic rupture
- 20-40% of bacteria
- Unique to bacteria
- Some antibiotics effect directly
  - Penicillin
Teichoic Acids

• Gram + only
• Glycerol, Phosphates, & Ribitol
• Attachment for Phages
Cell Membrane

- Bilayer Phospholipid
- Water can penetrate - slowly
- Flexible
- Not strong, ruptures easily
  - Osmotic Pressure created by cytoplasm
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Diagram of a lipid bilayer:
- **Hydrophilic region**
- **Hydrophobic region**
- **Fatty acids**
- **Glycerol**
- **Phosphate**
- **H₂O**
WHAT DOES THE FIGURE SHOW?
Cytoplasm

• 80% Water; 20% Salts-Proteins
  – Osmotic Shock important

• DNA is circular, Haploid not Diploid
  – Advantages of 1N DNA over 2N DNA
    – More efficient; grows quicker
    – Mutations allow adaptation to environment quicker

• Plasmids; extra circular DNA
  – Antibiotic Resistance

• No nuclei or organelles (Mitochondria, Golgi, etc.)
Lipopolysaccharide (LPS)

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

- **Structure**
  - Lipid A
  - Polysaccharide
    - O Antigen of E. coli, Salmonella

- **G- bacteria only**
  - Alcohol/Acetone removes
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Polysaccharide

Repeat units
Core
Glucosamine = pyrophosphate polymer
Long chain fatty acids
LPS (cont’d)

• **Functions**
  – Toxic; kills mice, pigs, humans
    • G- septicemia; death due to LPS
  – Pyrogen; causes fever
    • DPT vaccination always causes fevers
  – Adjuvant; stimulates immunity

• **Heat Resistant; hard to remove**

• **Detection (all topical & IV products)**
  – Rabbits (measure fever)
  – Horse shoe crab (Amoebocytes Lyse in presence of LPS)
LPS (cont’d.)

• Appearance of Colonies
  – Mucoid = Smooth (lots of LPS or capsule)
  – Dry = Rough (little LPS or capsule)

• O Antigen of Salmonella and E. coli
  – 2,000 different O Ags of Salmonella
  – 100’s different O Ags of E. coli
    • E. coli O157

• O Ags differ in Sugars, not Lipid A
Endospores

• Resistant structure
  – Heat, irradiation, cold
  – 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
Classify spore location
G+ vs. G-

- G+
  - Thicker cell wall
  - Teichoic Acids

- G-
  - Endotoxin - LPS

- Which are more sensitive to Penicillin?
- Alcohol/Acetone affects which more?
Eukaryote Cell Structure
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Compare and Contrast
Prokaryotes vs. Eukaryotes