Ch 4

Functional Anatomy of Prokaryotic and Eukaryotic Cells
Objectives

Compare and contrast the overall cell structure of prokaryotes and eukaryotes.

Identify the three basic shapes of bacteria.

Describe structure and function of the glycocalyx, flagella, axial filaments, fimbriae, and pili.

Compare and contrast the cell walls of gram-positive bacteria, gram-negative bacteria, acid-fast bacteria, and mycoplasmas.

Differentiate between protoplast, spheroplast, and L form.

Describe the structure, chemistry, and functions of the prokaryotic plasma membrane.

Identify the functions of the nuclear area, ribosomes, and inclusions.

Describe the functions of endospores, sporulation, and endospore germination.

What you should remember from Bio 31:

Define organelle. Describe the functions of the nucleus, endoplasmic reticulum, ribosomes, Golgi complex, lysosomes, vacuoles, mitochondria, chloroplasts, peroxisomes. Explain endosymbiotic theory of eukaryotic evolution.
Comparing Prokaryotic and Eukaryotic Cells

Common features:
- DNA and chromosomes
- Cell membrane
- Cytosol and Ribosomes

Distinctive features: ?
Prokaryotes

- One circular chromosome, not membrane bound
- No histones
- No organelles
- Peptidoglycan cell walls
- Binary fission
Size, Shape, and Arrangement

Average size: 0.2 - 1.0 µm × 2 - 8 µm

Three basic shapes

1. **Bacillus**, -i
2. **Coccus**, -i
3. **Spirals** (Vibrio, Spirillum, Spirochete)

Most monomorphomic, some pleomorphic

Variations in cell arrangements (esp. for cocci)

Review Figs. 4.1, 4.2, and 4.4
Spiral Bacteria

(a) Vibrio

(b) Spirillum

(c) Spirochete

Figure 4.4
Pleomorphic Corynebacteria

Monomorphic

E. coli
Cell Arrangement

(a) Diplococci

(b) Streptococci

(c) Tetrad

(d) Staphylococci

(a) Single bacillus

(b) Diplobacilli

(c) Streptobacilli

(d) Coccobacillus
External Structures
located outside of cell wall

- Glycocalyx
- Flagellum /-a
- Axial filaments
- Fimbria /-ae
- Pilus /-i
Glycocalyx

- Many bacteria secrete external surface layer composed of sticky polysaccharides, polypeptide, or both
- **Capsule**: organized and firmly attached to cell wall
- **Slime layer**: unorganized and loosely attached
- Allows cells to attach → key to biofilms
- Prevents phagocytosis → virulence factor
- *E.g.:* *B. anthracis, S. pneumoniae, S. mutans*
Flagellum – Flagella

- Anchored to wall and membrane
- Number and placement determines if atrichous, monotrichous, lophotrichous, amphitrichous, or peritrichous

Fig 4.7
Motility

- Due to rotation of flagella
- Mechanism of rotation: “Run and tumble”
- Move toward or away from stimuli (taxis)
- Chemotaxis (phototaxis and magnetotaxis)
- Flagella proteins are H antigens (e.g., *E. coli* O157:H7)
“Run and Tumble”

(a) No attractant or repellent

(b) Gradient of attractant concentration

Fig 4.9
**Axial Filaments**

- Endoflagella
- In spirochetes
- Anchored at one end of a cell
- Rotation causes cell to move

**Fimbriae and Pili**

- Fimbriae allow attachment
- Pili are used to transfer DNA from one cell to another
Cell Wall

- Rigid for shape & protection $\Rightarrow$ prevents osmotic lysis

- Consists of **Peptidoglycan** (murein) $\rightarrow$ polymer of 2 monosaccharide subunits:
  - N-acetylglucosamine (NAG)
  - N-acetylmuramic acid (NAM)

- Linked by **polypeptides** (forming peptide cross bridges) with tetrapeptide side chain attached to NAM

- Fully permeable to ions, aa, and sugars
  (Gram positive cell wall may regulate movement of cations)
(a) Structure of peptidoglycan in gram-positive bacteria
Gram + Cell Wall

- Thick layer of peptidoglycan
- Negatively charged teichoic acid on surface

Gram – Cell Wall

- Thin peptidoglycan
- Outer membrane
- Periplasmic space
Gram-Positive Cell Walls

- Teichoic acids
  - Lipoteichoic acid links to plasma membrane
  - Wall teichoic acid links to peptidoglycan
- May regulate movement of cations
- Polysaccharides provide antigenic variation
Lipid A of LPS acts as **endotoxin**; O polysaccharides are antigens for typing, e.g., *E. coli* O157:H7

Gram neg. bacteria are less sensitive to medications because outer membrane acts as additional barrier.

**LPS layer** = outer layer of outer membrane

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**Fig 4.13**

 Gram-negative Cell Wall

(c) Gram-negative cell wall

(protein rich gel-like fluid)
Gram Stain Mechanism

- Crystal violet-iodine crystals form in cell.
- Gram-positive
  - Alcohol dehydrates peptidoglycan
  - CV-I crystals do not leave
- Gram-negative
  - Alcohol dissolves outer membrane and leaves holes in peptidoglycan.
  - CV-I washes out

For further details and practical application see lab
Bacteria with No Cell Wall: Mycoplasmas

- Instead, have cell membrane which incorporates cholesterol compounds (sterols), similar to eukaryotic cells

- Cannot be detected by typical light microscopy

This EM shows some typically pleomorphic mycoplasmas, in this case *M. hyorhinis*
Acid-fast Cell Walls

- Genus *Mycobacterium* and *Nocardia*
- mycolic acid (waxy lipid) covers thin peptidoglycan layer
- Do not stain well with Gram stain → use acid-fast stain
Damage to Cell Wall

- **Lysozyme** digests disaccharide in peptidoglycan.

- **Penicillin** inhibits peptide bridges in peptidoglycan.

> The enzyme "stitches together" proteins of the cell wall.

> Penicillin bonds to the enzyme instead.

> The enzyme is no longer available to build the cell walls, so the bacteria cannot reproduce.
Internal Structures: Cell Membrane

Analogous to eukaryotic cell membrane:
- Phospholipid bilayer with proteins (Fluid mosaic model)
- Permeability barrier (selectively permeable)
- Diffusion, osmosis and transport systems

Different from eukaryotic cell membrane:
- Role in Energy transformation (electron transport chain for ATP production)

Damage to the membrane by alcohols, quaternary ammonium (detergents), and polymyxin antibiotics causes leakage of cell contents.
(a) Plasma membrane of cell

(b) Lipid bilayer of plasma membrane

(c) Phospholipid molecules in lipid bilayer

Fig 4.14
Movement of Materials across Membranes

See Bio 31!

Review on your own if necessary (pages 92 – 94)
Cytoplasm and Internal Structures

Location of most biochemical activities

- **Nucleoid**: nuclear region containing DNA (up to 3500 genes). Difference between human and bacterial chromosome?

- **Plasmids**: small, nonessential, circular DNA (5-100 genes); replicate independently

- **Ribosomes** (70S vs. 80S)

- **Inclusion bodies**: granules containing nutrients, monomers, Fe compounds (magnetosomes)
Endospores

Dormant, tough, non-reproductive structure; $\rightarrow$ germination $\rightarrow$ vegetative cells

Spore forming genera: ___________

Resistance to UV and $\gamma$ radiation, desiccation, lysozyme, temperature, starvation, and chemical disinfectants

Relationship to disease

Sporulation: Endospore formation

Germination: Return to vegetative state
Sporulation

1. Spore septum begins to isolate newly replicated DNA and a small portion of cytoplasm.
2. Plasma membrane starts to surround DNA, cytoplasm, and membrane isolated in step 1.
4. Peptidoglycan layer forms between membranes.
5. Spore coat forms.
6. Endospore is freed from cell.

(a) Sporulation, the process of endospore formation.

Fig. 4.21
Green endospores within pink bacilli. Many spores have already been released from the vegetative cells.
The Eukaryotic Cell

See Bio 31!

Review on your own if necessary (pages 98 – 106)