Chapter 2
Bacteria

Lecture Outline:

I) Bacterial cell **morphology**
  A) Bacterial cells can have several distinct morphologies:
    i) Cocci
    ii) Bacilli
    iii) Vibrios
    iv) Spirilla
    v) Pleiomorphic
  B) In some bacterial species, cells can stay attached after cell division.
    i) Leading to **clusters, chains** and **branching filaments**
    ii) Arrangement of cells is consistent within a given species
  C) Some bacteria grow more complex multicellular arrangements, forming:
    i) hyphae, mycelia or **trichomes**
  D) Cells range in size from 0.2 µm to 700 µm in diameter
    i) Average is 0.5 µm to 5 µm

II) Cytoplasm of bacterial cells
  A) Most massive component of the cytoplasm is the **nucleoid**.
    i) Consists of **chromosomal DNA** and associated proteins
    ii) Does not have a membrane
  B) Chromosomal DNA is influenced by the action of **topoisomerases**.
  C) **Ribosomes** are also found in the cytoplasm of bacterial cells.
  D) **Organic metabolites, inorganic ions** and **inclusion bodies** are also found in the cytoplasm of bacterial cells.
  E) In addition, some species have **sulfur globules, gas vesicles, carboxysomes,** and **magnetosomes** in the cytoplasm.

III) Internal structures that help organize bacterial cells
  A) Bacterial cells contain structures that provide cell shape and assist in division.
    i) **Z-ring** (derived from FtsZ protein) guides cell division and causes the plasma membrane to constrict.
    ii) **MrcB** controls cell shape in many bacteria.
    iii) **ParM** ensures plasmids are evenly distributed during cell division.
    iv) Some proteins have roles in the distribution of chromosomal DNA during cell division.

IV) Structural and functional properties of the bacterial cell envelope
  A) **Plasma membrane** is a **phospholipid bilayer** in which **proteins** are embedded. Some species have **hopanoids**.

B) Plasma membrane is involved in nutrient transport, energy metabolism, environmental sensing and protein secretion.
   i) **Aquaporins** regulate the movement of water across the plasma membrane.
   ii) **ABC transporters** (an active transport system) aid in transporting nutrients across the membrane using symport or antiport mechanisms.
   iii) Protein secretion involves a **general secretory pathway** and the presence of **signal peptides** on proteins targeted for secretion.
   iv) The bacterial cell wall is composed of **peptidoglycan** (which determines shape and provides mechanical strength and protection).
   v) **Lysozyme** hydrolyzes specific bonds within the peptidoglycan.
   vi) **Lysostaphin** affects the peptidoglycan of S. aureus.
   vii) **β-lactamases** destroy β-lactam antibiotics which provides bacteria with resistance to them.

C) Two types of **cell envelopes** in bacteria.
   i) They can be distinguished from one another by the Gram stain procedure.
   ii) **Gram-positive bacteria** have a thick cell wall composed of multiple layers of **peptidoglycan** along with **teichoic acid** and **lipoteichoic acid**.
      (1) Some Gram-positive bacteria form endospores under stressful conditions.
   iii) **Gram-negative bacteria** have an extra outer membrane outside a thin layer of peptidoglycan.
      (1) The space between the plasma and outer membranes in Gram-negative bacterial cells is called the periplasm.
      (2) The outer membrane of Gram-negative cells contains **lipopolysaccharide** and **transport systems** (such as porins and TonB-dependent transporters).

V) Structures on the surface of bacterial cells

A) **Flagella** propel bacteria through liquid environments.
   i) Types of flagella include **monotrichous**, **lophotrichous** and **peritrichous**.

B) **Chemotaxis** is used to direct bacterial motility in response to concentration gradients of attractants and/or repellants and involves **chemoreceptors**.

C) Some bacteria use non-flagellar-based motility (**pilus-mediated twitching** and **gliding motility**) and **actin-based motility**.

D) Adherence to surfaces or other cells can be mediated by cell surface proteins such as **pili, stalks, fimbriae, sex pilus** and **capsules.**
   i) Surface adhesion can be the first step in the creation of **biofilms**.

E) **Surface arrays** or **S-layers** surround some bacterial cells. They provide protection from bacteriophages or shield it from attacks of the host's immune response.

VI) Categorizing and naming bacteria

A) The **classification system** for bacteria is a hierarchical taxonomic system. The basic taxonomic level of **species** refers to groups of strains that share common physical, metabolic, and genetic features.

B) Culture collections contain reference specimens called type strains that are representative of each **taxon**.
C) The **principle of priority** ensures that the first validly named, described name takes precedence.
D) Bacterial taxonomy is not static. New taxa are continually described and new relationships are being discovered.

In Class Activities

Instructor Notes for In-Class Activity One

Title: Internal and External Structures

Time: 5 min prep; 20-25 min in class

Materials: Notecards

Handouts: None

Procedures: Have students create a set of flash cards using the following vocabulary: flagella, chemotaxis, pili, stalks, fimbriae, sex pilus, capsules, cytoskeleton, Z-ring, MrcB, ParM, nucleoid, ribosomes, inclusion bodies, gas vesicles, cytoplasm

Student Instructions: See instructions above.

Specific Suggestions: Have students form small groups and quiz one another with the new vocabulary. Recommend combining all of the flashcards into a pile and having each student one at a time select a flash card and make a question out of the definition for the remaining group members to answer. Continue this activity until students have gone through all of the flash cards in the pile at least one time.

Objectives: The objective of this exercise is to identify the various structures associated with helping bacterial cells to interact with the environment as well as those that help organize the cells internally.

Instructor Notes for In-Class Activity Two

Title: Morphology

Time: 5 min prep; 30 min in class time

Materials: White paper, Colored pencils or markers

Handouts: None

Procedure: Have students draw, color and label all of the different shapes of bacteria (cocci, bacilli, vibrio, spirilla, pleiomorphic). Also, have students add the various arrangements of the different shapes to the diagram (clusters, pairs, chains, etc …).

Student Instructions: See instructions above.

Specific Suggestions: Have students locate examples representative of the various categories and write those examples on the diagram.

Objectives: The objective of this exercise is to become familiar with the various morphologies of bacterial cells.

Instructor Notes for In-Class Activity Three

Title: Taxonomy of bacteria

Time: 5 min prep; 25 min in class time

Materials: Current edition of one volume of *Bergey's Manual*

Handouts: None

Procedure: Hold a class discussion on the discovery of a new bacterium. Have students suggest the criteria that would be used to classify it in the current *Bergey's* system of taxonomy.

Student Instructions: See instructions above.

Specific Suggestions: Have small groups of students take turns using *Bergey's Manual* for this exercise. Only allow 4-5 minutes per group.

Objectives: The objective of this exercise is to examine the physical, biochemical, physiological and genetic differences used to classify bacteria in the current *Bergey's* system of taxonomy.

Instructor Notes for In-Class Activity Four

Title: Gram Stain

Time: 5 min prep; 30 min in class time (student preparation outside of class)

Materials: White paper

Handouts: None

Procedures: Have students work in pairs to create a concept map using the following terms: Gram stain, Gram-negative bacteria, Gram-positive bacteria, crystal violet, safranin, Gram's iodine, alcohol, purple, red, peptidoglycan

Student Instructions: See instructions above.

Specific Suggestions: Explain to students what a concept map is by using a sample map. There are many websites which have sample concept maps.

Objective: The objective of this exercise is to show students the relationship between the various components involved in the Gram stain procedure.