Chapter 11: Bacteria

Bacterial Groups
- Most widely accepted taxonomic classification for bacteria is *Bergey’s Manual of Systematic Bacteriology*.
- 5000 bacterial species identified, 3100 classified.
- Bacteria are divided into four divisions (phyla) according to the characteristics of their cell walls.
- Each division is divided into sections according to:
  - Gram stain reaction
  - Cell shape
  - Cell arrangements
  - Oxygen requirements
  - Motility
  - Nutritional and metabolic properties
- Each section contains several genera.

Classification of Bacteria

Four Divisions of Bacteria

Division I. Gram-Negative Bacteria
1. Spirochetes
   - Helical shape. Flexible.
   - Contain two or more axial filaments (*endoflagella*).
   - Move in corkscrew pattern.
   - Medically important members:
     - *Treponema pallidum*: Syphilis
     - *Borrelia spp.*: Lyme disease, relapsing fever
     - *Leptospira*: Leptospirosis

Gram Negative Bacteria Spirochetes
Primary syphilitic chancre and secondary rash. 
Source: Tropical Medicine and Parasitology, 1997

Lyme Disease early lesion at tick bite site. 
Source: Medical Microbiology, 1998

2. **Aerobic, Motile, Helical/Vibroid Gram-Negative Bacteria**
- Rigid helical shape or curved rods.
- Lack axial filaments (endoflagella); have polar flagella instead.
- Most are harmless aquatic organisms.
- **Genus** *Azospirillum* fixes nitrogen in soil.
- **Genus** *Bdellovibrio* attacks other bacteria.
- Important pathogens include:
  - *Helicobacter pylori*: Causes most gastric ulcers in humans.
  - *Campylobacter fetus*: Abortions in domestic animals.

**Gram Negative Bacteria**
- **Aerobic, Motile, Helical/Vibroid**
- Contains many medically significant groups.
- **Genus** *Pseudomonas*: Rods with polar flagella. Many secrete pigments in media.
  - *Pseudomonas aeruginosa*: Urinary tract infections (UTIs), septicemia, abscesses, burns, pulmonary infections in cystic fibrosis patients, and meningitis.
- **Genus** *Legionella*: Rods that live in natural waters. Frequently found in air conditioning systems, humidifiers, showers, spas, and fountains.
  - *Legionella pneumophila*: Legionnaires' disease (pneumonia, 1976) and Pontiac fever.
- **Genus** *Neisseria*: Diplococci. Frequently found on human mucous membranes. Only grow well around body temperature.
  - *Neisseria gonorrhoea*: Gonorrhea.
  - *Neisseria meningitidis*: Meningitis.
4. Gram-Negative Aerobic Rods and Cocci (Continued)

  - *Moraxella lacunata*: Conjunctivitis.
  - *Moraxella osloensis*: Small, nonmotile, coccobacilli. Many have fimbriae for attachment to mucous membranes.
  - *Moraxella tobimensis*: Tularaemia.
  - *Moraxella gallinarum*: Forms nodules on legume roots and fix nitrogen in soil.
  - *Moraxella bovis*: Has capsules.

- **Genus *Brucella***: Small, nonmotile cocobacilli. All species are obligate parasites of mammals. Cause brucellosis. Can survive phagocytosis.
  - *Brucella melitensis*: Infects sheep and goats. Responsible for brucellosis.
  - *Brucella abortus*: Infects cattle. Responsible for brucellosis.
  - *Brucella suis*: Infects swine. Responsible for brucellosis.

- **Genus *Francisella***: Small, pleomorphic bacteria. Nonmotile rods. Virulent forms have capsules.
  - *Francisella tularensis*: Causes tularemia. Transmitted by fleas, respiratory droplet, and contact with infected animal tissue.
  - *Francisella novicida*: Causes ornithosis. Transmitted by fowl droppings.

- **Genus *Bordetella***: Small, pleomorphic bacteria. Nonmotile rods. Virulent forms have capsules.

- **Genus *Moraxella***: Small, pleomorphic bacteria. Nonmotile rods. Virulent forms have capsules.
  - *Moraxella sp.***: Causes respiratory and UTIs.
  - *Moraxella lacunata*: Pseudomonas. Cause respiratory and UTIs.
  - *Moraxella osloensis*: Pseudomonas. Cause respiratory and UTIs.
  - *Moraxella gallinarum*: Pseudomonas. Cause respiratory and UTIs.

- **Genus *Salmonella***: Almost all members are potential pathogens. Common inhabitants of human GI tract. Can contaminate food (eggs, meat).
  - *Salmonella typhi*: Typhoid fever, severe illness. Inhibits intestinal tracts of animals. Many cause diseases of gastrointestinal tract.
  - *Salmonella enterica*: Causes salmonellosis, the second most common bacterial food-borne disease. Over 1.3 million cases/year in the U.S.
  - *Salmonella anatum*: Causes salmonellosis.
  - *Salmonella bongori*: Causes salmonellosis.

- **Genus *Shigella***: Only found in humans. Second most common cause of traveler’s diarrhea.
  - *Shigella dysenteriae*: Causes dysentery.
  - *Shigella flexneri*: Causes dysentery.
  - *Shigella boydii*: Causes dysentery.

- **Genus *Proteus***: Actively motile. Cause UTIs, wound infections, and infant diarrhea (nosocomial).
  - *Proteus mirabilis*: Causes urinary tract infections, and infant diarrhea.
  - *Proteus vulgaris*: Causes urinary tract infections.
  - *Proteus morgani*: Causes urinary tract infections.

- **Genus *Yersinia***: Causes bubonic plague (black death). Transmitted by fleas, respiratory droplet, and contact with animals.
  - *Yersinia pestis*: Causes bubonic plague (black death).

5. Facultative Anaerobic Gram-Negative Rods

Many cause diseases of gastrointestinal tract. Contains three medically significant families.

I. Family Enterobacteriaceae (Enterics)

- Inhabit intestinal tracts of animals.
- Motile bacteria with peritrichous flagella or nonmotile.
- Many have fimbriae for attachment to mucous membranes and sex pili for exchange of DNA (antibiotic resistance genes).
- Most ferment glucose and other sugars.
  - *Genus *Escherichia***: *E. coli* is common inhabitant of human intestinal tract. Most strains are not pathogenic but others can cause UTIs (urinary tract infections), traveler’s diarrhea, and food-borne disease.

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5. Facultative Anaerobic Gram-Negative Rods

### II. Family Vibrionaceae
- Found in aquatic habitats.
- Straight or slightly curved rods
  - **Genus Vibrio**: Slightly curved rods.
    - **Vibrio cholerae**: Cholera, profuse & watery diarrhea.
    - **Vibrio parahaemolyticus**: Gastroenteritis, Shellfish.

Cholera is Caused by *Vibrio cholerae*

Rice-water stool of cholera.
Source: Tropical Medicine and Parasitology, 1995

### III. Family Pasterellaceae
- Found in aquatic habitats.
- Straight or slightly curved rods
  - **Genus Pasteurella**: Pathogens of domestic animals.
  - **Genus Hemophilus**: Important pathogens that inhabit mucous membranes of upper respiratory tract, mouth, vagina, and intestinal tract. Requires blood in culture.
    - **Hemophilus influenzae**: Causes meningitis, ear infections, bronchitis, arthritis, and pneumonia in children.
    - **H. ducreyi**: Cause of sexually transmitted chancroid.
  - **Genus Gardnerella**: Not assigned to any family.
    - **G. vaginalis**: Causes common form of vaginitis.

6. Anaerobic Gram-Negative Rods
   - May be straight, helical, or curved.
   - **Genus Bacteroides**: Nonmotile. Live in human intestine (1 billion/gram of feces) and gum crevices. Cause peritonitis, abscesses, and deep tissue infections.
   - **Genus Fusobacterium**: Long slender rods with pointed tips. Found in gingival crevices, cause dental abscesses.

7. Sulfur-Reducing Bacteria
   - Obligate anaerobes that release H₂S into the atmosphere.
   - Found in soil and intestinal tract of animals. Ecologically important.

8. Anaerobic Gram-Negative Cocci
   - Nonmotile cocci typically found in pairs.
     - **Genus Veillonella**: Cause dental plaque.

9. Rickettsias and Chlamydias
   - Gram negative bacteria. Obligate intracellular parasites.
   - **Rickettsias**: Rod shaped bacteria or coccobacilli, highly pleomorphic. Transmitted to humans by insects and ticks (except for *Coxiella burnetti* which causes Q fever).
     - **Genus Ehrlichia**: Live in white blood cells.
     - **Genus Rickettsia**: Cause spotted group fevers (Rocky mountain spotted fever, endemic typhus).

Chlamydias: Cocci shaped bacteria. Transmitted to humans by interpersonal contact or by airborne respiratory routes.

**Unique life cycle:** Form a reticulate and elementary bodies in infected cells.

**Three species:**
- **Chlamydia trachomatis**: Causes blindness in humans and nongonococcal urethritis (most common STD in U.S.).
- **C. psittaci**: Parrot fever.
- **C. pneumoniae**: Mild pneumonia.
Division II. Gram-Positive Bacteria
17. Gram-Positive Cocci
- Non-spore forming cocci.
- Aerobic to strictly anaerobic.
- Pyogenic (pus-forming)
  - **Genus Staphylococcus**: Tend to form grape-like clusters. Grow well under high osmotic pressure and low moisture. Very common infections, because almost always found on skin and in nasal mucous membranes.
    - *Staphylococcus aureus* (aureus = golden) Yellow pigmented colonies. Produce several toxins. Cause pimples, sties, skin abscesses, toxic shock syndrome, food poisoning, and nosocomial infections.
    - Antibiotic resistance is big problem.
    - Vancomycin is last line of defense against antibiotic resistant strains.

17. Gram-Positive Cocci
- **Genus Streptococcus**: Most are pathogens. Tend to appear in chains or pairs. Do not use oxygen, but most are aerotolerant. Classified based on their effect on red blood cells (hemolysis).
  - Cause a wide range of diseases: Strep throat, respiratory infections, abscesses, puerperal fever, and opportunistic infections.
  - A flesh eating Streptococcus strain emerged in 1994 and 1998. After initial infection, bacteria live on dead flesh, produce toxins, and are not treatable by antibiotics.
  - *Streptococcus pneumoniae*: Bacterial pneumonia, ear infections, meningitis, and sinus infections.
  - *Streptococcus pyogenes*: Strep throat, scarlet fever, rheumatic fever, impetigo, skin infections, erysipelas, puerperal fever, glomerulonephritis.

Diseases Caused by *Staphylococcus aureus*
- Scalded Skin Syndrome
- Sty
- Toxic Shock Syndrome

Scarlet Fever is Caused by a Strain of *Streptococcus pyogenes*

Flesh-Eating *Streptococcus pyogenes*
- Necrotizing fasciitis with blood filled vesicles.
  - Source: Perspectives in Microbiology, 1995

Erysipelas is Caused by *Strep. pyogenes*
- Erysipelas on face due to *S. pyogenes* infection
  - Source: Color Guide to Infectious Diseases, 1992
18. Endospore-Forming Gram-Positive Rods and Cocci
- Aerobic to strictly anaerobic.
- Motile and nonmotile.
- Survive harsh environmental conditions.
  - **Genus Bacillus**: Rod shaped bacteria.
    - *Bacillus anthracis*: Causes anthrax, a disease of cattle. Large (4–8 um) nonmotile facultative anaerobe.
    - *Bacillus thuringiensis*: Kills insects, used by gardeners.
  - **Genus Clostridium**: Rod shaped bacteria, obligate anaerobes.
    - *Clostridium tetani*: Causes tetanus (T in DPT vaccine).
    - *Clostridium botulinum*: Causes botulism.
    - *Clostridium perfringens*: Causes gas gangrene and foodborne diarrhea.

Tetanus is Caused by *Clostridium tetani*

Neonatal Tetanus (Wrinkled brow and risus sardonicus)
Source: Color Guide to Infectious Diseases, 1992

Gangrene Caused by *Clostridium perfringens*
Severe gangrene caused by *Clostridium perfringens*.
Source: Tropical Medicine and Parasitology, 1997

19. Regular Nonsporing Gram-Positive Rods
- **Genus Lactobacillus**: Produce lactic acid which inhibits the growth of other bacteria. In humans live in vagina, intestinal tract, and mouth. Used commercially to make yogurt, pickles, sauerkraut, and buttermilk.
- **Genus Listeria**: Contaminates dairy products.
  - *Listeria monocytogenes*: Survives in phagocytic cells and grows in refrigerators. Causes listeriosis. Infection of pregnant women can cause stillbirth or severe damage to fetus.

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20. Irregular Nonsporing Gram-Positive Rods
- Club shaped (Corynebacteria), pleomorphic.
- May be anaerobic or aerobic.

Important pathogens:
- *Corynebacterium diphtheriae*: Cause diphtheria (D in DPT vaccine).
- *Propionibacterium acne*: Causes acne.

21. Mycobacteria
- Aerobic, non-spore-forming rods.
- Stain Gram-positive, but cell wall structure is more similar to Gram-negative bacteria.
- Waxy cell wall with mycolic acids (instead of peptidoglycan).
- Acid-fast, drug resistant, resistant to drying, and pathogenic due to waxy cell wall.
- Grow very slowly.
- Tend to cause chronic infections.

Important pathogens:
- *Mycobacterium leprae*: Causes leprosy.
22. Nocardioforms
- Gram-positive, filamentous, aerobic.
- Many are acid fast.
- Common in soil.
- **Genus Nocardia**: Form filaments which fragment into short rods to reproduce.
  - *Nocardia asteroides*: Pulmonary infections, mycetoma, abscesses.

25. Actinomycetes
- Gram-positive, filamentous, resemble molds.
- Common in soil.

Division III. Wall-Less Bacteria
30. Mycoplasmas
- Do not form cell walls.
- Most are aerobes or facultative anaerobes.
- Highly pleomorphic.
- Can produce filaments that resemble fungi.
- Produce very small colonies (1 nm in diameter).
- Very small cells: 0.1 to 0.25 µm in diameter.
- Can pass through bacterial filters.
- Most important human pathogen:
  - **Mycoplasma pneumoniae**: Walking pneumonia.