Chapter 5
Pathogenic Microorganisms, Fungi and Animal Parasites

Learning Objectives
• Explain
  – Characteristics of bacteria
  – Major groups of pathogenic bacteria
• Describe
  – Inhibition of microbial growth by antibiotics
  – Adverse effects of antibiotics
  – Antibiotic sensitivity testing and interpretation of results
• Explain
  – Mode of action of viruses
  – Body’s response to viral infections
• Discuss infections caused by chlamydiae, mycoplasma, rickettsiae, and fungi

Pathogenic Microorganisms
• Bacteria
• Chlamydiae
• Rickettsiae and Ehrlichiae
• Mycoplasma
• Viruses
• Fungi

Classification of Bacteria
• Classified according to four major characteristics:
  – Shape and arrangement: coccus, bacillus, spiral
  – Gram stain reaction: gram-positive and gram-negative
  – Biochemical and growth characteristics
    • Aerobic and anaerobic
    • Spore formation
    • Biochemical profile
  – Antigenic structure: antigens in cell body, capsule, flagella

Shape and Arrangement
• Coccus (spherical)
  – Clusters: staphylococci
  – Chains: streptococci
  – Pairs: diplococci
  – Kidney bean-shaped, in pairs: Neisseriae

• Bacillus (rod-shaped)
  – Square ends: bacillus anthracis
  – Rounded ends: mycobacterium tuberculosis
  – Club-shaped: corynebacteria
  – Fusiform: fusobacteria
  – Comma-shaped: vibrio

• Spirochete (spiral)
  – Tightly-coiled: treponema pallidum
  – Relaxed coil: borrelia
Gram Staining

- Bacteria are classified as either gram-positive or gram-negative based on ability to resist or retain certain dyes
- Based on the chemical and physical properties of their cell walls

Gram Staining

- Dried fixed suspension of bacteria prepared on a microscopic slide
  - Step 1: Crystal violet (purple dye)
  - Step 2: Gram’s iodine (acts as a mordant)
  - Step 3: Alcohol or acetone (rapid decolorization)
  - Step 4: Safranin (red dye)
- Gram-positive: resists decolorization and retains purple stain
- Gram-negative: can be decolorized and stains red

Readily Gram-Stained Organisms
(1 of 3)

- **Gram-positive cocci**: Staphylococcus, Streptococcus, Enterococcus
- **Gram-negative cocci**: Neisseria, meningitis, gonorrhea
- **Gram-positive rods**: Bacillus, Corynebacterium, Clostridium, Listeria, Actinomyces, Nocardia

Readily Gram-Stained Organisms
(2 of 3)

- **Gram-negative rods**
- **Pathogenic inside and outside intestinal tract**: *Escherichia*, *Salmonella*
- **Pathogenic inside intestinal tract**: *Shigella*, *Vibrio*, *Campylobacter*, *Helicobacter*

Readily Gram-Stained Organisms
(3 of 3)

- **Pathogenic outside intestinal tract**: *Klebsiella*, *Enterobacter*, *Serratia*, *Pseudomonas*, *Proteus*, *Providencia*, *Morganella*, *Bacteroides*
- **Respiratory tract organisms**: *Hemophilus*, *Legionella*, *Bordetella*
- **Organisms from animal sources**: *Brucella*, *Francisella*, *Pasteurella*, *Yersinia*

Biochemical and Growth Characteristics (1 of 3)

- **Type of culture media**
- **Oxygen requirements**: obligate and facultative organisms
- **Nutritional requirements**
  - Fastidious organisms: can be grown only on enriched media under carefully controlled conditions of temperature and acidity (pH)
  - Hardy organisms: can grow on relatively simple culture media under a wide variety of conditions
  - Most bacteria have distinct biochemical characteristics, or "biochemical profile" that aids in identification
Biochemical and Growth Characteristics (2 of 3)

• Aerobic organisms: bacteria that grow best in the presence of oxygen (O$_2$)
• Anaerobic organisms: bacteria that only grow in the absence of oxygen (O$_2$) or under extremely low oxygen tension
• Other bacteria grow equally well under either conditions
• Flagella: hair-like processes covering the surface of some bacteria; responsible for the organism’s motility

Antigen Structure

• Contained in:
  – Cell body
  – Capsule
  – Flagella
• The antigenic structure can be determined by special methods, defining a system of antigens unique for each group of bacteria

Staphylococci

• Gram-positive cocci arranged in grapelike clusters
• Normal inhabitants of
  – Skin (Staphylococcus epidermidis)
  – Nasal cavity (Staphylococcus aureus)
• Commonly found on skin and in nose of patients and hospital staff
• Normally not pathogenic
• Opportunistic organisms
• Cause disease by producing toxins
  – Vomiting and diarrhea; toxic shock
  – Tissue necrosis
  – Hemolysis
• Cause disease by causing inflammation

Staphylococci Infections

• Skin infections: impetigo; boils (furuncles, carbuncles); nail infection (paronychia); cellulitis; surgical wound infection; eye infection; postpartum breast infections (mastitis)
• Sepsis: wounds and IV drug use
• Endocarditis: infection of lining of heart and valves
  – Normal and prosthetic valves, IV drug use
• Osteomyelitis and arthritis
• Pneumonia
• Abscess
• Some strains are highly resistant to antibiotics (MRSA or Methicillin-resistant Staphylococcus aureus)

Biochemical and Growth Characteristics (3 of 3)

• Spores: dormant, extremely resistant bacterial modification formed under adverse conditions
• Spores can germinate and give rise to actively growing bacteria under favorable conditions

Important pathogenic bacteria

<table>
<thead>
<tr>
<th>Type</th>
<th>Gram-stain status</th>
<th>Resistance</th>
<th>Other properties</th>
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<tbody>
<tr>
<td>Coagulase-positive</td>
<td>Staphylococcus aureus</td>
<td>Methicillin-resistant</td>
<td>MRSA</td>
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<tr>
<td>Coagulase-negative</td>
<td>Staphylococcus epidermidis</td>
<td>Non-resistant</td>
<td>NONA</td>
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<tr>
<td>Other</td>
<td>Staphylococcus pseudo aureus</td>
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Streptococci Classification

- Based on type of hemolysis and differences in carbohydrate antigens in the cell walls or C carbohydrate (Lancefield Classification Groups A to U)
- Beta hemolysis: complete lysis of red cells
  - Group A (Streptococcus pyogenes): causes pharyngitis
  - Group B (Streptococcus agalactiae): genital tract of women, neonatal meningitis, sepsis
  - Group D (Enterococcus faecalis, Strep. bovis) urinary, biliary, cardiovascular infections

Streptococci Classification

- Non-beta hemolysis
  - Alpha hemolysis: incomplete lysis of red cells (Streptococcus pneumoniae)
  - Gamma hemolysis: non-hemolytic, no lysis

Streptococci

- Gram-positive cocci arranged in chains or pairs
  - Normal inhabitants of skin, mouth, pharynx (Viridans strep), gut, female genital tract (Peptostreptococci)
  - Opportunistic organisms
- Diseases:
  - Pyogenic: pharyngitis, cellulitis, endocarditis, UTI
  - Toxigenic: scarlet fever, toxic shock syndrome
  - Immunologic: rheumatic fever, glomerulonephritis

Antibiotics

- One of the great discoveries and advances in medicine
- Antibiotic resistance
  - Over-prescribing
  - Inappropriate prescribing
  - Overuse as feed supplement for livestock
  - Improper use
  - Spread of resistant strains worldwide

Antibiotics: Mechanisms of Action

- Inhibits synthesis of bacterial cell wall and cell membrane
  - Penicillin family: penicillin, methicillin, nafcillin, oxacillin, amoxicillin, ampicillin, piperacillin, ticarcillin
  - Cephalosporin: cephalexin, cefoxitin, ceftazidime, ceftriaxone; vancomycin, bacitracin
- Inhibits synthesis microbial proteins
  - Chloramphenicol; tetracycline; macrolide: erythromycin, azithromycin, clarithromycin; clindamycin, gentamicin, netilmicin, streptomycin

Antibiotics: Mechanisms of Action

- Inhibits bacterial metabolic functions
  - Inhibit folic acid synthesis: sulfonamides, trimethoprim
- Inhibits bacterial DNA synthesis
  - Ciprofloxacin, norfloxacin, ofloxacin, sparfloxacin
- Competitive inhibition
Various sites of antibiotic action

Antibiotics: Adverse Effects
- Toxicity
- Hypersensitivity
- Alteration of normal bacterial flora
- Development of resistant strains
  - Spontaneous mutation
  - Plasmid-acquired resistance
- Mechanisms for circumventing effects of antibiotics
  - Develop enzymes (penicillinase)
  - Change cell wall structure
  - Change internal metabolic machinery

Antibiotic Sensitivity Tests
- Tube dilution: measures the highest dilution inhibiting growth in test tube
- Disk method: inhibition of growth around disk indicates sensitivity to antibiotic

Chlamydiae (1 of 2)
- Gram-negative, nonmotile bacteria
- Form inclusion bodies in infected cells
- Obligate intracellular parasites
- With rigid cell wall and reproduced by a distinct intracellular cycle
- Susceptible to tetracycline and erythromycin
- No vaccine available

Chlamydiae (2 of 2)
- Diseases
  - Psittacosis (pneumonia): inhalation of dried bird feces
  - Trachoma (C. trachomatis A, B, C): chronic conjunctivitis, blindness
  - Non-gonococcal urethritis (men): spread to other areas
  - Cervicitis (women): Lead to salpingitis, PID, infertility, ectopic pregnancy
  - Neonatal inclusion conjunctivitis:
    - Newborn from infected mom
  - Lymphogranuloma Venereum: sexually transmitted disease

Rickettsiae and Ehrlichiae (1 of 2)
- Disease: damage to small blood vessels of skin; leakage of blood into surrounding tissues (rash and edema)
- Rocky Mountain Spotted Fever (ticks)
  - East Coast spring and early summer; flu-like
  - Rash after 2-6 days, hands/feet then trunk, CNS
- Rickettsialpox (mites)
- Typhus: flu-like, rash (epidemic: lice; endemic: fleas; scrub: mites)
- Q Fever (aerosol): pneumonia-hepatitis combination, rash is rare
- Erlichiosis: Susceptible to tetracycline or chloramphenicol
**Rickettsiae and Ehrlichiae (2 of 2)**

- Obligate intracellular parasites
- Parasite of insects transmitted to humans
- Transmitted via bite of an arthropod vector (ticks, mites, lice, fleas)
- *Rickettsiae* multiply in endothelial cells of blood vessels while *Ehrlichiae* multiply in neutrophils or monocytes
- Cause febrile illness with skin rash
- Respond to some antibiotics
- Most rickettsial diseases are animal-borne
- Transmission enhanced by poor hygiene, overcrowding, wars, poverty

**Mycoplasma**

- Smallest, wall-less, free-living bacteria
  - About the size of a virus (0.3 micrometer)
- With cell membrane (cholesterol), no cell wall
  - Medical implications: Stain poorly
- Penicillin and cephalosporin are not effective
  - Can reproduce outside living cells, can grow on artificial media
- Primary Atypical Pneumonia: *Mycoplasma pneumoniae*
  - Most common in winter, young adults, outbreaks in groups
  - Cough, sore throat, fever, headache, malaise, myalgia
  - Resolves spontaneously in 10-14 days
  - Responds to antibiotics: tetracycline and erythromycin

**Virus (1 of 4)**

- Classification
  - Nucleic acid structure: Either DNA or RNA, with an outer envelope made of lipoprotein
  - Size and complexity of genome varies
  - Smaller than cells (20-300 nm diameter)
  - Cannot be seen under a light microscope
- Nucleoid: genetic material, DNA and RNA, not both
- Capsid: protective protein membrane surrounding genetic material

**Virus (2 of 4)**

- Obligate intracellular parasites
  - Must reproduce or replicate within cells
  - Lack metabolic enzymes; rely on host’s metabolic processes for survival
  - Do not have nucleus, ribosomes, mitochondria, and lysosomes; cannot synthesize proteins or generate energy
  - Do not multiply by binary fission or mitosis

**Virus (3 of 4)**

- Mode of action
  - Invasion of susceptible cell
    - Asymptomatic latent viral infection
    - Acute cell necrosis and degeneration
    - Cell hyperplasia and proliferation
    - Slowly progressive cell injury
    - Neoplasia
  - Formation of inclusion bodies

**Virus (4 of 4)**

- Bodily defenses against viral infections
  - Formation of interferon: “broad-spectrum” antiviral agent
  - Cell-mediated immunity
  - Humoral defenses
- Treatment with antiviral agents
  - Block viral multiplication
  - Prevent virus from invading cell
  - Limited application: toxicity and limited effectiveness
German Measles

Shingles or herpes zoster clusters of vesicles along a segment of skin supplied by a sensory nerve

Multiple warts

Mumps: Parotid glands swelling

Condylomas

Oral herpes virus type 1

Fungi

- Plantlike organisms without chlorophyll
- Two types: yeasts and molds
- Most are obligate aerobes, opportunistic
- Natural habitat: environment, except Candida
- Cell wall: chitin vs. peptidoglycan
- Cell membrane: ergosterol and zymosterol vs. cholesterol

Hyphae in vaginal smear, Candida albicans

Blastomycosis of the left lung, dense (white) area in upper part of lung
Discussion

- A young woman receives a course of antibiotics and soon afterward develops a vaginal infection caused by a fungus. Why?
- What factors render a patient susceptible to an infection by a fungus of low pathogenicity?
- How do antibiotics inhibit the growth of bacteria?
- How does penicillin kill bacteria?

Parasite and Host

- Animal parasites: organisms adapted to living within or on body of another animal (host)
- Not capable of free-living existence
- Have a complex life cycle
- Live within intestinal tract and discharge eggs in feces
- Transmission favored by poor sanitation, high temperature, humidity
- Common in tropical climates, less frequent in cold or temperate climates

Animal Parasites

- Protozoa
  - One-celled organisms
- Metazoa
  - Multicellular structures
  - Roundworms, tapeworms, flukes
- Arthropods
  - Small insects

Protozoal Infections (1 of 2)

- Malaria: caused by various species of Plasmodium
- Amebic dysentery: caused by pathogenic ameba, Entamoeba histolytica
- Genital tract trichomonad: caused by Trichomonas vaginalis
- Giardiasis: caused by Giardia lamblia, infects small intestine; crampy abdominal pain
- Toxoplasmosis: caused by Toxoplasma gondii, may infect fetus of pregnant women and cause congenital malformations

Protozoal Infections (2 of 2)

- Cryptosporidiosis
  - Caused by a parasite Cryptosporidium parvum; parasitizes the intestinal tract and can cause severe diarrhea
- Pneumocystis pneumonia
  - Caused by Pneumocystis jiroveci; does not cause disease in immunocompetent persons but causes a severe, sometimes fatal pulmonary infection in persons with HIV/AIDS
Metazoal Infections (1 of 2)

- **Roundworm**: three most important ones that parasitize human beings:
  - Ascaris: large roundworm that lives within intestinal tract and eggs discharge in feces
  - Pinworms: small roundworm that migrates out of colon through the anus while the infected individual is asleep; deposits its eggs on the perianal skin; frequent in children and spreads through a family
  - Trichinella: small roundworm that parasitizes humans and animals; most people become infected by eating improperly cooked pork

Metazoal Infections (2 of 2)

- **Tapeworms**
  - Long, ribbon-like worms that grow to a length of several feet that inhabit the intestinal tract.
  - Humans become infected by eating the flesh of an infected animal that contains the larvae of the parasite.

- **Flukes**
  - Thick, fleshy, short worms with suckers that attach to the host
  - Some live within the intestinal tract, liver, lungs, venous portal system, some (schistosomes) may infect skin.

Arthropod Infections

- Transmitted by close physical contact and often spread by sexual contact
- Scabies: small parasite burrows in the superficial layers of the skin, where it lays eggs that hatch in a few days
- Crab louse: lives in anal and genital hairs; causes intense itching

Discussion (1 of 2)

1. How is malaria transmitted? How does malaria differ from *babesiosis*?
2. How do people become infected with pinworms? *Ascaris* infection?
3. What are “crabs”? What symptoms do they cause? How are they acquired?
Discussion (2 of 2)

- **CASE STUDY**
  - Young male, intense itching in pubic area. Small crab lice in pubic hair on exam with numerous eggs on hair shaft. Patient and sexual partner treated with anti-parasitic drug (Kwell)
- **CASE STUDY**
  - 8 year old, female, attended a slumber party at neighbor's house. Experienced perianal and vulvar itching that awakened her at night. Mom examined daughter on one such occasion and found 1 cm.-long worm moving around perianal area.