Chapter 08
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Biology of Infectious Diseases
Points to ponder

• What is the connection between microbes and humans?
• What is an epidemic? How is an outbreak different from a pandemic?
• What are the phases of an HIV infection?
• What is the structure of HIV, and how is the virus replicated?
• How is HIV transmitted, and how can HIV infection be prevented?
Points to Ponder

• What is the causative agent of tuberculosis (TB)? What are the symptoms?
• What is the causative agent of malaria? What are the symptoms?
• What is the structure of the influenza virus? How are the H and N spikes significant?
• What are emerging and reemerging diseases?
• How does antibiotic resistance arise?
How do microbes and humans interact?

• Microbes are very abundant, both in the environment and as inhabitants of our bodies.

• We use microbes to make many foods and we even use them to make drugs.

• Microbes are important as decomposers to recycle nutrients.

• Some microbes cause disease in humans; we call these pathogens.
What are microbes?

- Microbes are microscopic organisms and particles that include
  - bacteria,
  - viruses,
  - prions,
  - and other organisms such as fungi, multicellular parasites, and single-celled protistans.
How do the sizes of our cells, bacteria, and viruses compare?

Figure 8.3
Comparative sizes of viruses, bacteria, and eukaryotic cells.
What are bacteria?

- **Bacteria** are single-celled, prokaryotic organisms.
- They almost all have a cell wall.
- Bacteria have DNA in a single chromosome.
- They have ribosomes.
- Some bacteria have accessory rings of DNA called **plasmids**.
- Typically, they reproduce by binary fission, resulting in 2 cells that are identical to the original cell.
What are specific structures and shapes of bacteria?

Figure 8.1 Typical shapes of bacteria.
What are viruses?

- **Viruses** are small, nonliving obligate parasites.
- They must reproduce inside of a host cell.
- They are acellular (not composed of cells).
- All viruses have an outer protein coat called a capsid and nucleic acid (RNA or DNA) inside.
- Some viruses have an envelope.
- Viruses are specific to which cell type they will attach to and enter.
What are viruses?

Figure 8.4 Typical virus structures.
What are prions?

- **Prions** are infectious protein particles.
- They cause degenerative disease of the nervous system.
- Normal proteins change their shape.
Infectious diseases

- **Epidemiology**: the study of diseases in populations

- **Infectious diseases**: diseases caused by pathogens
  - Bacteria
  - Viruses
  - Fungi
  - Parasites
  - Protozoans
  - Prions
Infectious diseases

- **Epidemic**: more cases of the disease than expected in a certain area for a certain period

- **Outbreak**: the epidemic is confined to a local area

- **Pandemic**: a global epidemic
History of HIV

• Origins in Africa: HIV was originally found in nonhuman primates and may have mutated.

• Exact dates of the first human cases are still being investigated.

• The first documented death in the US was in 1969.

• HIV was found to be the cause of AIDS in 1983-1984.
Prevalence of HIV

- 34 million people are living with HIV.
- At least 0.8% of adults have HIV.
- 1.6 million people died from HIV/AIDS in 2012.
- Over 36 million people have died since the beginning of the epidemic.
- Most people living with HIV live in developing countries.
8.2 Infectious Diseases and Human Health

Prevalence of HIV

Figure 8.5 Worldwide cases of HIV/AIDS.
### Prevalence of HIV

#### Table 8.1: HIV Global Statistics, 2012

<table>
<thead>
<tr>
<th>Region</th>
<th>People Living with HIV</th>
<th>New Infections</th>
<th>AIDS Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Saharan Africa</td>
<td>25.0 million</td>
<td>1.6 million</td>
<td>1.2 million</td>
</tr>
<tr>
<td>East, South, and Southeast Asia</td>
<td>4.8 million</td>
<td>351,000</td>
<td>261,000</td>
</tr>
<tr>
<td>Latin America</td>
<td>1.5 million</td>
<td>86,000</td>
<td>52,000</td>
</tr>
<tr>
<td>Caribbean</td>
<td>250,000</td>
<td>12,000</td>
<td>11,000</td>
</tr>
<tr>
<td>North America</td>
<td>1.3 million</td>
<td>48,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Western and Central Europe</td>
<td>860,000</td>
<td>29,000</td>
<td>7,600</td>
</tr>
<tr>
<td>Eastern Europe and Central Asia</td>
<td>1.3 million</td>
<td>130,000</td>
<td>91,000</td>
</tr>
<tr>
<td>North Africa and the Middle East</td>
<td>260,000</td>
<td>32,000</td>
<td>17,000</td>
</tr>
<tr>
<td>Oceania</td>
<td>51,000</td>
<td>2,100</td>
<td>1,200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>35.3 million</strong></td>
<td><strong>2.3 million</strong></td>
<td><strong>1.6 million</strong></td>
</tr>
</tbody>
</table>
Phases of HIV infection

Category A, Acute Phase:
- Asymptomatic but highly infectious
- CD4 count above 500 cells/mm$^3$

Category B, Chronic Phase:
- Has one or more of a variety of symptoms related to an impaired immune system
- CD4 count between 200-499 cells/mm$^3$

Category C, AIDS:
- Has one or more of the opportunistic infections that eventually cause death
- CD4 count has fallen below 200 cells/mm$^3$
8.2 Infectious Diseases and Human Health

Stages of HIV infection

Figure 8.7 Stages of an HIV infection.
8.2 Infectious Diseases and Human Health

Structure of HIV

- Two single strands of RNA
- Enveloped with spikes (Gp120)
- Carries 3 enzymes
  - Reverse transcriptase
  - Integrase
  - Protease

Figure 8.8 The structure of the human immunodeficiency virus.
HIV life cycle/replication

- **Attachment**: Gp120 binds to CD4 receptors.

- **Fusion**: HIV fuses with the cell membrane.

- **Entry**: Uncoating occurs to release the RNA.

- **Reverse transcription**: RNA is transcribed into double-stranded DNA.

- **Integration**: New DNA becomes part of the host cell’s DNA in the nucleus (**provirus**).
HIV life cycle/replication

• **Biosynthesis and cleavage:** Cell produces more viral RNA and proteins.

• **Assembly:** New parts are assembled into viral particles.

• **Budding:** Viral particles bud from the cell membrane, acquiring envelopes.

• **Transmission:** Virus is passed to a new host.
8.2 Infectious Diseases and Human Health

HIV life cycle

**Figure 8.9** HIV replication in a host cell.
Transmission and prevention of HIV

- Transmission is through sexual contact, dirty needles, a blood transfusion, or to a baby from the mother.

- Globally, heterosexual sex is the most common mode of transmission.

- HIV is not passed through casual contact.

- Prevention is through abstinence, sex with only one uninfected partner, and proper, consistent use of condoms.
HIV testing and treatment

• HIV tests detect antibodies, not the virus itself.

• Most people develop antibodies within 2-8 weeks of infection but it can take 3-6 months, so consider this when being tested!

• Treatments:
  – **Drug therapy**: Highly active antiretroviral therapy (HAART) uses a combination of drugs to inhibit HIV replication.

  – **Vaccines**: Scientists have studied more than 50 different preventive vaccines and 30 therapeutic vaccines.
Science Focus: AIDS vaccines

• Difficulties in vaccine development:
  – No vaccine has ever proven to be 100% effective at blocking a virus from entry into cells.
  
  – HIV viruses are genetically different locally and globally.
  
  – Vaccines may only provide short-term protection from infection.
Science Focus: AIDS vaccines

• Difficulties in vaccine development:
  – There are concerns that the vaccine may increase the chances of getting the disease or even cause the disease.
  – HIV inserts its genetic material into human cells and hides from the immune system.
  – There is no ideal animal model for testing besides humans themselves.
Tuberculosis

- An estimated 1/3 of the world’s population has been exposed to TB.

- Approximately 8.6 million people are infected and 1.3 million people die each year.

- Cause and Transmission:
  - Caused by rod-shaped bacterium, *Mycobacterium tuberculosis*.
  - Disease spread when an infected person coughs, sings, or sneezes.
  - Likelihood of infection increases with length and frequency of exposure.

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Tuberculosis

• Disease:
  – Incubation period is from 4 to 12 weeks.
  – Latent TB patients do not feel sick, and they are not contagious.
  – Active TB patients have symptoms and are contagious.

• Treatment and Prevention:
  – Multiple anti-TB drugs are given simultaneously for 12 to 24 months.
  – Common drugs are isoniazid, rifampin, ethambutol, and pyrazinamide.
  – It takes at least 6 months to kill all of the TB bacteria in the body.
  – Active TB patients are isolated and anyone exposed is treated.
Malaria

• Over 200 million cases occur per year with over 627,000 deaths.

• Cause and Transmission:
  – Four species of *Plasmodium* infect humans.
  – *Plasmodium* is transmitted by the female *Anopheles gambiae* mosquito.
Malaria

• Disease:
  – Incubation period is from 7 to 30 days.
  – Symptoms range from very mild to fatal.
  – People develop a flulike illness with chills and fever.

• Treatment and Prevention:
  – Antimalarial drugs include quinine and artesunate.
  – Prevention includes eliminating the mosquito by removing its breeding sites.
Malaria around the globe

Figure 8.12 Areas of the world that are hardest hit by malaria.
Influenza

• Each year influenza affects 5-20% of Americans and causes an estimated 36,000 fatalities.

• Cause and Transmission:
  – Influenza virus is contracted by inhaling droplets that have been coughed or sneezed into the air, or by contact with contaminated objects.
  – Viruses infect cells of the respiratory tract.

• Disease:
  – Causes runny nose, cough, chills, fever, head and body aches, and nausea.

• Prevention:
  – Vaccine is available, even for recent H5N1 bird flu.
Influenza

• The influenza virus has an H (hemagglutinin) spike and an N (neuraminidase) spike.
  – H spike allows the virus to bind to its receptor.
  – N spike attacks host plasma membranes.

• Both H spikes and N spikes have variations in their shapes.
  – Each type of spike can occur in different varieties called subtypes.
  – The immune system can recognize only the particular variety of H spikes and N spikes it has been exposed to in the past.
Structure and mutation of influenza viruses

a. Viral genetic mutations occur in a bird host.

b. Combination of viral genes occurs in human host.

Figure 8.13 The bird flu virus.
Emerging diseases

- **Emerging diseases:** National Institute of Allergy and Infectious Diseases (NIAID) lists 18 pathogens that are newly recognized in the last two decades.
  - Avian influenza (H5N1)
  - Swine flu (H1N1)
  - Severe acute respiratory syndrome (SARS)

- **Reemerging diseases:** Diseases that have reappeared after a significant decline in incidence
  - *Streptococcus:* bacteria that causes strep throat and other infections
Emerging diseases

- Middle East respiratory syndrome (MERS): coronavirus known to cause respiratory problems
  - Precise animal host is unknown
  - Can be transmitted between individuals by close contact
  - Infection by MERS may be very dangerous, with complications such as pneumonia and kidney failure
Antibiotic resistance

• Penicillin was introduced in 1943.
  – Four years later, resistant bacteria were noted.

• Antibiotic use does not cause humans to become resistant to the drugs; pathogens become resistant.

• Resistant strains of the TB bacterium and *Staphylococcus aureus* are of particular concern.

• The best way to fight antibiotic resistance is by using antibiotics wisely.
8.4 Antibiotic Resistance

How does antibiotic resistance develop?

a. Initial population of microbes

b. Weaker (non resistant) cells killed by antibiotic; resistant cells survive.

c. Most cells are now resistant.

**Figure 8.15** Development of antibiotic resistance.