I. Bacteria (Chapter 19)
   a. Classifying Prokaryotes - See chart on differences in domains and archaea vs bacteria.
   b. Identifying Prokaryotes
      i. Shapes
         1. Bacillus - rod shaped
         2. Cocci - ball shaped
         3. Spirilla - spirals
         4. Pre fixes
            a. Staph - clusters
            b. Strep - chains
      ii. Cell Walls - There are two different cell wall types that can be determined by a method of staining called the Gram stain. Named after its inventor, the Danish scientist Hans Christian Gram (1853 – 1938), who developed the technique in 1884 to discriminate between two types of bacteria with similar clinical symptoms.
            1. Gram +: have a thick peptidoglycan wall, which stain dark violet. These bacteria usually form toxins when eaten.
            2. Gram -: have much thinner cell walls, stain pink. This type usually result in an infection when eaten.
      iii. Movement - either nonmotile, or move by flagella.
   c. Metabolic Diversity
      i. Heterotrophs
         1. Photoheterotroph - organisms are photosynthetic, but also need to take in organic compounds as a carbon source.
         2. Chemoheterotroph - ingest organic molecules for both energy and a carbon source.
      ii. Autotrophs
         1. Photoautotroph - use photosynthesis for nutrient source.
         2. Chemoautotroph - use chemosynthesis for nutrients. They do not require sunlight; instead they use energy from breaking inorganic bonds to make organic compounds.
      iii. Oxygen Use
         1. Obligate aerobes - require a constant supply of oxygen in order to live.
         2. Obligate anaerobes - do not require oxygen, must live in the absence of oxygen.
         3. Facultative anaerobes - survive with or without oxygen.
   d. Growth and Reproduction
      i. Binary Fission - bacteria can reproduce by doubling their size and DNA, then dividing in half to produce two identical daughter cells.
      ii. Conjugation - bacteria can also reproduce by exchanging DNA. During conjugation a hollow bridge forms between two bacteria and genetic material moves from one side to another, so that the bacteria exchange genes.
      iii. Transformation - bacteria can pick up DNA from other live or dead bacteria. This is a one-way sharing.
      iv. Spore Formation - Some bacteria may be able to grow spores when conditions are unfavorable. An endospore is formed when bacteria produce a thick internal wall that closes off all the DNA and small portion of the cytoplasm. Spores can remain dormant for long periods of time.
         1. Allows bacteria to survive extreme heat, dryness, or lack of nutrients that might otherwise kill them.
e. Importance of Bacteria
   i. Decomposer - recycle nutrients from dead organic matter or waste.
   ii. Nitrogen-fixation - since plants and animals require nitrogen to live, and cannot use atmospheric nitrogen, bacteria chemically change atmospheric nitrogen into a form plants can use.
      1. Nodules - a mutualistic relationship between legume plant roots and bacteria.
   iii. Human Uses
      1. Food - are essential to the production of legumes, yogurt, cheese, butter, sauerkraut, kimche, pickles, sourdough bread, olives, coffee, chocolate, soy sauce, and bologna.
      2. Industry - can digest petroleum, which aides in oil spills
      3. Water treatment - can remove waste and poisons from water
      4. Medicine - used in research to make new drugs and antibiotics, as well as research into genetic engineering.
      5. Digestion - *Escherichia coli* is a bacterium in the human gut that helps aid in digestion. Other bacteria in the human digestive tract can make vitamins which are essential for humans.
      6. Ward off infection - when bacteria have established populations they can prevent infection by new, harmful bacteria.

f. Bacterial Diseases
   i. Human
      1. Diphtheria - caused by *Corynebacterium diphtheria*, which infects the tissues of the throat and release toxins into the bloodstream, where they destroy tissues. Can lead to breathing problems, heart failure, paralysis, and death.
      2. Streptococcus - caused by a species of *Streptococci* which grow in chains in the back of the throat. They release toxins into the bloodstream that cause scarlet fever, a high fever and characteristic red rash appear on the infected.
      3. Tuberculosis - caused by *Mycobacterium tuberculosis*, which is inhaled. It uses cells in the lungs for food. It can spread to the bloodstream and destroy cells as it move through the body.
   ii. How to Prevent Bacterial Disease
      1. Prevented with vaccines
      2. Refrigerate food
      3. Cook your food
      4. Wash hands frequently
      5. Keep environment free of raw, contaminated, or decaying food/matter.
   iii. How to Treat Bacterial Infections
      1. Antibiotics block the growth and reproduction of bacteria. Examples are: penicillin, tetracycline, ciproflaxin, etc...
   iv. Other Animals
      1. Anthrax - caused by *Bacillus anthracis*, this bacterium can infect both humans and other animals. Anthrax is found in herd animals like sheep and cattle, where it can spread to humans. This bacterium produces spores that can last for many years. It is can also be used as an agent of bio-warfare.
   v. Controlling Bacteria
      1. Sterilization by heat
      2. Disinfectants (soaps, cleaners, antibacterial lotions) Overuse of antibacterial compounds can lead to common bacteria becoming resistant to antibiotics therefore be extremely hard to kill.
      3. Food Storage and Processing

II. Viruses (Chapter 19)
   a. What is a Virus?
      i. Non living infections agents that must use living cells to reproduce. All viruses enter and take over host cells to produce more viruses.
      ii. Three parts to a Virus
         1. **Nucleic Acid** - DNA or RNA
         2. **Capsid** - protein coat that surrounds the nucleic acid. This coat binds to host cell receptors (which are lipids) and tricks the cells into allowing them to enter. Due to this, viruses are highly specific
b. Viral Infection
   i. **Lytic Infection** - virus enters the cell, copies itself, and causes the cell to burst.
   ii. **Lysogenic Infection** - virus enters the cell and integrates its DNA into the DNA of the host cell (prophage).
   This type of infection can stay as a permanent fixture in the host's DNA reappearing as a viral outbreak at different times throughout the host's life.

c. **Retroviruses** - Viruses that contain RNA as their nucleic acid instead of DNA. These viruses have to produce a copy of their DNA from RNA when they infect a cell, therefore their genetic information is copied backward (RNA → DNA)
   i. **Reverse Transcriptase** - the enzyme responsible for the “backward transcription” of a retrovirus.

d. **Viruses vs Living Cells**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Virus</th>
<th>Cell</th>
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</thead>
<tbody>
<tr>
<td>Structure</td>
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<tr>
<td>Reproduction</td>
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<td>Genetic Code</td>
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<td>Growth and Development</td>
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<tr>
<td>Obtain and Use Energy</td>
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<tr>
<td>Respond to the Environment</td>
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</tbody>
</table>
e. Viral Diseases
   i. Humans- Viral diseases cannot be treated with antibiotics. The best way to protect against most viral
diseases lies in prevention by the use of vaccines.
      1. Vaccinations- Edward Jenner created vaccinations by taking pus from a woman with an outbreak
of cow pox and injecting it into a healthy boy, to keep him from contracting smallpox. He
became ill for a few days, but quickly made a full recovery and the boy never contracted
smallpox.
      2. Human Viruses

<table>
<thead>
<tr>
<th>Illness</th>
<th>Virus</th>
<th>Effect on Body</th>
<th>Transmission</th>
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</thead>
<tbody>
<tr>
<td>AIDS</td>
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<td>Common Cold</td>
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<td>Influenza</td>
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<td>Smallpox</td>
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<td>Warts</td>
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</tbody>
</table>

   ii. Other Animals-
      1. Foot and mouth disease in livestock
      2. Can cause cancer (now studying)

   iii. Plants- many transmitted by insects, it is harder to infect plant cells than animal cell because plants have
a cell wall.

   iv. Viroids and Prions
      1. Viroids are single stranded RNA molecules that have no capsid and infect plants like a virus.
      2. Prions do not contain DNA or RNA they are protein. These proteins are infections, when eaten
they can accumulate in large numbers and when they reach a threshold they start to form
protein clumps. These clumps occur in nerve tissue and damage cells. Mad cow disease and
Creutzfeldt-Jacob disease are examples.
HOW HIV INFECTS CELLS

In general, viruses have very small genomes which means they can encode a very limited number of their own proteins. For this reason, most viruses must use the proteins provided by their host in order to reproduce (make more viruses). In a way, viruses are parasitic, they bring very little with them and steal what they need from the host cell. Because they cannot reproduce on their own, viruses are not considered living organisms, they are simply genetic information, either DNA or RNA packaged within a protein coat.

The Structure of HIV
The HIV (human immunodeficiency virus) has a lipid membrane similar to the cell membranes of other organisms. Color the lipid membrane (d) light green. Attached to the membrane are several envelope proteins (a) which are used to attach to the host cell. Color the envelope proteins brown. Within the membrane is another layer of proteins that comprise the capsule (b), color the capsule dark green. The most important part of the virus is its genome, which is two strands of RNA. Color the viral RNA (c) pink. On the picture, there are several instances of the viral RNA, make sure they are all colored pink. Also important to the virus are the enzymes that will convert the RNA to DNA - reverse transcriptase, an enzyme that is unique to viruses. Color the reverse transcriptase yellow. Because the HIV virus uses the reverse transcriptase and RNA method, it is known as a retrovirus. The Flu is another example of a retrovirus. Because it is single stranded genetic material, it develops mutations more frequently than DNA viruses - this changing nature of a retrovirus makes it particularly difficult to develop vaccines for them - hence why you must get a flu shot every year but only need a polio vaccine once in your life. Drugs such as AZT work by inhibiting the function of reverse transcriptase, thus preventing the virus from converting the RNA to DNA.

HIV Infection
HIV infects a particular type of immune system cell, the CD4 + T Helper cell, or just plainly, the T Helper Cell. Once infect, the T-Helper cell turns into an HIV replicating cell. There are typically 1 million T-cells per one milliliter of blood. HIV will slowly reduce the number of these cells until the person develops the disease AIDS.

Step 1 - HIV enters the host by attaching to specific host receptors. It is as if the virus has a specific key that only works on the host cell with the right lock. In the case of HIV, the lock is the CD4 cell-surface antigen located on the surface of T Helper cells. Color the CD4 antigens (labeled q) dark green. CD4 antigens are located on the cell membranes of the cell (f) which should be colored black. At this point, the virus and the cell membrane fuse and the virion core enters the cell. The core contains the viral genes.

Step 2 - The viral RNA and core proteins are released into the cytoplasm where reverse transcriptase converts the viral RNA to DNA. The viral RNA is colored as above, and the viral DNA (h) should be colored red.

Step 3 - Viral DNA, now doublestranded is transported into the nucleus (continue to color all instances of viral DNA red) and the nuclear membrane (n) grey. In the nucleus, the enzyme called integrase fuses it with the host cell's normal DNA. Viral DNA can persist within the cell's DNA for many years in a latent state, which further complicates efforts to treat or cure the disease. Lightly color the host cell DNA blue in all instances (labeled g). Using the cellular enzyme RNA polymerase, the viral DNA is transcribed into two splices of RNA, a shorter splice (j) and a longer splice (i) which are destined for two different things. Color the short splices yellow and the long splices orange in all instances.

Step 4 - The short spliced RNAs are transported to the cytoplasm and the golgi apparatus where their message is used to create viral proteins which will become part of the completed virus. Color the golgi apparatus (k) purple and the viral proteins as you did in the other instances (brown). The longer splices are the full length viral RNA and will become the core of new viruses. Another enzyme, called protease is needed to assemble the proteins into their final functional forms. Protease inhibitors are another drug used to combat AIDS.

Step 5 - Using the proteins assembled from the golgi apparatus and the completed viral RNA from the long strands, the mature virus buds off from its host cell. The process of budding destroys the host cell.

Questions
1. Explain the role of each of the following in HIV infection:
   --protease
   --reverse transcriptase
   --CD4 receptors
   -- RNA polymerase
   -- integrase
2. What is a retrovirus?

3. There are several drugs that can reduce the spread of HIV infection in cells. Design a drug that might also slow the rate of cellular infection (use existing drugs as a model). Describe how the drug will work either on the virus or the host cell.