Viruses and Bacteria
Teacher Lecture Notes

I. What is a Virus?

A. Virus: An infectious particle that is nonliving.
B. The word virus comes from the Latin word meaning "poison."
C. All viruses are parasites. All viruses require a host.
D. Parasites live in or on other living organisms, causing them harm.
E. Host: The living organism the parasite lives on.

F. Martinus Beijerinck – Dutch scientist
1. Beijerinck is considered the founder of virology. Virology is the study of viruses.
2. In 1898, he used filtration experiments to prove that an agent smaller than a bacterium was causing tobacco mosaic disease.
3. He was the first to name these very small particles "viruses."

G. Wendell Stanley – American biochemist
1. In 1935, Stanley was able to isolate crystals of the tobacco mosaic virus.
2. Living organisms do not crystallize, so Stanley inferred that viruses were not "alive."
3. Stanley was awarded the Nobel Prize in chemistry.

II. Characteristics of Viruses

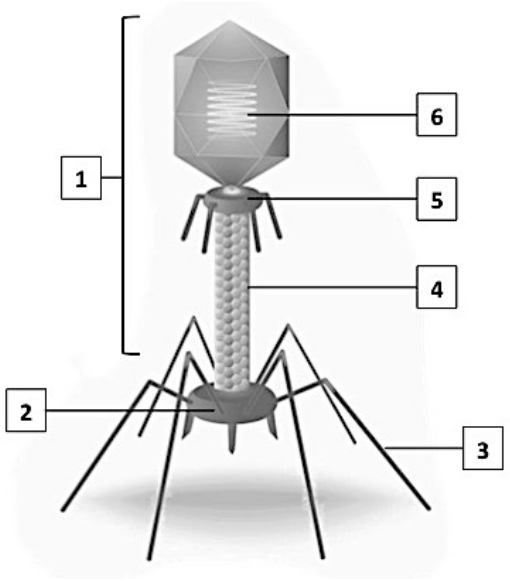
A. Viruses are extremely small. Most can be seen only with an electron microscope.

B. A virus is active only when inside a living cell. When removed from a living cell, it ceases all activities but retains its ability to infect the cell. They may be crystallized and stored indefinitely, but even after longs periods of time, they retain their ability to infect a living cell.

C. Viruses vary widely in terms of size and structure, but they all have one thing in common. They enter living cells and use the machinery of the cell to produce more viruses.

D. Label the parts of the virus:

1 – Capsid
2 – Base plate
3 – Tail fibers
4 – Sheath
5 – Collar
6 – DNA or RNA



E. Viruses are non-cellular
1. They are not made of cells and have no cell parts.
2. Viruses consist of two parts:
DNA or RNA surrounded by a protein coat.
3. Capsid: The protein coat that surrounds the DNA or RNA is called a capsid.

F. The Viral Capsid
   1. The capsid is made of proteins that enable the virus to enter a host cell.
   2. The capsid has a particular shape that must match receptors on the surface of a host cell.
   3. When the virus attaches to these receptors, the cell is "tricked" into letting the virus inside.

G. Viruses can reproduce, but only inside a living cell. They reproduce inside a cell by getting the cell to produce viral parts instead of cell parts.

H. Since viruses must bind precisely to proteins on the cell surface, they are highly specific to the cells they infect.
   1. Plant viruses can only infect plant cells.
   2. Animal viruses can only infect animal cells.
   3. Viruses of eukaryotes are usually tissue specific. Example: Human cold viruses infect only the cells lining the upper respiratory system, ignoring all other tissues.
   4. Bacteriophages are viruses that infect only certain types of bacteria.

I. Viruses are not affected by any known antibiotic. Anything that will kill the virus will also kill the host.

III. Viruses – Are They Living or Nonliving?

A. Living Characteristics of Viruses
   1. They can reproduce, but only inside a living cell.
   2. They can mutate or change.
   3. They have DNA or RNA. Their genome may consist of only four genes, or up to a hundred genes.

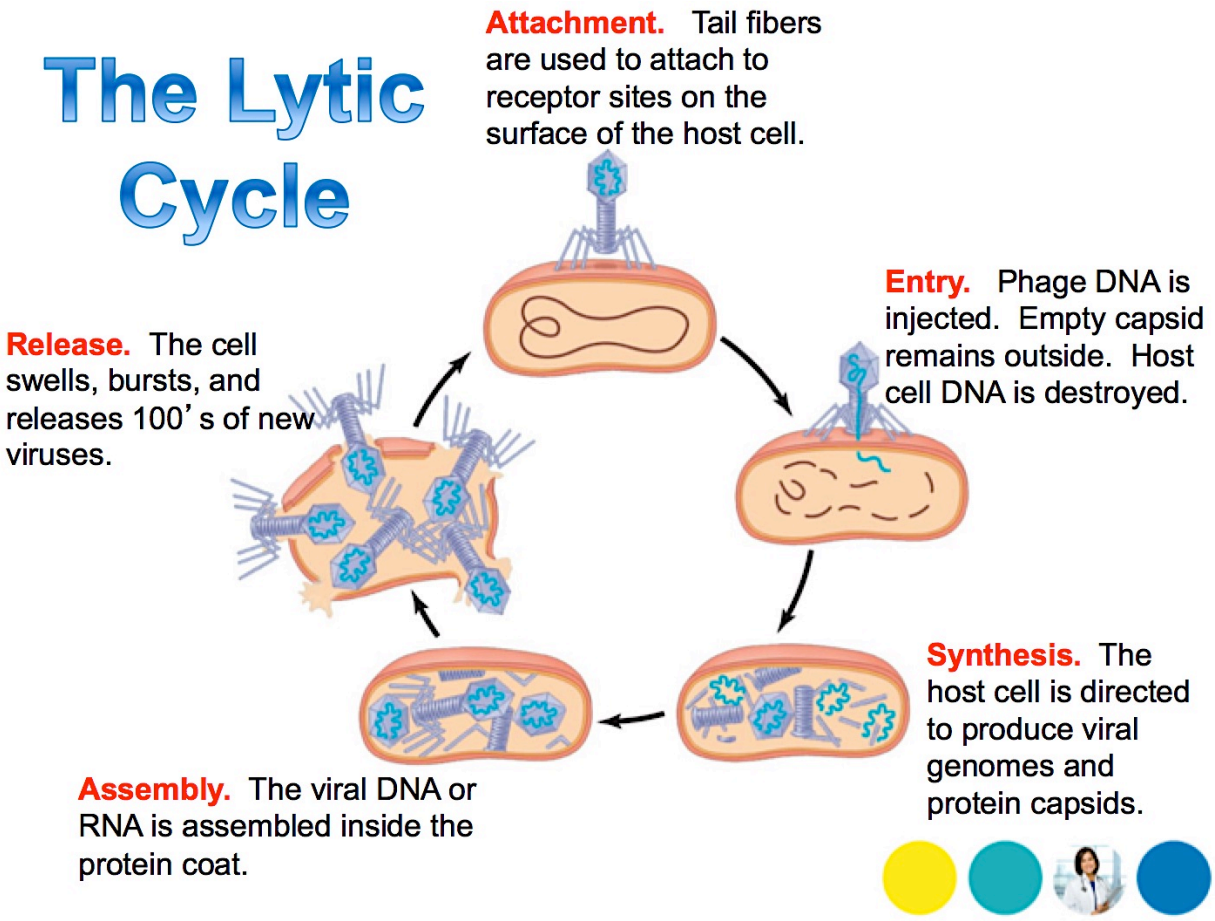
B. Non-living characteristics of viruses.
   1. They are non-cellular.
   2. They have no metabolism. They have no food or energy requirements.
   3. They can be crystallized and dehydrated and stored indefinitely. They come to "life" only when injected inside a living cell.

IV. Viral Reproduction

A. How Do They Do It?
   1. Since viruses have no enzymes and no cell parts, they force the host cell to start making viral parts.
   2. A viral infection begins when the genetic material (DNA or RNA) of a virus makes its way into a host cell.
   3. Once inside, the virus hijacks the cell, reprogramming the cell.
   4. The viral genome takes over the host cell and makes the host cell start producing viral parts.
   5. The host cell will begin to make copies of the viral DNA and producing the protein capsids.
   6. The host cell assembles the parts into viruses.
   7. The reproductive cycle ends with the exit of hundreds or thousands of viruses from the infected host cell.
   8. This often destroys the host cell. Each of these viral progeny has the capacity to infect neighboring cells, thereby spreading the infection.

B. The Two Reproductive Possibilities:
1. Once a virus is inside a host cell, two different processes may occur.
2. Some viruses replicate themselves immediately, killing the host cell.
3. Other viruses replicate themselves in a way that does not destroy the host cell.
4. These two processes are called:
   a) the lytic cycle
   b) the lysogenic cycle

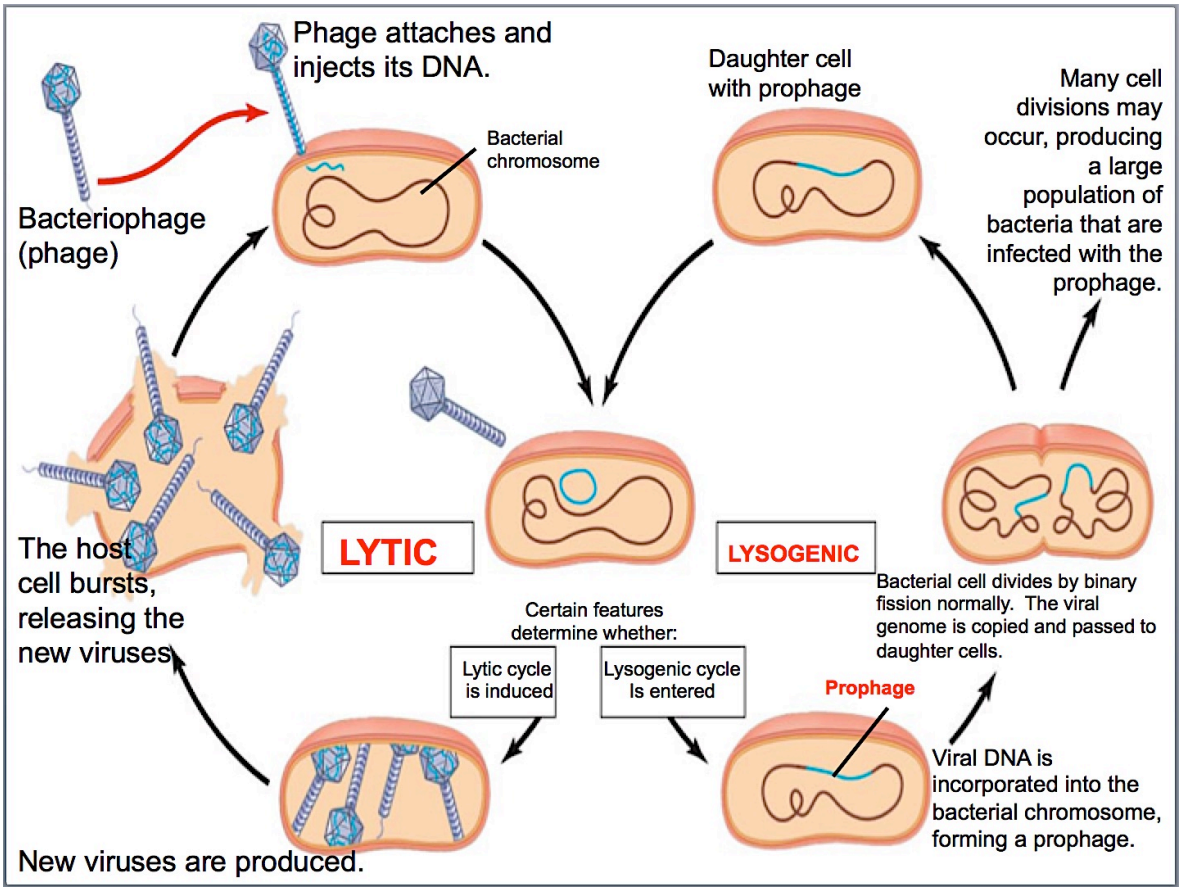
C. The Lytic Cycle
1. In a lytic infection, a virus enters a cell, makes copies of itself, and causes the cell to burst.
2. Bacteriophage T4 is an example of a bacteriophage that causes a lytic infection.
3. The steps of the lytic cycle are shown in the below diagram:



4. A phage that reproduces only by a lytic cycle is called a virulent phage.

D. The Lysogenic Cycle
1. In this type of viral reproduction, the host cell makes copies of the viral genetic material indefinitely.
2. The virus incorporates its DNA into the DNA of the host cell. The viral DNA is then replicated along with the host cell's own DNA.
3. Lysogenic viruses do not kill the cell right away. A lysogenic virus may remain inactive for some period of time.

4. The lysogenic cycle is seen in the diagram below.



5. Prophage: The viral DNA embedded into the host cell's DNA.
6. The prophage may remain part of the host for many generations before becoming active.
7. Eventually, certain environmental conditions (chemicals, radiation) may trigger the switchover from the lysogenic cycle to the lytic cycle.

V. Retroviruses

A. Retroviruses have RNA as their genetic information rather than DNA.
B. These viruses have an enzyme called reverse transcriptase, which transcribes their RNA template into DNA. The newly made DNA then enters the cell's nucleus and integrates into the DNA of a chromosome.
C. In this way, the retrovirus may remain dormant for some length of time.
D. It will eventually become active, causing the host cell to make new viruses and causing the death of the host cell.
E. Retroviruses are responsible for some types of cancer.
F. The AIDS virus is a retrovirus.

VI. Comparison of Viruses and Cells

Viruses and Cells		
Characteristic	**Viruses**	**Cells**
Structure	DNA (or RNA) and capsid	Cell membrane, cytoplasm, nucleus, cytoplasmic organelles
Reproduction	Only within a host cell	Reproduce independently either sexually or asexually
Genetic Code	DNA or RNA	DNA
Growth and Development	None	Yes, in multicellular organisms
Obtain and Use Energy	No	Yes
Respond to the Environment	No	Yes
Change Over Time	yes	Yes

VII. Viral Diseases

A. There is little that can be done to cure a viral infection. Antibiotics are effective against bacteria but not against viruses. A few new drugs have been developed that interfere with the reproduction of the virus, but they only seem to slow the effect of the virus. They do not provide a cure.

B. The battle against viral diseases lies in the use of vaccines.
1. Vaccines: Contain a harmless variation of the pathogen.
2. Our immune system launches a response to the harmless form, thereby learning to recognize it the next time that we are exposed to it.
3. When we are exposed to the "real" pathogen, our immune system can respond much faster since it has already learned to recognize the pathogen.

C. Common viral diseases include:
1. Colds
2. Influenza
3. AIDS
4. Chicken Pox
5. Hepatitis
6. West Nile

VIII. Viroids and Prions

A. Viroids
1. They are known for their extreme simplicity and small size.
2. They are much smaller than a virus.
3. They consist of small circular molecules of RNA, but they have no protein coat. They are tiny molecules of naked circular RNA.
4. They have only been identified in plants, but they are suspected of causing some diseases in animals for which no pathogen has ever been isolated.
5. The important lesson we have learned from viroids is that a ***molecule*** can be an infectious agent and cause disease.

B. Prions
1. These are disease-causing particles that do not contain DNA or RNA.
2. They are tiny bits of protein.
3. Prions cause degenerative brain diseases such as Mad Cow Disease.
4. How can a protein, which cannot replicate itself, be a pathogen? The leading hypothesis is that a prion is a misfolded form of a protein normally present in brain cells. When a prion enters a cell that contains the normal form of the protein, the prion converts the normal protein to the prion version.

IX. The Bacteria

A. The bacteria are prokaryotes. A prokaryotic cell does not have a true nucleus or membrane-bound organelles.
B. Prokaryotes dominate the biosphere. Their collective biomass outweighs all eukaryotes combined by at least 10 fold.
C. Some are harmful and cause diseases, but most bacteria are benign or beneficial. A relatively small number of species cause disease.
D. They are successful because of their rapid cell division (reproduction) and their great metabolic diversity. They can double their numbers every 20 minutes and live in environments that support no other forms of life.

X. Classification of Prokaryotes

A. Until recently, all prokaryotes were placed in a single kingdom called the Monera kingdom. However, biologists now recognize that there are such great differences between two distinct groups of prokaryotes that they should be separated into separate domains.

B. In today's classification system, the bacteria are separated into two different domains:

Domain - Archaea
Kingdom: Archaebacteria

Domain – Bacteria
Kingdom: Eubacteria

C. Archaebacteria
   1. Under a microscope, archaebacteria look very similar to the eubacteria. They are equally small, lack nuclei, and have cell walls.
   2. Chemically, the archaebacteria are very different.
   3. The archaebacteria lack the peptidoglycans found in the eubacteria. They also have different membrane lipids.
   4. Further, the DNA sequences of key archaebacterial genes are more like those of eukaryotes than those of eubacteria.
   5. The archaebacteria live in extremely harsh environments, such as swamps, salt lakes and hot springs. In fact, the word "archaea" means "archaic or ancient" since many of the known species of archaea live in extreme environments thought to resemble the harsh environments present millions of years ago.

D. Three Archaeal Groups
   1. Genetic analysis of the archaea reveals at least three different groups of archaea.
   2. Methanogens:
      a) These archaea have a unique way of getting energy. They convert hydrogen gas and carbon dioxide into methane gas.
      b) Oxygen is poisonous to these archaea. They must live in anaerobic environments such as deep fresh water, marine mud, swamp mud and sewage.
      c) Methanogens also thrive in the digestive tracts of cows and termites. A cow can release 200 to 400 liters of methane gas per day.
   3. Halophiles:
      a) These are the "salt-loving" archaea. These organisms live in environments that have very high salt concentrations, such as the Great Salt Lake and the Dead Sea.
   4. Thermoacidophiles:
      a) These archaea live in very acidic environments that have very high temperatures, such as the hot springs in Yellowstone National Park.
      b) These organisms can thrive in temperatures of 110 °C and at a pH of less than 2.
      c) They are often found around "black smokers" which are hydrothermal vents that leak very hot, dark-colored, acidic water. Large communities of worms, clams, and crabs live near these vents and utilize the thermoacidophilic archaea as a primary food source.

E. Eubacteria
   1. These are the "true" bacteria.
   2. There is great variety in the organisms that belong to this kingdom. These bacteria are found in every environment on Earth.
   3. The eubacteria have a cell wall that contains a polysaccharide called peptidoglycan.

XI. Characteristics of Bacteria

A. Found almost everywhere. The best environment for growth has:
   1. Suitable temperature: 80-100 degrees F.
   2. Moisture
   3. Suitable food source
   4. Darkness
   5. Space to grow

B. Very large compared to a virus

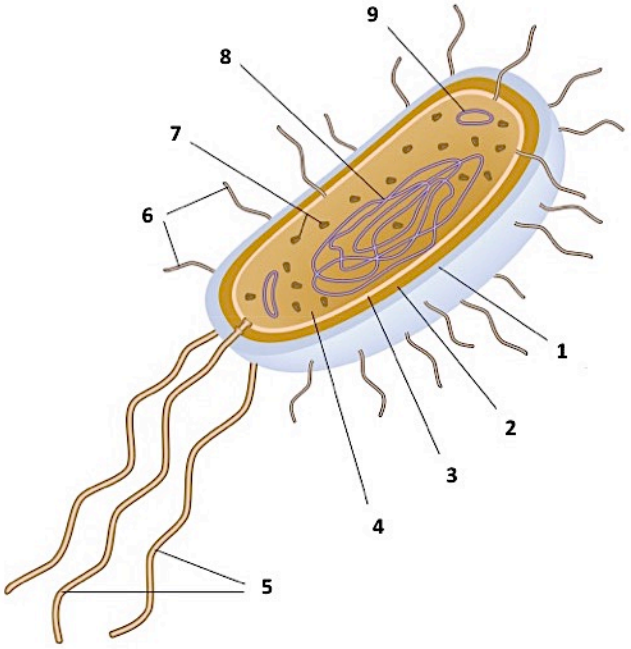
C. Prokaryotes are identified by several characteristics:
   1. Shape.
   2. The materials composing the cell wall.
   3. The way they move.
   4. The way they obtain energy.

D. They exist in three basic shapes:
   1. Cocci are spherical.
   2. Bacilli are rod-shaped.
   3. Spirilla are spiral shaped or curved.

E. Movement
   1. Some bacteria are motile and others do not move at all.
   2. Some move by means of flagella, which are whiplike structures used for movement.
   3. Some lash or snake forward.
   4. Others glide slowly over a layer of slime they secrete.

F. Most bacteria are harmless. Some are pathogenic (cause diseases.)

XII. Structure of Bacteria



A. Label the structures seen in the prokaryotic cell:
   1 – capsule
   2 – cell wall
   3 – plasma membrane
   4 – cytoplasm
   5 – flagella
   6 – pili
   7 – ribosomes
   8 – Chromosomal DNA (single, circular strand)
   9 – Plasmid DNA

B. The cytoplasm does not contain any membrane bound organelles.

C. The chromosome consists of one single, circular, continuous molecule of DNA.

D. The cytoplasm is filled with many ribosomes.

E. A capsule may be present outside of the cell wall. It is composed of a gluey polysaccharide. It enables prokaryotes to adhere to their substrate or to other individuals in the colony. Some capsules protect against dehydration. Some capsules shield pathogenic bacteria from attacks by their host's immune system.

F. Flagella: Long whip like structure used for movement.

G. Pili are shorter and thinner than flagella. Pili serve to attach bacteria to a food source, to the surface of a liquid, or to another bacteria during reproduction.

H. Plasmid DNA: A small circular piece of DNA that is separate from the chromosome. A plasmid is generally one gene.

XIII. Metabolic Diversity – How Do Bacteria Obtain Energy?

A. Most bacteria are heterotrophs. They do not have the ability to make their own food. The heterotrophic bacteria are further divided into saprophytes and parasites.
   1. Saprophytes
      (a) Saprophytes live on dead organic matter.
      (b) Saprophytes are very important as decomposers.

   2. Parasites
      (a) A parasite is an organism that invades plants and animals and lives off of them.
      (b) Host: The organism that the parasite is living off of.

B. A few bacteria are autotrophs. They have the ability to make their own food.
   1. Photoautotrophs: Photosynthetic organisms that use light energy from the sun to convert carbon dioxide and water into the organic molecule glucose, and oxygen.

   2. Chemoautotrophs: Use the energy from inorganic reactions as a source of energy to build molecules of glucose.

C. Bacteria release energy through the processes of cellular respiration or fermentation or both.
   1. Obligate aerobes:
      a) Obligate aerobes are organisms that require a constant supply of oxygen in order to live.

   2. Obligate anaerobes:
      a) Some bacteria do not require oxygen and are killed in its presence. These organisms are called obligate anaerobes.
      b) These organisms must live in the absence of oxygen.

   3. Facultative anaerobes:
      a) These organisms can survive with or without oxygen.
      b) Facultative anaerobes do not require oxygen, but neither are they killed by its presence.
      c) This ability allows these organisms to live just about anywhere.

XIV. Growth and Reproduction

A. If conditions are favorable for growth, bacteria can grow and divide at incredible rates. Many bacteria can divide every 20 minutes (under ideal conditions). If reproduction continued unchecked at this rate, a single prokaryotic cell could give rise to a colony outweighing Earth in three days.

   In reality, prokaryotic reproduction is limited by the following:
   a) the eventual exhausting of food supply.
   b) poisoned by their own metabolic waste.
   c) competition from other microbes.
   d) consumed by other organisms.

B. Binary Fission
1. Binary fission is a type of asexual reproduction where one cell undergoes cell division to form two cells.
2. When the bacterium has grown to nearly double its size, it replicates its DNA and divides in half.
3. Two identical daughter cells are formed.

C. Conjugation
1. During conjugation, a hollow bridge forms between two bacterial cells.
2. Through this tube, genes move from one cell to the other.
3. There is no increase in numbers, but they have redistributed the genetic information. The transfer of genetic information increases genetic diversity in future populations.
4. Now they can go back to binary fission and increase their numbers.

D. Endospore Formation
1. When conditions for growth become unfavorable, many bacteria form structures called endospores.
2. An endospore is formed inside of a cell. The contents of the cytoplasm draw up together and a thick wall is formed around it.
3. These endospores can survive extreme dryness, heat or cold. They can remain dormant for months or years while waiting for favorable growth conditions to return.

XV. The Importance of Bacteria

A. Bacteria are vital to maintaining the living world. The prokaryotes can easily survive without the eukaryotes, but the eukaryotes are totally dependent on the prokaryotes.

B. Decomposers
1. All living things depend upon a constant supply of carbon, nitrogen, and other essential elements.
2. These essential elements must be recycled when an organism dies.
3. Bacteria are decomposers that help to recycle these essential chemical elements.
4. When an organism dies, it is attacked by bacteria and broken down into simpler materials.

C. Nitrogen Fixation
1. Plants and animals must have nitrogen to build amino acids. Amino acids are needed to build proteins.
2. Nitrogen gas makes up about 80% of Earth's atmosphere, but plants and animals are not capable of using nitrogen gas directly.
3. In a process called nitrogen fixation, bacteria are able to convert nitrogen gas into nitrates, a form that plants can use.
4. Plants take up these nitrates through their roots and use them to build plant proteins.
5. Animals eat the plants, and convert the plant proteins into animal proteins.
6. When an organism dies, bacteria decompose the organism, returning this nitrogen to the ecosystem to be used again.

D. Human Uses for Bacteria
1. Bacteria are used to produce a wide variety of foods and beverages. Examples: sour cream, yogurt, cheese.
2. Some bacteria can digest oil and are helpful in cleaning up oil spills.

XVI. Bacterial Diseases in Humans

A. Some bacteria are pathogens. A pathogen is a disease-causing agent.

B. Bacteria produce diseases in one of two ways:
   1. Some bacteria damage the cells and tissues by breaking down the cells for food.
   2. Other bacteria release toxins or poisons in the body of the host.

C. Many of the diseases caused by bacteria can be prevented with the use of vaccines.
   1. Vaccine: A weakened or killed form of the pathogen that stimulates the body's immune system to produce antibodies.
   2. Once the body has "learned" to make the correct antibody, the body will be able to respond rapidly if infected with the living, active form of the pathogen.
   3. This rapid response of the immune system is called immunity.

D. Antibiotics
   1. Antibiotics are compounds that kill bacteria.
   2. They are effective against bacteria, but have no affect on viruses.

XVII. Symbiotic Relationships between Organisms

A. Symbiosis is a close and permanent association between organisms of different species.

B. There are three types of symbiotic relationships:
   1. Mutualism: The relationship is beneficial to both species.
   2. Commensalism: A relationship in which one species benefits from the association while the other is neither harmed nor helped.
   3. Parasitism: A relationship in which one species benefits and the other is harmed.