Chapter 19: Viruses and Prokaryotes

Dr. Bertolotti

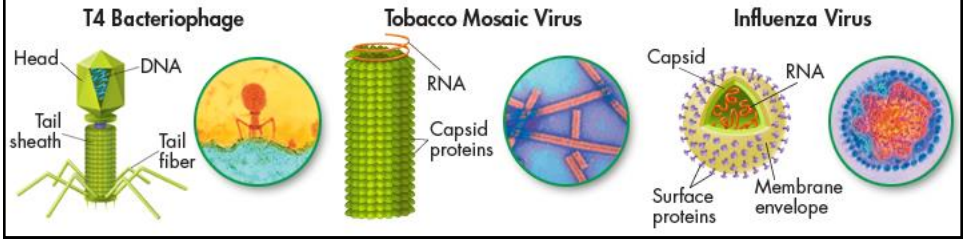
Essential Question

Are all microbes that make us sick made of living cells?

How do viruses reproduce?

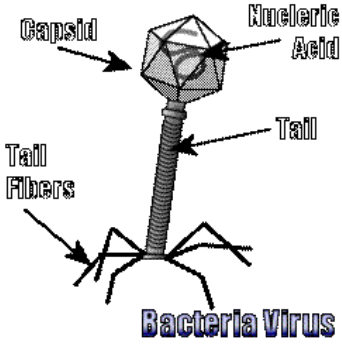
Viruses

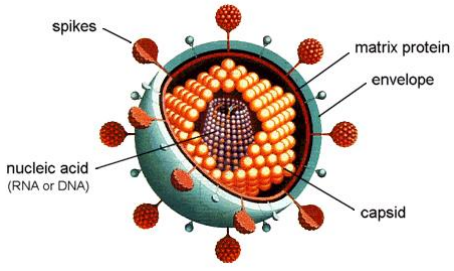
- A **virus** is a non-living particle made up of nucleic acid, protein, and in some cases lipids.
  - They can replicate only by infecting living cells
  - 100% of viruses are pathogenic
  - Viruses are non-living!!!



Ebola virus

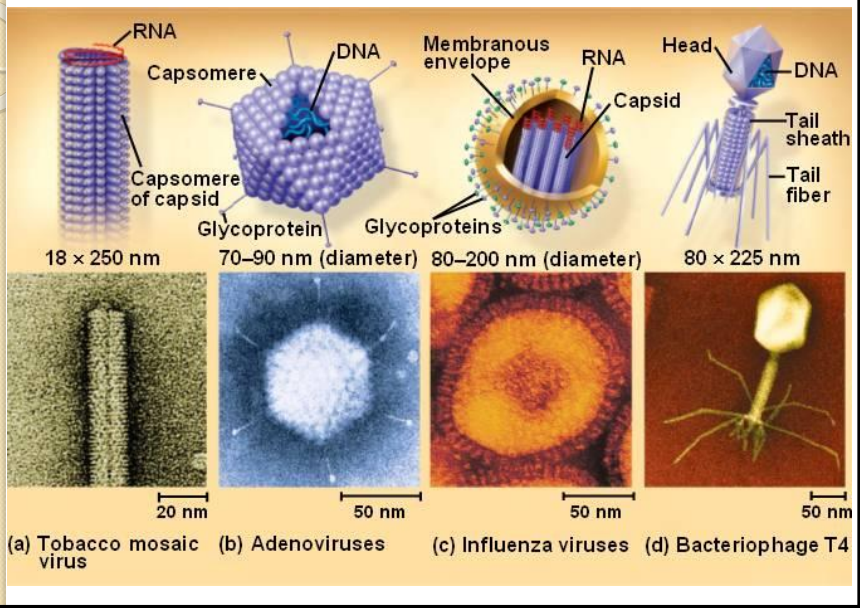
Structure of a Virus





- All viruses have nucleic acids surrounded by a protein coating (capsid).
- The nucleic acid can be DNA or RNA

Diversity of Viral Forms



Virus structure and composition

- Viruses differ widely in terms of size and structure.
- A virus's protein coat is called its **capsid.**
- To enter a host cell, most viruses have proteins on their surface membrane or capsid that bind to receptor proteins on the cell. In either case, the proteins "trick" the cell to take in the virus, or in some cases just the genetic material. Once inside the cell, the viral genes are eventually expressed and may destroy the cell.
- Most viruses infect only a specific type of cell.
  - Viruses that infect bacteria are called **bacteriophages**
  - Plant viruses infect plant cells

Viral Reproduction

- Viruses are Parasites
  - **Parasites** are dependent on host for reproducing
- Steps of viral reproduction:
  1.) Recognition of marker protein
  2.) Attachment
  3.) Injection (of nucleic acid)
  4.) Assembly
  5.) Lysis (cell bursting)

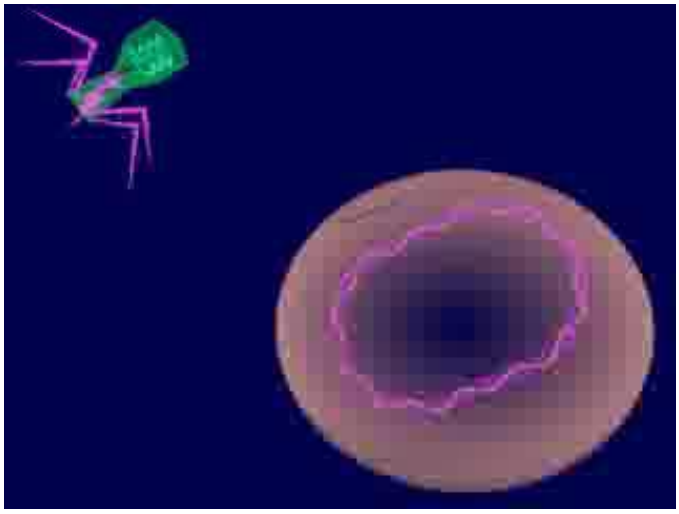
Viral infections

- Inside living cells, viruses use their genetic information to make multiple copies of themselves. Some viruses replicate immediately, while others initially persist in an inactive state within the host.
- 2 main patterns of infection:
  - 1. Lytic Infection
  - 2. Lysogenic Infection

Lytic Infections

- 1. **Lytic Infection**: process in which a virus enters a cell, makes a copy of itself, and causes the cell to burst (or lyse).
  - Under the control of viral genes, the host cell's metabolic system now makes thousands of copies of viral nucelic acid and capsid proteins.
  - The viral DNA is assembled into new virus particles. Before long, the infected cell lyses, releasing hundreds of virus particles that may go on to infect other cells.
    - Example: T4 Bacteriophage

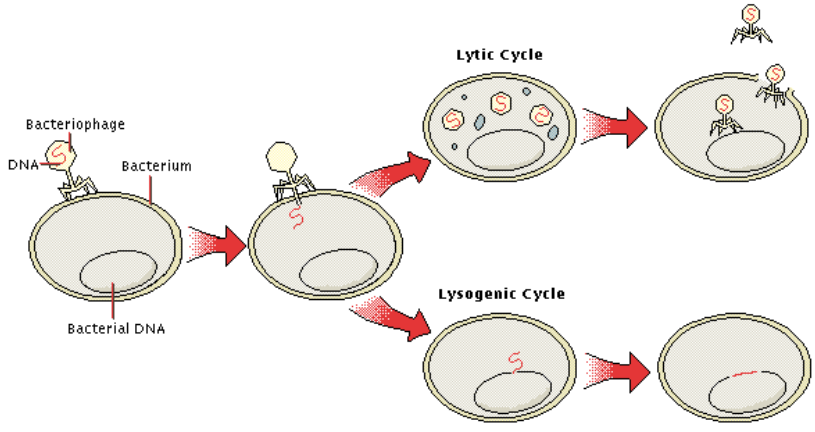
The Lytic Cycle



Lysogenic Infection

- **2. Lysogenic Infection:** process by which a virus embeds its DNA into the DNA of the host cell and is replicated along with the host cell's DNA without damaging the host cell's DNA.
  - Examples: HIV and Herpes
  - Viral DNA multiplies as the host cells multiply. In this way, each generation of daughter cells derived from the original host cell is infected.
  - Bacteriophage DNA that becomes embedded in the bacterial host's DNA is called a **prophage**.
    - The prophage may remain part of the DNA of the host cell for many generations.
    - Influences from the environment- including radiation, heat, and certain chemicals- trigger the prophage to become active. It then removes itself from the host cell DNA and directs the synthesis of new virus particles. The lysogenic infection now becomes an active lytic infection.

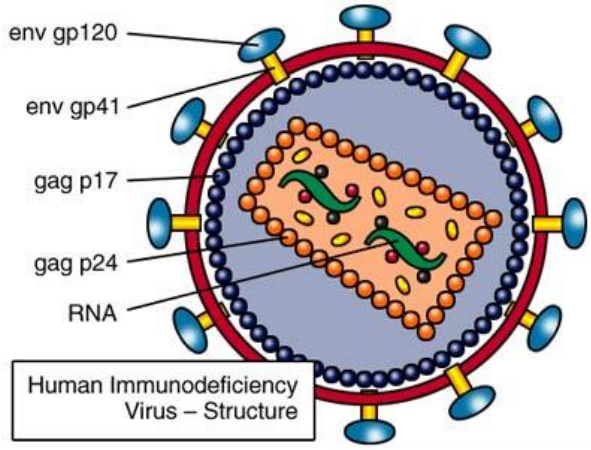
Lytic vs Lysogenic infections



HIV

- HIV is a retro virus.
  - It contains RNA that is reverse transcribed to DNA by the HIV enzyme, reverse transcriptase. This DNA is then incorporated into the host cell's (helper T cells) DNA by the HIV enzyme integrase
  - HIV can only replicate inside human T cells
  - The process begins when a virus bumps into a cell that carries on its surface a special protein. The spikes on the surface of the HIV particle stick to the protein and fuses. The contents of the HIV particle are then released into the cell
  - For long periods the viral DNA can remain inactive and simply get passed on to daughter cells with the host cell genome.
    - No disease symptoms will be shown because the viral DNA is not producing anything.
    - When the HIV DNA is activated it will begin to produce components of the virus. At this point disease symptoms will begin as the infected cells of immune system will be damaged or destroyed by the production of new viruses. As HIV infects more cells, the immune system becomes weaker- which can lead to a person developing AIDS

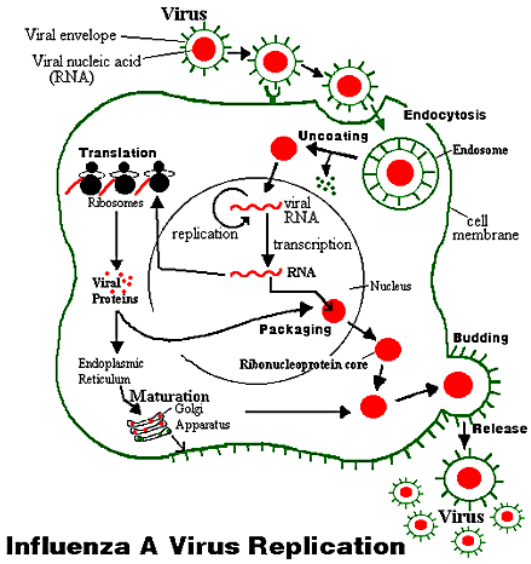
HIV



INFLUENZA

- The influenza virus is a retrovirus (genetic material is RNA) that can only replicate in living cells (specifically epithelial cells in the upper and lower respiratory tract).
  - First, the virus binds to and enters the cell through endocytosis
  - The viral genes on RNA are transcribed and translated by the cell's enzymes and ribosomes.
    - In this way, the virus takes over the cell's productivity. Now, instead of producing only new cellular material, the cell produces hundreds of new virus particles.
  - The new virus particles are eventually released from the cell and drift off, and some may land on a host cell of their own to pirate.

INFLUENZA VIRUS REPLICATION



Influenza A Virus Replication

QUESTION AND ANSWER

How do viruses reproduce?

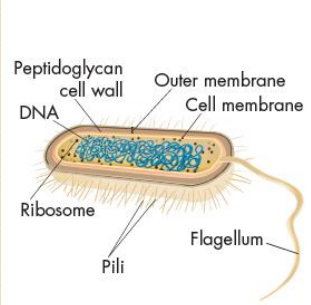
How do prokaryotes vary in their structure and function?

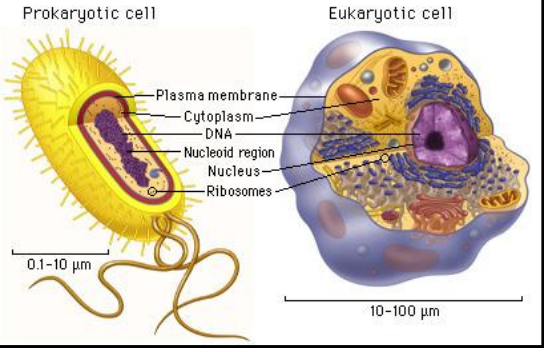
Bacteria

- Earth's oldest life forms
  – between 3.5 and 3.8 billion years old
- Most abundant life form – up to 2.5 billion individual bacteria in 1 gram of fertile soil
- Very adaptable – found in all of Earth's ecosystems

Bacteria=Prokaryotes

Prokaryotes	Eukaryotes
* No organelles except ribosomes	* Lots of organelles
* NO NUCLEUS!	* CONTAINS A NUCLEUS!

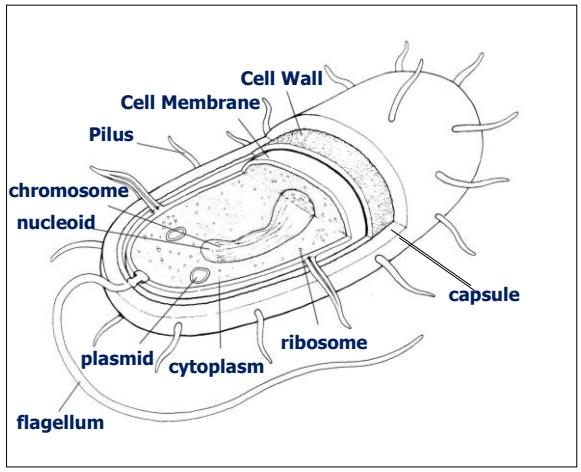


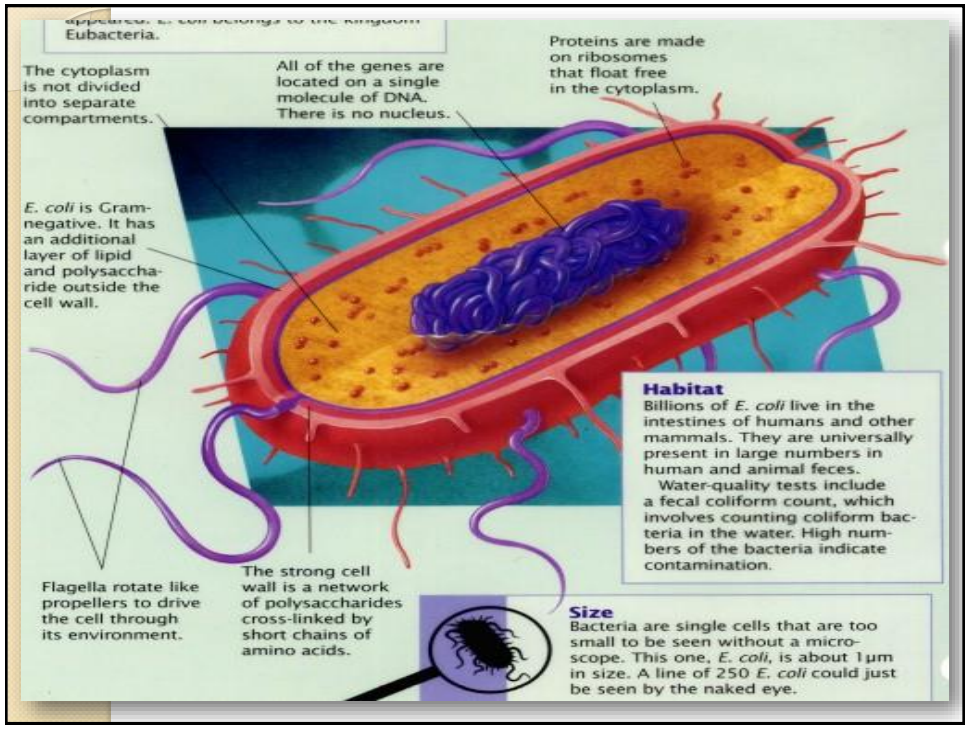


Bacteria

- Is a **prokaryote**- unicellular organism that lacks a nucleus that is typically approximately 1-5 micrometers (μm) in length
- 2 main groups or kingdoms
  - **1. Eubacteria**
    - live almost anywhere, very diverse.
    - Contains a cell wall made of peptidoglycan
      - Example: *Escherichia coli* (E. coli)
  - **2. Archaebacteria**
    - live in extreme environments, example: hot springs.
    - they lack the peptidoglycan cell wall and have different membrane lipids.
    - The DNA sequences of key archaebacterial genes are similar to those of eukaryotes (thus they may have been the ancestors of eukaryotes).

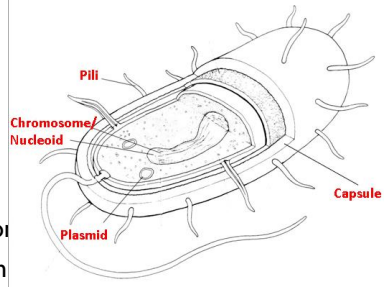
Bacterial Structure





Bacterial Structure continued

- Pili – hairlike structures usually found in Gram neg. bacteria. Help the bacteria stick to surfaces.
  Also forms conjugation bridge
- Chromosome – a single loop of DNA that is folded on itself
  - controls the cell's functio
- Nucleoid – the region of the cytoplasm where the DNA is found



- Plasmid – an accessory loop of DNA – small contains only a few genes - can be responsible for: conjugation, antibiotic resistance, unique metabolic properties – like the ability to use hydrocarbons
- Capsule – found outside some bacteria stores nutrients and protects the bacteria from changing environmental conditions

Identifying prokaryotes

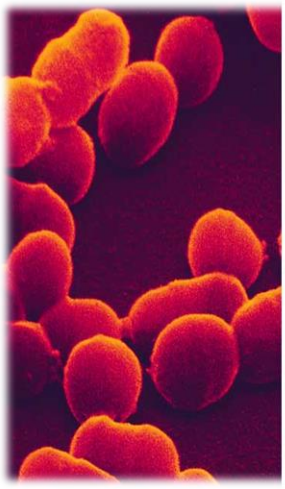
- Prokaryotes vary in their:
- size and shape,
- in the way they move, and
- in the way they obtain and release energy.

Size, Shape, and Movement

- Bacteria range in size from 1-5 μm (micrometers)
- Bacteria come in a variety of shapes:
  - Rod shaped bacteria = bacilli
  - Spherical bacteria = cocci
  - Spiral and corkscrew shaped = spirilla
- Bacteria can be distinguished by whether they move and how they move.
  - Some don't move
  - Others are propelled by flagella
  - Some glide slowly along a layer of slime-like material they secrete

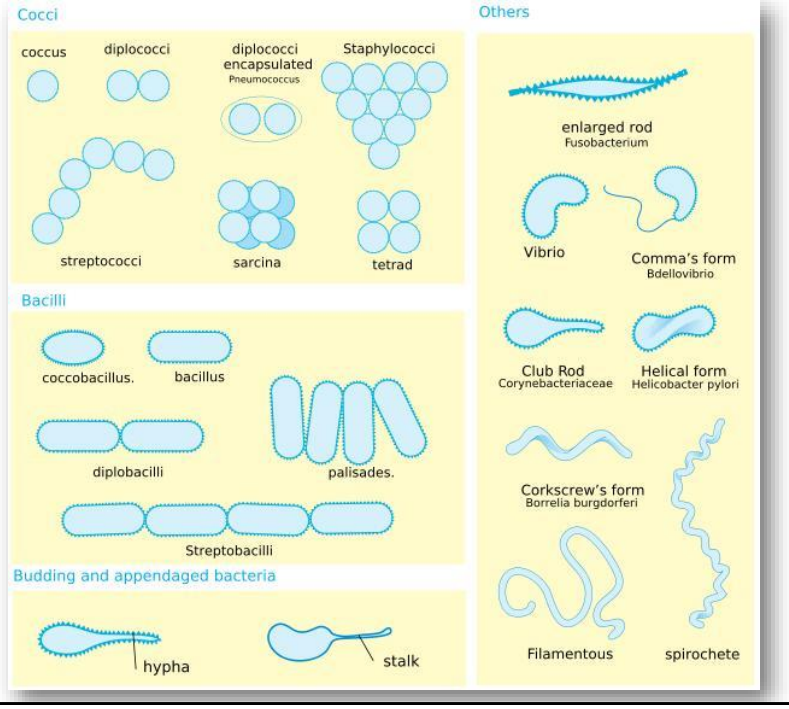
Shape of Bacteria

Cocci



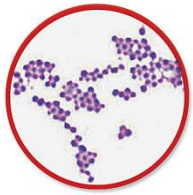
Bacillus

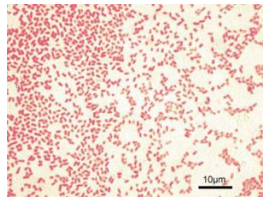
Spirilla



Cell walls

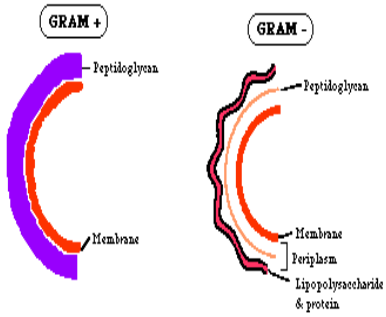
- Gram staining is used to differentiate the 2 types of cell walls
  - Gram positive bacteria have a dark purple appearance due to their thick peptidoglycan cell wall
  - Gram negative bacteria appear pink or light red because of their thin cell walls





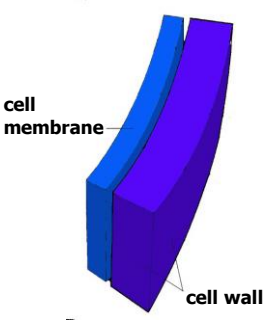
2 Types of Cell Walls

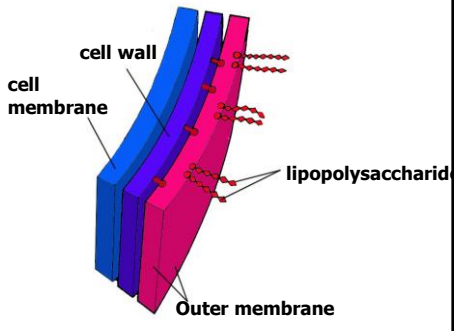
- 2 types of cell walls found in bacteria
- Identified as Gram **+** (Gram positive) or Gram – (Gram negative)
- There's a chemical difference between them.



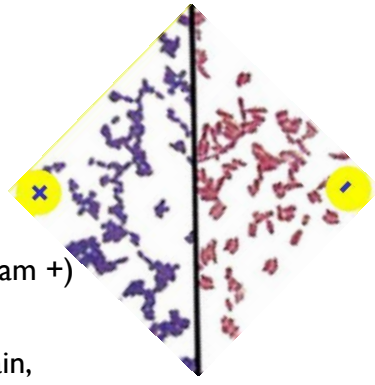
Bacterial Structure: Cell Wall

- Made of peptidoglycan – a combination of protein and polysaccharides
- Some bacteria called Gram negative bacteria have an additional layer of membrane that contains lipopolysaccharide
  - this extra layer inhibits the uptake of antibiotics – protecting the bacteria



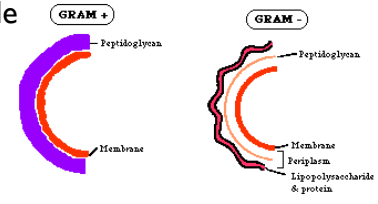


2 Types of Cell Walls



- Gram positive (Gram +)
  - Thick cell wall
  - Holds purple stain, so cells look purple

- Gram negative (Gram -)
  - Two thin layers make up cell wall
  - Doesn't hold purple stain so appears pink



Metabolic diversity

- Can be identified based on the way they obtain energy
  - Most prokaryotes are **heterotrophs**- they get their energy by consuming molecules
  - Others are **photoheterotrophs**- they use sunlight for energy as well as inorganic compounds as their carbon source
  - Others are **photoautotrophs**- use light energy to convert CO2 and water to carbon compounds and oxygen
  - Some are **chemoautotrophs**- make organic carbon molecules from carbon dioxide

Releasing energy

- **Obligate aerobes-** organisms that require a constant supply of oxygen in order to live
- **Obligate anaerobes-** bacteria that must live in the absence of oxygen
- **Facultative anaerobes-** group of bacteria that can survive with or without oxygen- they don't require oxygen but are not killed in its presence

Growth and reproduction

- **Binary fission** is a type of asexual reproduction in which an organism replicates its DNA and divides in half, producing 2 identical cells

- **Spore formation-** unfavorable growth conditions will result in bacteria forming a structure known as a spore.
  - An **endospore** is formed when a bacterium produces a thick internal wall that encloses its DNA and a portion of its cytoplasm.
  - Spores can remain dormant for months and years and germinate when conditions improve

Exchanging Genetic Information

- Bacterial cells need to be able to exchange genetic information

  - creates new genetic combinations which increases the ability of the bacteria to survive

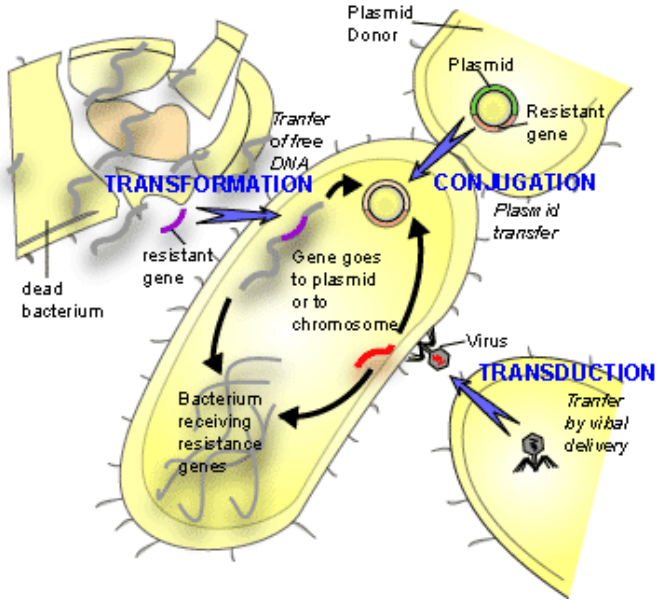
- Bacteria have 3 methods for exchanging DNA

-Transduction – viruses carry DNA from one bacterial cell to another

-Transformation – bacteria can absorb "naked" DNA released by dead bacteria from the environment

- Conjugation – two bacteria join at a conjugation bridge, one bacteria passes on a copy of its plasmid or chromosome

Exchanging Genetic Information



QUESTION AND ANSWER

How do prokaryotes vary in their structure and function?

What roles do prokaryotes play in the living world?

Useful Bacteria

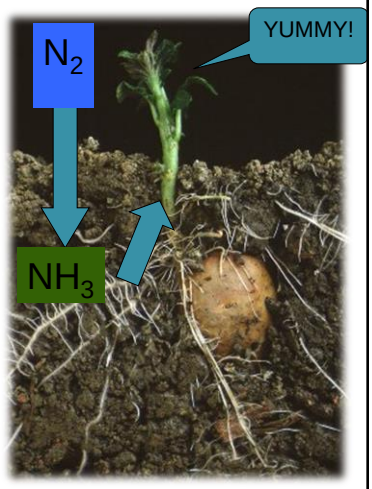
- Decomposers
  - Recycle nutrients such as CO_2, water, nitrogen, and phosphorus
- Producers
  - Cyanobacteria are photosynthetic bacteria which act as producers in many aquatic ecosystems

Useful Bacteria

•Soil nitrogen-fixing bacteria fix nitrogen from the air into a useable form (NH_3-ammonia) for plants.

•Plants need the nitrogen that bacteria make to produce their proteins and DNA.

•Some bacteria are photosynthetic and provide oxygen



Useful Bacteria

- Food-- yogurt, pickles, and cheese
- Drugs -- insulin production
- Clean up oil spills
- Animal digestion, including our own

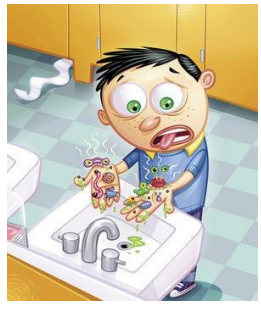
QUESTION AND ANSWER

What roles do prokaryotes play in the living world?

Bacterial Roles: Symbiotic Bacteria

Many bacteria live in or on other organisms (including humans) and aid their host

- some live in the gut of herbivores helping to digest cellulose
- bacteria in the gut of humans aid digestion and produce vitamins
- bacteria on skin and in body openings help prevent infection by harmful organisms



How do bacteria and viruses cause diseases?

Diseases caused by bacteria and viruses

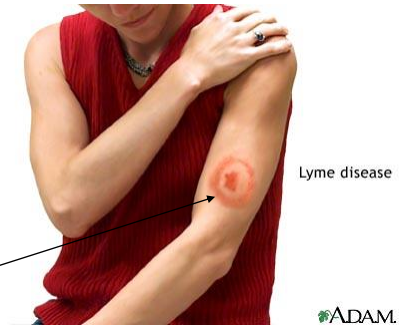
- Bacteria cause disease by destroying living cells or by releasing chemicals that upset homeostasis
- Bacteria produce disease in 1 of 2 ways:
  - 1) some bacteria damage the cells and tissues of the infected organism directly by breaking down the cells for food
    - Example: Tuberculosis
  - 2) some bacteria release toxins (poisons) that travel throughout the body interfering with normal activity of the host
    - Example: Botulism (deadly form of food poisoning)

Harmful Bacteria

- Pathogen- Disease causing organisms.
- Not many bacteria are pathogenic— ONLY 1%!
- Disease Transmission:
  a.) Water
  b.) Air
  c.) Food
  d.) Animals/Insects
  e.) Human Contact

Bacterial Diseases

- Tuberculosis
- Syphilis
- Bubonic Plague
- Typhus
- Tetanus
- Lyme Disease

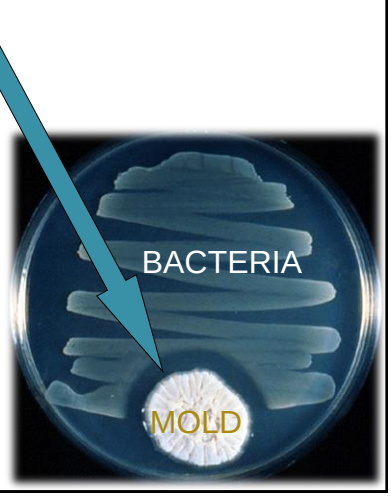


Controlling Growth

- Antibiotics
  - Antibiotic resistance?
- Physical Removal
- Sanitizing--Antiseptics and Disinfectants
- Freezing
- Cooking
- Pasteurizing
- Dehydrating
- Vaccination

Antibiotics

- Discovered by Alexander Fleming
- Noticed mold on his Petri dish had a zone of inhibition around it where bacteria didn't grow.
- The mold had released an antibiotic called penicillin
- Antibiotic=against life; any substance produced by a microorganism that slows the growth of other microorganisms.



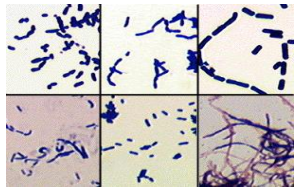
Antibiotics

- 2 types of antibiotics that control bacteria:
  - Bacteriocidal- kill bacteria by blocking protein synthesis
  - Bacteriostatic- prevent bacteria from undergoing binary fission (prevents them from making new cell walls.)

BACTERIA

Each paper disk has antibiotics on it.
Which antibiotic is more powerful?

Antibiotics



- Antibiotics are made by fungus (mold) or even other bacteria, the most common being bacterium *Streptomyces*.
- Present day antibiotics are synthetic modifications of naturally occurring ones.
- Work on Gram + bacteria
- Gives the immune system a chance to catch up and get rid of them.

Antibiotic Resistance

- Antibiotic resistant bacteria are not affected by antibiotics!
- Can be resistant due to:
  - Special cell walls (i.e. Gram – bacteria) OR
  - Special antibiotic resistant genes
- Don't finish antibiotics, then only weaker bacteria are destroyed by your immune system.
- ** Resistant bacteria still live and pass on their antibiotic resistant genes through binary fission, conjugation and transformation

Sanitizing

- **Antiseptics**
  - Chemicals used to inhibit growth of bacteria <u>on living tissues</u>

Sanitizing

- **Disinfectants**
  - Chemicals used to inhibit growth of bacteria <u>on NON-living things.</u>

Freezing

- Extreme freezing can generally stop bacterial growth and/or kill bacteria.
- The colder the temperature, the fewer bacteria that can survive and grow.
  - That is why keeping food cool retards spoilage.

Cooking

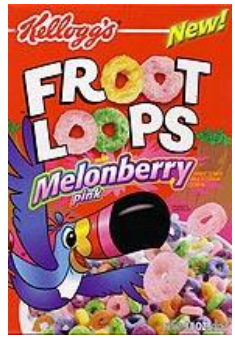
- Cooking can control bacterial growth and kill most bacteria if heated to certain temperatures—**165°F** or hotter.
- Use a meat thermometer
- Wash hands after handling raw meat

Pasteurizing

- Uses heat to kill bacteria in food, usually liquids, to a specific temperature for a definite length of time, and then cooling it immediately.
  - Examples: milk, ice-cream, and juices.

Dehydrating

- How would this control the growth of bacteria?
  - Dehydration kills bacteria by removing water and sometimes by also adding salt or sugar.



Vaccination

- **Prevents** you from getting the disease. DOES NOT CURE YOU!
- Vaccines are typically weakened or killed forms of the pathogen, virus particles, or the poison of the pathogen
- How do they work?
  - Fast and strong immune system memory cells produced!
  - This provides immunity just like if you got the disease (i.e. chicken pox.)

Viral Diseases

- In many viral infections, viruses attack and destroy certain cells in the body, causing the symptoms of the associated disease/
  - Example: Poliovirus destroys cells in the nervous system, producing paralysis.
- Other viruses cause infected cells to change their patterns of growth and development, sometimes leading to cancer.
  - Example: Hepatitis B
- **Viruses cause disease by directly destroying living cells or by affecting cellular processes in ways that upset homeostasis.**

Viral disease prevention and treatment

- The best way to protect against most viral diseases lies in prevention, often by the use of vaccines.
- Personal hygiene also matters so effective ways to help prevent infection include washing your hands frequently, avoiding contact with sick individuals, and coughing and sneezing into a tissue or sleeve, not in your hands.
- Viral diseases cannot be treated with antibiotics. Some treatments include an antiviral medication that can help speed recovery from the virus.

Protection Against Viruses

- **ANTIBIOTICS DON'T WORK ON VIRUSES!!!**
- Vaccines:
  - Used as prevention. NOT A CURE!
  - Only useful against viruses that do not evolve (change) rapidly.
  - HIV, common cold viruses and flu virus- DNA mutates rapidly. Therefore No permanent vaccine can be created!

QUESTION AND ANSWER

How do bacteria and viruses cause diseases?

Why are emerging diseases particularly threatening to human health?

Emerging Diseases

- An unknown disease that appears in a population for the first time or a well-known disease that suddenly becomes harder to control is called an **emerging disease**.
  - Examples: MRSA, West Nile Virus, Ebola, Multi-drug Resistant Tuberculosis, E. coli, Cholera, Diptheria, SARS
- The pathogens that cause emerging diseases are particularly threatening to human health because human populations have little or no resistance to them, and because methods of control have yet to be developed.
- Unfortunately the short time between successive generations of these pathogens allows them to evolve rapidly, especially in response to human efforts to control them.
  - Changes in lifestyle and commerce have increased the possibility of the spread of diseases globally.
  - The widespread use of antibiotics has lead to the process of natural selection that favors the emergence of resistance to powerful drugs. Thus, "superbugs" are created. Example: bacteria resistance to penicillin.

Emerging Diseases

- Because viruses replicate so quickly, their genetic makeup can change rapidly, sometimes allowing a virus to jump from one host species to another.
  - Example: AIDS origination
- Some diseases are caused by prions.
  - Example: Scrapie in sheep
    - **Prions** are protein infectious particles
      - Prions are formed when a protein is improperly folded
      - An accumulation of prions can damage nerve cells.

Opportunistic Diseases

- An opportunistic disease is a disease that will most often make you sick given the "opportunity" of a damaged or weakened immune system (weakened because of AIDS, various forms of cancer or other causes).
  - Generally speaking, if you are exposed to an opportunistic disease, and you have a fully-functioning immune system, these illnesses will cause few, if any symptoms. If any symptoms are seen at all, they tend to be mild and of short duration. This is because a healthy immune system is able to successfully fight off the disease, or keep it under control.
  - Examples: cervical cancer and pneumonia

QUESTION AND ANSWER

Why are emerging diseases particularly threatening to human health?

Essential Question

Are all microbes that make us sick made of living cells?