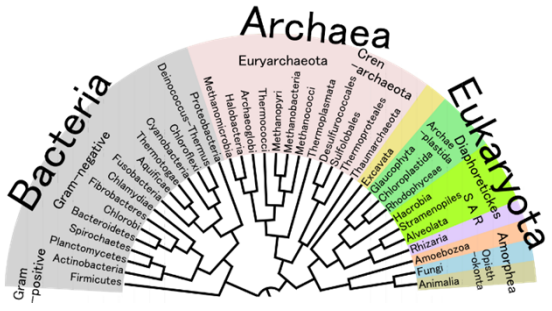
Prokaryotes

The current model of the evolution is that **the first organisms on Earth were some sort of prokaryotes**, which evolved out of protocells. The more structurally complex cells of the eukaryotes are thought to have evolved later. Some scientists have argued that the three domains of life arose simultaneously, from a set of cells that formed a single gene pool.



Most prokaryotes are unicellular organisms a few, like cyanobacteria, can create large colonies.

Cyanobacteria (Domain: Bacteria) are **aquatic and photosynthetic**. They have the distinction of being some of the oldest known fossils, more than 3.5 billion years old and are one of the most important groups of bacteria on earth.

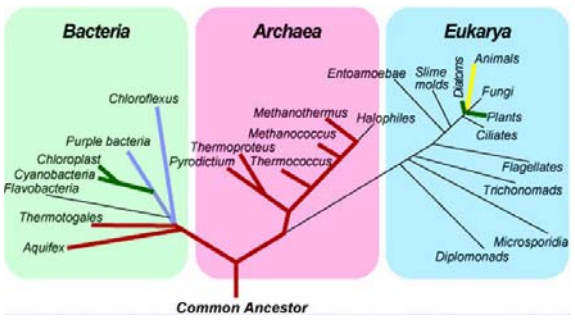
Cyanobacteria are responsible for the **oxygen atmosphere** that we depend on today as it was generated by numerous cyanobacteria during the Archaean and Proterozoic Eras.

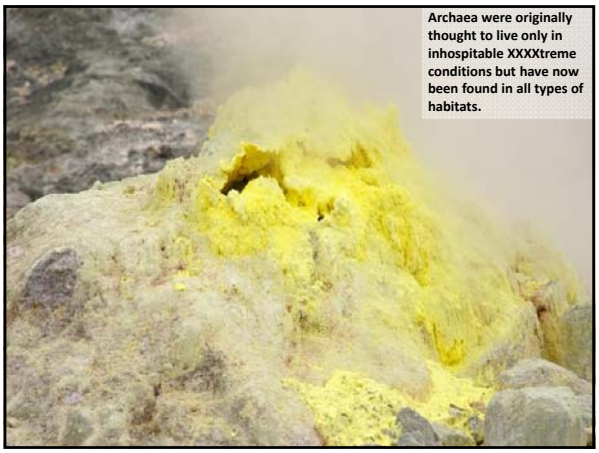
Prokaryotes do not have:

- a membrane around their nucleus
- mitochondria
- membrane-bound organelles

Prokaryotes make up two of the three domains of life:

- **the Bacteria**
- **the Archaea.**

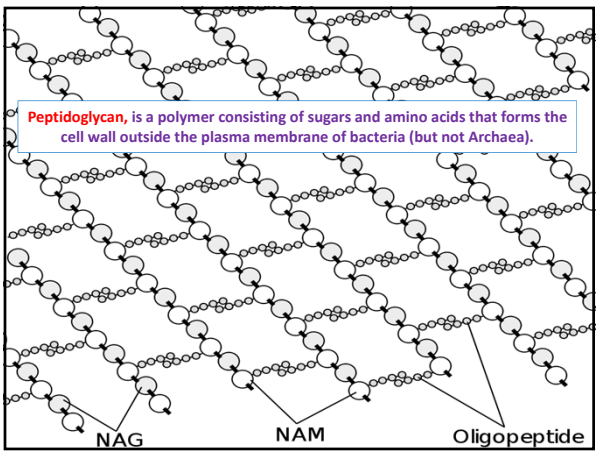




Archaea were originally thought to live only in inhospitable XXXXtreme conditions but have now been found in all types of habitats.

Most prokaryotes do have:

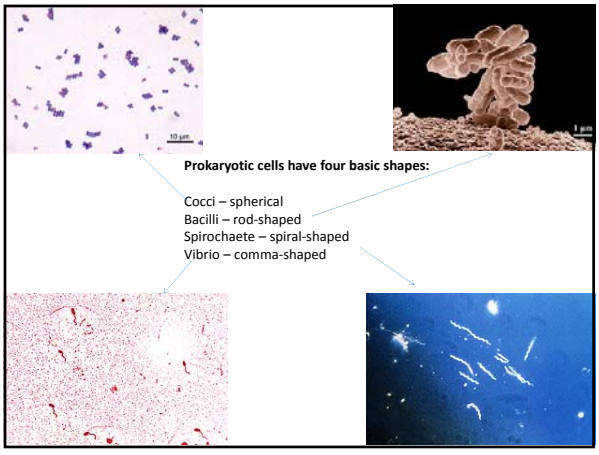
- A cell wall
- Ribosomes
- A single circular chromosome

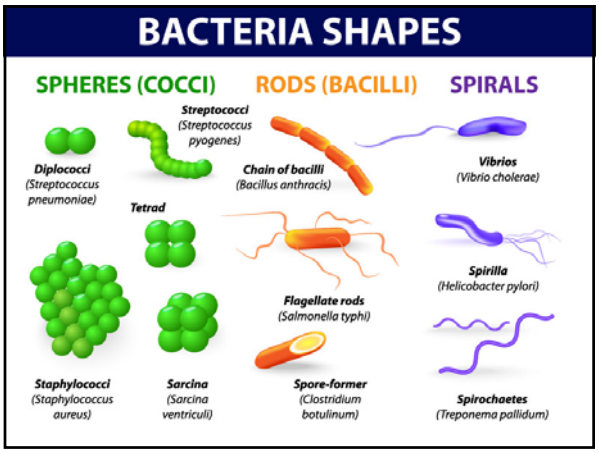


Peptidoglycan, is a polymer consisting of sugars and amino acids that forms the cell wall outside the plasma membrane of bacteria (but not Archaea).

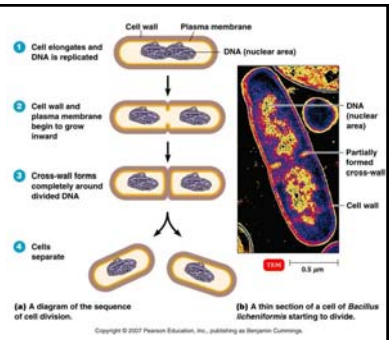
Comparing the Three Domains

Comparing the 3 Domains: Archaea with Bacteria and Eukaryotes			
Feature	**Bacteria**	**Archaea**	**Eukaryotes**
Type of Cell	Prokaryotic	Prokaryotic	Eukaryotic
Cell wall contains peptidoglycan?	Yes	No	No
Ribosomes	Yes	Yes	Yes
Reproduce via binary fission	Yes	Yes	No
Initial amino acid in translation	fMet	Met	Met

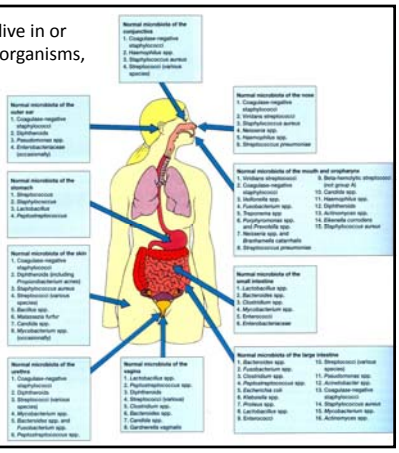


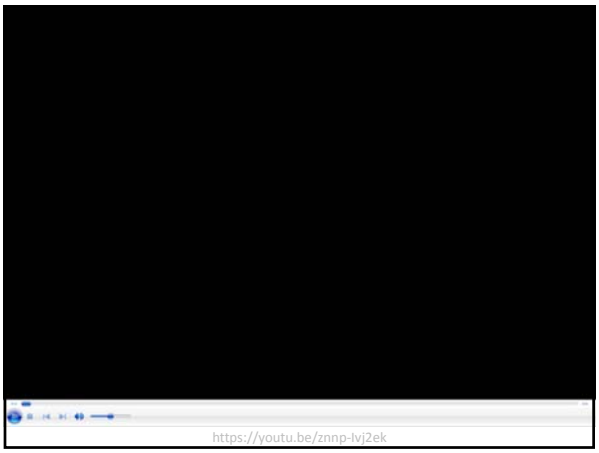


Prokaryotes reproduce through asexual reproduction usually by binary fission.



Symbiotic prokaryotes live in or on the bodies of other organisms, including humans.



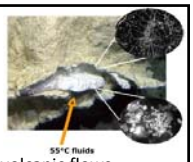


How do antibiotic-rich environments like hospitals speed up the rate at which superbugs increase their percentage of the bacteria population?

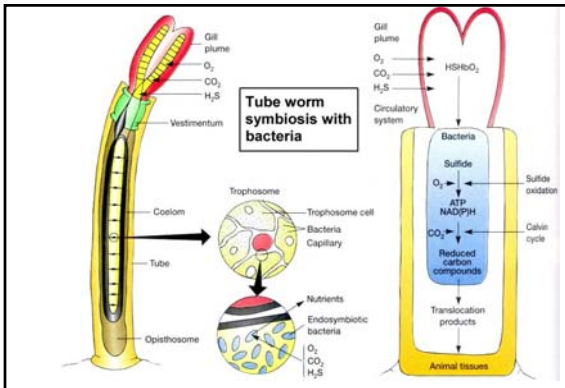
Archaea

- Archaea occur in a wide range of habitats, but are associated particularly with extreme environments, such as hot springs and salt lakes. Some of these bacteria have changed little since their ancestral forms first appeared on
- Earth over three billion years ago. Archaea are thought to retain features of the earliest living cells.

Hyperthermophilic Archaea ("extremely heat-loving")



- Found typically in and around hot springs or volcanic flows, where temperatures can exceed 100°C and there are high concentrations of sulfuric acid.
- Pyrodictium- Live in undersea volcanic vents that emit water (not steam) at temperatures over 100°C.
- Cells of Pyrodictium grow best at 105°C, and are attached to a mass of filaments composed of protein subunits, that anchor the bacteria to the substrate.



Tube worms carry bacteria in their blood which use O2 to oxidize H2S from the thermal vent. The oxidation of H2S releases energy, which is used to fix CO2 into body parts of the animal.

Hydrothermal vent communities exist because of Archaea (sometimes called Archaebacteria) converting chemical energy into organic energy

Archae don't just live in extreme environments.

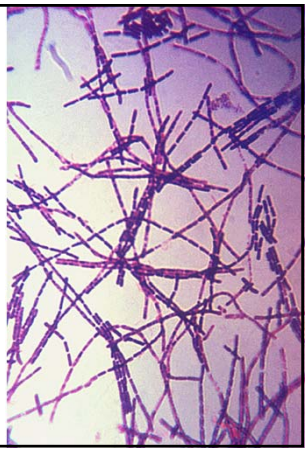
Some Archae are useful to humans

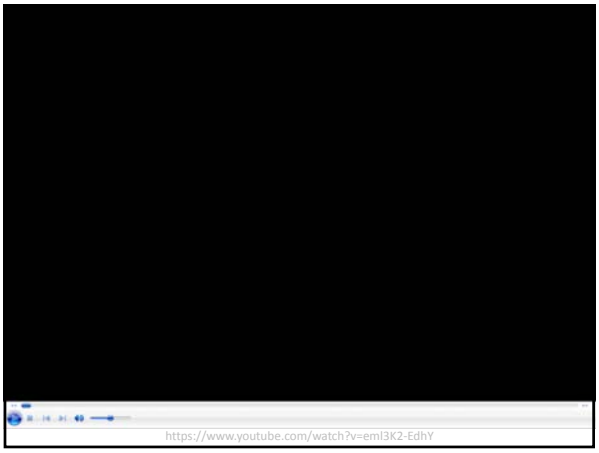
For example, methanogenic archaea live in anoxic sediments in marshes and are used in sewage treatment facilities.

Another archaean, Methanobrevibacter smithii, lives and generates methane in the human colon. (This allows the guys on the show Jackass to light their farts on fire)

Domain Bacteria

Bacteria are **unicellular** microorganisms. They are typically a few micrometers long and have **many shapes including spheres, rods, and spirals**. Bacteria are found in every habitat on Earth, growing in soil, hot springs, radioactive waste, seawater, and deep in the earth's crust.
Some bacteria can even survive in the extreme cold and vacuum of outer space.
There are typically 40 million bacterial cells in a gram of soil





How does the immune system protect the body from invasion?

A virus consists of a nucleic acid surrounded by a protein coat

Viruses are not cells

Depending on its type of nucleic acid, a virus is called a DNA virus or an RNA virus

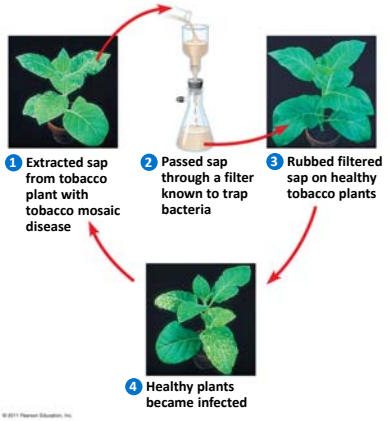
Viruses replicate only in host cells

Viruses are intracellular **parasites**

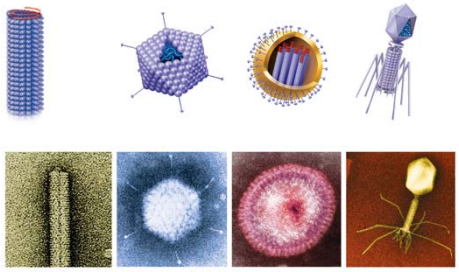
A virus is not alive

The Discovery of Viruses

- Tobacco mosaic disease stunts growth of tobacco plants and gives their leaves a blotchy pattern.
- In the late 1800s, researchers hypothesized that a particle smaller than bacteria caused the disease.
- In 1935, Wendell Stanley confirmed this hypothesis by crystallizing the infectious particle, now known as tobacco mosaic virus (TMV).



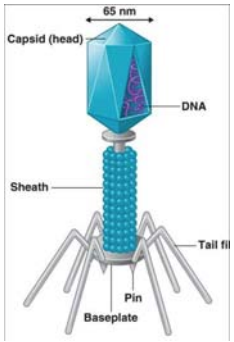
A capsid is the protein shell that encloses the viral genome



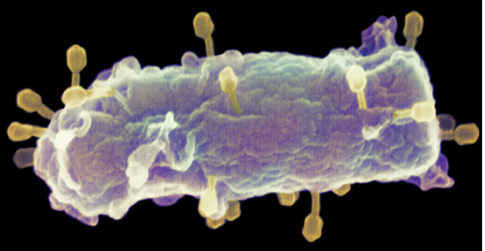
Bacteriophages, also called phages, are viruses that infect bacteria

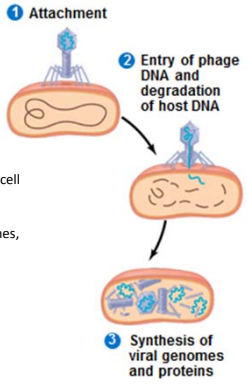
They have the most complex capsids found among viruses

Phages have an elongated capsid head that encloses their DNA



Bacteriophages can infect and take over bacteria, such as Escherichia coli

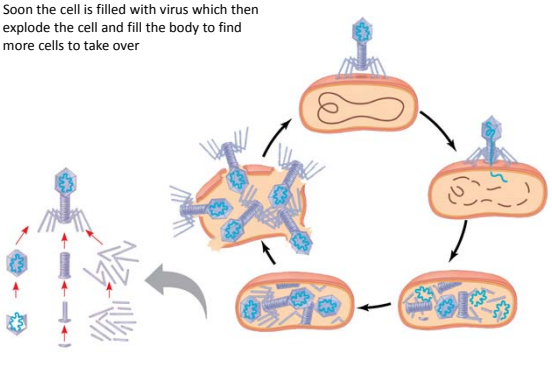




Once the viral genome has entered a cell, the cell begins to manufacture viral proteins

The virus makes use of host enzymes, ribosomes, tRNA, amino acids, ATP, and other molecules

Soon the cell is filled with virus which then explode the cell and fill the body to find more cells to take over



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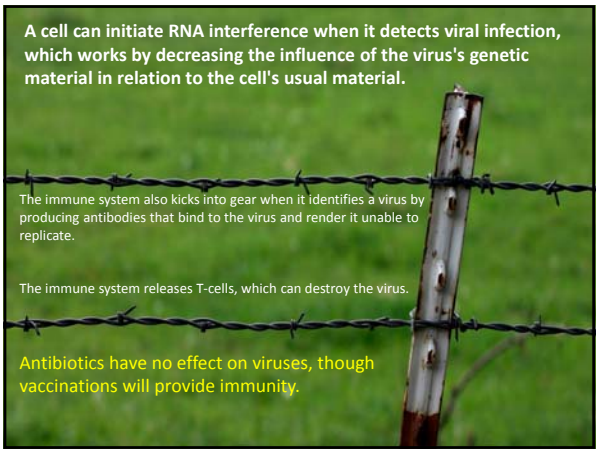
A cell can initiate RNA interference when it detects viral infection, which works by decreasing the influence of the virus's genetic material in relation to the cell's usual material.



The immune system also kicks into gear when it identifies a virus by producing antibodies that bind to the virus and render it unable to replicate.

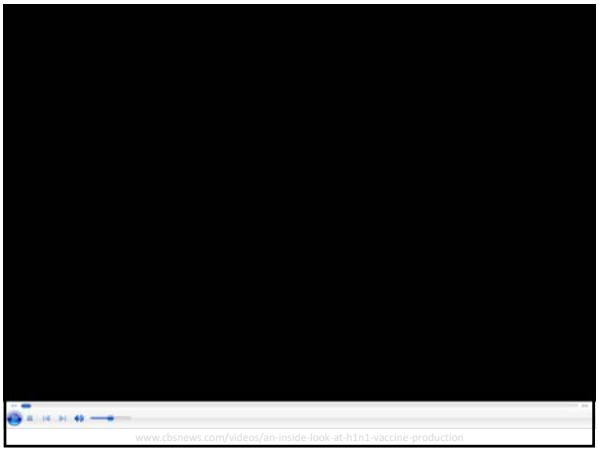
The immune system releases T-cells, which can destroy the virus.

Antibiotics have no effect on viruses, though vaccinations will provide immunity.

A vaccine is a biological preparation that improves immunity to a particular disease.

The vaccine stimulates the body's immune system to recognize the pathogen as foreign, destroy it, and keep a record of it, so that the **immune system can more easily recognize and destroy** any of these microorganisms that it later encounters.

Think getting the flu is no big deal?



Disease Name	Virus Type	Organs Affected	Transmission
• Influenza	RNA	Respiratory Tract	Droplets
• Adenovirus Infections	DNA	Lungs, Eyes	Droplets, Contact Droplets
• Respiratory Syncytial Disease	RNA	Respiratory Tract	Droplets
• Rhinovirus Infections	RNA	Upper Respiratory Tract	Droplets,Contact
• Herpes Simplex	DNA	Skin,Pharynx, Genital organs	Contact
• Chicken pox (Varicella)	DNA	Skin, Nervous System	Droplets, Contact
• Measles (Rubeola)	RNA	Respiratory Tract, Skin	Droplets, Contact
• German Measles (Rubella)	RNA	Skin	Droplets, Contact
• Mumps (Epidemic Parotitis)	RNA	Salivary Glands, Blood	Droplets
• Small Pox (Variola)	DNA	Skin, Blood	Contact, Droplets
• Warts Kawasaki Disease	DNA	Skin	?
• Yellow Fever	RNA	Liver, Blood	Mosquito (Aedes Aegypti)
• Dengue Fever	RNA	Blood, Muscles	Mosquito (Aedes Aegypti)
• Hepatitis A	RNA	Liver	Food, Water, Contact
• Hepatitis B	DNA	Liver	Contact with body Fluids
• NANB Hepatitis	RNA	Liver	Contact with body Fluids
• Viral Gastroenteritis	Many RNA Viruses	Intestine	Food, Water
• Viral Fevers	Many RNA Viruses	Blood	Contact,arthropods
• Cytomegalovirus Disease	DNA	Blood, Lungs	Contact, Congenital transfer
• AIDS	Retrovirus (RNA)	T-lymphocytes	Contact with body Fluids
• Rabies	RNA	Brain, Spinal cord	Conact with body Fluids
• Polio	RNA	Intestine,Brain, Spinal Cord	Food, Water, Contact
• Slow Virus Disease	Prions	Brain	?
• Arboviral Enephalitis	Many RNA viruses	Brain	Anthropods

Poliomyelitis (polio or infantile paralysis) is an acute, viral, infectious disease spread from person to person, primarily via the fecal-oral route.

First recognized in 1840 as a disease it wasn't until 1908 that the poliovirus was identified.

Major polio epidemics started to appear in the late 19th century and it became one of the most dreaded childhood diseases of the 20th century.

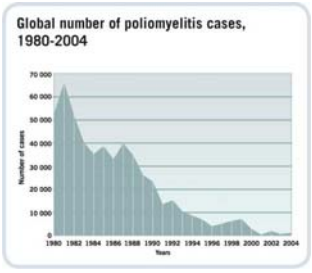
By 1910, much of the world experienced a dramatic increase in polio cases and epidemics became regular events, primarily in cities during the summer months.

These epidemics left thousands of children and adults paralyzed provided the impetus for a "Great Race" to develop a vaccine.

Two types of vaccine are used throughout the world to combat polio. Both types induce immunity to polio, efficiently blocking person-to-person transmission of wild poliovirus, thereby protecting both individual vaccine recipients and the wider community (so-called herd immunity).

The inactivated virus vaccine was developed in 1952 by Jonas Salk at the University of Pittsburgh, and announced to the world on 12 April 1955.

The Salk vaccine, or inactivated poliovirus vaccine (IPV), is based on poliovirus grown in a type of monkey kidney tissue culture (vero cell line), which is chemically inactivated with formalin. After two doses of IPV (given by injection), 90% or more of individuals develop protective antibody to all three serotypes of poliovirus, and at least 99% are immune to poliovirus following three doses.



The Los Angeles Times
May 29, 2008 Jenny Jarvie

Dianne Odell, 61, exceeded expectations after polio paralyzed her at 3. This was not her first power outage.

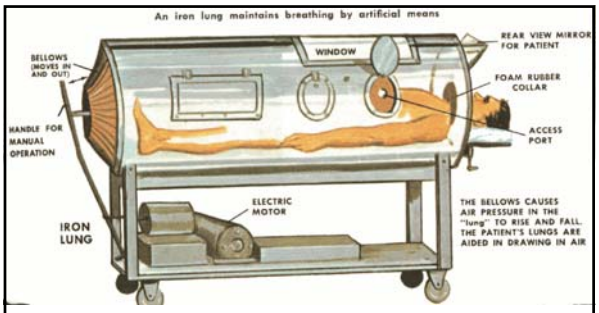
ATLANTA — For the first time in more than half a century, the Odell residence is quiet.

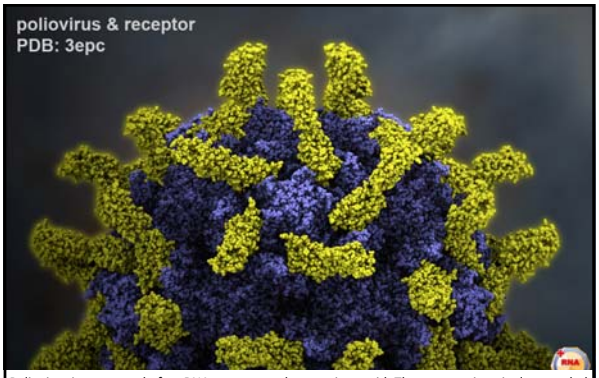
There are no squeaks and pops from the electric motor that powered an "iron lung" pumping air in and out of Dianne Odell's body. A thunderstorm knocked out the power to her home Wednesday, shutting off the massive metal machine that had helped her breathe for nearly 60 years.

It was about 3 a.m. when the electricity went out at Odell's home in Jackson, a small Tennessee town about 90 miles northeast of Memphis. An emergency generator did not start, and Odell died as her father and brother-in-law took turns pumping the iron lung manually.

Dianne Odell, 61, was believed to be the nation's oldest survivor of polio to have spent almost all of her life inside an iron lung. She had been confined within the 7-foot-long, 750-pound machine ever since she was paralyzed at the age of 3 by bulbospinal polio. That was in 1950, just a few years before a polio vaccine was discovered.

Her parents, Freeman and Geneva Odell, were determined to care for her at home, even though her entire body was encased in a cylindrical metal chamber. Only her head extended outside of it.





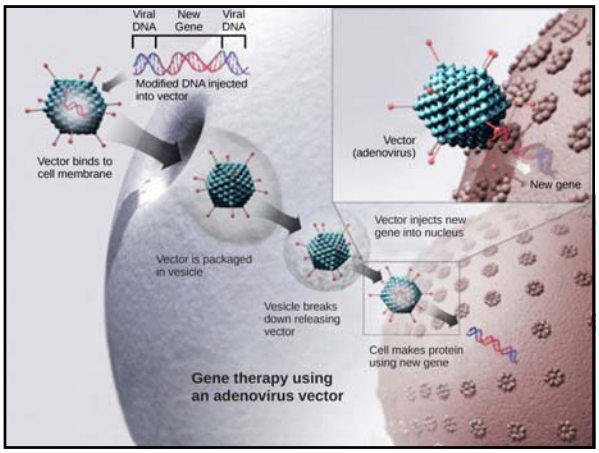
Poliovirus is composed of an RNA genome and a protein capsid. The genome is a single-stranded positive-sense RNA genome that is about 7500 nucleotides long. Because of its short genome and its simple composition—only RNA and a non-enveloped icosahedral protein coat that encapsulates it—poliovirus is widely regarded as the simplest significant virus.

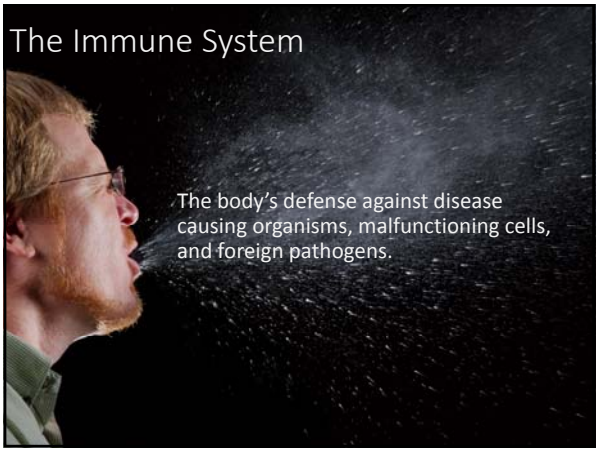
Viruses are not just used for evil.

Viruses are the vectors of choice for inserting new genes into animal cells.

When the virus reproduces within the animal cell, it also reproduces the foreign gene that it carries. The gene is therefore cloned.

Biotechnology refers to technology used to manipulate DNA and often referred to as genetic engineering.





One key development that changed the nature of human diseases was the beginning of farming and herding about 10,000 years ago. When humans began to keep large herds of domesticated animals, such as cattle and sheep, **they were exposed to the pathogens of these animals.** Some of these pathogens apparently began infecting humans. Measles, tuberculosis, smallpox, influenza, and pertussis (whooping cough) are among the diseases that appear to have been transmitted to humans from domesticated animals.

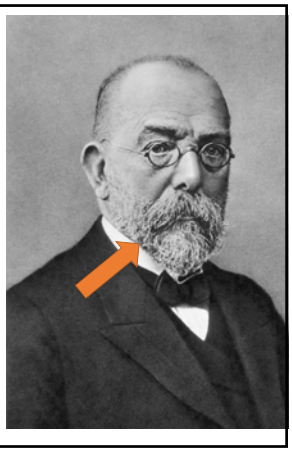
Robert Koch (1843-1910), a German physician, was the first scientist to establish a step-by-step procedure for identifying the particular pathogen responsible for a disease.

In the 1870s, Koch was studying anthrax, a disease of cattle that can spread to humans.

Koch observed that cattle with anthrax had bacteria in their blood.

He hypothesized that these bacteria caused anthrax.

As a result of his groundbreaking research on tuberculosis, Koch received the Nobel Prize in Medicine in 1905.

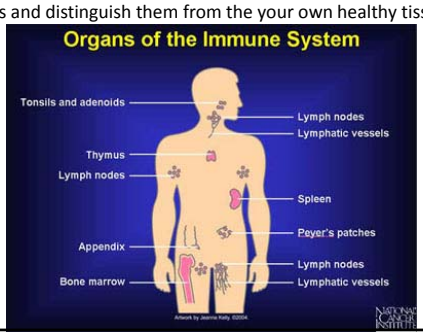


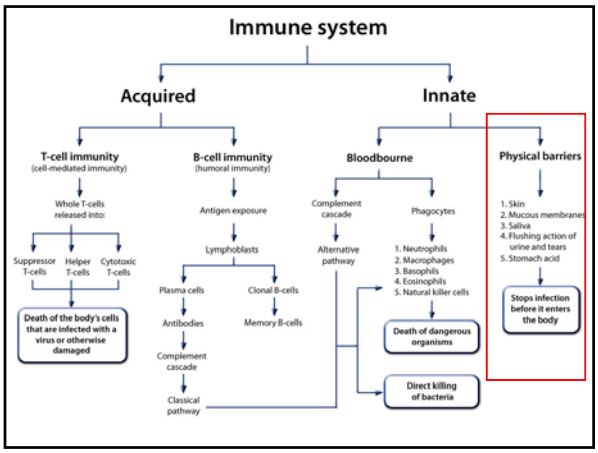
Koch's postulates are the following:

1. The microorganism must be found in abundance in all organisms suffering from the disease, but should not be found in healthy organisms.
2. The microorganism must be isolated from a diseased organism and grown in pure culture.
3. The cultured microorganism should cause disease when introduced into a healthy organism.
4. The microorganism must be reisolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent.

The immune system is a system of biological structures and processes within an organism that protects against disease.

To function properly, an immune system must detect a wide variety of pathogens and distinguish them from the your own healthy tissue.





First line of defense – surface defenses

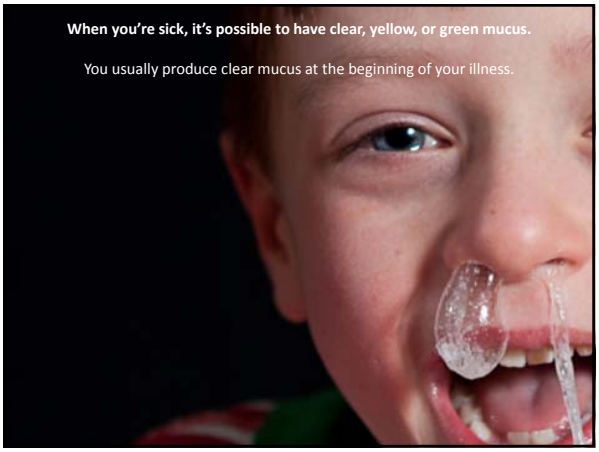
Skin is a Barrier to Infection

- The dead, outer layer of skin, known as the **epidermis forms a shield** against invaders and secretes chemicals that kill potential invaders
- You shed between 40 – 50 thousand skin cells every day.

Your mouth, nose, throat, sinuses and lungs are lined with mucus membranes.

These membranes contain mucus glands that produce mucus.

Mucus is a mixture of water, sugars and proteins and its job is to be a slippery, gooey liquid.

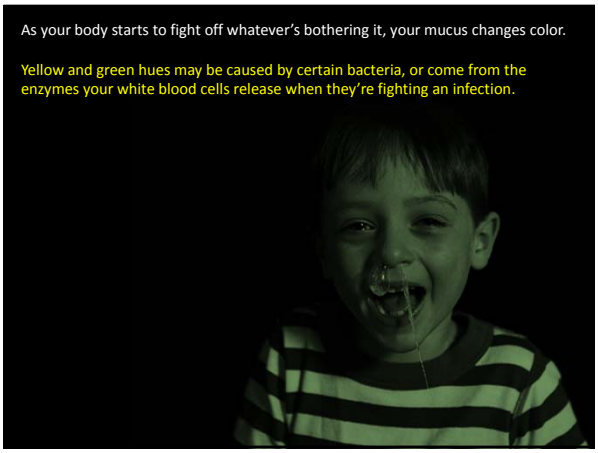


When you're sick, it's possible to have clear, yellow, or green mucus.

You usually produce clear mucus at the beginning of your illness.

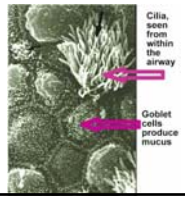
As your body starts to fight off whatever's bothering it, your mucus changes color.

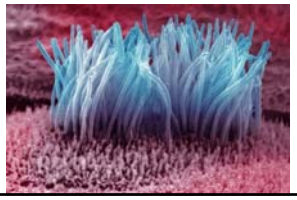
Yellow and green hues may be caused by certain bacteria, or come from the enzymes your white blood cells release when they're fighting an infection.



The mucus that's produced in your respiratory tract has 3 important jobs:

1. **MUCUS PROTECTS.** Mucus moistens and warms inhaled air and keeps the mucus membrane cells and the little hairs called "cilia" lubricated. Cilia help to remove inhaled particles that have gotten trapped by the mucus layer covering the cilia.
2. **MUCUS ACTS AS A BARRIER.** Mucus traps inhaled particles (like dust, allergens, bacteria, or viruses) and keeps them from getting deeper into your lungs. The cilia transport the mucus layer toward your throat, where it could either get spit out or swallowed.
3. **MUCUS DEFENDS YOUR BODY.** Mucus contains antibodies, enzymes, and proteins that work to help get rid of whatever's in the air you've inhaled that could make you sick.





Second line of defense – internal defenses

THE INFLAMMATORY RESPONSE

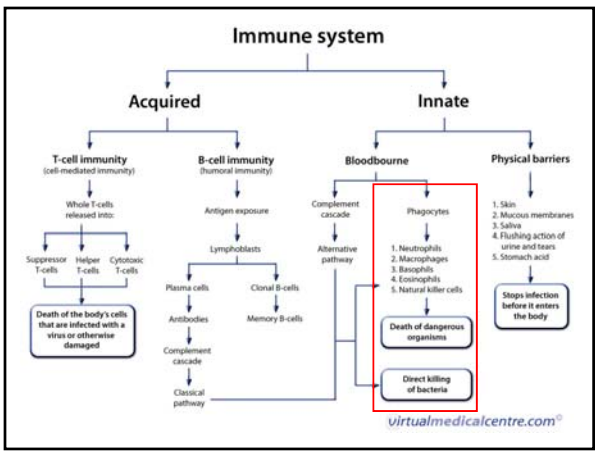
Whenever an injury occurs, such as a cut or a splinter, some damaged cells release the chemical histamine . Histamine increases blood flow to the injured area and increases the permeability of the surrounding capillaries.
As a result, fluids and white blood cells pass through capillary walls to the injured area.

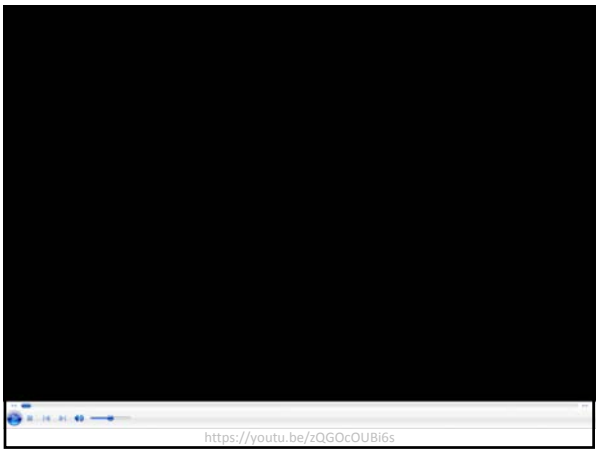
The changes caused by histamine result in redness, swelling, warmth, and pain- the familiar symptoms of inflammation.

Fever

Fever is an elevation in body temperature above the normal 37°C (98.6°F).

- Fever is not a disease; it is a sign that the body is responding to an infection. Some pathogens trigger fever, as do chemical signals released by macrophages.
- Research suggests that a moderate fever stimulates the body's defense mechanisms.
- Fever suppresses the growth of some bacteria and may promote the action of white blood cells.

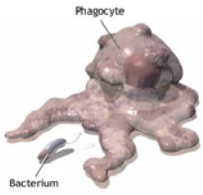



https://youtu.be/zQGOcOUBi6s

Phagocytes – macrophages, neutrophils, mast cells, eosinophils

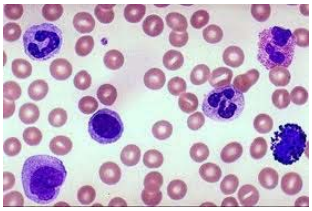
White Blood Cells

- White blood cells are responsible for eating foreign particles by engulfing them
- Once engulfed, the phagocyte breaks the foreign particles apart using lysosomes



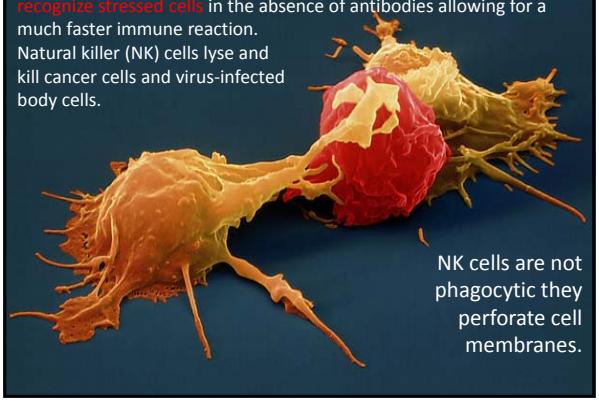
White Blood Cells

- If pathogens get inside the body, then your white blood cells begin their attack



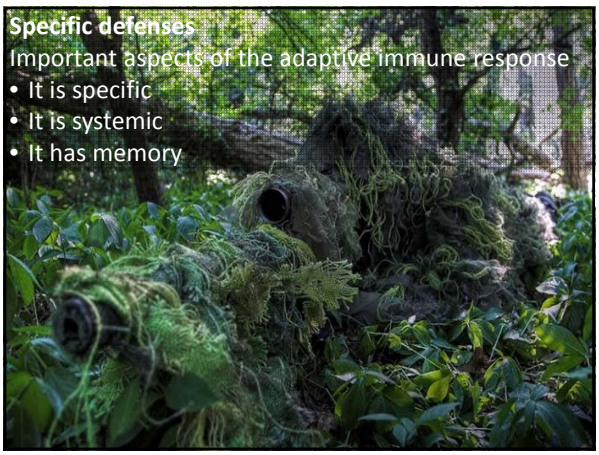
Leukocytes (white blood cells) normally circulate throughout the blood, but will enter the body's tissues if invaders are detected

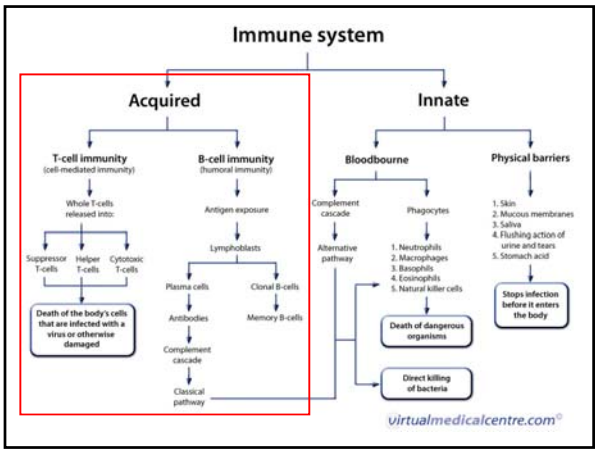
Natural Killer Cells (NK cells) are unique as they have the ability to recognize stressed cells in the absence of antibodies allowing for a much faster immune reaction.
Natural killer (NK) cells lyse and kill cancer cells and virus-infected body cells.



NK cells are not phagocytic they perforate cell membranes.

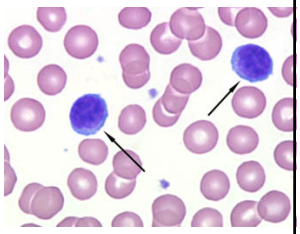
Specific defenses
Important aspects of the adaptive immune response
- It is specific
- It is systemic
- It has memory





RECOGNIZING PATHOGENS

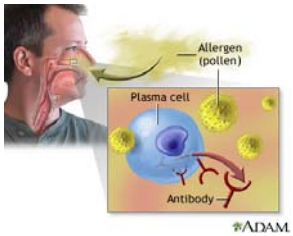
Lymphocytes are the body's specific defenses.



Lymphocytes attack pathogens via an immune response to eliminate the pathogen.

In order to respond lymphocytes must be able to distinguish foreign invaders from the cells of the body.

RECOGNIZING PATHOGENS

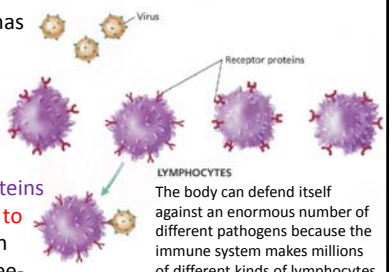


Any substance that provokes an immune response is known as an **antigen.**

Antigens can be: pathogens or parts of pathogens, bacterial toxins, insect venom, and pollen.

Every lymphocyte has receptor proteins scattered over the surface of its cell membrane.

These receptor proteins recognize and bind to antigens that match their particular three-dimensional shape.

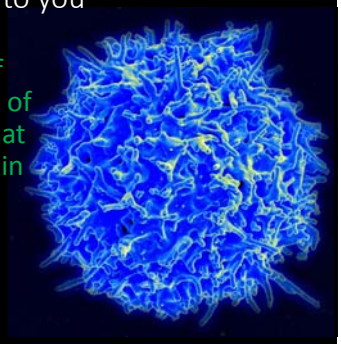


LYMPHOCYTES

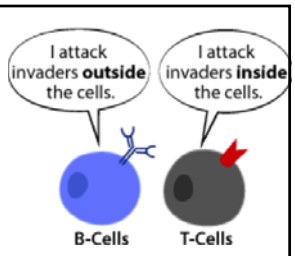
The body can defend itself against an enormous number of different pathogens because the immune system makes millions of different kinds of lymphocytes

White Blood Cells
That's Mr. T-Cells to you

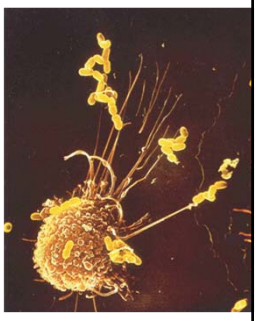
T cells are a type of lymphocyte (a type of white blood cell) that plays a central role in cell-mediated immunity.



- T cells (thymus cells) are often called killer T-cells, recognize infected human cells and cancer cells and kill them.
- Provide cell-mediated immunity



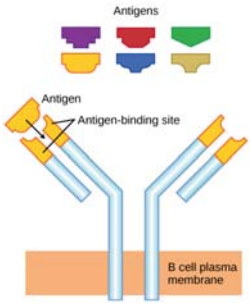
Antibody Production

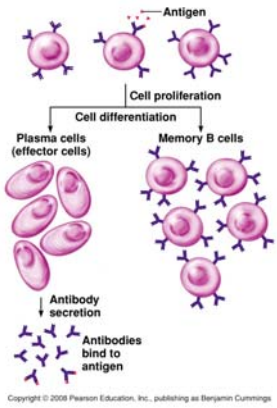


- After they phagocytize the foreign particles and break them down they show the pieces to the T-cells, who identify the pieces and find specific B-cells (bone marrow derived cells) to help
- B-cells produce antibodies that are equipped to find that specific piece on a new particle and attach.
- Humoral Immunity (antibody-mediated)

Synthesized exclusively by B cells, antibodies are produced in billions of forms, each with a different different antigen-binding site.

Collectively called immunoglobulins they are among the most abundant protein components in the blood, about 20% of the total protein in plasma by weight.





Memory Cells

If your body fights a virus once, the same virus will probably try to attack again. An amazing feature of your immune system is that it remembers the infections it has fought. This makes it much easier to fight the same virus or bacteria a second, or third, or fourth time.

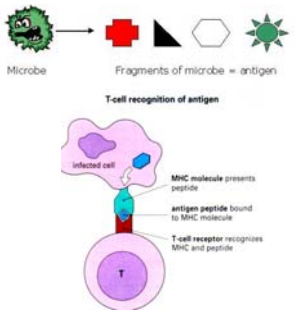
A Memory Cell never forgets

Towards the end of each battle to stop an infection, some T-cells and B-cells turn into Memory T-cells and **Memory B-cells**. These cells live in the body for a long time, even after all the viruses from the first infection have been destroyed.

They stay in the ready-mode to quickly recognize and attack any returning virus or bacteria.

Specific immunity

- Specificity: based on shape recognition of cell surface antigens
- Diversity: Any shape can be recognized by a B or T-lymphocyte and trigger an immune reaction
- Memory: once a pathogen has activated the immune system, memory cells remain and will protect against a secondary infection
- Self-tolerance: the immune system does not attack itself



Cell-Mediated Immune Response

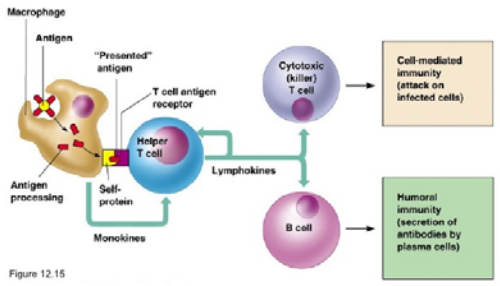


Figure 12.15

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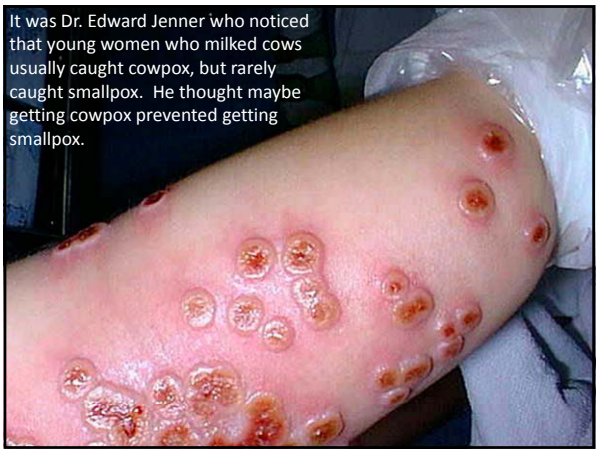
Slide 12.43

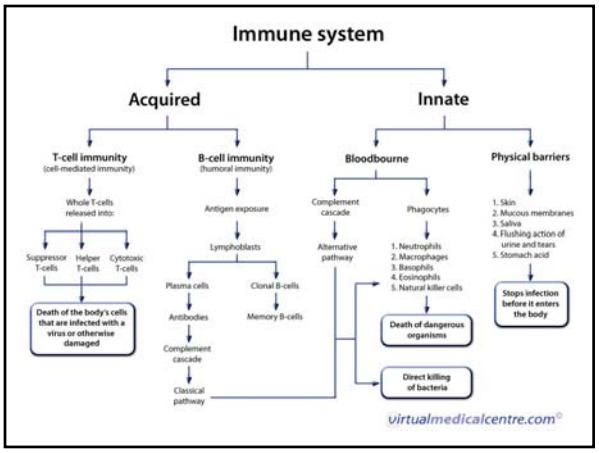
The first successful vaccine was against smallpox in 1796.

It was Dr. Edward Jenner who noticed that young women who milked cows usually caught cowpox, but rarely caught smallpox. He thought maybe getting cowpox prevented getting smallpox.



To test his idea, Dr. Jenner tried infecting people with cowpox on purpose, and then exposed them to smallpox.

He didn't know exactly how it worked, but we now know that cowpox and smallpox have **antigens** with similar shapes.

This means that Memory Cells to fight cowpox can also fight smallpox.

Because vacca means cow in Latin, Dr. Jenner called this type of disease prevention vaccination. It has been so successful that since 1979 there have been no smallpox infections.