Unit 3: Cells

Ms. Randall

Essential Questions:

- What role does the cell membrane play in cell communication?
- Why is cancer a disease that can affect any living organism? Why is it so difficult to cure?

Unit Objectives:

- Relate structure to function for the components of animal cells.
- Explain the role of cell membranes as a highly selective barrier (passive & active).
- Explain the relationship between mutation, cell cycle, and uncontrolled cell growth potentially resulting in cancer

Unit Vocabulary:

Cell theory
Cell membrane
Nucleus
Vacuole
Ribosomes
Cytoplasm
Transport (active and passive)
Mitochondria
Prokaryote
Eukaryote
Cell
Diffusion
Osmosis
Respiration
ATP(energy)
Aerobic respiration

Lesson 1: Cells and their Organelles

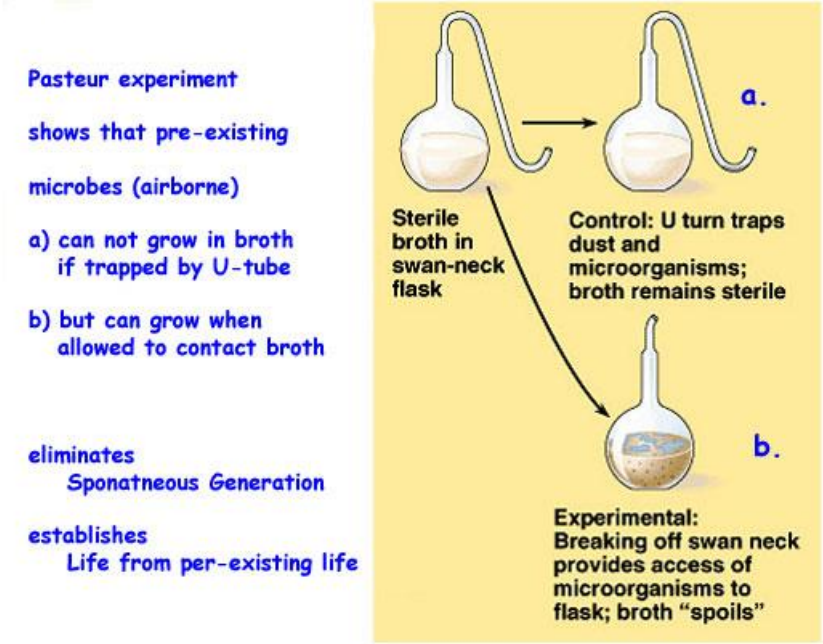
Objective:

- To describe the role of the microscope and early experiments to cell theory
- To compare and contrast the function of cell organelles

The improvement of the microscope and microscopic techniques in the last four centuries has allowed scientists to observe cells better and develop the cell theory.

History of the Cell

1665-Robert Hooke-described a cork cell through one of the first microscopes
1674-Anton Van Leewenhoek-Observed tiny organisms in drops of pond water through his simple microscope.
1831- Robert Brown-Noticed a small round structure inside a plant cell and named it the nucleus.
1838-Matthias Schleiden-Concluded that all plants are made up of cells.
1839-Theodor Schwann- Concluded that all animals are made up of cells.
1855- Rudolph Virchow-Proposed that all cells come from existing cells, completing the cell theory.
1862- Louis Pasteur-Proved Virchow's theory with a famous experiment…
1970-Lynn Margulis-Proposed that certain organelles, tiny structures within the cell, were once free-living cells themselves.



Modern Cell Theory-

1. The cell is the unit of structure and function in living things. All livings things are made up of cells

2. All cells arise from preexisting cells.

3. The cells of all living things carry on similar chemical activities.

4. All cells carry on their metabolic activities in organelles.

Exceptions to the Cell Theory:

1. Viruses are not made up of cells. They do contain genetic material. Viruses reproduce inside another cell called a host cell.

2. The first cell could not have arisen from a previously existing cell. Scientists do not know the origin (beginning) of the first cell.

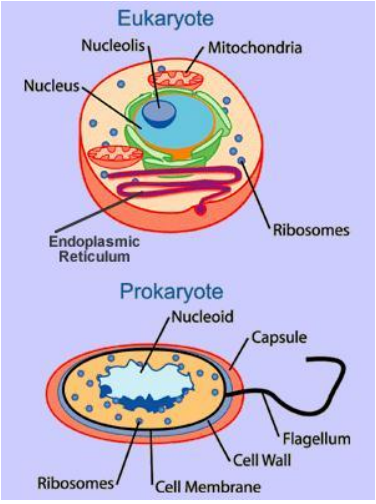
Two Types of Cells

Prokaryotes:

- Have genetic material NOT contained in a nucleus.
- May contain less complex internal membranes
  Example: Bacteria

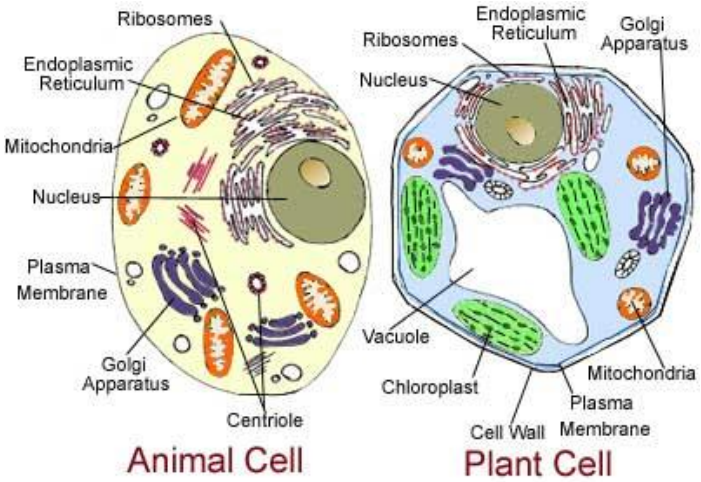
Eukaryotes:

- Contain a nucleus with genetic material inside
- Can make up single cellular or multicellular organisms
  Example: Plants, animals, fungi, and protists



Taking a look inside a cell

Have you ever wondered what the inside of a cell looks like? If you think about the rooms in our homes, the inside of any animal or plant cell has many similar room-like structures called organelles. Both plant and animal cells have many of the same organelles. In some cases, like plant cells, there are more types of organelles than are found in animal cells. All organelles in a cell perform different functions. Here are some names and descriptions of organelles commonly found in cells.



A. **Nucleus**

- cellular control center
- contains hereditary material (DNA in chromosomes)
- self-duplicating structure--divides when the cell divides

B. **Nuclear membrane**

- Surrounds nucleus allowing certain materials to enter and leave

C. **Nucleolus**

- Round organelle in the nucleus--usually a pair
- Involved with the synthesis of RNA in the ribosomes.

D. **Ribosomes**

- Sites of protein synthesis in the cytoplasm
- May be free in the cytoplasm or attached to the endoplasmic reticulum

E. **Endoplasmic reticulum**

- Cytoplasm channels from the cell membrane to the nuclear membrane
- Associated with the storage, synthesis, and transport of materials within the cell

F. **Cytoplasm (protoplasm)**

- Fluid like material between the cell membrane and the nucleus
- Over 80 % water
- Site of most organelles and cellular chemical reactions

G. **Vacuole**

- Membrane bound cytoplasmic spaces containing materials

  Two Types:
  - Food vacuole--store and digest ingested food
  - Contractile vacuole-pumps excess water from cells maintaining homeostasis

H. L**ysosome**

- Pouch containing digestive enzymes
- Digest bacteria and some foods entering the cell
- Important in the work of some white blood cells
- Breakdown worn out cell organelles

I. **Mitochondrion**

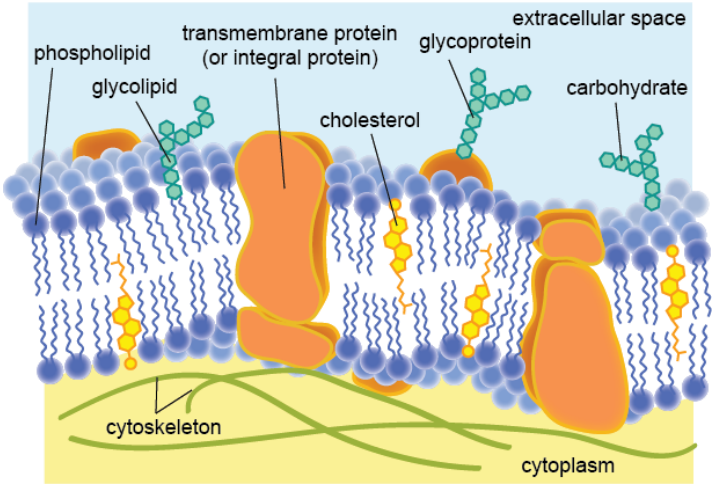
- "Powerhouse of the cell"
- Carries on cellular respiration (contains respiratory enzymes that make ATP) (energy molecule)
- May contain DNA--is self-duplicating-- divides when the cell divides
- found in greater nos. in active cells

J. Golgi Body (apparatus)

- Usually located near the nucleus
- Synthesizes, packages, and secretes cellular products

K**. Plasma (cell) membrane**

- Surrounds the cell
- Is semi-permeable--selectively regulates the flow of materials to and from the cell--thus maintaining chemical homeostasis within the cell
- Consists of two layers of fat or lipid--an outer and an inner layer--and an inner layer of protein with globular proteins found throughout the "Fat sandwich"
- Transport through the plasma membrane likely occurs through these globular proteins (Fluid mosaic model)



L. **Cytoskeleton**

- Network of protein filaments
- Maintains cell shape
- Involved in cellular and cytoplasmic movement

M. **Centriole**

- a cylindrical structure found in the cytoplasm which appears to function during the division of certain animal cells (usually near the nucleus)

Lesson 2: Cell Processes

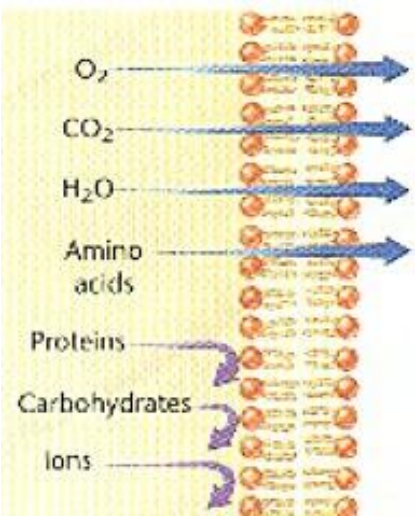
Objective:

- To describe how materials enter or leave a cell
- To describe the process in which cells make energy

Cell Transport

In a way a cell is like a miniature version of you. It requires nutrients and, in the process of breaking down the nutrients, the cell produces wastes. So there has to be a way to get nutrients in and wastes out. This process in cells is called **cell transport**

The organelle responsible for cellular transport is the **plasma membrane.**



The **plasma membrane** is a **selectively-permeable lipid bi-layer** with embedded **proteins**. It has **receptors** that act like doormen only allowing certain things to enter. The shape of the molecule must fit the shape of the receptor similar to how an enzyme fits its substrate (remember lock and key???) Molecules that are **small can pass** between the lipid bi-layers. Molecules that are too **big must pass through a protein** channel or cannot enter at all. Molecules will easily move in a direction of high concentration to low concentration requiring no energy. For example, most people will easily move from a crowded elevator to an empty hallway. But to move in the opposite direction requires energy. Nobody wants to be in a crowded elevator! **Passive Transport** is the movement of molecules through the cell membrane without using cellular energy. **Active Transport** is the movement of molecules through the cell membrane using cellular energy.

There are two types of Passive Transport. **Diffusion** is the movement of particles from an area of higher concentration to lower concentration. Molecules move when there is a **concentration gradient**, a difference in concentration across the membrane. Once molecules have equalized on both sides of the membrane there is a **Dynamic Equilibrium**. Changes within a system occur in order to keep a balanced state.

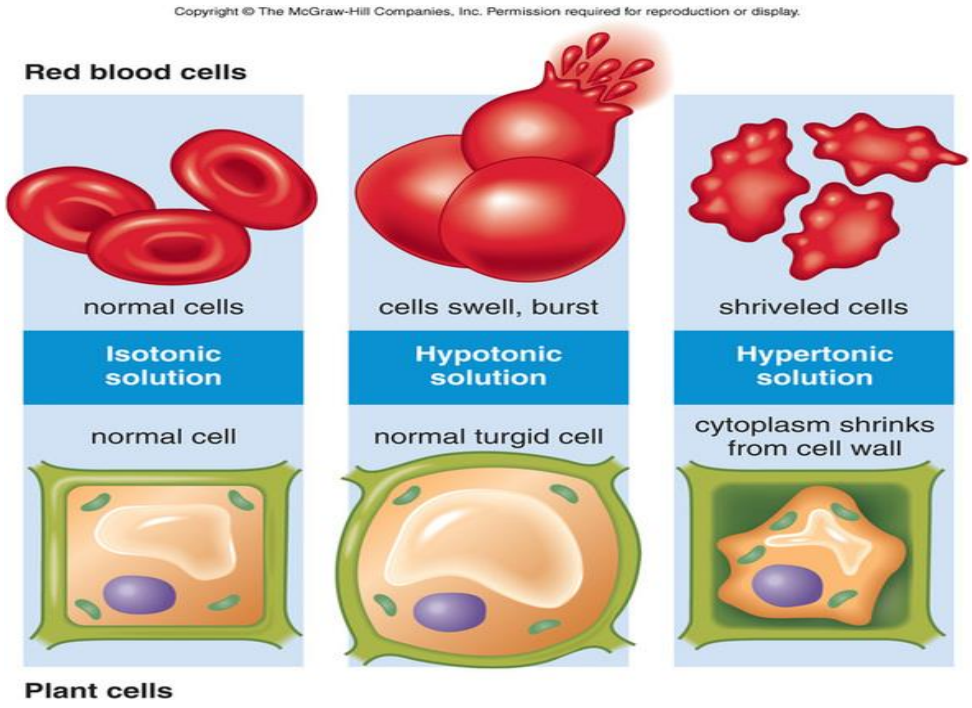
Osmosis is the diffusion of water across a selectively permeable membrane. Water goes through the membrane from a high concentration of water molecules to a lower concentration of water molecules. When the concentration of dissolved substances outside the cell is the same as inside the cell we have an **isotonic solution**. A **Hypertonic solution** exists when the concentration of dissolved substances outside the cell is

higher than inside the cell. When the concentration of dissolved substances outside the cell is less than inside the cell it is called a **hypotonic solution**.

OSMOSIS OCCURS IN RESPONSE TO THE CONCENTRATION OF SOLUTES DISSOLVED IN WATER.

- **SOLUTES ARE DISSOLVED SUBSTANCES IN A SOLUTION**. Cytoplasm (jelly-like substance in the cell) is mostly water containing many dissolved solutes.
- Because no TWO Molecules can occupy the same space at the same time, the more Solutes there are in a certain volume of Water, The FEWER Water Molecules there can be in the same volume.
- Solutions with many Solutes contain FEWER Water Molecules than do solutions with fewer solutes.
- Water will cross the Membrane toward the Higher Solute Concentration until the Concentration Gradients of BOTH WATER and SOLUTES EVEN OUT.
- The Net Direction of Osmosis DEPENDS on the Relative Concentration of Solutes on the TWO Sides of the Cell Membrane.

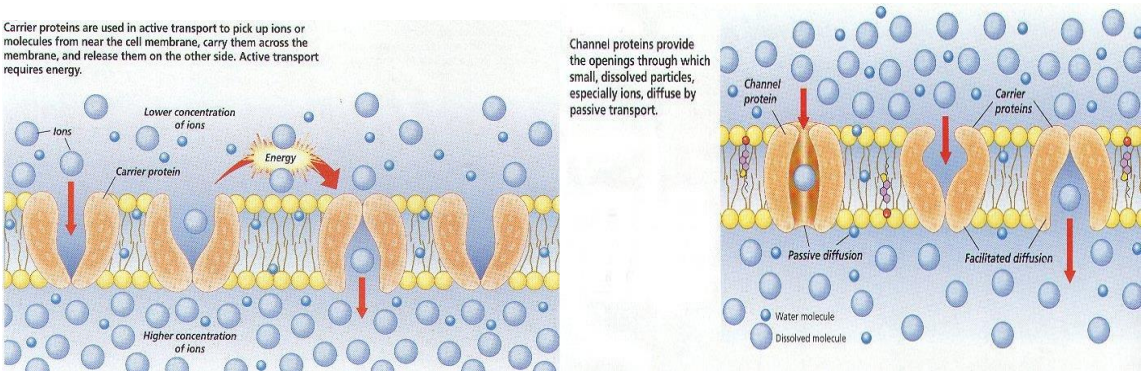
What Happens to the Cell? If the cell loses too much water, the cell will shrivel and shrink.
The flow of water into a cell causes it to swell. Animal cells placed in distilled water will swell and often burst because of Osmosis. The bursting of cells is called **CYTOLYSIS**. (sie-TAHL-uh-suhs). In a **solution** , where THE CONCENTRATION OF SOLUTES OUTSIDE AND INSIDE THE CELL ARE **EQUAL**, water will diffuse into and out of the Cell at EQUAL RATES so there is no net movement of Water



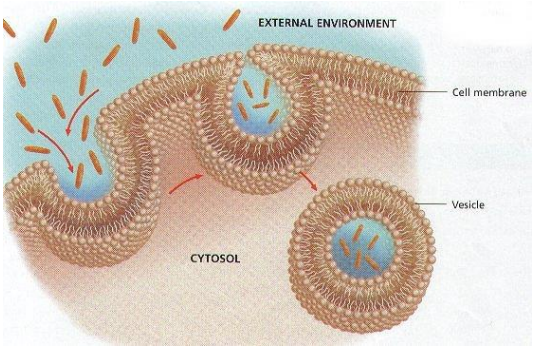
There are other forms of Passive transport. **Channel proteins** form channels for molecules to move down their concentration gradient. **Carrier proteins** change shape to allow a substance to pass through the plasma membrane. These are called **facilitated diffusion**.

Active transport on the other hand is the movement of materials through a membrane against a concentration gradient. This allows for the transport of larger molecules, groups of molecules or whole cells. The energy

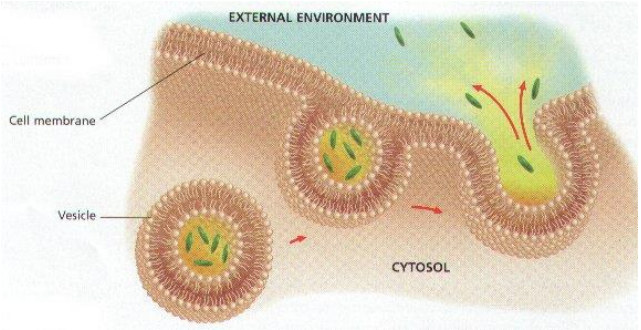
comes in the form of a molecule called **Adenosine Triphosphate (ATP)**. It is a high energy molecule produced in the mitochondria during cellular respiration.



Endocytosis occurs when a cell surrounds material and takes it in. **Pinocytosis** is the transport of solutes or fluids while **Phagocytosis** is the transport of large particles, whole cells.



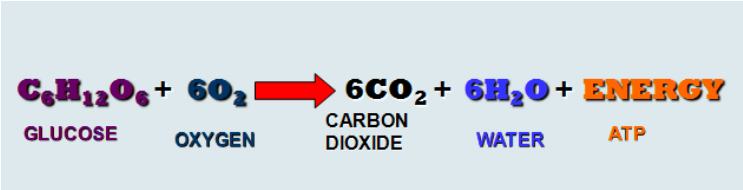
Exocytosis occurs when there is a secretion or expulsion of materials from a cell.

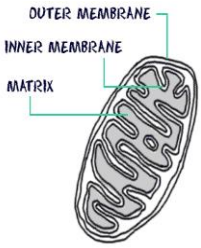


Cells and Energy

Mitochondria are known as the powerhouses of the cell. They are **organelles** that takes in nutrients, break them down, and creates energy for the cell. The process of creating cell energy is known as **cellular respiration.** Most of the chemical reactions involved in cellular respiration happen in the mitochondria. A mitochondrion is shaped perfectly to maximize its efforts.

Organisms, such as plants and algae, can trap the energy in sunlight through photosynthesis and store it in the chemical bonds of carbohydrate molecules. The principal carbohydrate formed through photosynthesis is **glucose**. Other types of organisms, such as animals, fungi, protozoa, and a large portion of the bacteria, are unable to perform this process. Therefore, these organisms must rely on the carbohydrates formed in plants to obtain the energy necessary for their metabolic processes. This means they must eat plants and other animals in order to gain energy.

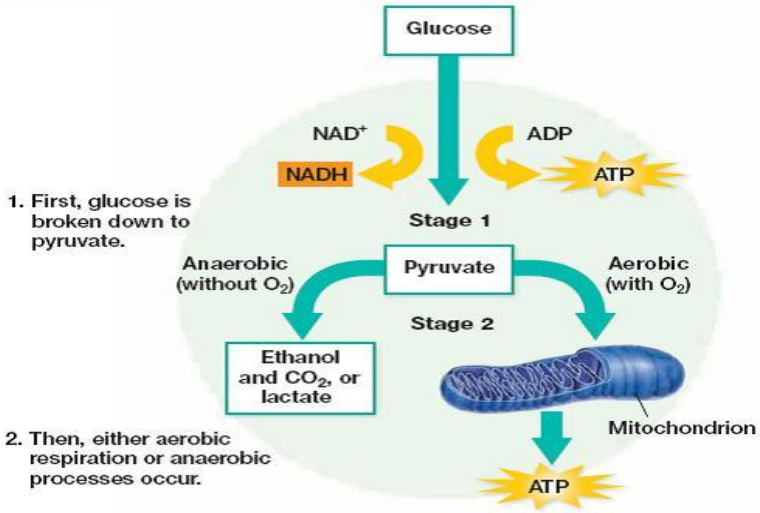




Cells take the carbohydrates into their cytoplasm, and through a complex series of metabolic processes, they break down the carbohydrates and release the energy. It is an **aerobic process**, meaning that it requires the presence of **oxygen** (O_2). In the process of cellular respiration, oxygen gas is required to serve as an acceptor of electrons. This oxygen is identical to the oxygen gas given off during photosynthesis.

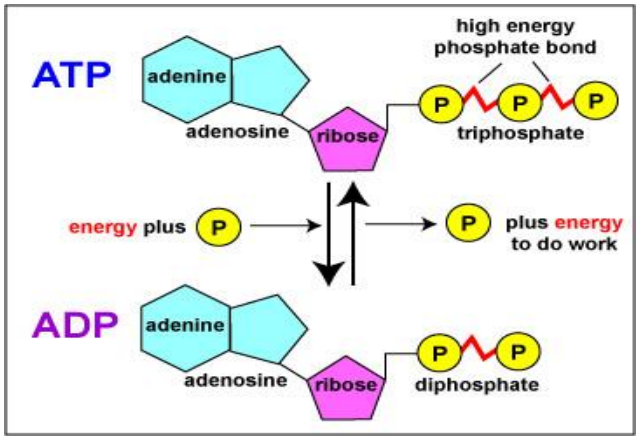
The energy is generally not needed immediately; rather it is used to combine adenosine diphosphate (ADP) with another phosphate to form **adenosine triphosphate (ATP) molecules**. A net gain of about 36 molecules is made as 2 are used to start the process. The **ATP** can then be used for processes in the cells that require energy, much as a battery powers a mechanical device. During the process of cellular respiration, carbon dioxide is given off. Plant cells can use this carbon dioxide during photosynthesis to form new carbohydrates.

When oxygen is not present a process called **fermentation** occurs. It is an **anaerobic process** meaning it occurs in the absence of oxygen (O_2). Lactic acid is a product of anaerobic respiration in muscle cells. Yeast creates alcohol and carbon dioxide in this process. It is less efficient since it only nets 2 ATP



How Do We Get Energy From ATP?

By breaking the bonds between the last two phosphates in ATP the cell release energy that can be used for life functions. All living things need energy to carry out life processes so all living things have mitochondria to make energy including plants!!!!

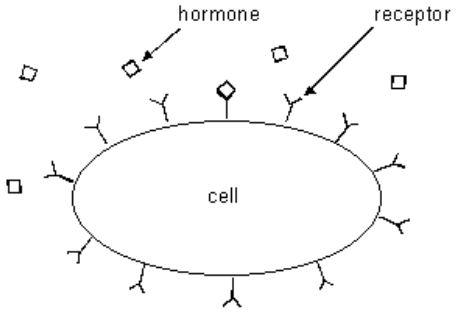


Lesson 3: Cellular Communication

Objective:

- To describe the role of receptors in cellular communication.

In order to respond to changes in their immediate environment, cells must be able to receive and process **signals** that originate outside their borders. Individual cells often receive many signals simultaneously, and they then integrate the information they receive into a unified action plan. But cells aren't just targets. They also send out messages to other cells both near and far.

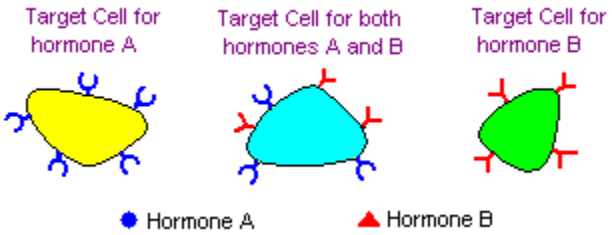


What Kind of Signals Do Cells Receive?

Most cell signals are **chemical in nature**. For example, prokaryotic organisms have sensors that detect nutrients and help them navigate toward food sources. In multicellular organisms, growth factors, hormones, neurotransmitters, and extracellular matrix components are some of the many types of chemical signals cells use. These substances can exert their effects locally, or they might travel over long distances. For instance, **neurotransmitters** are a class of short-range signaling molecules that travel across the tiny spaces between adjacent neurons or between neurons and muscle cells. Other signaling molecules must move much farther to reach their targets. One example is follicle-stimulating hormone, which travels from the mammalian brain to the ovary, where it triggers egg release.

How Do Cells Recognize Signals?

Cells have **proteins** called **receptors** that bind to signaling molecules and initiate a physiological response. Different receptors are **specific** for different molecules. Dopamine receptors bind dopamine, insulin receptors bind insulin, and nerve growth factor receptors bind nerve growth factor, and so on. In fact, there are hundreds of receptor types found in cells, and varying cell types have different populations of receptors. Receptors can also respond directly to light or pressure, which makes cells sensitive to events in the atmosphere.



Cell receptors can be blocked by a molecule or drug that permanently or temporarily binds the receptor. This is how many pain medicnes and cancer medicines work.

Lesson 4: Cell Reproduction

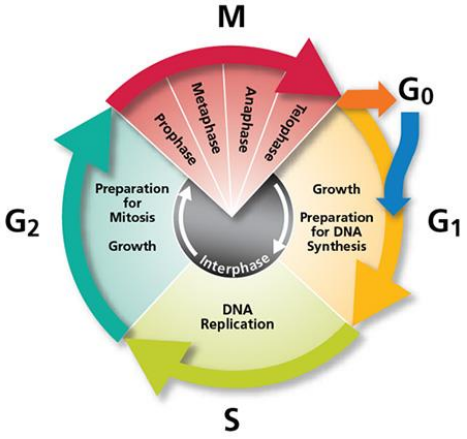
***Objective*:**

- To define the process in which cells create new cells.

When Do Cells Divide? Cells can only reach a certain size and then they must divide to form new cells. Cell membranes help determine cell size because it has to be large enough to obtain all the nutrients it needs. The larger a cell then the harder it is to transport nutrients. When a cell reaches its maximum size then it has to start dividing. **Growth** results from cells dividing and creating new cells. **Repair** occurs when cells regenerate by dividing and making new ones.
Cells get old and die and new cells must replace them. Organisms grow bigger and must make new cells.

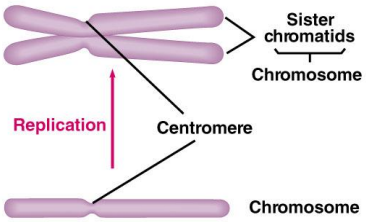
How do cells divide?

The **Cell Cycle** is the time it takes from one cell division to the next. The process in which cells make identical copies of themselves is called **Mitosis.** It takes place in a number of steps.



1. Interphase- in between division, it looks like a cell is resting but it's not, during this time chromosomes replicate.

   a. Replication- when material copies itself
   b. Chromatin- the form that DNA is in during interphase.
   c. Sister chromatids- two identical chromatids that are formed during replication
   d. Centromere- point where the sister chromatids attach to each other.



Chromosome replication

B. Cell Division- Mitosis- the process when a cell's nucleus divides

1. Prophase- chromatids condense (become smaller) so they can be seen, also spindle fibers start to form.
    a. Spindle fibers- bridges of proteins that form across the cell, this is where the chromosomes attach.
2. Metaphase- all the sister chromatids line up in the center of the cell

3. Anaphase- the chromatids split and ½ goes to one pole and the other ½ move to the other end.
4. Telophase- opposite of prophase the new nuclei are formed, the spindle is now gone.
5. Cytokinesis (after mitosis) - membranes fold inward until the 2 separate and there are 2 cells.

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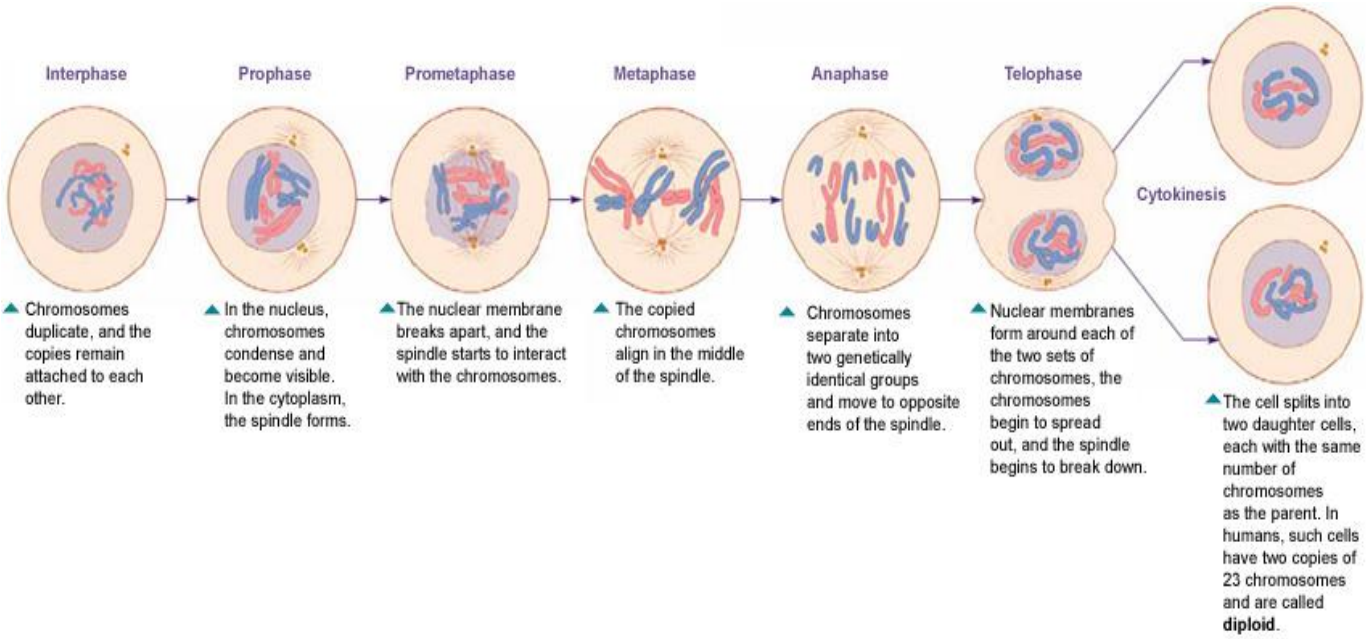
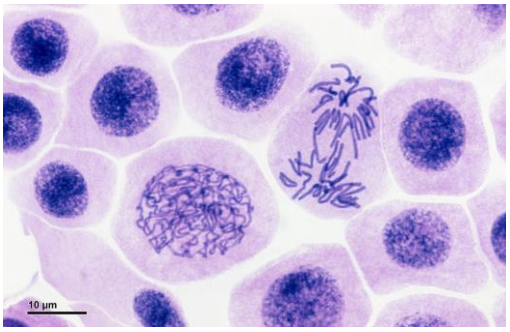




Cells do not live forever, and they will reach a point where they will divide through mitosis, or die through a process called **apoptosis**. Cancer cells are the exception; these cells do not die and divide uncontrollably as they crowd out healthy, productive cells. Cancer can have many causes, but most are thought to be related to **carcinogens** in the environment. Carcinogens are chemicals that can damage DNA and interfere with a cell's normal cycle, thus disrupting the cells ability to control when and how often it divides.

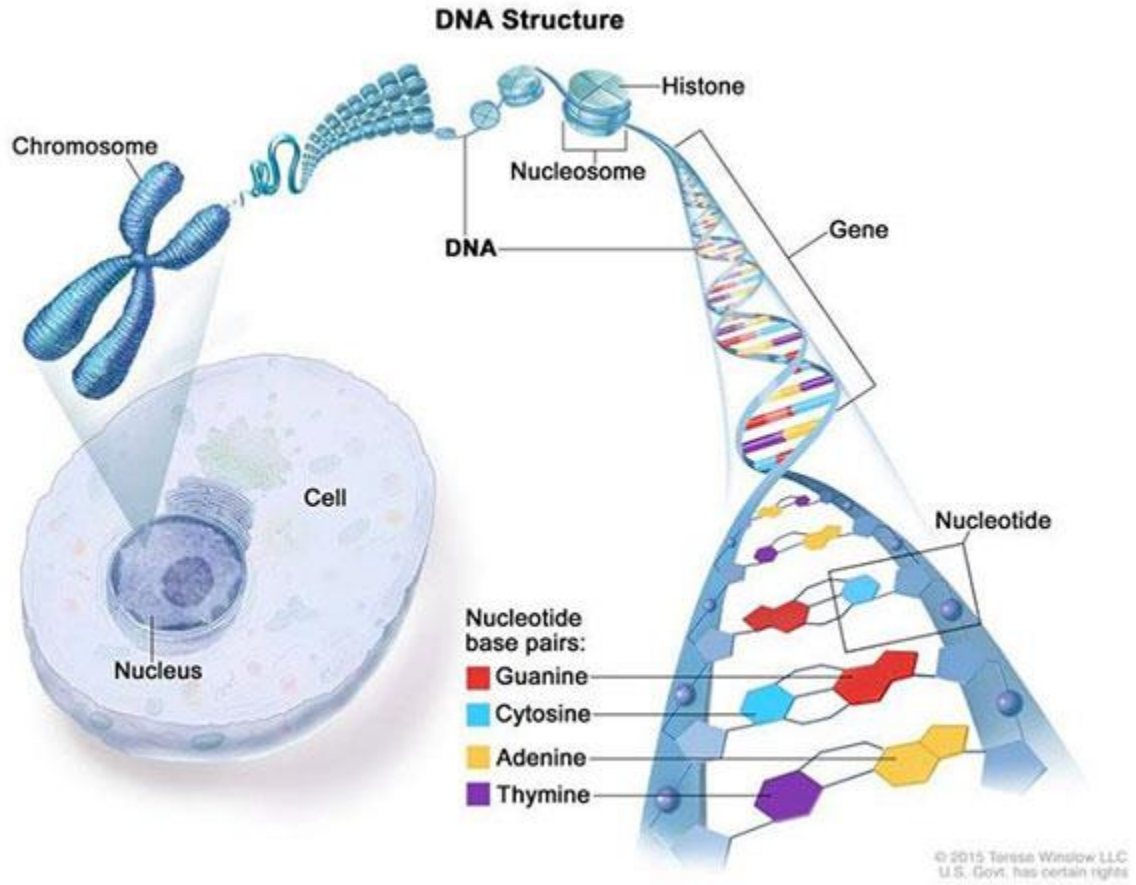
Cancer Cells

Cancer is the name given to a collection of related diseases. In all types of cancer, some of the body's cells begin to divide without stopping and spread into surrounding tissues. Cancer can start almost anywhere in the human body, which is made up of trillions of cells. Normally, human cells grow and divide to form new cells as the body needs them. When cells grow old or become damaged, they die, and new cells take their place.
When cancer develops, however, this orderly process breaks down. As cells become more and more abnormal, old or damaged cells survive when they should die, and new cells form when they are not needed. These extra cells can divide without stopping and may form growths called **tumors**. Many cancers form solid tumors, which are masses of tissue. Cancers of the blood, such as leukemia, generally do not form solid tumors.
Cancerous tumors are **malignant,** which means they can spread into, or invade, nearby tissues. In addition, as these tumors grow, some cancer cells can break off and travel to distant places in the body through the blood or the lymph system and form new tumors far from the original tumor. Unlike malignant tumors, benign tumors do not spread into, or invade, nearby tissues. Benign tumors can sometimes be quite large, however. When removed, they usually don't grow back, whereas malignant tumors sometimes do. Unlike most benign tumors elsewhere in the body, benign brain tumors can be life threatening.

Differences between Cancer Cells and Normal Cells

Cancer cells differ from normal cells in many ways that allow them to grow out of control and become **invasive**. One important difference is that cancer cells are less specialized than normal cells. That is, whereas normal cells mature into very distinct cell types with specific functions, cancer cells do not. This is one reason that, unlike normal cells, cancer cells continue to divide without stopping. In addition, cancer cells are able to ignore signals that normally tell cells to stop dividing or that begin a process known as programmed cell death, or apoptosis, which the body uses to get rid of unneeded cells. Cancer cells may be able to influence the normal cells, molecules, and blood vessels that surround and feed a tumor—an area known as the microenvironment. For instance, cancer cells can induce nearby normal cells to form blood vessels that supply tumors with oxygen and nutrients, which they need to grow. These blood vessels also remove waste products from tumors.
Cancer cells are also often able to evade the **immune system**, a network of organs, tissues, and specialized cells that protects the body from infections and other conditions. Although the immune system normally removes damaged or abnormal cells from the body, some cancer cells are able to "hide" from the immune system. Tumors can also use the immune system to stay alive and grow. For example, with the help of certain immune system cells that normally prevent a runaway immune response, cancer cells can actually keep the immune system from killing cancer cells.

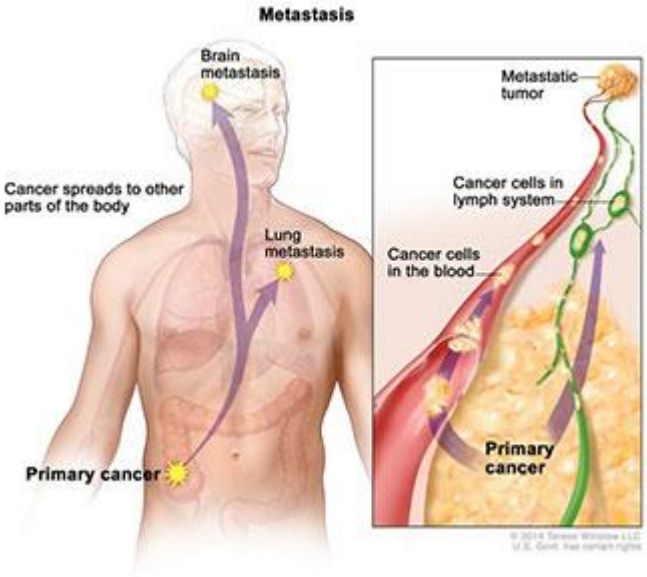
How Cancer Arises



Cancer is caused by certain changes to genes, the basic physical units of inheritance. Genes are arranged in long strands of tightly packed DNA called chromosomes.
Credit: Terese Winslow

Cancer is a genetic disease—that is, it is caused by changes to genes that control the way our cells function, especially how they grow and divide. Genetic changes that cause cancer can be inherited from our parents. They can also arise during a person's lifetime as a result of errors that occur as cells divide or because of damage to DNA caused by certain environmental exposures. Cancer-causing environmental exposures include substances, such as the chemicals in tobacco smoke, and radiation, such as ultraviolet rays from the sun.
Each person's cancer has a unique combination of genetic changes. As the cancer continues to grow, additional changes will occur. Even within the same tumor, different cells may have different genetic changes.
In general, cancer cells have more genetic changes, such as mutations in DNA, than normal cells. Some of these changes may have nothing to do with the cancer; they may be the result of the cancer, rather than its cause.

When Cancer Spreads



In metastasis, cancer cells break away from where they first formed (primary cancer), travel through the blood or lymph system, and form new tumors (metastatic tumors) in other parts of the body. The metastatic tumor is the same type of cancer as the primary tumor.

A cancer that has spread from the place where it first started to another place in the body is called **metastatic cancer.** The process by which cancer cells spread to other parts of the body is called **metastasis.**
Metastatic cancer has the same name and the same type of cancer cells as the original, or primary, cancer. For example, breast cancer that spreads to and forms a metastatic tumor in the lung is metastatic breast cancer, not lung cancer. Under a microscope, metastatic cancer cells generally look the same as cells of the original cancer. Moreover, metastatic cancer cells and cells of the original cancer usually have some molecular features in common, such as the presence of specific chromosome changes. Treatment may help prolong the lives of some people with metastatic cancer. In general, though, the primary goal of treatments for metastatic cancer is to control the growth of the cancer or to relieve symptoms caused by it. Metastatic tumors can cause severe damage to how the body functions, and most people who die of cancer die of metastatic disease.

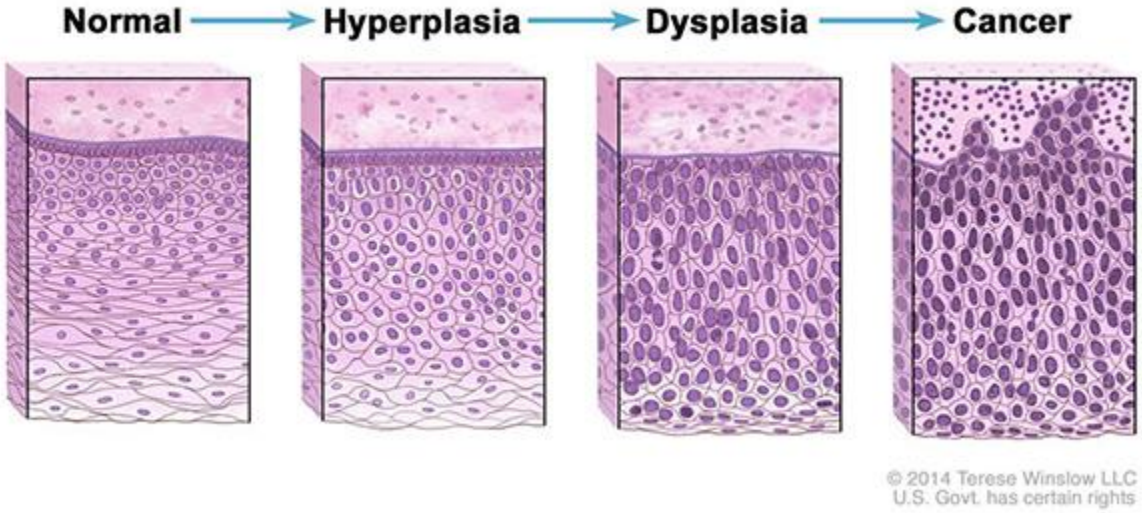
Tissue Changes that Are Not Cancer

Not every change in the body's tissues is cancer. Some tissue changes may develop into cancer if they are not treated, however. Here are some examples of tissue changes that are not cancer but, in some cases, are monitored:

Hyperplasia occurs when cells within a tissue divide faster than normal and extra cells build up, or **proliferate**. However, the cells and the way the tissue is organized look normal under a microscope. Hyperplasia can be caused by several factors or conditions, including chronic irritation.

Dysplasia is a more serious condition than hyperplasia. In dysplasia, there is also a buildup of extra cells. But the cells look abnormal and there are changes in how the tissue is organized. In general, the more abnormal the cells and tissue look, the greater the chance that cancer will form. Some types of dysplasia may need to be monitored or treated. An example of dysplasia is an abnormal mole (called a dysplastic nevus) that forms on the skin. A dysplastic nevus can turn into melanoma, although most do not.

An even more serious condition is **carcinoma in situ**. Although it is sometimes called cancer, carcinoma in situ is not cancer because the abnormal cells do not spread beyond the original tissue. That is, they do not invade nearby tissue the way that cancer cells do. But, because some carcinomas in situ may become cancer, they are usually treated.



Normal cells may become cancer cells. Before cancer cells form in tissues of the body, the cells go through abnormal changes called hyperplasia and dysplasia. In hyperplasia, there is an increase in the number of cells in an organ or tissue that appear normal under a microscope. In dysplasia, the cells look abnormal under a microscope but are not cancer. Hyperplasia and dysplasia may or may not become cancer.