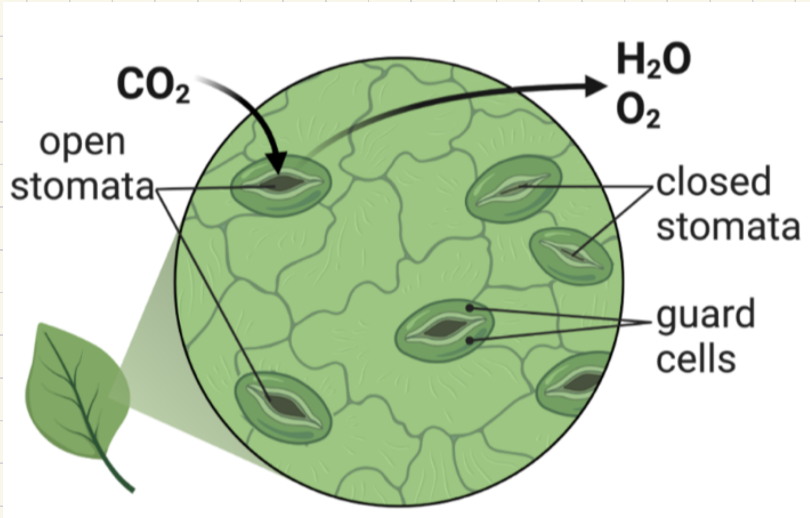
- Sunlight causes stomata to open, allowing CO2 to enter the leaves for photosynthesis. Stomata also open in response to decreased CO2 levels in leaf tissues.
- At the same time, plants monitor their internal water status. When water levels drop too low, the plant hormone abscisic acid (ABA) signals the stomata to close.

Plants can open and close their stomata to varying degrees as they balance the competing priorities of gas exchange and water retention. In fact, plants are constantly monitoring and adjusting for this balance—even a passing cloud can affect stomatal opening and the rate of transpiration!



Example #3: Regulation of breathing

Humans have some control over breathing—we can hold our breath or breathe deeply when we want to. However, most of the time, breathing is controlled by involuntary mechanisms. For example, certain mechanisms keep us breathing while we sleep or increase our breathing rate during exercise. Breathing allows O2 to enter and CO2 to exit the body. This is important because cells use O2 to generate usable energy for the body, and they produce CO2 as a by-product. A person's breathing rate is directly related to how much energy the body is using at any given time. So, if energy usage increases (such as during exercise), the breathing rate must also increase. This relationship between energy generation and breathing is controlled through negative feedback loops:

- As a person exercises, CO2 builds up in the blood. This causes the pH of the blood and the fluid surrounding the brain to decrease (become more acidic). more CO_2, blood becomes more acidic
- Sensory neurons associated with blood vessels and the brain detect this change in pH. They signal to the control center of the brain that regulates breathing—the medulla oblongata—to initiate a response.
- The medulla oblongata signals the muscles involved in breathing to increase the rate and depth of the breath. This accelerated breathing expels CO2 more rapidly from the body, helping to reduce its concentration in the blood and return blood pH to its set point.

medulla oblongata → part of a brain that regulates breathing

Example #4: Regulation of water balance

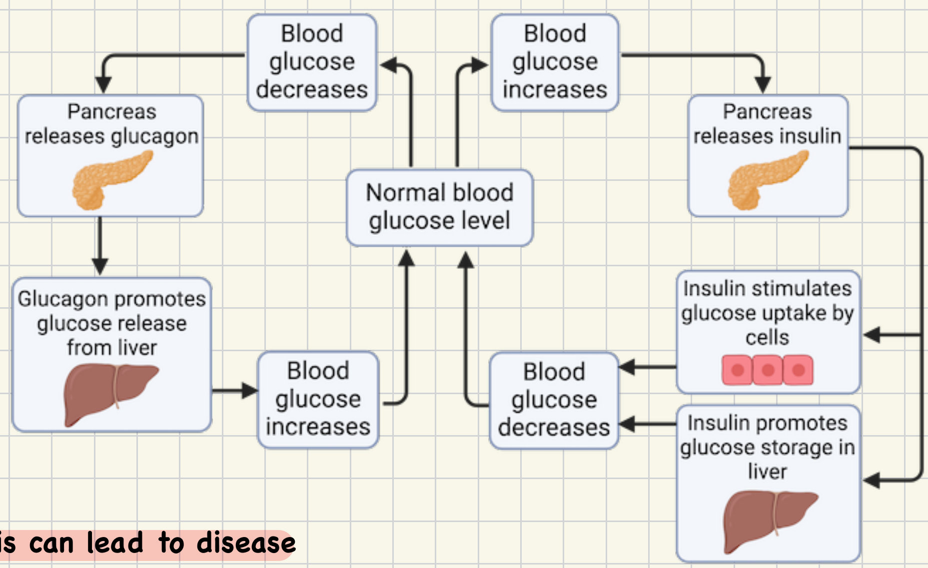
Water balance is crucial for the proper functioning of cells and organs. So, an important part of homeostasis is balancing water intake and loss through negative feedback loops:

- Water levels in the body can drop if a person doesn't drink enough water, or loses too much water through sweating. When blood water levels drop, the concentration of substances dissolved in the blood increases.
- The hypothalamus detects this change in the blood and signals the posterior pituitary gland to release antidiuretic hormone (ADH) into the blood.
- ADH travels to the kidneys, where it prompts them to reduce the amount of water entering the urine (which in turn keeps more water inside the body). The hypothalamus also initiates the feeling of thirst so that the person will drink more water.
- If the body has too much water, the production of ADH is suppressed and the kidneys allow more water to enter the urine. As a result, urine with a higher water content leaves the body, helping to restore water balance.

Example #5: Regulation of blood sugar

The human body relies on glucose (a type of sugar) as a source of energy for its cells. Glucose travels from the digestive tract, or from areas in the body where it is stored, to cells via the bloodstream. The concentration of glucose in the blood is tightly regulated by hormones so that it stays within an optimal range. This regulation occurs through negative feedback loops:

- When a person eats, their digestive system begins to break down the food, releasing the nutrients within. Glucose and other nutrients go into the bloodstream, causing blood glucose levels to rise.
- Increased blood glucose levels trigger the pancreas (an organ) to secrete the hormone insulin into the bloodstream. Insulin promotes the uptake of glucose into the body's cells, where it is used for energy. Insulin also stimulates the liver and muscle cells to store excess glucose, further reducing glucose levels in the blood.
- As blood glucose levels begin to fall between meals, the pancreas secretes a different hormone called glucagon. Glucagon promotes the release of glucose into the bloodstream from the liver, which increases blood glucose concentrations. This allows cells to have steady access to glucose over time.



Disrupted homeostasis can lead to disease

Negative feedback loops maintain homeostasis—an ideal, balanced state. Disruptions to these feedback loops can affect homeostasis and lead to disease.

For example, diabetes is a disease caused by disruptions to the feedback loop involving insulin. Because of these disruptions, it is difficult or impossible for the body to bring high blood glucose down to an optimal level. This can be harmful to the body, causing damage to the kidneys, nerves, and blood vessels. There are two types of diabetes: type 1 and type 2.

- In type 1 diabetes, the immune system mistakenly attacks and destroys insulin-producing cells in the pancreas. Without insulin, glucose remains in the bloodstream, resulting in high blood glucose levels. Individuals with type 1 diabetes require regular insulin injections or insulin pump therapy to manage their blood sugar levels.
- In type 2 diabetes, the body becomes resistant to the effects of insulin. Despite the presence of insulin, glucose is not effectively taken up by the cells, resulting in high blood glucose levels. Management of type 2 diabetes includes lifestyle changes, oral medications, and sometimes insulin injections if the pancreas has lost its ability to make its own insulin.

Positive feedback loops drive processes to completion

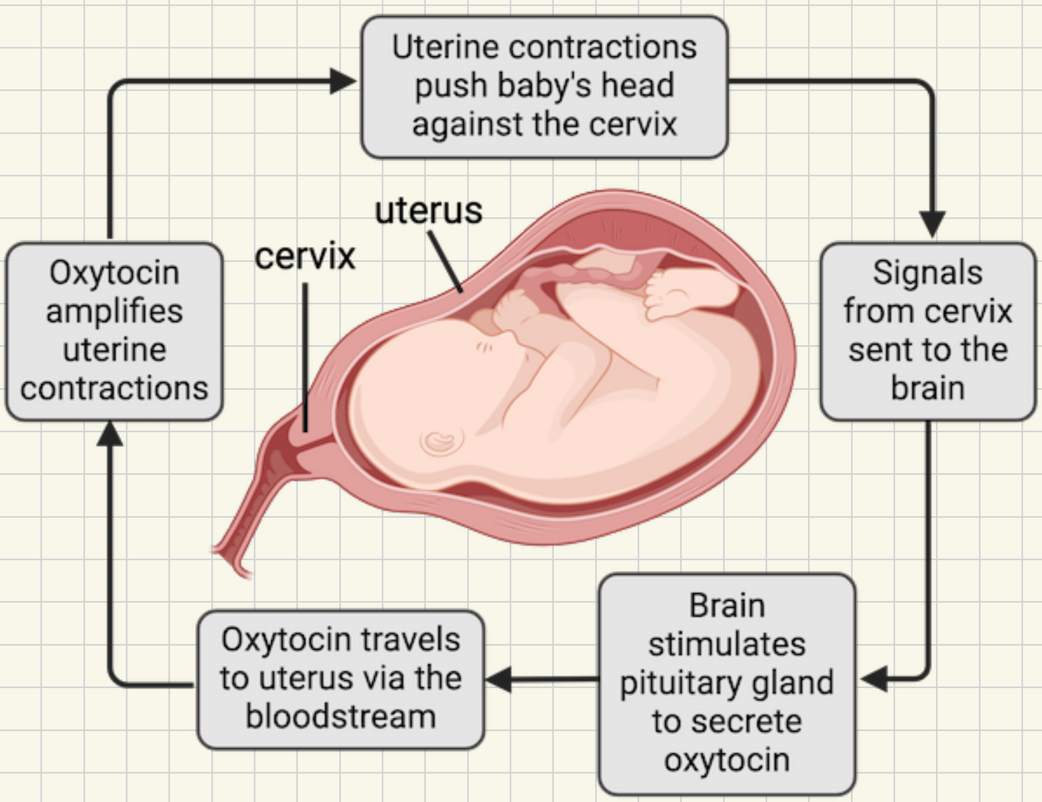
Feedback loops are a critical part of homeostasis, which is the tendency of organisms to maintain relatively stable internal environments. Maintaining homeostasis typically occurs through negative feedback loops. These loops counteract a change, bringing the value of a physiological variable (such as temperature or blood sugar) back to a set point.

Some biological processes, however, require positive feedback loops. These loops amplify a starting signal, moving a system away from its starting point. Positive feedback loops are usually found in processes that need to be pushed to completion, not when conditions need to be maintained. Now, let's look at some examples of positive feedback loops in organisms.

Example #1: Childbirth

During childbirth, the muscles of the uterus contract, or tighten. These contractions push the baby's head against the cervix, located at the bottom of the uterus. The pressure of the baby's head activates neurons in the mother's brain, which stimulate the pituitary gland to release the hormone oxytocin.

Oxytocin causes an increase in the frequency and intensity of uterine contractions. So, when oxytocin is released and acts on the uterus, stronger contractions cause the pressure on the cervix to increase. This causes the release of even more oxytocin, which produces even stronger contractions. This positive feedback loop continues until the pressure causes the cervix to fully dilate (widen), and the baby is born.



Example #2: Fruit ripening

The process of ripening transforms immature, hard, and inedible fruits into the ripe and delicious fruits that we (and other organisms) enjoy. Ripening is regulated by the hormone ethylene.

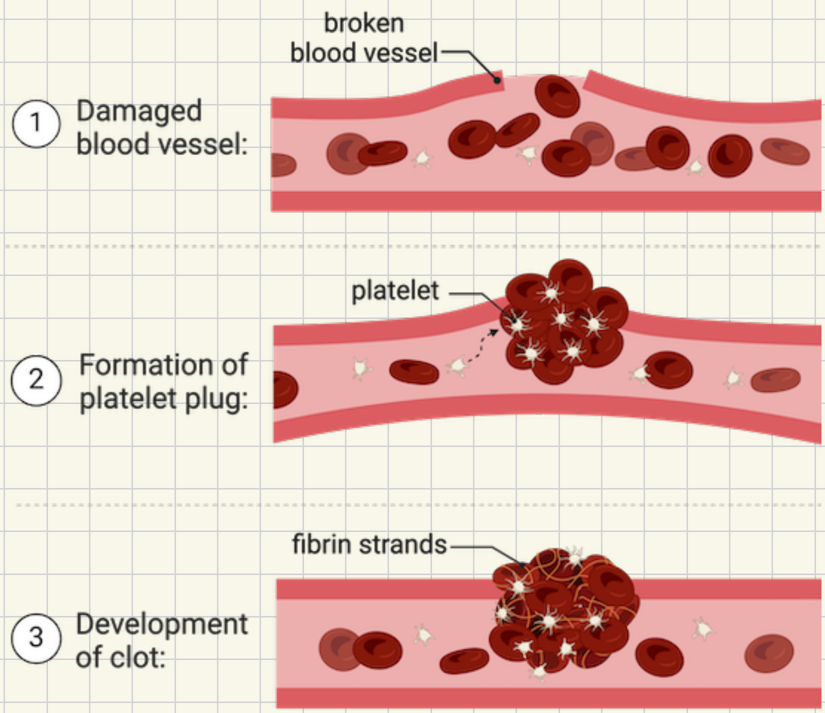
When fruits begin to ripen, they release a small amount of gaseous ethylene. As ripening continues, the fruits release more ethylene, which promotes ripening even further. Eventually, the ripening process is driven to completion.

The fact that ethylene is released as a gas means that other fruits nearby are also induced to ripen. This is why if you have unripe fruits such as bananas, tomatoes, or avocados, you can put them together in a bag. The build-up of ethylene inside the bag will cause the fruits to ripen more quickly!

Example #3: Blood clotting

When a blood vessel is injured, platelets (components of the blood) stick to the damaged site and release chemicals. These chemicals attract more platelets, which eventually form a platelet plug and start to seal off the damaged blood vessel.

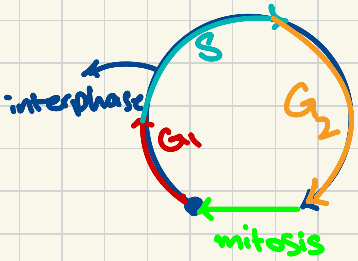
The plug, in turn, initiates a series of reactions that produce long protein strands called fibrin. These protein strands wind around the platelet plug, which can then trap more platelets and blood cells. This positive feedback loop helps the body rapidly form a stable clot around a damaged site and prevent further blood loss.



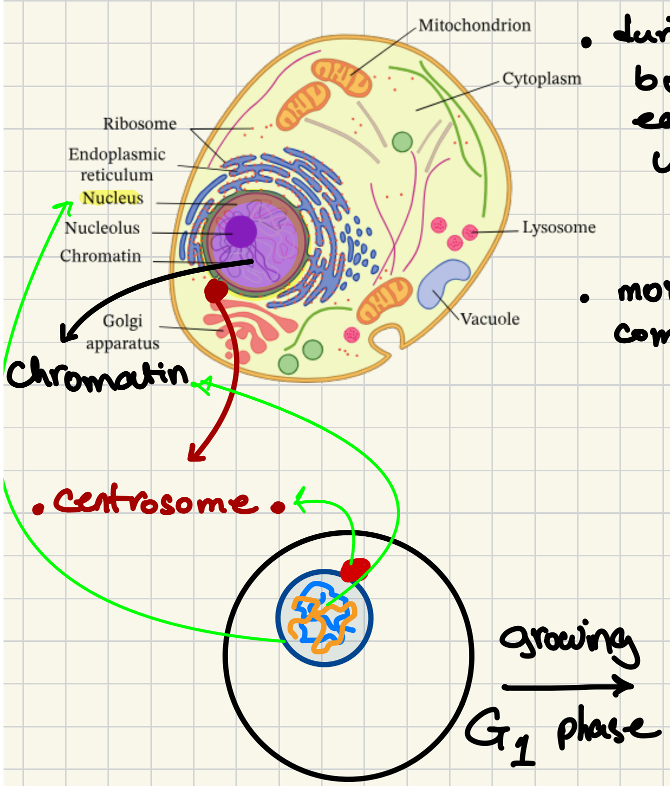
Unit 3 - the cell cycle and differentiation

life cycle of a cell → specifically we are going to learn about interphase.

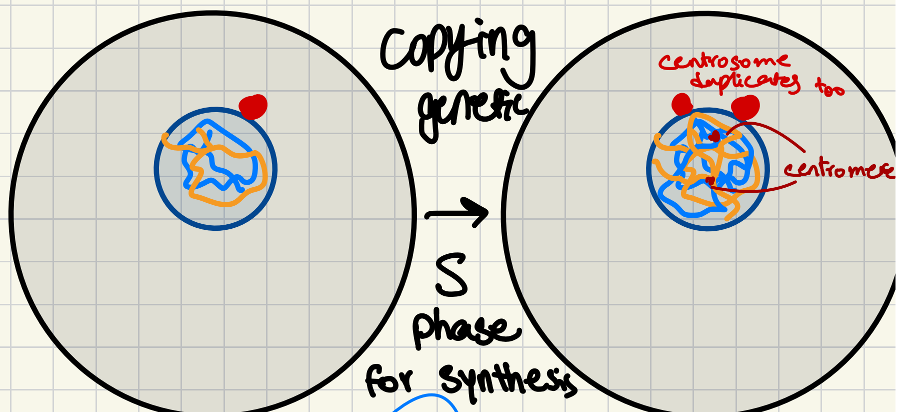
- interphase is where cell spends most of its life.
- new cell goes through interphase → ready to divide (mitosis)

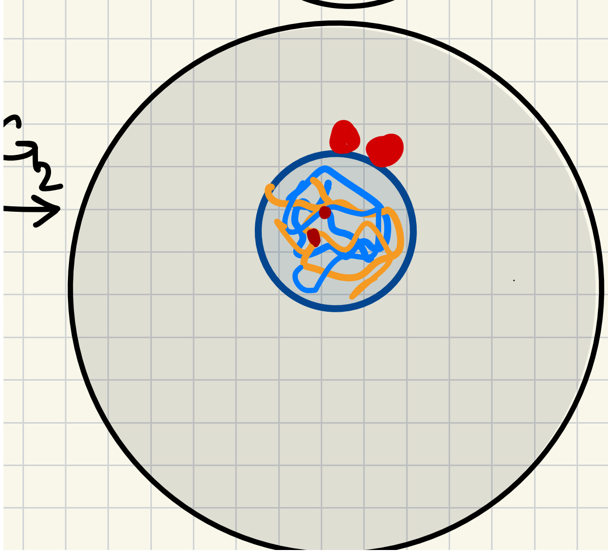


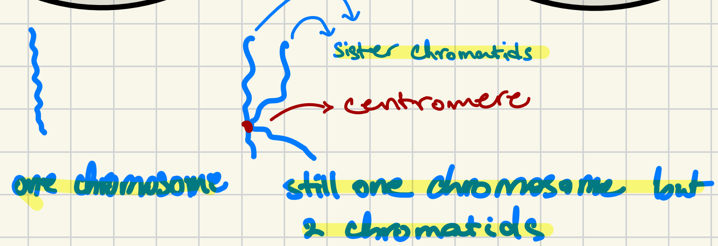
mitosis: a process through which a nucleus turns into two nuclei → cell division



- during interphase the chromosomes aren't that bound → in their chromatin form, they're easy to see from a traditional or a simple light microscope!
- most of cell's life, their chromosome are completely unwound → chromatin: رشته رشته، درهم تنیده نشده







now ready for mitosis!

Mitosis

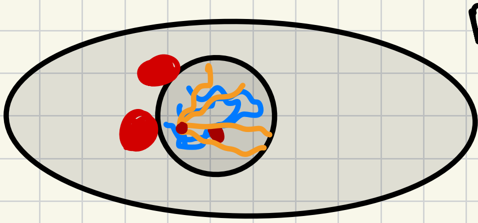
a process that a nucleus will turn into two nuclei that each have the original genetic information.

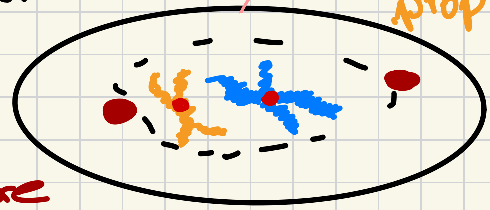
- after mitosis, after having two nuclei, the cell goes through cytokineses to divide the cytoplasm, so that each nucleus becomes a complete cell.

phases of Mitosis

- the DNA, chromosomes, go from being in their chromatin form to more condense form that you can see them through a light microscope.
- the nucleus walls membrane starts to disappear.
- the 2 centrosomes go to different sides of the cell, migrating to opposite sides.
- cells don't have brains, so all these happen through different chemical & thermodynamical reactions.
-

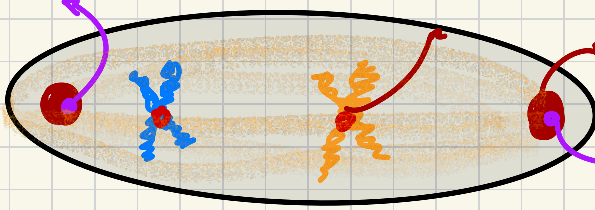
phase 1 of mitosis





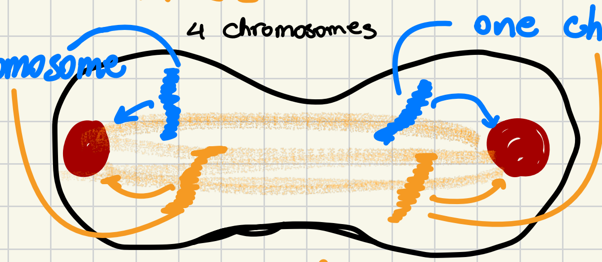
prophase of mitosis

phase 2

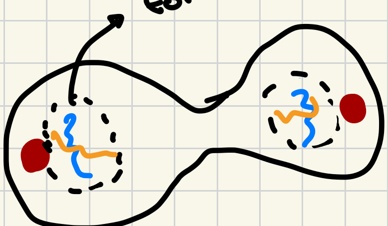


: makes sure the centromeres repell each other. Then, it pulls one of the sister chromatids toward itself.

metaphase of mitosis



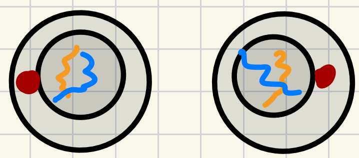
Anaphase of mitosis



Telophase of mitosis

nucleus membrane comes back

then we will have

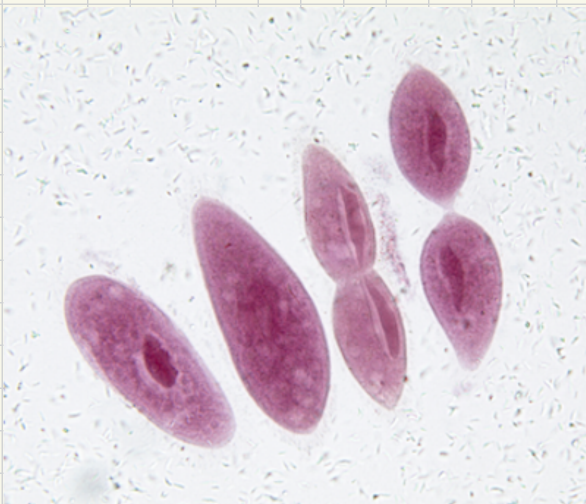


Cytokineses : cell gets fully divided.

Cell division produces new cells

All cells are produced through the process of cell division, during which one cell splits into two. Cell division is central to three biological processes: reproduction, organism growth, and cell replacement.

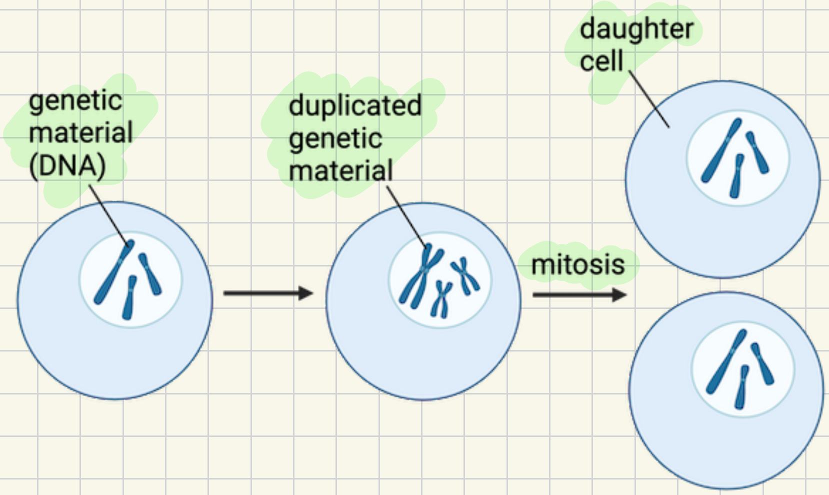
- Reproduction: Cell division is essential for reproduction, or the process by which parent organisms give rise to offspring. In sexual reproduction, two parents produce offspring through the fusion of sex cells, which are the product of cell divisions. In asexual reproduction a single parent produces offspring. This is common in unicellular organisms, where a single cell divides to produce a new, genetically identical organism. In some cases, multicellular organisms can also reproduce asexually through cell division.
- Organism growth: Sexually reproducing, multicellular organisms start life as a single, fertilized egg. This single cell then grows into a mature organism, which can contain anywhere from thousands to trillions of cells! This increase in cell number is the result of repeated cell divisions.
- Cell replacement: When cells are damaged, they are replaced via the division of healthy cells. This process is essential for healing wounds and regenerating tissues. In addition, some tissues require a continuous replacement of cells. For example, bone marrow continuously makes new blood cells to replace those that are naturally degraded or lost due to an injury or bleeding.



→ asexual reproduction in a unicellular organism.

Mitosis is a type of cell division that produces genetically identical daughter cells

Mitosis is a form of cell division that produces two cells with identical genetic information. These cells are referred to as daughter cells. Prior to mitosis, a cell duplicates its DNA so that it can evenly distribute its genetic material to each daughter cell.

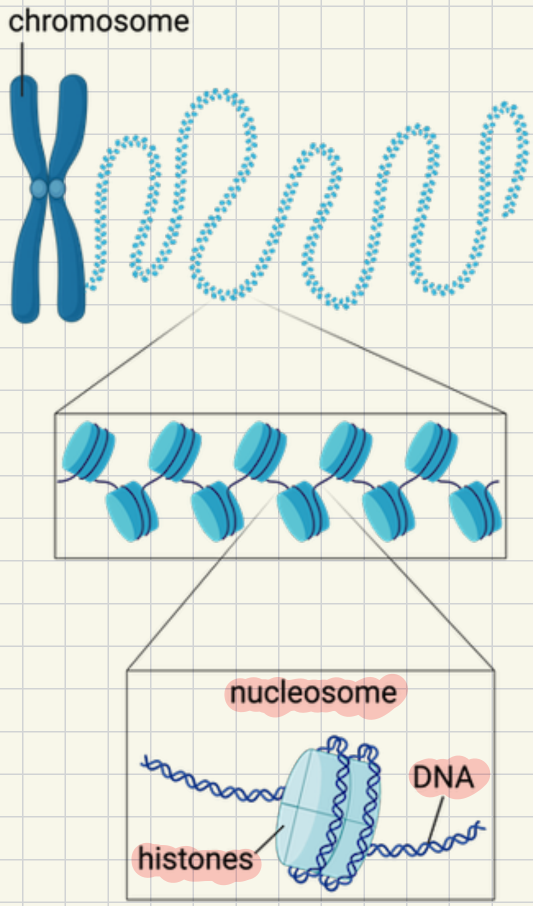


Mitosis involves the splitting of the nucleus, and so only occurs in eukaryotic cells. In unicellular eukaryotes, cell division by mitosis results in asexual reproduction. In multicellular eukaryotes, cell division by mitosis is responsible for organism growth, tissue repair, and (in some cases) asexual reproduction.

The accurate division of genetic material relies on chromosome structure

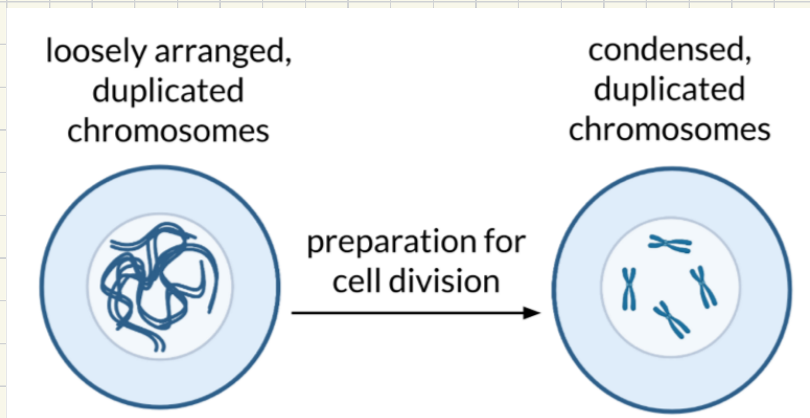
A eukaryotic organism's genome is split into multiple DNA molecules that are organized into structures called chromosomes, which are found in the nucleus. Each chromosome consists of a single, long DNA molecule (that contains many genes) plus supporting proteins.

Together, the DNA and proteins that make up a chromosome are referred to as chromatin. Chromatin's primary role is to tightly package the long strands of DNA into a dense structure that fits inside the nucleus. The basic structural units of chromatin are called nucleosomes, which consist of DNA coiled around proteins called histones.



Chromosomes during mitosis

Prior to mitosis, chromatin is loosely arranged in the nucleus, which means chromosomes cannot be seen individually under a light microscope. As a cell gets ready to divide, its chromatin condenses, making its duplicated chromosomes visible under a light microscope. Condensed, duplicated chromosomes are often depicted with an "X" shape in diagrams. The condensed form of chromatin ensures that replicated chromosomes are accurately distributed to each of the two daughter cells during mitosis.



mitosis → cell division in eukaryotic cells

Mitosis is part of the cell cycle

When we use the term "mitosis," we are often referring to the general process of cell division in eukaryotes. However, "mitosis" technically describes only one part of the cell division process—the splitting of replicated chromosomes into two nuclei.

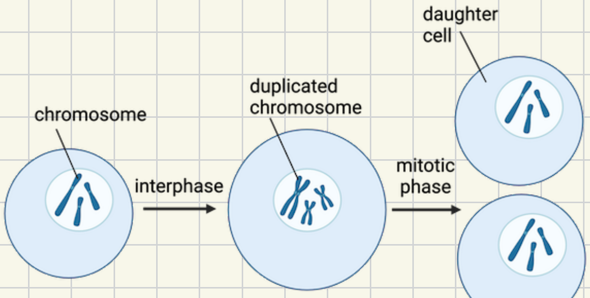
In reality, mitosis is just one part of the cell cycle, a series of organized and regulated events through which cells grow, replicate their DNA, and ultimately divide. This cycle helps cells grow and reproduce properly, ensuring the accurate transmission of genetic material to daughter cells.

Cell division is part of the cell cycle

All cells are produced through the process of cell division, during which one cell splits into two. To divide, a cell must complete several important tasks: it must grow, copy its genetic material (DNA), and physically split into two daughter cells. Cells perform these tasks in an organized, regulated series of steps known as the cell cycle.

The cell cycle is split into two primary phases: interphase and the mitotic (M) phase.

- During interphase, the cell grows and replicates (makes a copy of) each of its chromosomes.
- The mitotic (M) phase is when the cell divides. During the \[\text{M}\] phase, the cell separates its chromosomes into two sets and then divides its cytoplasm, forming two genetically identical daughter cells.



interphase: G_1: cell Growth; S: DNA Replication; G_2: Cell Growth

m phase:
- m-phase: division of chromosome into 2 nuclei
  1- prophase, 2- metaphase, 3- anaphase 4- telophase
- cytokinesis: division of cell's cytoplasm

Interphase has three subphases

Interphase can be further divided into three subphases known as the G1, S, and G2 phases.

- The G1 phase is when a cell does most of its growing, which requires the cell to take in extra nutrients. During this phase, the cell increases in size, and synthesizes new proteins and organelles.
- The S phase (synthesis phase) is when a cell replicates its DNA. At the end of this phase, the cell contains a complete copy of each of its chromosomes. In this stage, chromosomes are not condensed; instead, they are loosely arranged in the nucleus and cannot be seen individually under a light microscope. The cell also continues to grow during this phase.
- During the G2 phase, the cell grows even more and continues to synthesize proteins and organelles. In particular, the cell makes many of the molecules and structures required for the process of cell division, and it also begins to reorganize its contents in preparation for the M phase.

mitosis

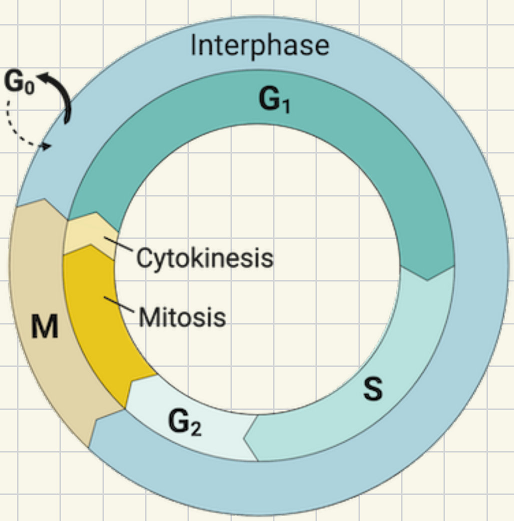
Cells that are ready to divide will complete G2 and enter the M phase. However, many cells in the body, such as nerve and muscle cells, reach a point where their specialized functions are prioritized over cell division, and they no longer divide. These types of mature cells exit the G2 phase and enter a state called G0. Some cells remain here indefinitely, while others may re-enter the process of cell division under the right conditions.

The mitotic (M) phase consists of mitosis and cytokinesis

The mitotic (M) phase is the part of the cell cycle in which cell division occurs. The M phase is divided into mitosis and cytokinesis.

- Mitosis is the division of the cell's genetic material. Mitosis is broken up into multiple stages, with the later stages overlapping with cytokinesis.
- Cytokinesis is the division of the cell's cytoplasm.

Note that we often use the term "mitosis" to refer to the entire process of cell division. However, mitosis technically describes the splitting of chromosomes into two nuclei, while "cytokinesis" describes the splitting of the cell itself into two new cells.

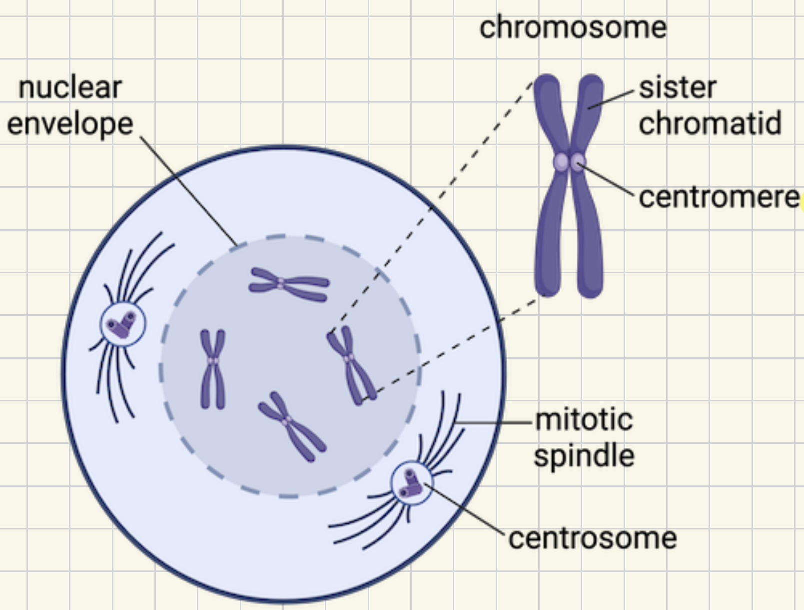


Mitosis consists of prophase, metaphase, anaphase, and telophase

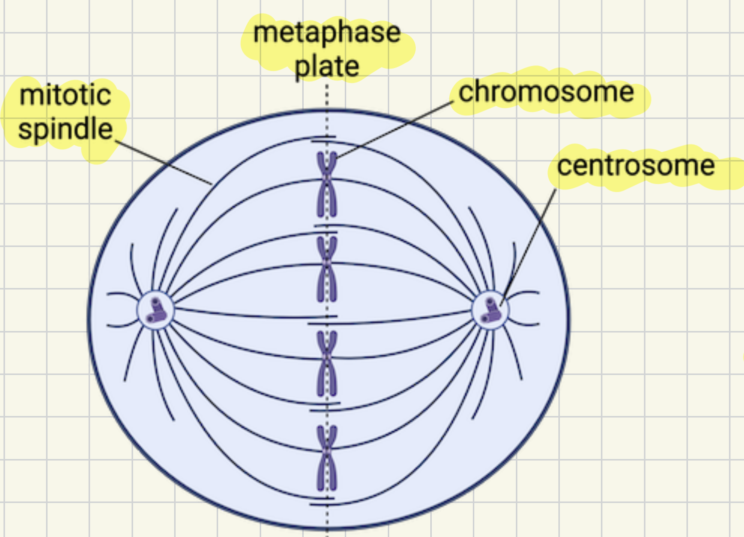
Mitosis is typically described as happening in stages: prophase, metaphase, anaphase, and telophase. These stages are highly regulated and involve detailed coordination of several cell structures. One of these structures is the mitotic spindle, which is made up of the same materials as the cytoskeleton, and ensures the equal division of chromosomes between daughter cells.

In order to understand mitosis, it is helpful to consider what is happening to the chromosomes, nucleus, and the mitotic spindleat each stage of the process: m

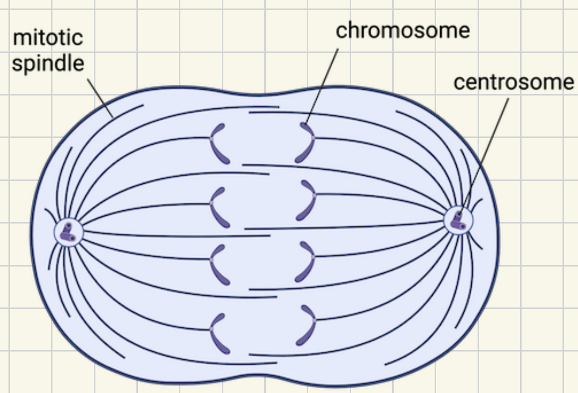
1. Prophase (sometimes divided into prophase and prometaphase):
Chromosomes: In prophase, the chromosomes condense, forming the characteristic "X" shape that is often shown in diagrams. Each "X" is a duplicated chromosome. The two sides of the "X" are called sister chromatids, and they are attached at a point called the centromere. Even though the chromosome has been copied at this point of the cell cycle, as long as the two copies (sister chromatids) are attached, they are considered a single chromosome.
Nucleus: The nuclear envelope (the membrane that surrounds the nucleus) breaks into pieces and doesn't reappear until a later phase (telophase).
Mitotic spindle: The mitotic spindle begins to form during prophase, starting at regions called centrosomes. These regions contain the material needed for building the spindle, and also function to regulate the spindle throughout mitosis.



2. Metaphase
Chromosomes: In metaphase, the chromosomes are lined up along the metaphase plate (an area in the middle of the cell where chromosomes align). The mitotic spindle is attached to the centromere of each sister chromatid.
Mitotic spindle: At this stage, the centrosomes are at opposite ends of the cell and the mitotic spindle is complete. The fibers of the mitotic spindle are elongated. Some fibers overlap at the metaphase plate—these will help push the poles of the cell apart as the cell divides. Other fibers are attached to sister chromatids—these will help pull the sister chromatids apart.

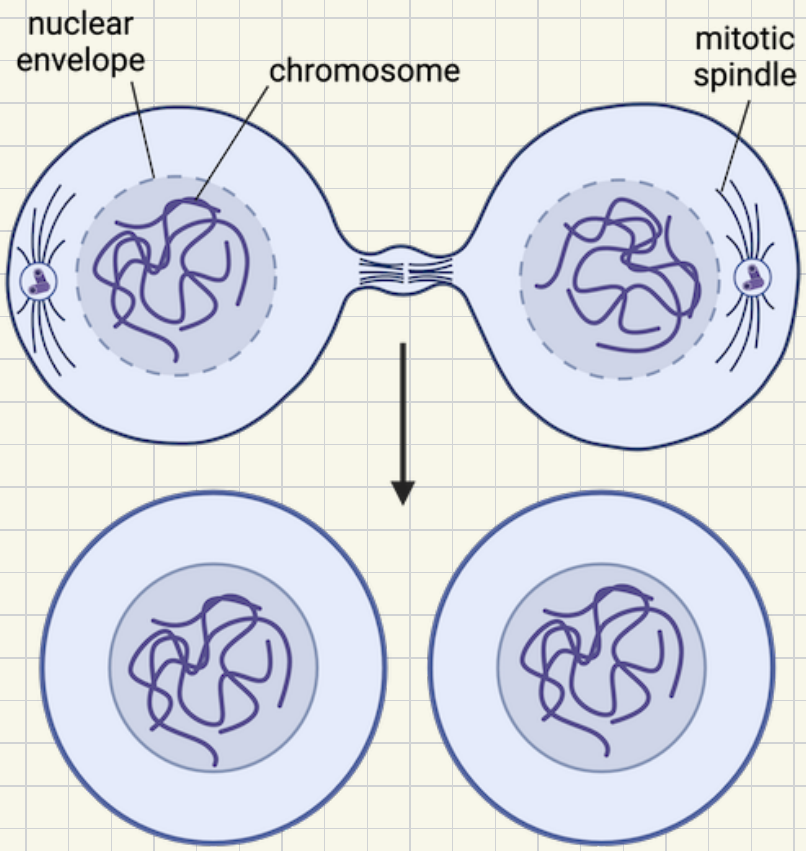


3. Anaphase
Chromosomes: In anaphase, sister chromatids separate and begin to move apart. Once separated, each sister chromatid is now considered an individual chromosome.
Mitotic spindle: The spindle fibers attached to chromosomes are broken down as the chromosomes move apart. The overlapping spindle fibers push against each other to help the cell elongate.



4. Telophase:
Chromosomes: In telophase, there is now one full set of chromosomes on either side of the cell. At this stage, chromosomes begin to decondense (become loose again).
Nucleus: A nuclear envelope begins to assemble around each set of chromosomes.
Mitotic spindle: The mitotic spindle completely breaks down.

5. Cytokinesis:
Cytokinesis begins during the late stages of mitosis, typically in anaphase or telophase. During cytokinesis, the plasma membrane is drawn inward until the cytoplasm is pinched in two. Now, each new cell contains its own nucleus and organelles.



The cell cycle is essential for tissue growth, renewal, and repair
The cell cycle is essential for tissue growth, repair, and renewal due to its role in regulating cell division. During growth, cells multiply to promote development and increase tissue mass. When tissues are damaged, the cell cycle is activated to replace cells that have been lost or injured. For tissue renewal (such as in the skin, blood, or intestinal lining) cells divide to replace old and dying cells, thereby ensuring tissue health. Overall, the cell cycle and its regulation of cell division play a crucial role in maintaining healthy tissues in an organism.

M-Phase

Summary:

Chromosomes condense and the nuclear envelope breaks down.
The mitotic spindle helps chromosomes line up along the metaphase plate.
Sister chromatids separate into individual chromosomes.
Chromosomes move to opposite ends of the cell.
The mitotic spindle breaks down and nuclear envelopes form.
The cell's cytoplasm is split, forming two new cells.

M_Phase

① nucleic membrane breaks down & chromosomes begin to condense. prophase

② mitotic spindle forms by the centrosomes. prometaphase

③ Mitotic spindle helps the chromosomes to line up along the metaphase plate. metaphase

④ sister chromatids seperate forming individual chromosomes. mitotic spindle helps with moving chromosomes to either side of the cell. anaphase

⑤ chromosomes are now a set of full chromosomes. The mitotic spindle breaks down, and the nucleic envelope starts to form. telophase

⑥ The cell's cytoplasm splits and forms two new cell. cytokinesis

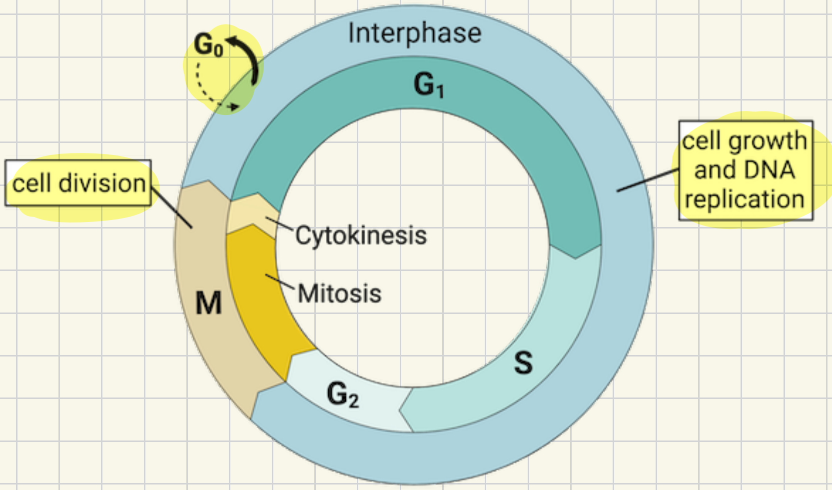
The cell cycle is split into phases

As cells grow and divide, they go through a series of organized, regulated events called the cell cycle.

The cell cycle is split into two primary phases: interphase and the mitotic M phase.

- Interphase consists of the G1 (growth), S (DNA synthesis), and G2 (growth) phases. Cells that exit the cell cycle during interphase enter a non-dividing state called G0.
- The mitotic M phase consists of mitosis (division of genetic material) and cytokinesis (division of the cytoplasm). During the M phase, the cell divides to form two new daughter cells.

The cell cycle is essential for cell growth and reproduction, as well as the repair of damaged tissues.



The cell cycle is highly regulated

Uncontrolled cell division can be harmful to an organism, so the cell cycle is highly regulated. This regulation is carried out by specific proteins and other molecules, which ensure that the cell only divides when appropriate (such as when enough nutrients are available). A cell's regulatory factors can be categorized as either internal or external regulators.

- Internal regulators are proteins and other molecules within the cell that help it to divide at the correct rate and under the right conditions. These regulators allow the cell cycle to move forward only after certain events inside the cell have taken place.
- External regulators are signals from outside the cell. These signals help regulate the cell cycle based on environmental conditions and other external factors.

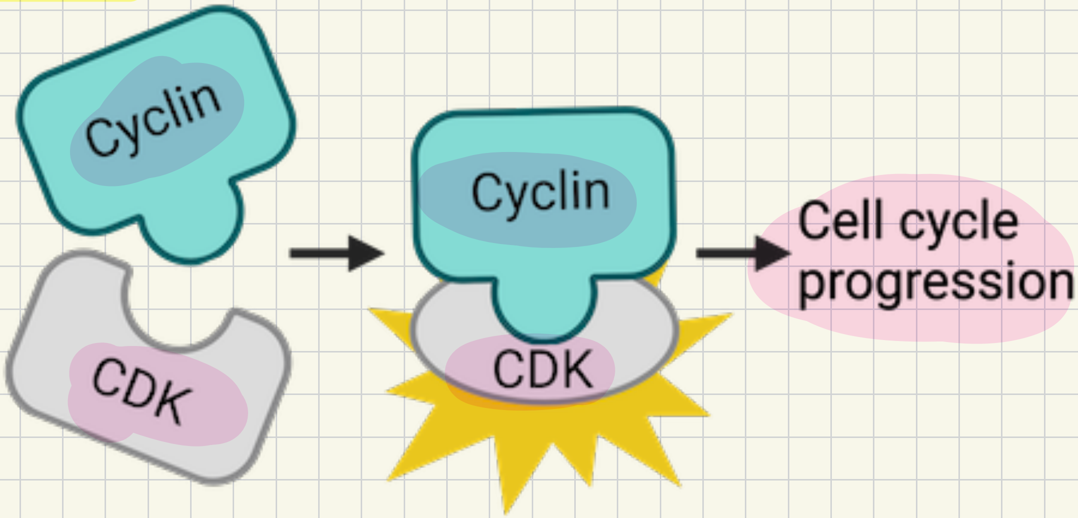
Internal regulators include cyclins and cyclin-dependent kinases

Internal regulators are part of the cell cycle control system—a set of molecules whose abundance and/or activity repeatedly rises and falls in the cell, helping to coordinate key events of the cell cycle, such as the entry into mitosis.

Two important regulators in the cell cycle control system are cyclins and cyclin-dependent kinases (CDKs).

- Cyclins are proteins that are synthesized (made) and broken down at specific times during the cell cycle, which causes their levels to rise and fall at different points in time. When cyclins are present, they bind (attach) to and activate another key internal regulator: the cyclin-dependent kinases (CDKs).
- Cyclin-dependent kinases (CDKs) are enzymes that interact with specific cellular components related to the cell cycle. CDKs are typically present in the cell but are inactive, requiring the presence of cyclins to become active.

When cyclins bind to CDKs, the shape of the CDKs change, causing them to become active. These active cyclin-CDK complexes then interact with specific molecules in the cell, leading to events necessary for the cell cycle to move forward.



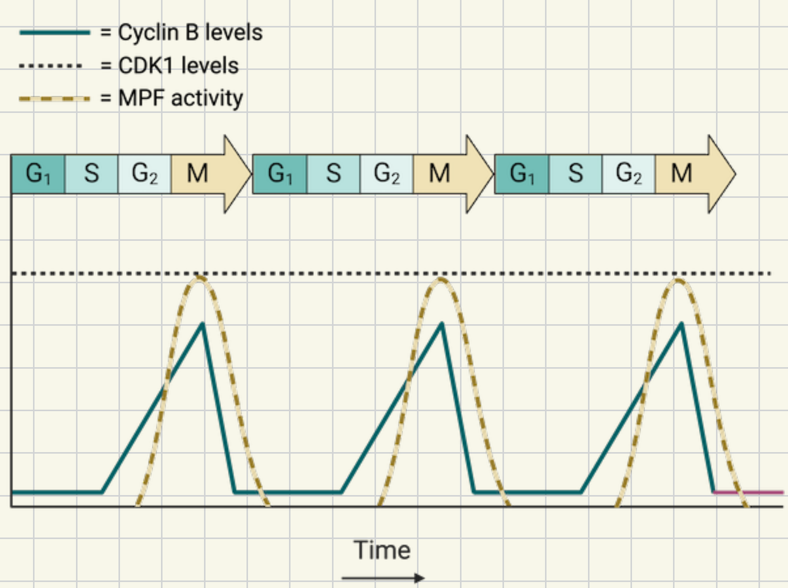
MPF is a cyclin/CDK complex that regulates entry into M phase

Maturation-promoting factor (MPF) (also known as M-phase-promoting factor or mitosis-promoting factor) is a cyclin-CDK complex that regulates the transition of a cell from the G2 to the mitotic M phase of the cell cycle. MPF is made up of two proteins: cyclin B and CDK1.

- Cyclin B is a cyclin whose levels vary during the cell cycle. Cyclin B levels increase during the S and G2 phases, and peak during the M phase.
- CDK1 is a cyclin-dependent kinase that is always present in the cell, but is only activated when bound to cyclin B.

When cyclin B and CDK1 bind, they become active MPF. So, as cyclin B levels increase, the activity of MPF in the cell also increases. MPF affects downstream targets involved in chromosome condensation, nuclear envelope breakdown, and the formation of the mitotic spindle. When the level of MPF activity is high enough, the cell enters mitosis.

Toward the end of mitosis, cyclin B is broken down, leading to a decrease in MPF activity. As a result, the cell exits mitosis and completes the cell division process. This allows the cell to enter the G1 phase, thus beginning the cell cycle again.



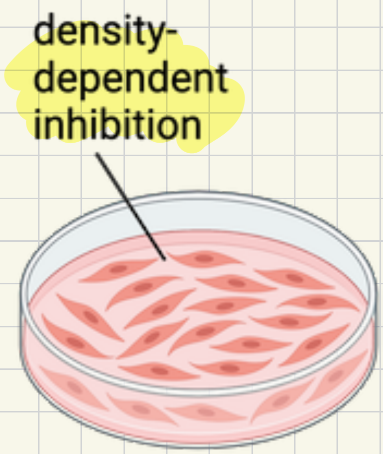
External regulators are signals from outside the cell

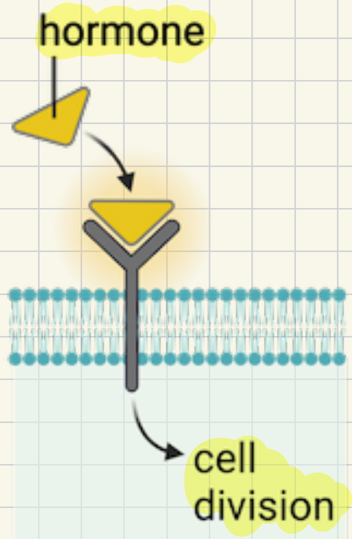
External regulators are signals from outside the cell that influence cell division. These signals allow the cell to respond to its environment, and to the needs of the organism as a whole. External regulators can be physical or chemical in nature. Two important physical regulators are known as density-dependent inhibition and anchorage dependence.

- Density-dependent inhibition (or contact inhibition) describes a cell's response to physical contact with cells. When cell-surface proteins on two adjacent cells bind, signals are sent to both cells to stop dividing. This ensures that cells are growing at an optimal density in the body.
- Anchorage dependence describes how a cell must be attached to some sort of surface or extracellular matrix in a tissue in order to divide. This ensures that cells are growing in an optimal location in the body.

Important chemical regulators of the cell cycle include hormones and growth factors.

- Hormones are molecules produced by certain glands in the body and released into the bloodstream. Once in the blood, they can travel to and act on distant target cells. Hormones can act to encourage or suppress cell division, depending on the needs of the organism.
- Growth factors are proteins that are released by certain cells into the extracellular environment. These proteins then bind to and stimulate other cells to divide. For example, platelet-derived growth factor (PDGF) is a type of molecule that stimulates cell division to help repair wounds and damaged blood vessels.





Checkpoints of the cell cycle

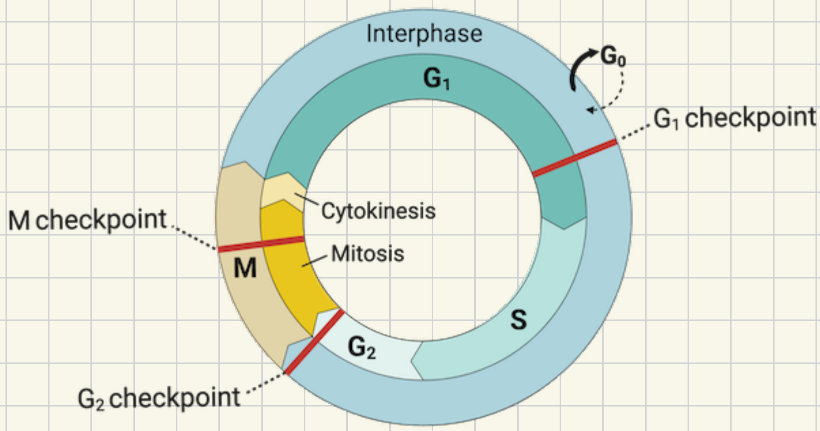
Cell cycle **checkpoints** are quality control mechanisms that make sure the cell cycle progresses without errors. At each checkpoint, certain internal and external conditions must be met in order for the cell to move forward with the cell cycle. Cell cycle checkpoints help avoid errors in cell division that could lead to diseases such as cancer.

There are a number of checkpoints, but the three most important ones are the G_1, G_2, and M checkpoints.

- The $\mathbf{G}_1$ **checkpoint** occurs at the G_1/S transition of the cell cycle. At this checkpoint, factors such as cell size, nutrient availability, molecular signals (such as growth factors), and whether the cell's DNA is damaged determine if the cell moves to the next phase. If conditions are suitable, then the cell progresses from the G_1 phase to the S phase. If not, the cell will exit the cell cycle and enter the non-dividing G_0 state.

- The $\mathbf{G}_2$ **checkpoint** occurs at the G_2/M transition of the cell cycle. A cell will only move past this checkpoint if its DNA was correctly replicated during the S phase. If errors or damage to DNA are detected, the cell will pause at the G_2 checkpoint so that the DNA can be repaired. If the damage is irreparable, the cell may self-destruct in a process known as **apoptosis**, or programmed cell death.

- The $\mathbf{M}$ **checkpoint** (also called the **spindle checkpoint**) occurs between metaphase and anaphase of mitosis. At this checkpoint, chromosomes must be properly attached to the mitotic spindle at the metaphase plate for the cell to move to the next phase. Only then will the separation of sister chromatids begin. This checkpoint ensures that daughter cells receive the correct number of chromosomes.



- cancer: uncontrolled cell division.

- Tumor-Suppresser genes: inhibit cell division
  - ↳ if mutated → promote cell division → cancer

- Proto-oncogenes: promote cell division
  - ↳ if mutated → more strongly promote → cancer

Cell Cycle	what causes it to fail?
G_1 checkpoint	insufficient cell growth
G_2 checkpoint	errors in DNA replication
M checkpoint	misaligned chromosomes

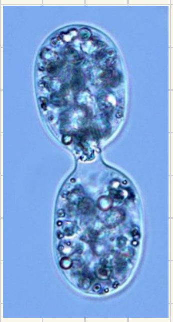
- CDKs and cyclins: CDK levels typically remain steady throughout the cell cell cycle, while cyclin levels rise and fall.

Scenario	Effect
• a cell touches other cell via cell-surface receptors	inhibits cell division
• a cell attaches to a tissue's extracellular matrix.	promotes cell division
• a cell recieves cell growth signal from its environment	promotes cell division
• cyclin B level increases	promotes cell division

Sexual and asexual reproduction

Reproduction is the process by which parent organisms create new organisms (offspring). When organisms reproduce, they pass their genetic information to their offspring. There are two main forms of reproduction: asexual and sexual reproduction.

- During asexual reproduction, a single parent produces offspring. Each of the offspring has the same genetic information as the parent. This type of reproduction is common among single-celled organisms such as bacteria and protists.
- During sexual reproduction, two parents together produce offspring. The offspring have a mix of genetic information from both parents. This type of reproduction is common among multicellular eukaryotic organisms, which includes humans.

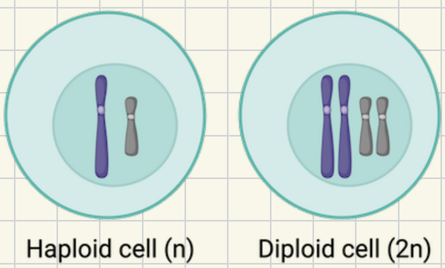


Fertilization is the fusion of gametes

During sexual reproduction, sex cells (known as gametes) from two different individuals (parents) fuse to form a new organism. Each gamete has half of the number of chromosomes compared to a typical body cell. In biological males, gametes are called sperm, and in biological females, gametes are called eggs.
The fusion of gametes (an egg and a sperm) is called fertilization. When the egg and sperm cell fuse, they become a zygote. The zygote now has the full number of chromosomes that the organism needs.
After fertilization, the zygote undergoes many mitotic cell divisions, growing into a mature organism through a process called development.

Haploid and diploid cells

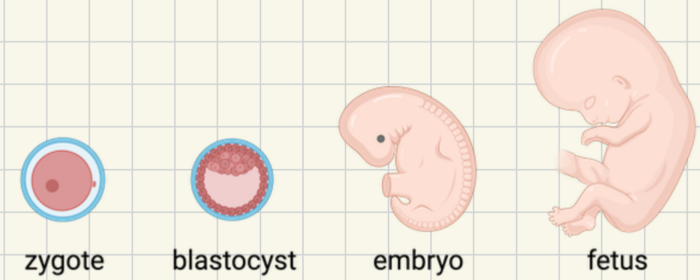
Cells can be classified as haploid or diploid based on the number of chromosome sets they contain. Haploid cells have one complete set of chromosomes, while diploid cells contain two complete sets of chromosomes. The haploid state is designated as "n", and the diploid state is designated as "2n".
Gametes are haploid, while most somatic (body) cells are diploid. The transition between these two states is crucial in reproduction, where haploid gametes merge during fertilization to form a diploid zygote, setting the stage for the development of a new organism.



Human development

Human development begins with fertilization, then progresses through multiple stages as cells divide and change, and organs form. The main stages of human development are the zygotic, embryonic, and fetal stages.

- Zygotic stage: The zygotic stage begins at fertilization with the fusing together of a sperm and an egg. The single-celled zygote contains all of the genetic material needed to develop into a mature human.
- Embryonic stage: As soon as the zygote divides, it becomes an embryo. Early in embryonic development, the embryo is a blastocyst—a hollow ball of cells with an inner cell cluster. During later stages of embryonic development, the basic outline of the body forms, and the heart, brain, and spinal cord become visible.
- Fetal stage: At about eight weeks into pregnancy, all of the major structures of a human are present in rudimentary form, and the embryo becomes a fetus. As the fetus continues to develop, the body's structures are refined, and the fetus grows in size.



Development involves cell differentiation and morphogenesis

How does a single cell (the zygote) develop into a mature organism with multiple cell types and complex structures? This occurs as a result of two critical processes: cell differentiation and morphogenesis.

Cell differentiation

Cell differentiation is the process by which unspecialized cells are transformed into specialized cells. Specialized cells are those with specific structures and functions, such as nerve cells, muscle cells, and blood cells.

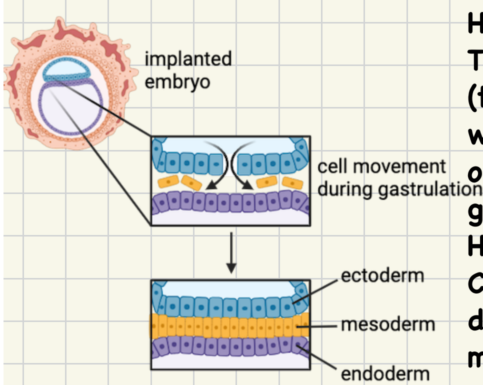
The zygote and the cells of the early embryo can give rise to the specialized cells of the mature organism because they are stem cells. Stem cells have the ability to divide many times while remaining unspecialized, and also to differentiate into specific cell types. Stem cells differ in the number of cell types they can become.

- The zygote is a totipotent stem cell, which means it can give rise to any kind of human cell. This includes the cells that make up the embryo, and also the cells that make up tissues that support the embryo during pregnancy, such as those of the placenta.
- The blastocyst's inner cell cluster is pluripotent, which means the cells can give rise to any type of cell in the embryo.

Morphogenesis

Following cellular differentiation, the embryo undergoes morphogenesis, which is the process that shapes the physical form of the developing organism.

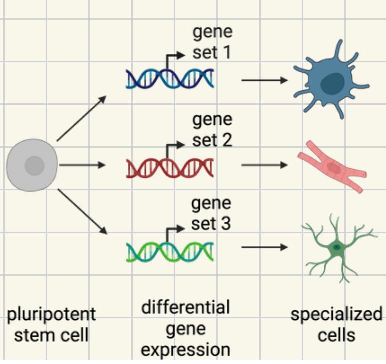
During morphogenesis, specialized cells move around and rearrange themselves, organizing into complex structures and tissues. For example, after the embryo implants into the wall of the uterus, gastrulation occurs. During this process, cells move to form three layers, each of which turns into specific parts of the body: the ectoderm becomes the skin and nervous system, the mesoderm becomes the muscles and bones, and the endoderm becomes internal organs, such as the lungs and liver.



How is cell fate determined during cell differentiation and morphogenesis?

The cells in a mature multicellular organism are derived from a single cell (the zygote), so each cell contains the same genetic information. In other words, liver cells, muscle cells, epithelial cells, and almost every other type of cell in the body contain the same chromosomes, and therefore the same genes.

How, then, can specialized cells have such unique structures and functions? Cells specialize by using only a subset of their genes during and after differentiation. In other words, only certain genes are expressed, or used to make proteins, in a given cell type.



The different patterns of gene expression that lead to specialized cells begin early in the embryo's development. There are two primary mechanisms by which these gene expression patterns are established: cytoplasmic determinants and inductive signals.

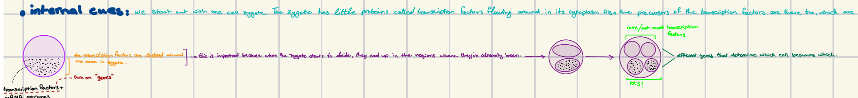
Cytoplasmic determinants are substances found in the cytoplasm that influence gene expression patterns. These substances, which include specific RNA and protein molecules, are unevenly distributed within the cytoplasm of an egg cell. This means that when a zygote undergoes its first few divisions, the resulting cells have different groups of substances in their cytoplasms. As a result, each nucleus is exposed to different cytoplasmic determinants, and therefore initiates different patterns of gene expression.

Inductive Signals are messages sent between neighboring cells that influence how each cell behaves and develops. For example, when a cell touches or is very close to another cell, it can receive signals through contact with molecules on the surface of the neighboring cell or through growth factors released by the cell. These signals can trigger changes in the receiving cell's gene expression, leading it to follow a specific developmental pathway. As a result, the cell begins to produce proteins that are specific to a certain type of tissue, helping to form the body's different tissue types.

notes.

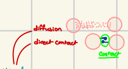
- fertilized egg has the potential of turning into an organism, that organism can be anything including a human being.
- one of millions of sperm cells get to fertilized the egg.
- in each DNA pair, there's one from mom and one from dad; 23 pairs of chromosomes → DNA
- the sex cells are called gametes.
  - ↳ sperm is a gamete coming from your dad, the egg cell (or an ovum) is another gamete coming from your mom
- gametes have half the number of chromosomes: each 23 chromosomes, not pairs!
- after fertilizing happens, we will have a zygote.
  - ↳ a fertilized egg with 23 pairs of chromosomes (or 46 chromosomes)
- in a zygote, we can still see 2 nuclei from both gametes. those aren't completely fused yet.
- Zygote starts dividing; after having 16 cells → morula : after 2 or 3 days
- morula keeps dividing through mitosis, after 5 to 9 days, there'll be 200-300 cells → Called a blastocyst
- blastocyst turns into an embryo : almost 7 weeks after conception.
- embryo turns into a fetus which is bigger and more resembles a human being : after 12th week
- all cells come from stem cells. stem cell (unspecialized cells) → tissue → organ → system → organism
- different tissue cells have different genes & proteins; that's why they act different.
- Cells are using different genes to make their protein.
- When cells actively using certain genes, it's said to be expressing those genes.
- A gene being expressed is said to be turned on.
- A gene not being expressed is turned off.
- if a stem cell turning into a specialized tissue cell, the stem cell turns on its "specific" genes to become that tissue.
  - ↳ stem cell becoming muscle tissue: 

    the stem cell expresses ("turns on") the muscle genes!
- Then proteins get made within a cell that changes how the cell looks.
- Stem cells are pluripotent, meaning they can turn into any kind of cells.
- Once a stem cell turns into a specialized cells, it cannot differentiate into other cells.
- Tissue cells (specialized stem cells) actually cannot de-differentiate either. (can't go backwards)
- what determines what genes in the given cell are turned on or off? The cell decides what they're going to grow up to be based on cues (internal / external) they get.
- internal cues: we start out with one cell zygote. The zygote has little proteins called transcription factors floating around in its cytoplasm. Also the precursors of the transcription factors are there too, which are called mRNA.



Asymmetric Segregation of cellular Determinants

- external cues : (Inductive Signaling / induction) : really strong encouragement; like peer pressure. A group of cells can induce other groups of cells to differentiate by using some signals.



Formation of Biomolecules

- All organisms need food.
- ↳ a tree without a mouth: makes its own food through photosynthesis! → CO_2 + water $\xrightarrow[\text{photosynthesis}]{\text{through}}$ produces glucose which is the food for the tree!

a plant produces its own food through photosynthesis, then when needed, they metabolize it through respiration.
everything needs energy.

- Glucose, Carbohydrate : Carbon + Water $C - H_2O$ ⋮ $C_n - H_{2n}O_n$

$C_n H_{2n} O_n$

also important in biochem

thymidine monophosphate (one phosphate) — Ribosome $C_5H_{10}O_5$

how do molecules rearrange themselves in presence of energy to get metabolized (to release energy)?
↳ when we talk about metabolism pathways, enzymes come to the picture. Enzymes facilitate the chemical reaction, making the energy release process faster.

Rubisco Enzyme → one of the enzymes in the metabolic pathways that's able to take CO_2 and attach it to another molecule that eventually can get us to forming a glucose molecule.

Enzymes are proteins that are made up of amino acids which contain carbons, oxygens, and hydrogens in them!

Introduction to Carbohydrates

many of carbs are edible.
carb + hydrate
C + H_2O → any combination with n:2n:n (C H O) ratio.

(↱ greek for sweet)
saccharide is another name for carbohydrates.

Glucose can be a standalone molecule, meaning that it's a simple sugar.
↳ building blocks
glucose: monosaccharide → monomer

or we can build up larger molecules with glucose, like glycogen which is a repeating sequence of glucose molecules.
↳ glycogen: polysaccharide → polymer

Role of Carbohydrates in Biological Systems

Carbohydrates : source of energy → both glucose and glycogen
carbohydrates: play a role in structure → like cellulose

Polysaccharides are a part of another group called macromolecules.
↳ large molecules with thousands of atoms.

Introduction to Amino Acids & Proteins

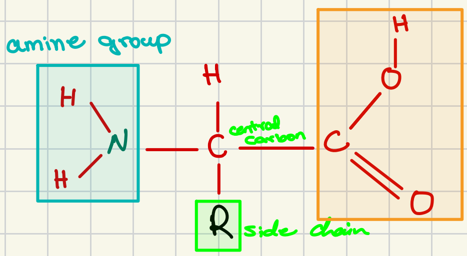
proteins : macromolecules, made up of chains of amino acids, long chains,
amin group
monomer : mono peptide
polymer of amino acids are called polypeptide
they connect to each other & bend to form the shapes of proteins

Sometimes a polypeptide is a protein, but sometimes proteins are made up of multiple polypeptides.

amino acid's bending & forming the proteins' shapes is what gives proteins their power.

Proteins are involved in every single biological function.
- Signaling → Neurons
- structural role
- mechanical role
- Enzymes : catalysts
- Immune system

Amino Acids →

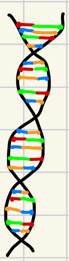


Introduction to Nucleic Acids

Nucleic Acid: the most important macromolecule in life
first observed in nucleus of cells & has acidic properties!

the most important nucleic acid → DNA : DeoxyriboNucleic Acid

DNA: the molecule that stores our hereditary & genetic information → Macromolecule



double helix of DNA, and rungs of this twisted ladder

A chromosome is a really long DNA molecule! And can have 100s of rungs for its ladder!

Nucleic Acids : polymers that the building blocks are called nucleotides.
↳ e.g.

- Adenosine monophosphate
- → a nucleotide found in DNA
  Deoxyadenosine monophosphate
- Thymidine Monophosphate
- Cytidine monophosphate

RNA: RiboNucleic Acid, the second most important nucleic acid

why nucleotides are acidic?
↳ The basic parts shape the steps of the ladder which aren't that reactive since they are closer to the inside of the molecule. The acidic parts (the phosphates → outside), though, they are on the outside of the ladder, so they're going to be more reactive. Thus nucleotides, or the whole nucleic acids, have an acidic characteristic.

Introduction to Lipids

Fats are lipids but not all Lipids are fats.

Lipids: a class of molecules that you often see in biological systems that are not so ___ water soluble.

Not all parts of Lipids are hydrophobic. → they have both hydrophobic & hydrophilic parts.

hydrophobic ↳ Not attracted to water.

hydrophilic ↳ Parts that like water!

Roles of lipids in the body:
- protection
- energy storage
- signaling / later we will learn about hormones that are carriers of signals and many of them are nothing but lipids.
- membranes

examples of lipids that are not fats:

→ Sphingomyelin

→ cholesterol

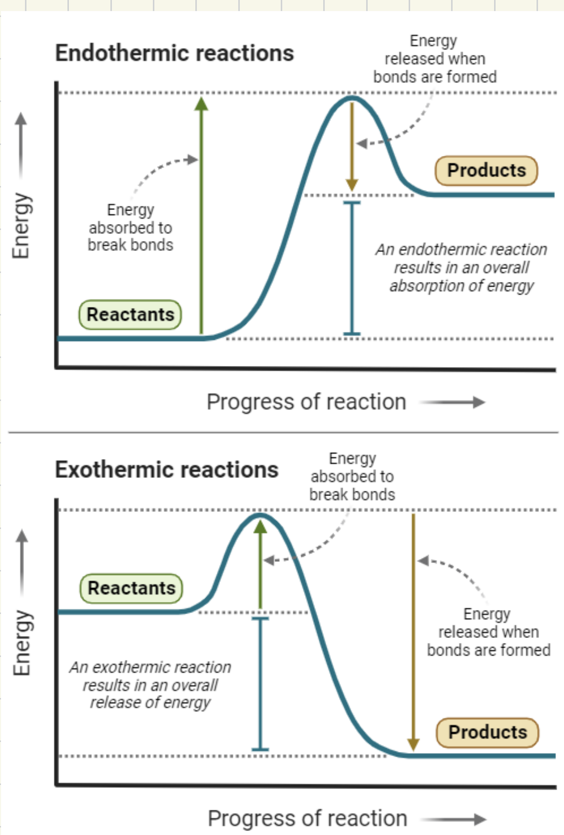
A fat molecule : Triglyceride : three fatty acid + glycerol

→ why fat molecules are not very soluble in water?
↳ because of long hydrocarbon chains that make the molecule non-polar (no partial charge → even distribution.
↳ solubility in water depends on polarity of a molecule.

Saturated or Unsaturated fat : related to what's going on with hydrocarbon chain
↳ If carbons are bonded to as many hydrogens as they can, the fat is called saturated
↳ If the carbons are not bonded to the maximum number of hydrogen atoms, the fat is called unsaturated.

without fat you might die!!
↳ many vitamins that are not soluble in water, need fat in order to be absorbed into the body properly.

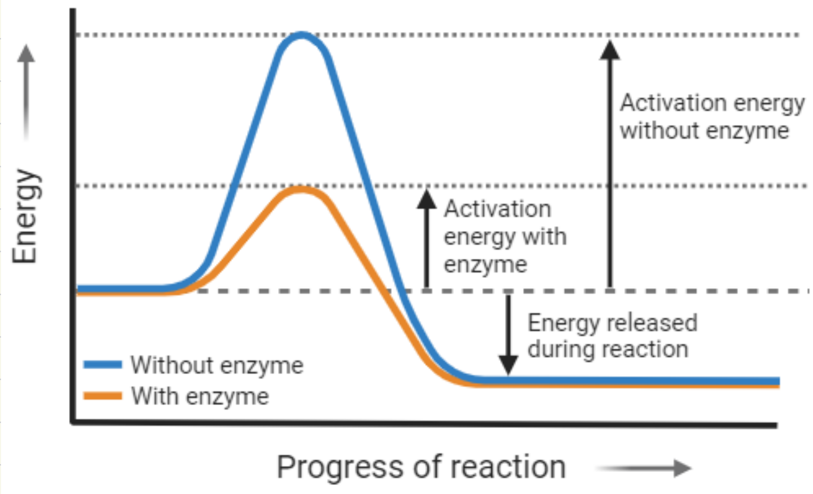
Notes from the articles



In endothermic reactions, more energy is absorbed to break the bonds in the reactants than is released when new bonds are formed in the products. So, endothermic reactions result in an overall absorption of energy.
In exothermic reactions, more energy is released when new bonds are formed in the products than is used to break bonds in the reactants. So, exothermic reactions result in an overall release of energy.

Chemical reactions in cells
The term metabolism describes the thousands of chemical reactions that occur in cells to keep an organism alive. An organism's metabolism is made up of many interconnected metabolic pathways.
Each metabolic pathway is a series of connected chemical reactions. In this series of reactions, the products of one reaction become the reactants in the next, until the final products are formed.
Metabolic pathways can be divided into two categories based on their effects.
Anabolic pathways build up (or synthesize) biomolecules and result in an overall absorption of energy.
Catabolic pathways break down biomolecules and result in an overall release of energy.

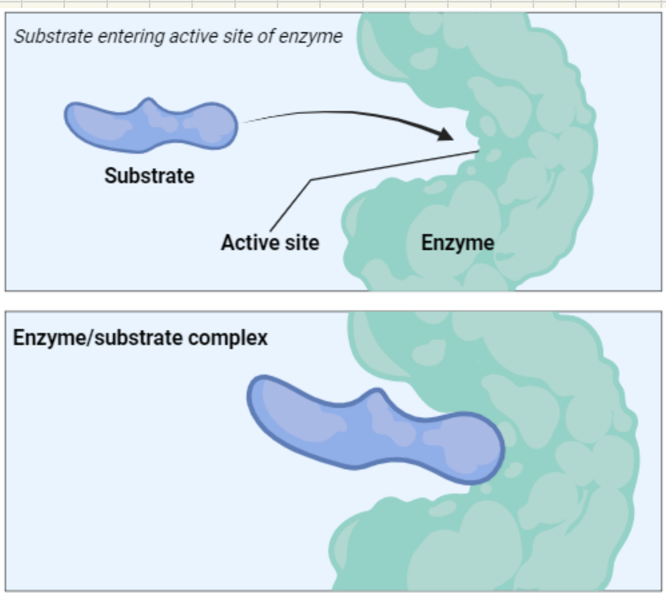
In metabolic pathways, the product of one chemical reaction becomes the reactant in the next reaction. During these reactions, atoms are rearranged.



A catalyst is a substance that can speed up a chemical reaction by providing an alternative pathway that requires less activation energy. Biological catalysts are proteins known as enzymes. These proteins speed up chemical reactions that take place in cells.

To catalyze a reaction, an enzyme will bind (or grab on) to one or more reactant molecules. These molecules are the enzyme's substrates. The part of the enzyme where the substrate binds is called the active site. The enzyme holds the substrate in a specific way (called the enzyme/substrate complex), which allows the reaction to happen more efficiently.

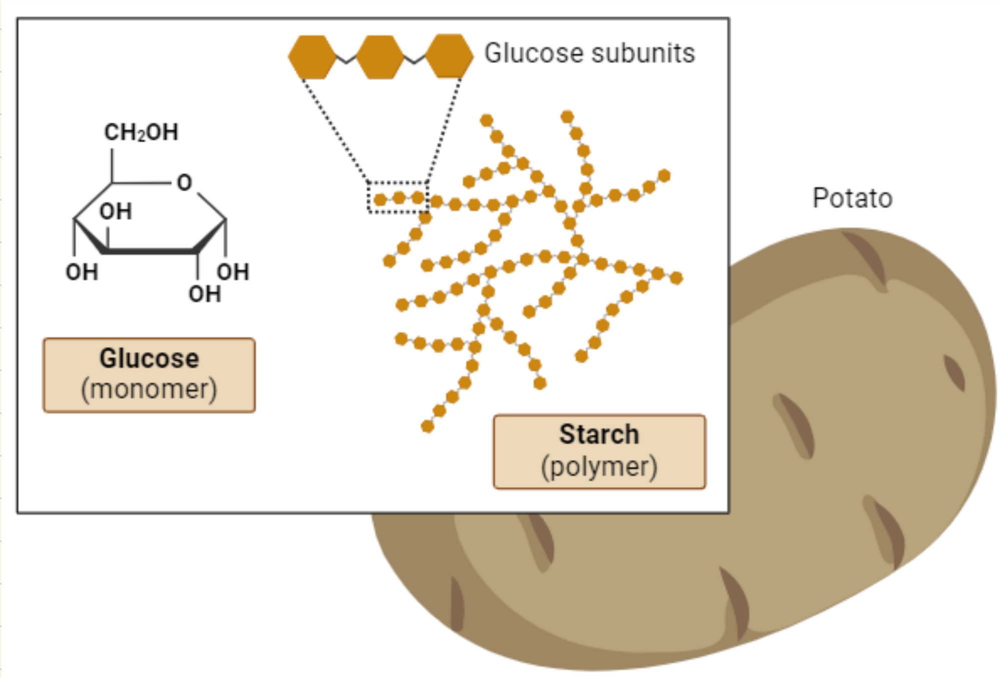
Enzymes have two additional, important features:
Enzymes are specific; each enzyme catalyzes only one or a few types of reactions. So, the reactions in a metabolic pathway are typically carried out by a series of different enzymes.
Enzymes are reusable. They are not reactants, so they are not used up during a chemical reaction.

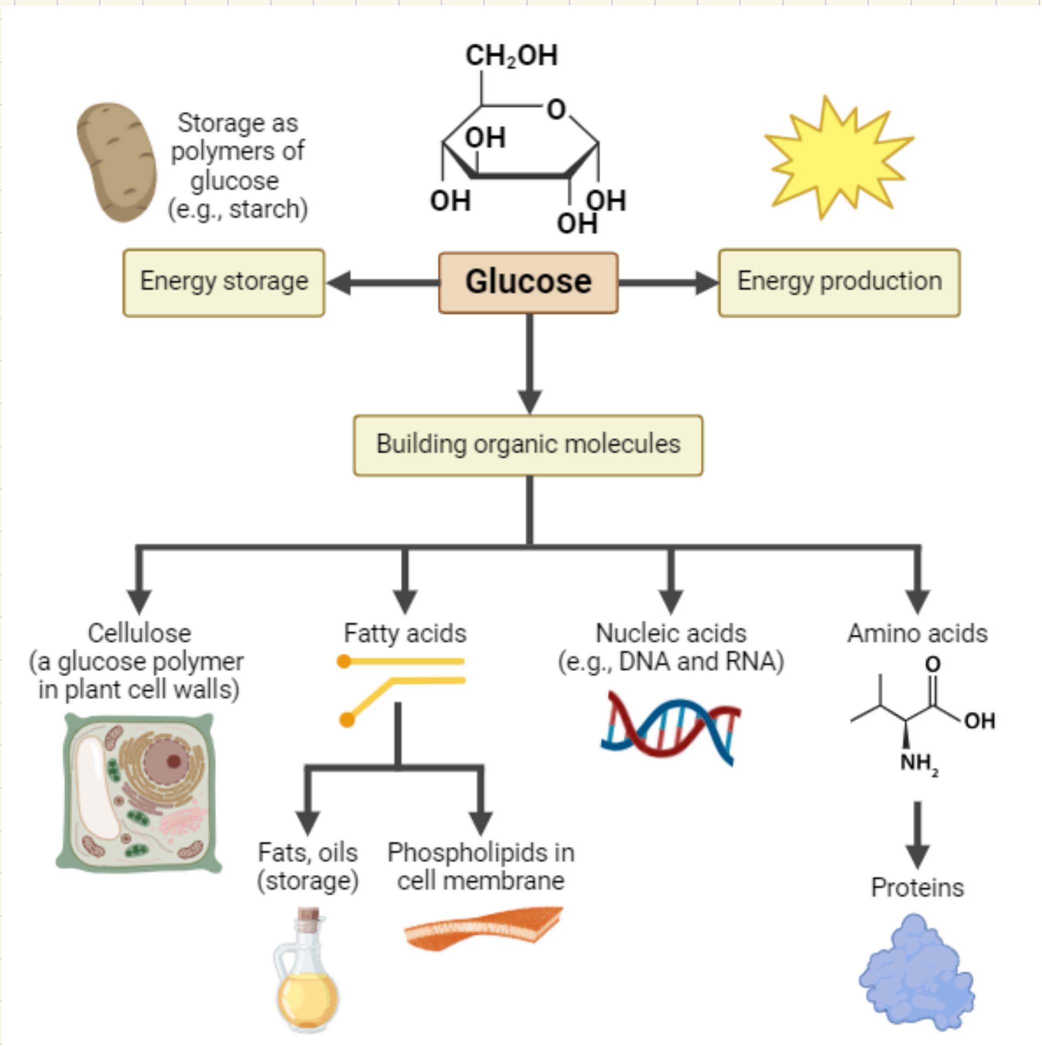


The speed of chemical reactions can also change based on the concentration (or amount) of enzymes and substrates.
Increasing enzyme concentration can speed up reactions, as long as there is substrate available to which the enzymes can bind. Once all of the substrate is bound to enzymes, the reaction will no longer speed up. This is because there will be no substrate for the additional enzymes to bind to.
Increasing substrate concentration also speeds up reactions. However, once all of the enzymes have bound to substrate, adding more substrate will have no effect on the rate of reaction. This is because all the enzymes will be bound and working at their maximum rate.

An organism's metabolism processes the biomolecules in food for two purposes:
to gain energy
to obtain molecular building blocks (monomers) for building new molecule

Organisms get energy from food via catabolic pathways. These pathways break down biomolecules such as carbohydrates and lipids. Catabolic pathways are exothermic processes, so they result in an overall release of energy. Organisms use this energy to power cellular processes.





Glucose is one of the most abundant carbohydrates. Cells can use glucose for immediate energy or store glucose for later use as a polysaccharide, such as starch. In addition, cells use glucose to build various organic molecules.

Anabolic pathways → Absorption → Breaking Down

Catabolic pathways → Release of Energy → Built Up

Lesson 3: photosynthesis

Photosynthesis is a prerequisite for everything around us!

People say: a process through which plants make sugour from light. (light doesn't have mass!)

wrong! X

Light = Energy = The capacity to do work

photosynthesis: light + to put together → greek word

$$6CO_2 + 6H_2O \xrightarrow[\text{sunlight}]{\text{energy of}} C_6H_{12}O_6 + 6O_2$$

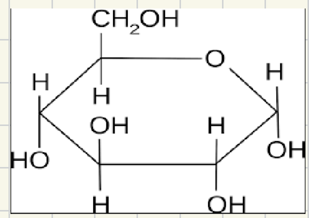
CO_2: from atmosphere

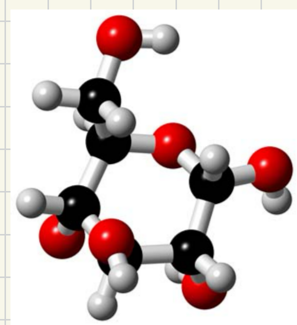
H_2O: from ground

carbohydrate: Glucose → $C_6H_{12}O_6$

watered Carbon

Glucose: has much more chemical (bonding) energy than the molecules of water and carbon dioxide





Glucos

exergonic reactions release energy (negative change in Gibbs free energy), while endergonic reactions require energy input (positive change in Gibbs free energy) to proceed.

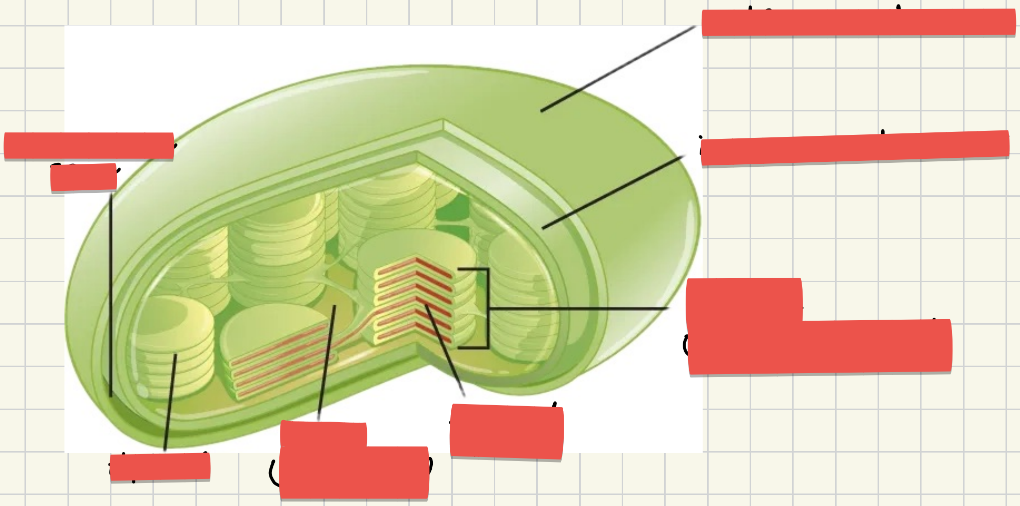
Chloroplast: where the process of photosynthesis happens.
(Chloro = green, plast = maker)

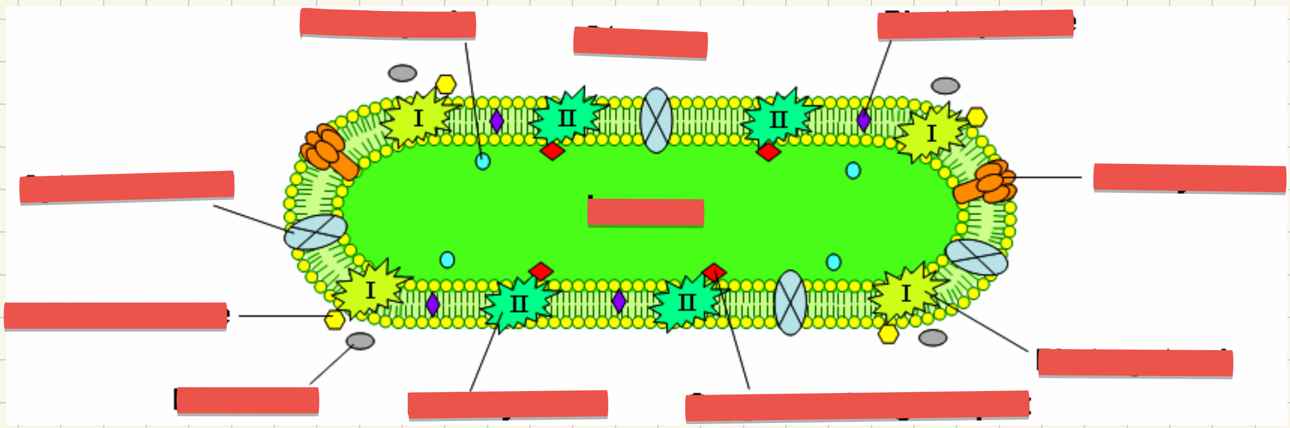
Chloroplast: a little organelle present in some plant cells which makes plants green! This because chloroplast has the green pigments called chlorophyll

Photosynthesis:
1) charging step: The energy from light is converted into chemical energy. → direct input of light → light_dependent
2) Synthesis Step: The energy is used to do the work of actually synthesizing the end product: typically a carbohydrate → glucose! → No need to light → light independent

Light-dependent reaction happens in a section of chloroplast called Thylakoid. (pouch_like)

forms little pouches that the inside of it is called lumen & outside of it is called stroma.





Light-dependent

when a photon of light end its eight minutes journey from the surface of the sun to the surface of a leaf, its energy is absorbed by the chlorophyll embedded in the thylakoid membrane. This energy powers a pump, which literally changes the inside of the thylakoids like a battery by moving the ions inside. As the charge builds up, the energy can be used to do work. But the next segment of this process happen outside of the thylakoids in the stroma. Now, energy is transferred to a molecule named ADP, Adenosine Diphosphate. By adding another phosphate, makes ATP, Adenosine Triphosphate. The next segment of photosynthesis is gonna need some electrons too that light energy is used to do the work of loading up a mobile electron carriers with electrons and protons. This carrier is called NADP

highly energetic molecules

$NADP^+ + H^+ \rightarrow NADPH$

when chlorophyll gets excited by that photon of light, turns into a real bully! The work it's doing creates such a powerful electro-chemical imbalance, and the chlorophyll balances the equation by stealing an electron from water, breaking down the water molecules, letting go (releasing) the oxygen by the plant.

Light-independent Reactions:

↳ AKA Calvin Cycle : which happens in the stroma of chloroplast
↳ chemical reactions : inorganic carbon → organic carbon → fixation
↳ with the help of the plant enzymes
↳ fixes CO_2 from the air into a chain of carbon

ATP & NADPH from light-dependent cycle provide the energy and the electrons to create 2 energetic reactive molecules that can be combined to make glucose or other useful molecules.

And the beauty of it is that the byproducts of the light independent reactions, ADP and NADP plus are shuttled off from the stroma back to the thylakoids for more light dependent reactions where they can be recharged and recycled for use again later. And, wow, photosynthesis. The takeaway here is that photosynthesis allows you to go from the intangible energy of the sun to the stored chemical energy that life on this planet is based on. The sun's energy is converted to the chemical energy of a carbohydrate molecule in the chloroplast. That molecule can later be broken down in most of that energy reclaimed either by the plant or by creatures that eat that plant. All life on earth is carbon-based. And every single molecule of that carbon once existed in the atmosphere in gaseous form as carbon dioxide until some enterprising plant or microorganism synthesized it into something you can use. And while they were added many of them filled the atmosphere with the oxygen that we all need to breathe. So the next time you see a plant, shake its leaf and say thank you.

Photosynthesis, a process vital for life, involves two main stages: light-dependent reactions and the light-independent reactions (also called the Calvin cycle). Light-dependent reactions use light energy and water to produce ATP, NADPH, and oxygen. Light-independent reactions then uses ATP, NADPH, and carbon dioxide to create sugar. This process transforms light energy into a usable form, supporting life on Earth. Created by Sal Khan.

light energy ⟶ sugar + molecular Oxygen

by product of photosynthesis

H_2O : for H

CO_2 : for Carbon

① light-dependent

energy + H_2O → ATP + NADPH + O_2

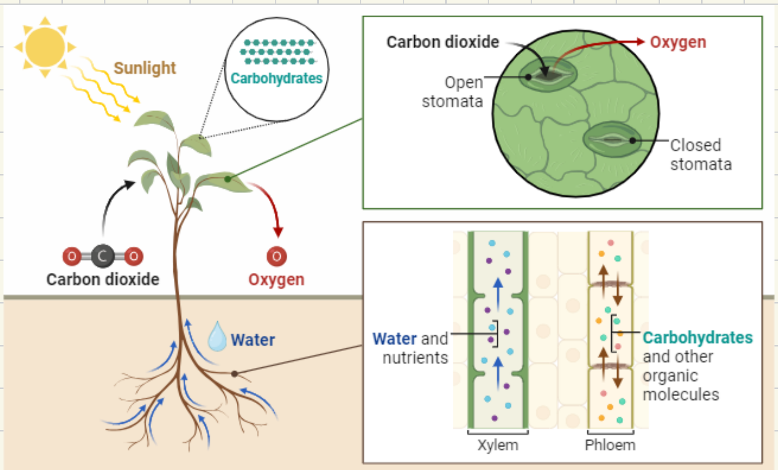
② Calvin cycle

ATP + NADPH + CO_2 → sugar

Photoautotrophs carry out photosynthesis
All living organisms need energy to survive, grow, and reproduce. Organisms get this energy from the food they consume, which contains energy-rich biomolecules. Organisms fall into two broad categories based on how they get their food.
Heterotrophs get their food by consuming other organisms.
Autotrophs make their own food inside their cells. like what a plant does through Photosynthesis
One type of autotroph—the photoautotrophs—produce food through the process of photosynthesis. Plants, algae, and some bacteria are photoautotrophs.

photoautotrophs use sunlight to produce carbohydrates—which are their primary source of food!

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$



Photosynthesis is an endothermic process

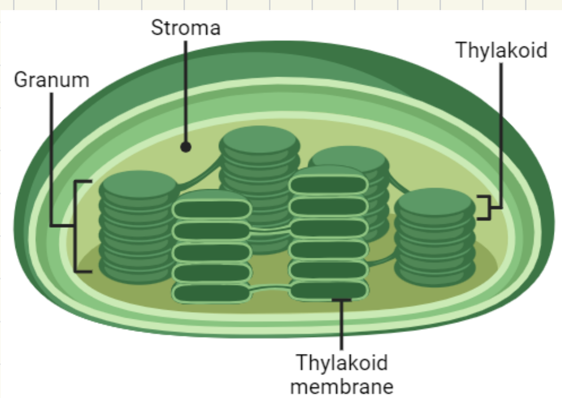
During photosynthesis, the bonds in the reactants (carbon dioxide and water) are broken, atoms are rearranged, and bonds in the products (glucose and oxygen) are formed. Importantly, the energy required to break the bonds in the reactants is greater than the energy released during the formation of bonds in the products. This energy difference is stored as chemical energy in carbohydrate molecules.

In other words, photosynthesis is an endothermic process, which results in an overall absorption of energy. Photoautotrophs can then use this energy to power cellular processes.

In plants, photosynthesis takes place in chloroplasts

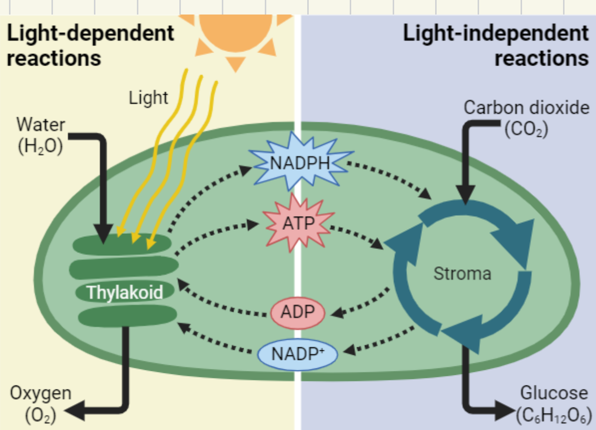
In most plants, photosynthesis occurs in the leaves, specifically in cells of the middle layer of leaf tissue called mesophyll cells. Each mesophyll cell contains chloroplasts, which are specialized organelles that carry out photosynthesis.

Within each chloroplast are disc-like structures called thylakoids, which are organized into stacks known as grana (singular: granum). The membrane of each thylakoid contains green-colored pigment molecules called chlorophylls that absorb light. The fluid-filled space around the grana is called the stroma. Different chemical reactions happen in the different parts of the chloroplast.



The light-dependent reactions take place in the thylakoid membrane and need light energy to proceed. Chlorophylls absorb light energy, which eventually breaks the bonds of water molecules. Through a series of chemical reactions, light energy is converted into chemical energy that is stored in two compounds (called ATP and NADPH) and oxygen is produced.

The light-independent reactions take place in the stroma and do not directly need light energy to proceed. Instead, the light-independent reactions use ATP and NADPH molecules from the light-dependent reactions to build carbohydrates (glucose) from carbon dioxide.



In summary, the light-dependent reactions capture light energy and temporarily store it as chemical energy in ATP and NADPH. Then, in the light-independent reactions, ATP and NADPH are used to convert carbon dioxide into carbohydrates. Overall, the energy that enters the light-dependent reactions as sunlight leaves the light-independent reactions as chemical energy stored in glucose.