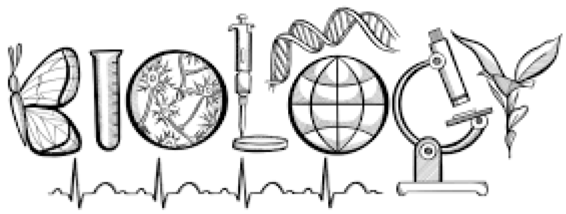
BIOLOGY REVIEW

Biology Basics



Properties of Life

Biologists have identified various traits common to all the living organisms we know of. Although nonliving things may show some of these characteristic traits, only living things show *all* of them

1. Organization

Living things are highly organized, meaning they contain specialized, coordinated parts. All living organisms are made up of one or more **cells**, which are considered the fundamental units of life.

Even **unicellular/Prokaryotic** organisms are complex! Inside each cell, atoms make up molecules, which make up cell organelles and structures. In multicellular organisms, similar cells form tissues. Tissues, in turn, collaborate to create organs (body structures with a distinct function). Organs work together to form organ systems.

Multicellular/Eukaryotic organisms—such as humans—are made up of many cells. The cells in multicellular organisms may be specialized to do different jobs and are organized into **tissues**, such as connective tissue, epithelial tissue, muscle, and nervous tissue. Tissues make up **organs**, such as the heart or lungs, which carry out specific functions needed by the organism as a whole.

2. Metabolism

Life depends on an enormous number of interlocking chemical reactions. These reactions make it possible for organisms to do work—such as moving around or catching prey—as well as growing, reproducing, and maintaining the structure of their bodies. Living things must use energy and consume nutrients to carry out the chemical reactions that sustain life. The sum total of the biochemical reactions occurring in an organism is called its **metabolism**.

Metabolism can be subdivided into anabolism and catabolism. In **anabolism**, organisms make complex molecules from simpler ones, while in **catabolism**, they do the reverse. Anabolic processes typically consume energy, whereas catabolic processes can make stored energy available.

3. Homeostasis

Living organisms regulate their internal environment to maintain the relatively narrow range of conditions needed for cell function. For instance, your body temperature needs to be kept relatively close to 98.6 degrees. This maintenance of a stable internal environment, even in the face of a changing external environment, is known as **homeostasis**.

4. Growth

Living organisms undergo regulated growth. Individual cells become larger in size, and multicellular organisms accumulate many cells through cell division. You yourself started out as a single cell and now have tens of trillions of cells in your body. Growth depends on anabolic pathways that build large, complex molecules such as proteins and DNA, the genetic material.

5. Reproduction

Living organisms can reproduce themselves to create new organisms. Reproduction can be either **asexual**, involving a single parent organism, or **sexual**, requiring two parents. Single-celled organisms, like the dividing bacterium can reproduce themselves simply by splitting in two!

In sexual reproduction, two parent organisms produce sperm and egg cells containing half of their genetic information, and these cells fuse to form a new individual with a full genetic set. This process is called fertilization

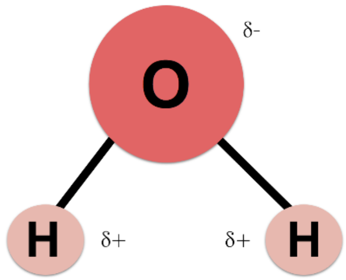
6. Response

Living organisms show “irritability,” meaning that they respond to stimuli or changes in their environment. For instance, people pull their hand away—fast!—from a flame; many plants turn toward the sun; and unicellular organisms may migrate toward a source of nutrients or away from a noxious chemical.

7. Evolution

Populations of living organisms can undergo **evolution**, meaning that the genetic makeup of a population may change over time. In some cases, evolution involves **natural selection**, in which a heritable trait, such as darker fur color or narrower beak shape, lets organisms survive and reproduce better in a particular environment. Over generations, a heritable trait that provides a fitness advantage may become more and more common in a population, making the population better suited to its environment. This process is called **adaptation**.

Water



Important Terms

Polar molecule	A neutral, or uncharged molecule that has an asymmetric internal distribution of charge, leading to partially positive and partially negative regions
Cohesion	The attraction of molecules for other molecules of the same kind
Adhesion	The attraction of molecules for other molecules of a different kind
Density	The mass per unit volume of a substance
Specific heat capacity	The amount of heat needed to raise the temperature of one gram of a substance by one degree Celsius
Heat of vaporization	The amount of energy needed to change one gram of a liquid substance to a gas at constant temperature

Important Characteristics of Water

Water is polar. Water molecules are polar, with partial positive charges on the hydrogens, a partial negative charge on the oxygen, and a bent overall structure. This is because oxygen is more *electronegative*, meaning that it is better than hydrogen at attracting electrons.

Water is an excellent solvent. Water has the unique ability to dissolve many substances. This is important to all living things because, as water travels through the water cycle, it takes many valuable nutrients along with it!

Water has high heat capacity. It takes a lot of energy to raise the temperature of a certain amount of water by a degree, so water helps with regulating temperature in the environment. For example, this property allows the temperature of water in a pond to stay relatively constant from day to night, regardless of the changing atmospheric temperature.

Water has high heat of vaporization. Humans (and other animals that sweat) use water's high heat of vaporization to cool off. Water is converted from its liquid form to steam when the heat of vaporization is reached. Since sweat is made mostly of water, the evaporating water absorbs excess body heat, which is released into the atmosphere. This is known as *evaporative cooling*.

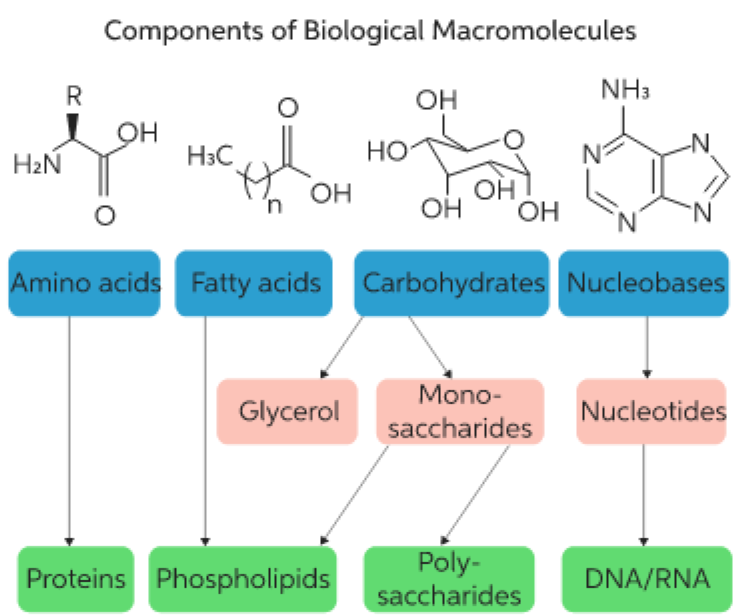
Water has cohesive and adhesive properties. Water molecules have strong *cohesive* forces due to their ability to form hydrogen bonds with one another. Cohesive forces are responsible for *surface tension*, the tendency of a liquid's surface to resist rupture when placed under tension or stress. Water also has *adhesive* properties that allow it to stick to substances other than itself.

These cohesive and adhesive properties are essential for fluid transport in many forms of life. For example, they allow nutrients to be transported to the top of a tree against the force of gravity.

Water is less dense as a solid than as a liquid. As water freezes, the molecules form a crystalline structure that spaces the molecules further apart than in liquid water. This means that ice is less dense than liquid water, which is why it floats.

This property is important, as it keeps ponds, lakes, and oceans from freezing solid and allows life to continue to thrive under the icy surface.

Macromolecules



Large biological molecules: carbohydrates (such as sugars), lipids (such as fats), proteins, and nucleic acids (such as DNA and RNA).

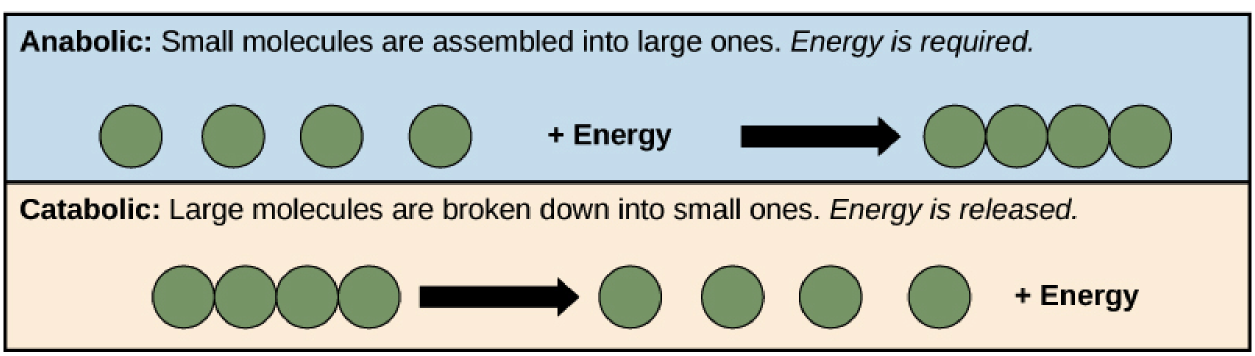
Together, the four groups of large biological molecules make up the majority of the dry weight of a cell. (Water, a small molecule, makes up the majority of the wet weight).

Large biological molecules perform a wide range of jobs in an organism. Some carbohydrates store fuel for future energy needs, and some lipids are key structural components of cell membranes. Nucleic acids store and transfer hereditary information, much of which provides instructions for making proteins. Proteins themselves have perhaps the broadest range of functions: some provide structural support, but many are like little machines that carry out specific jobs in a cell, such as catalyzing metabolic reactions or receiving and transmitting signals.

Metabolism

In the metabolic web of the cell, some of the chemical reactions release energy and can happen spontaneously (without energy input). However, others need added energy in order to take place. Just as you must continually eat food to replace what your body uses, so cells need a continual inflow of energy to power their energy-requiring chemical reactions. In fact, the food you eat is the source of the energy used by your cells!

Metabolic pathways



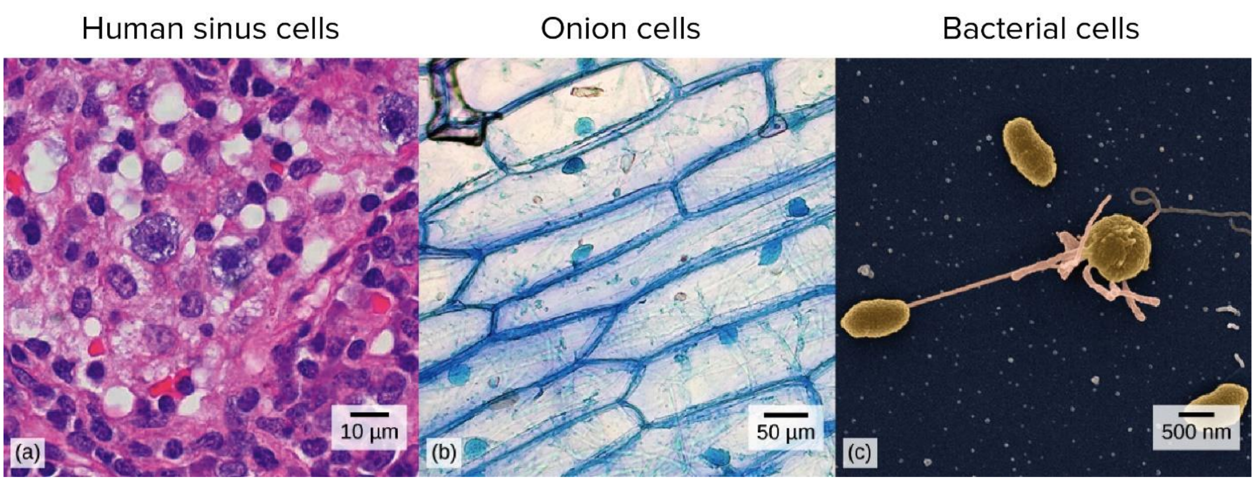
The processes of making and breaking down glucose molecules are both examples of metabolic pathways. A **metabolic pathway** is a series of connected chemical reactions that feed one another. The pathway takes in one or more starting molecules and, through a series of intermediates, converts them into products.

Metabolic pathways can be broadly divided into two categories based on their effects. Photosynthesis, which builds sugars out of smaller molecules, is a "building up," or **anabolic**, pathway. In contrast, cellular respiration breaks sugar down into smaller molecules and is a "breaking down," or **catabolic**, pathway.

Anabolic pathways build complex molecules from simpler ones and typically need an input of energy. Building glucose from carbon dioxide is one example. Other examples include the synthesis of proteins from amino acids, or of DNA strands from nucleic acid building blocks (nucleotides). These biosynthetic processes are critical to the life of the cell, take place constantly, and use energy carried by ATP and other short-term energy storage molecules.

Catabolic pathways involve the breakdown of complex molecules into simpler ones and typically release energy. Energy stored in the bonds of complex molecules, such as glucose and fats, is released in catabolic pathways. It's then harvested in forms that can power the work of the cell (for instance, through the synthesis of ATP).

The Cell



Cell theory

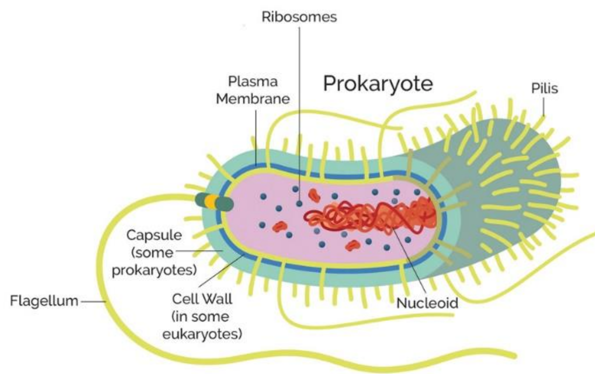
All living things are composed of one or more cells.

The cell is the basic unit of life.

New cells arise from pre-existing cells.

There are <u>two</u> major cell types: prokaryotic & Eukaryotic

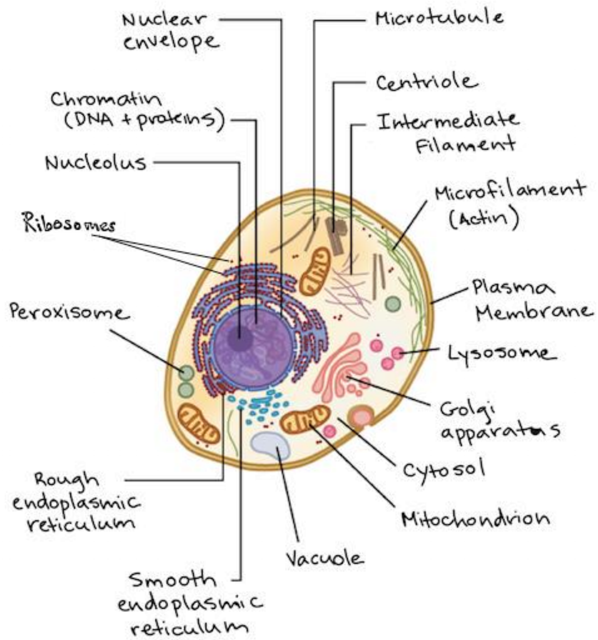
All cells fall into one of these two broad categories. Only the single-celled organisms of the domains Bacteria and Archaea are classified as prokaryotes



There are some key ingredients that a cell needs in order to be a cell, regardless of whether it is prokaryotic or eukaryotic. All cells share four key components:

1. The **plasma membrane** is an outer covering that separates the cell's interior from its surrounding environment.
2. **Cytoplasm** consists of the jelly-like cytosol inside the cell, plus the cellular structures suspended in it. In eukaryotes, cytoplasm specifically means the region outside the nucleus but inside the plasma membrane.
3. **DNA** is the genetic material of the cell.
4. **Ribosomes** are molecular machines that synthesize proteins.

Animals, plants, fungi, and protists are all eukaryotes. An Important difference between prokaryotes and eukaryotes, is compartmentalization. Eukaryotic cells contain a variety of different compartments with specialized functions, neatly separated from one another by layers of membrane. This organization lets each compartment maintain its own conditions, the ones it needs to carry out its job.



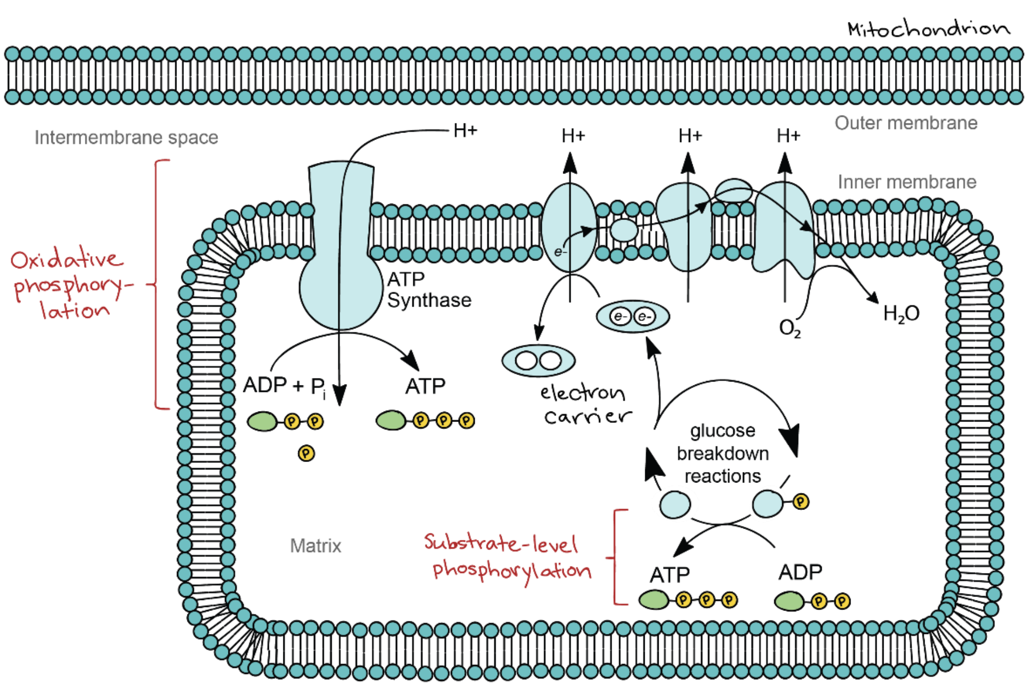
Organelle	Function	Factory part
Nucleus	DNA Storage	Room where the blueprints are kept
Mitochondrion	Energy production	Powerplant
Smooth Endoplasmic Reticulum (SER)	Lipid production; Detoxification	Accessory production - makes decorations for the toy, etc.
Rough Endoplasmic Reticulum (RER)	Protein production; in particular for export out of the cell	Primary production line - makes the toys
Golgi apparatus	Protein modification and export	Shipping department
Peroxisome	Lipid Destruction; contains oxidative enzymes	Security and waste removal
Lysosome	Protein destruction	Recycling and security

Cellular respiration is the process by which living cells break down glucose molecules and release energy.
The process is similar to burning, although it doesn't produce light or intense heat.
This is because cellular respiration releases the energy in glucose *slowly* and in many small steps. It uses the energy released to form molecules of **ATP**, <u>the energy-carrying molecules that cells use to power biochemical processes</u>. In this way, cellular respiration is an example of energy coupling: glucose is broken down in an exothermic reaction, and then the energy from this reaction powers the endothermic reaction of the formation of ATP.
Cellular respiration involves many chemical reactions, but they can all be summed up with this chemical equation:

$$\mathbf{C_6H_{12}O_6\ \ 6O_2 \rightarrow 6CO_2\ \ 6H_2O\ \text{Chemical Energy (in ATP)}}$$

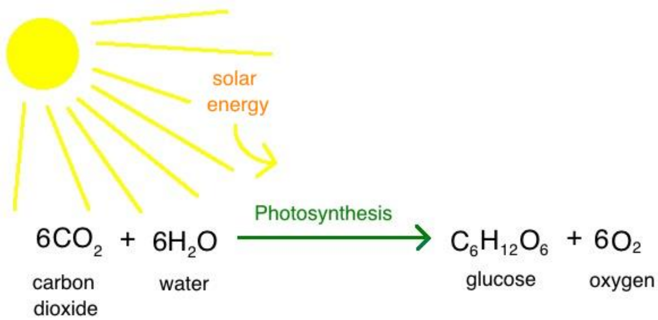
In words, the equation shows that glucose ($C_6H_{12}O_6$) and oxygen (O_2) react to form carbon dioxide (CO_2) and water (H_2O), releasing energy in the process. Because oxygen is required for cellular respiration, it is an **aerobic** process.

Cellular respiration occurs in the cells of all living things, both autotrophs and heterotrophs. All of them burn glucose to form ATP. The reactions of cellular respiration can be grouped into three stages: glycolysis, the Krebs cycle (also called the citric acid cycle), and electron transport.

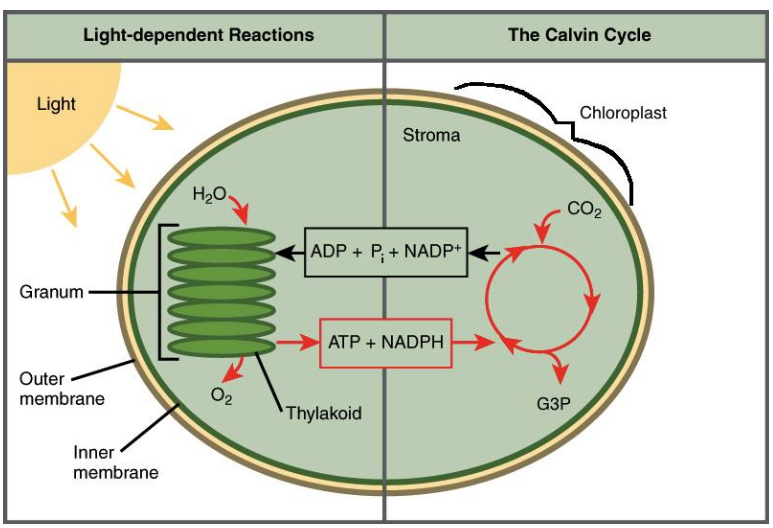


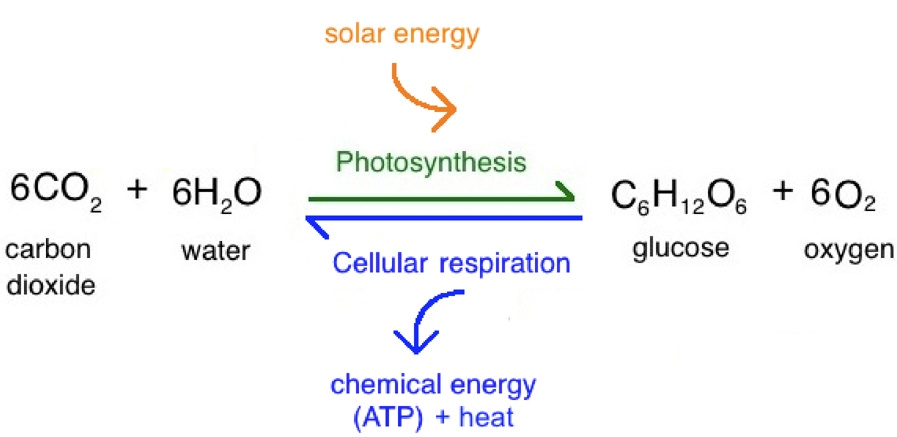
VIDEO →Click here to go more in-depth

Photosynthesis



Photosynthesis is the process in which light energy is converted to chemical energy in the form of sugars. In a process driven by light energy, glucose molecules (or other sugars) are constructed from water and carbon dioxide, and oxygen is released as a byproduct. The glucose molecules provide organisms with two crucial resources: energy and fixed—organic—carbon.



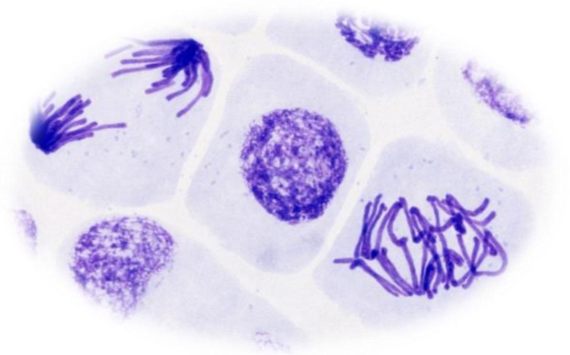


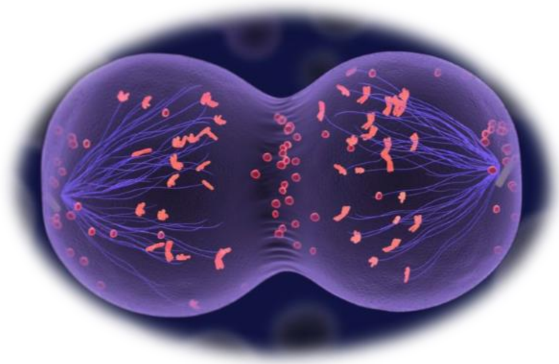
VIDEO → Click here to go more in-depth

Cellular reproduction

Mitosis – growth and repair

Meiosis – to make gametes





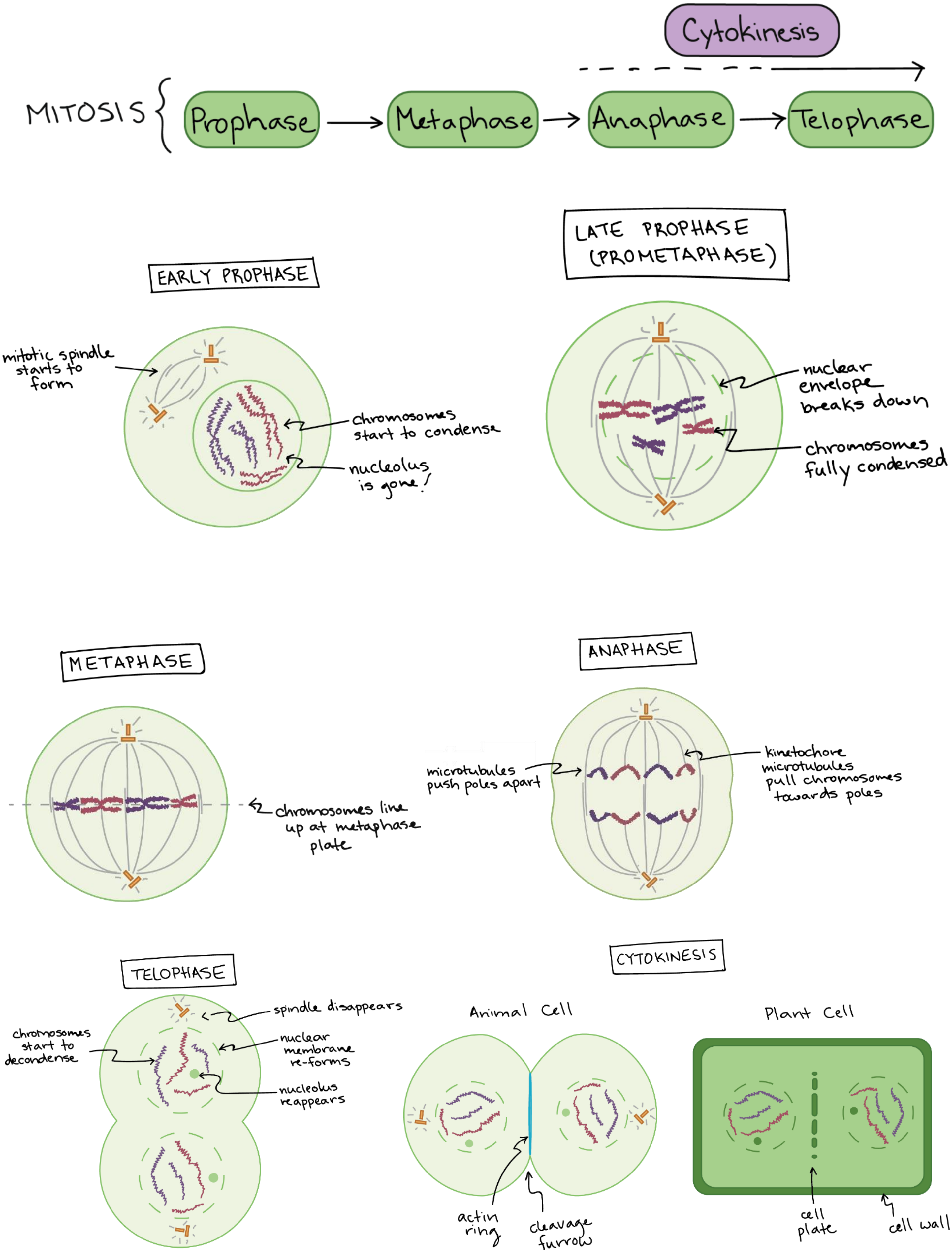
2 types of division with eukaryotes we will talk about

Mitosis is a type of cell division in which one cell (the **mother**) divides to produce two new cells (the **daughters**) that are genetically identical to itself. In the context of the cell cycle, mitosis is the part of the division process in which the DNA of the cell's nucleus is split into two equal sets of chromosomes.

In all of these cases, the “goal” of mitosis is to make sure that each daughter cell gets a perfect, full set of chromosomes. Cells with too few or too many chromosomes usually don’t function well: they may not survive, or they may even cause cancer.

Phases of mitosis

Mitosis consists of four basic phases: prophase, metaphase, anaphase, and telophase. Some textbooks list five, breaking prophase into an early phase (called prophase) and a late phase (called prometaphase). These phases occur in strict sequential order, and cytokinesis - the process of dividing the cell contents to make two new cells - starts in anaphase or telophase.


Cytokinesis
MITOSIS
Prophase
Metaphase
Anaphase
Telophase
EARLY PROPHASE
mitotic spindle starts to form
chromosomes start to condense
nucleolus is gone!
LATE PROPHASE (PROMETAPHASE)
nuclear envelope breaks down
chromosomes fully condensed
METAPHASE
chromosomes line up at metaphase plate
ANAPHASE
microtubules push poles apart
kinetochore microtubules pull chromosomes towards poles
TELOPHASE
spindle disappears
chromosomes start to decondense
nuclear membrane re-forms
nucleolus reappears
CYTOKINESIS
Animal Cell
actin ring
cleavage furrow
Plant Cell
cell plate
cell wall

Meiosis

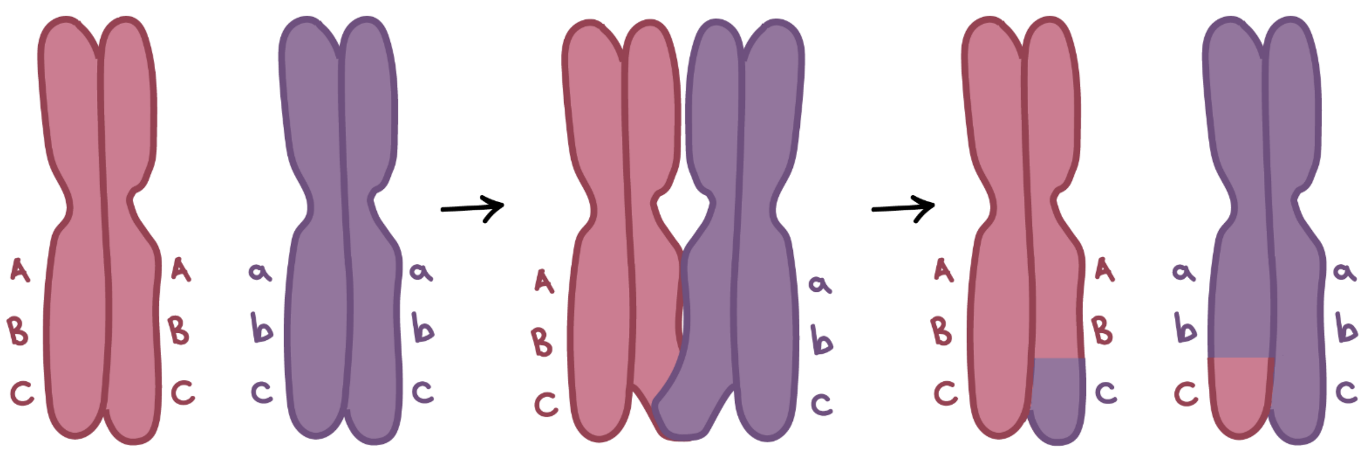
Meiosis, on the other hand, is used for just one purpose in the human body: the production of gametes—sex cells, or sperm and eggs. Its goal is to make daughter cells with exactly half as many chromosomes as the starting cell.

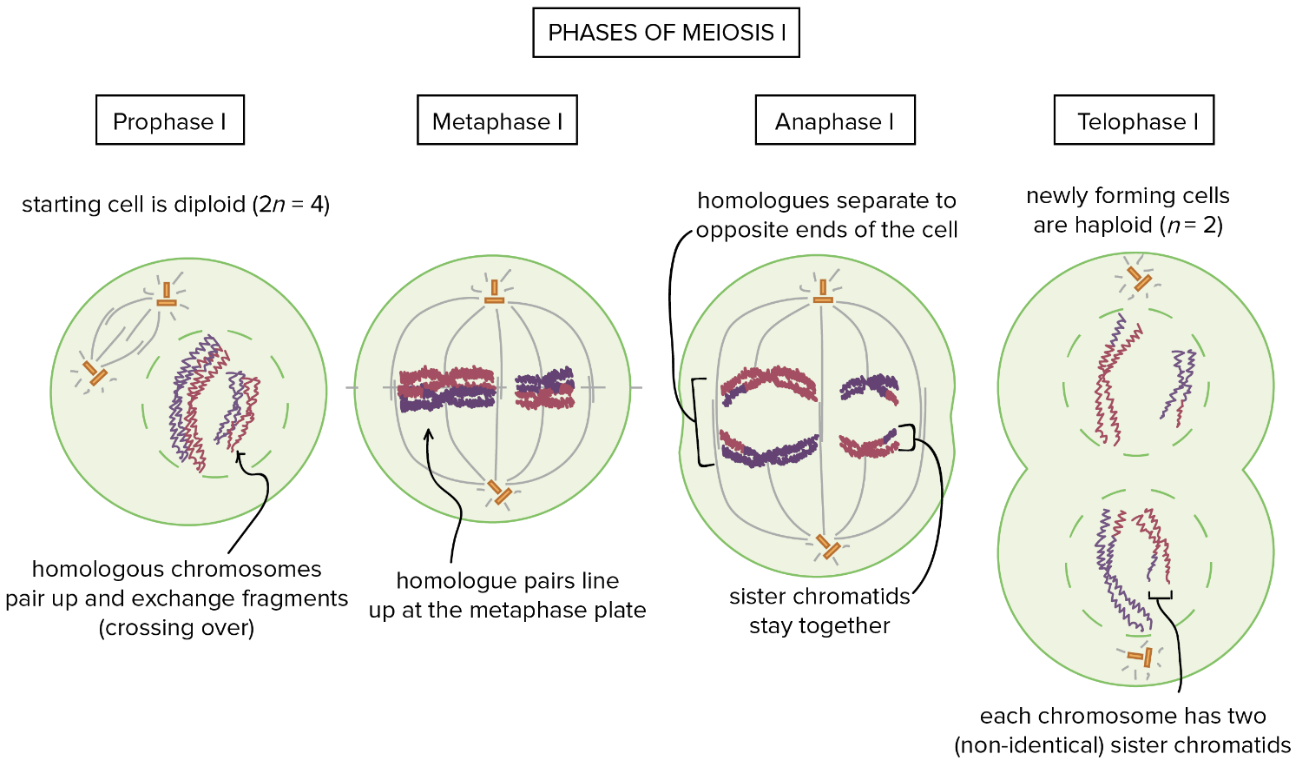
In many ways, meiosis is a lot like mitosis. The cell goes through similar stages and uses similar strategies to organize and separate chromosomes. In meiosis, however, the cell has a more complex task.

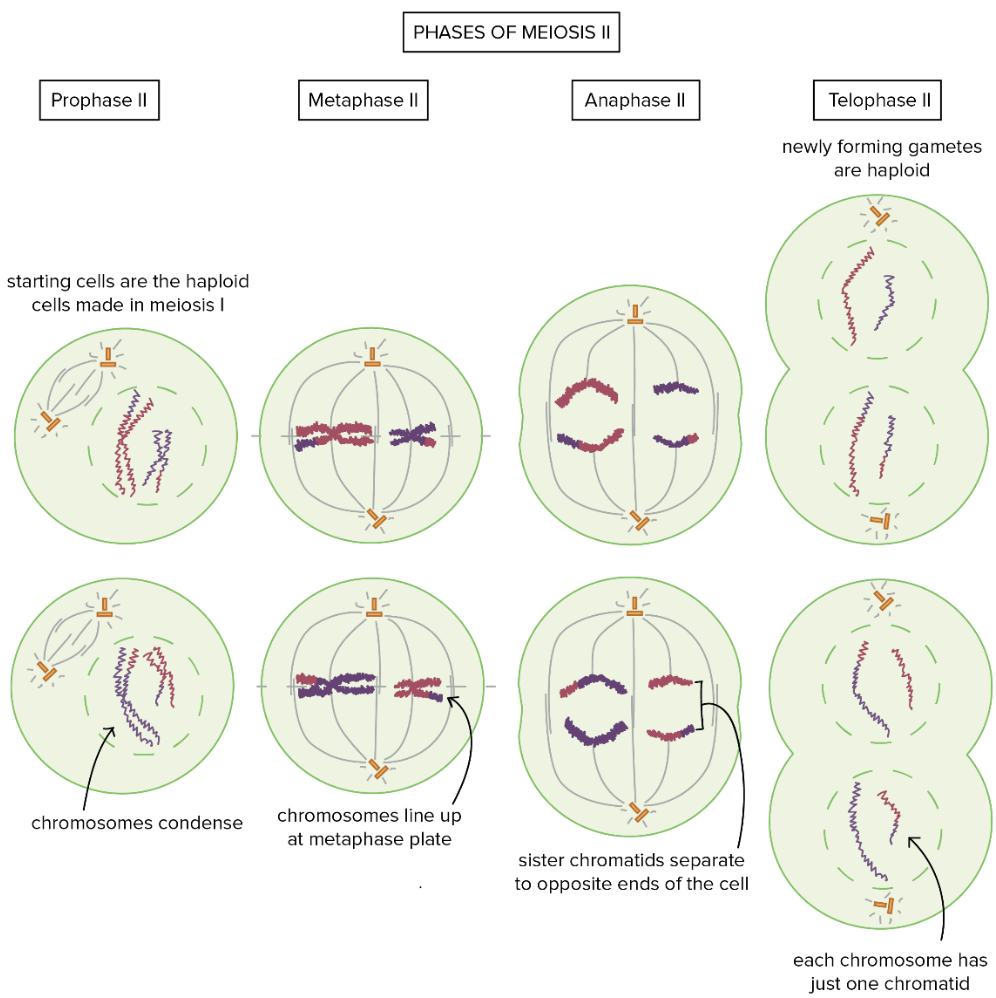
Since cell division occurs twice during meiosis, one starting cell can produce four gametes (eggs or sperm). In each round of division, cells go through four stages: prophase, metaphase, anaphase, and telophase.

Crossing Over

This process, in which homologous chromosomes trade parts, is called crossing over. This allows for Genetic diversity. This occurs in Prophase I.




PHASES OF MEIOSIS I
Prophase I
Metaphase I
Anaphase I
Telophase I
starting cell is diploid (2n = 4)
homologues separate to opposite ends of the cell
newly forming cells are haploid (n = 2)
homologous chromosomes pair up and exchange fragments (crossing over)
homologue pairs line up at the metaphase plate
sister chromatids stay together
each chromosome has two (non-identical) sister chromatids


PHASES OF MEIOSIS II
Prophase II
Metaphase II
Anaphase II
Telophase II
newly forming gametes are haploid
starting cells are the haploid cells made in meiosis I
chromosomes condense
chromosomes line up at metaphase plate
sister chromatids separate to opposite ends of the cell
each chromosome has just one chromatid

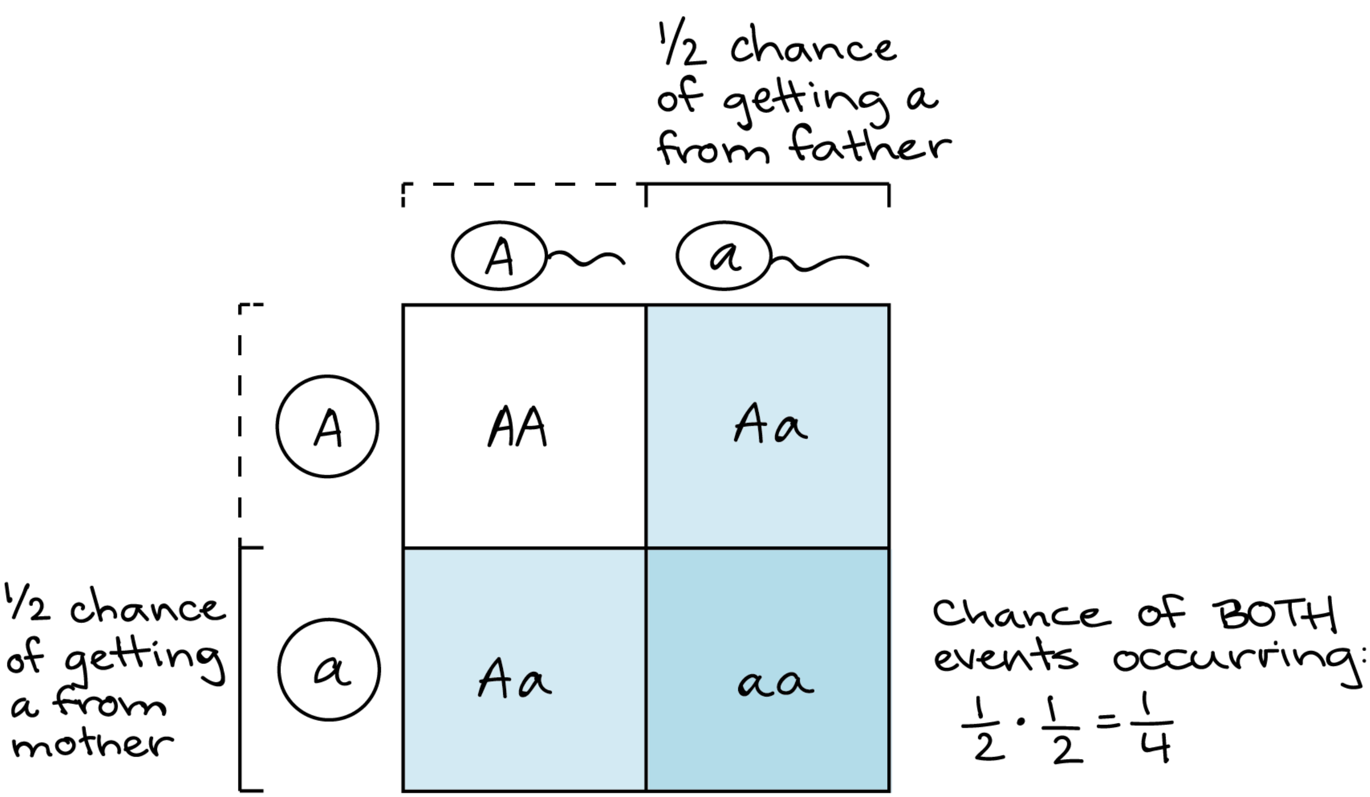
VIDEO →Click here to go more in-depth (Mitosis)

VIDEO →Click here to go more in-depth (Meiosis)

Genetics

Key points:

- Gregor Mendel studied inheritance of traits in pea plants. He proposed a model where pairs of "heritable elements," or **genes**, specified traits.
- Genes come in different versions, or **alleles**. A **dominant** allele hides a **recessive** allele and determines the organism's appearance.
- When an organism makes gametes, each gamete receives just one gene copy, which is selected randomly. This is known as the **law of segregation**.
- A **Punnett square** can be used to predict **genotypes** (allele combinations) and **phenotypes** (observable traits) of offspring from genetic crosses.
- A **test cross** can be used to determine whether an organism with a dominant phenotype is homozygous or heterozygous



VIDEO →Click here to go more in-depth (Genetics/Heredity)

DNA

- ✓ DNA is the information molecule. It stores instructions for making other large molecules, called proteins.
- ✓ These instructions are stored inside each of your cells, distributed among 46 long structures called chromosomes.
- ✓ These chromosomes are made up of thousands of shorter segments of DNA, called genes.
- ✓ Each gene stores the directions for making protein fragments, whole proteins, or multiple specific proteins.

DNA molecules are polymers

Polymers are large molecules that are built up by repeatedly linking together smaller molecules, called **monomers.**

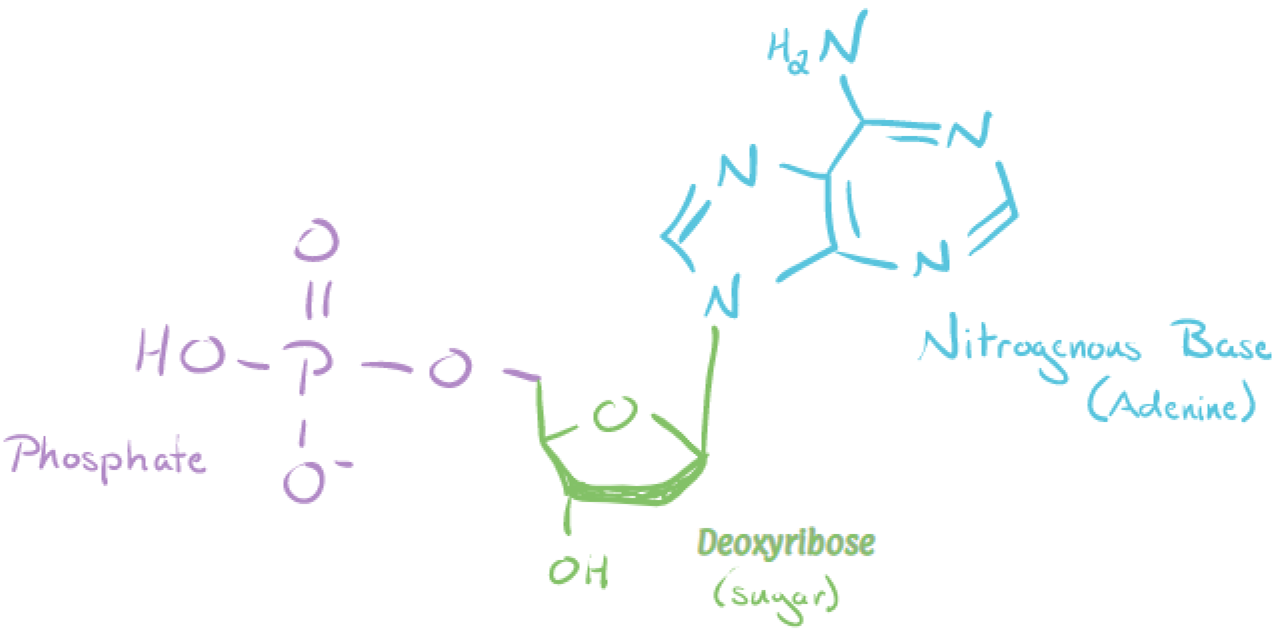
DNA monomers are called nucleotides

Just like a sentence "polymer" is composed of letter "monomers," a DNA polymer is composed of monomers called **nucleotides**. A molecule of DNA is a bunch of nucleotide monomers, joined one after another into a very long chain.

There are four nucleotide monomers

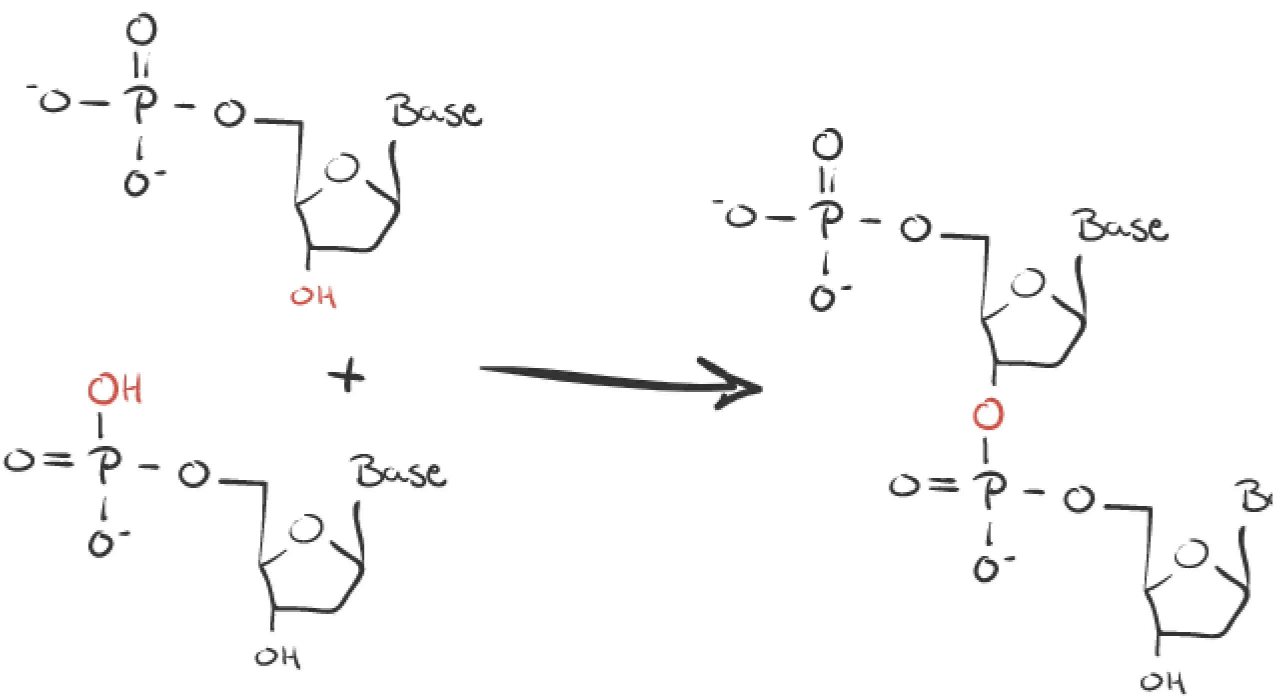
DNA "alphabet" has only four "letters," the four nucleotide monomers. They have short and easy to remember names: A, C, T, G. Each nucleotide monomer is built from three simple molecular parts: **a sugar**, a **phosphate group**, and a **nucleo(nitrogenous)base**.

Nucleotide Structure



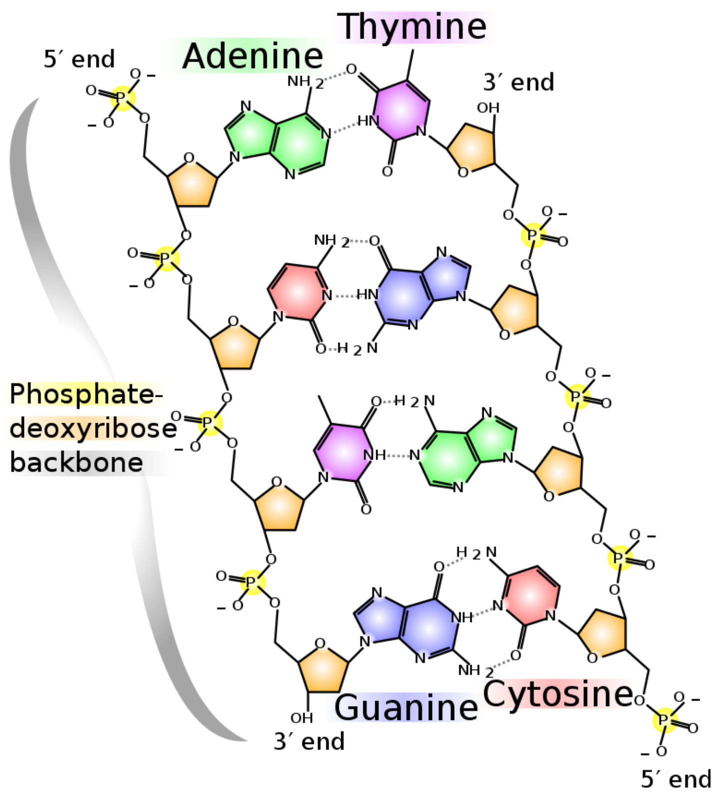
The phosphodiester bonds that join one DNA nucleotide to another always link the 3' carbon of the first nucleotide to the 5' carbon of the second nucleotide.

These bonds are called <u>3'-5' phosphodiester bonds</u>



Purines & Pyrimidines

There are 4 Nucelotides, Adenine, Thymine, Guanine, Cytosine, and in RNA Uracil.



Purines

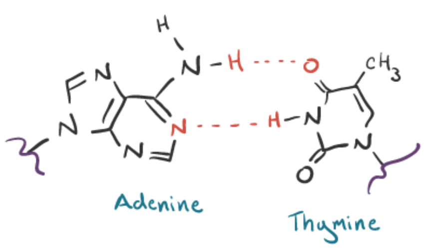
Adenine and guanine are **purines**, meaning that their structures contain two fused carbon-nitrogen rings.

Pyrimidines

Cytosine and thymine, in contrast, are **Pyrimidines** and have a single carbon-nitrogen ring. In RNA, there is no Thymine, rather there is Uracil.

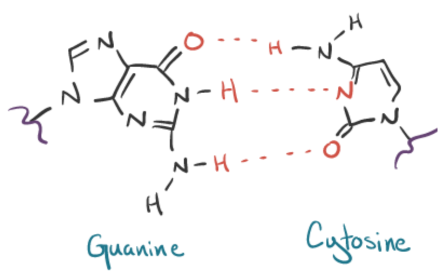
Chargaffs Rule

- Erwin Chargaff determined that
  - Amount of adenine = amount of thymine
  - Amount of cytosine = amount of guanine
  - Always an equal proportion of purines (A and G) and pyrimidines (C and T)



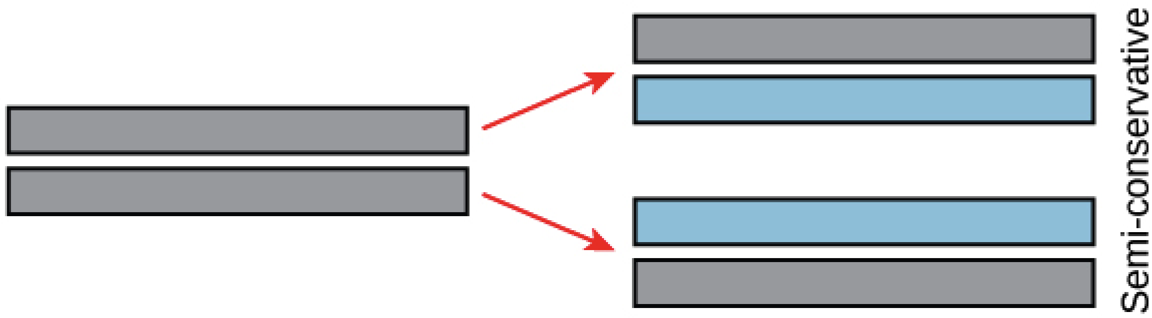
Base Bonds

- Complementarity of bases
- A forms 2 hydrogen bonds with T
- G forms 3 hydrogen bonds with C
- Gives consistent diameter

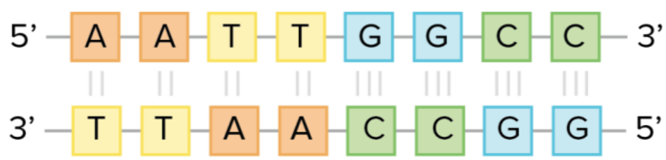


DNA Replication

– DNA replication is **semiconservative**. Each strand in the double helix acts as a template for synthesis of a new, complementary strand.



– New DNA is made by enzymes called **DNA polymerases**, which require a template and a **primer** (starter) and synthesize DNA in the 5' to 3' direction.



– During DNA replication, one new strand (the **leading strand**) is made as a continuous piece. The other (the **lagging strand**) is made in small pieces.

– DNA replication requires other enzymes in addition to DNA polymerase, including **DNA primase**, **DNA helicase**, **DNA ligase**, and **topoisomerase**

Steps of Replication

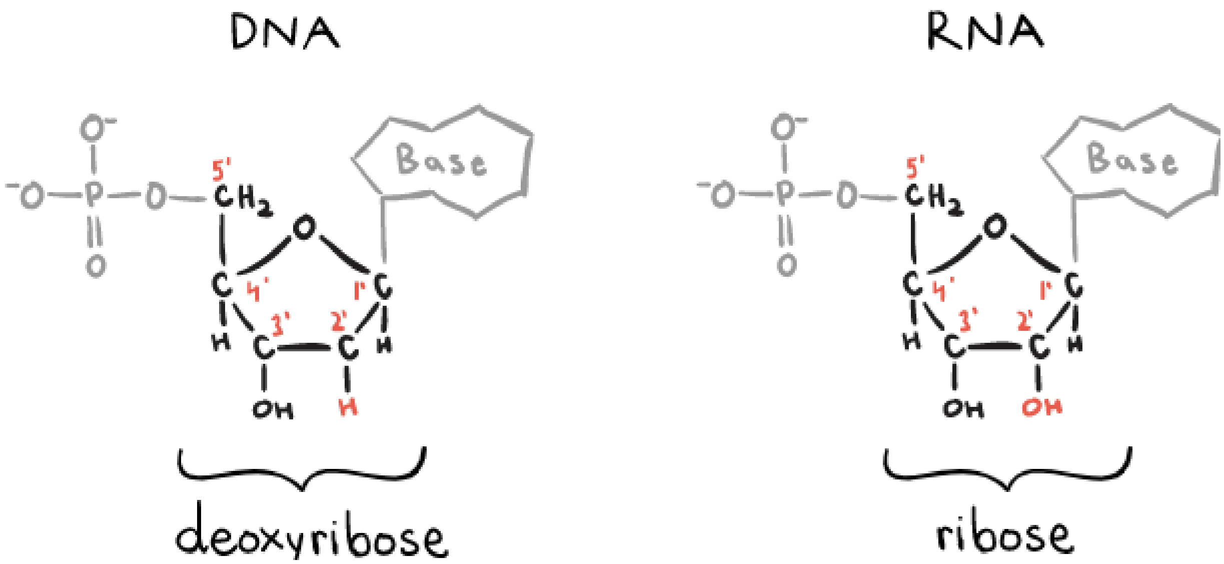
- DNA replication includes
  - **Initiation** – replication begins
  - **Elongation** – new strands of DNA are synthesized by DNA polymerase
  - **Termination** – replication is terminated

A DNA molecule isn't just a long, boring string of nucleotides. Instead, it's divided up into functional units called **genes**. Each gene provides instructions for a functional product, that is, a molecule needed to perform a job in the cell. In many cases, the functional product of a gene is a protein. For example, Mendel's flower color gene provides instructions for a protein that helps make colored molecules (pigments) in flower petals.

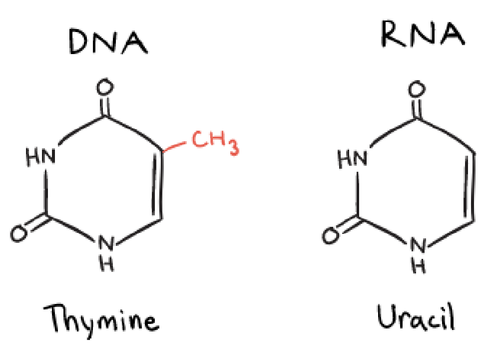
Transcription & Translation

Transcription

DNA → RNA



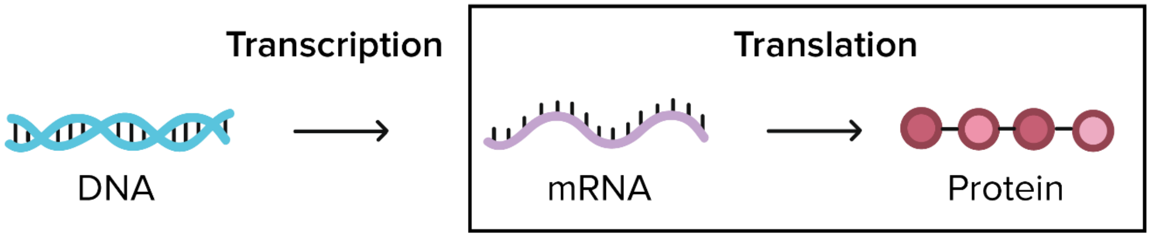
The instructions in a gene (written in the language of DNA nucleotides) are transcribed into a portable gene, called an mRNA transcript. These mRNA transcripts escape the nucleus and travel to the ribosomes, where they deliver their protein assembly instructions. The creation of mRNA transcripts (the creation of these portable genes) is called gene transcription.



Translation

RNA → Protein

In this stage, the mRNA is "decoded" to build a protein (or a chunk/subunit of a protein) that contains a specific series of amino acids.

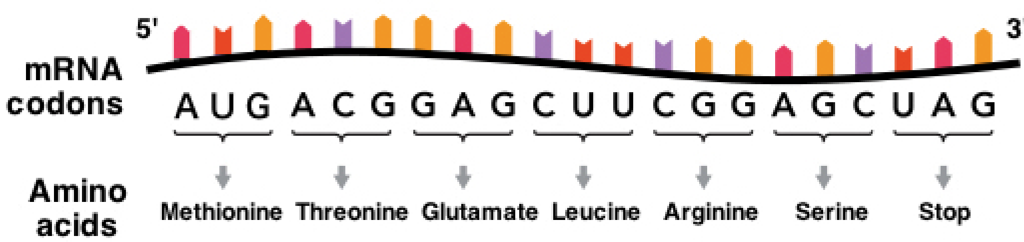


During translation, a cell “reads” the information in a messenger RNA (mRNA) and uses it to build a protein

In an mRNA, the instructions for building a polypeptide are RNA nucleotides (As, Us, Cs, and Gs) read in groups of three. These groups of three are called **codons**.

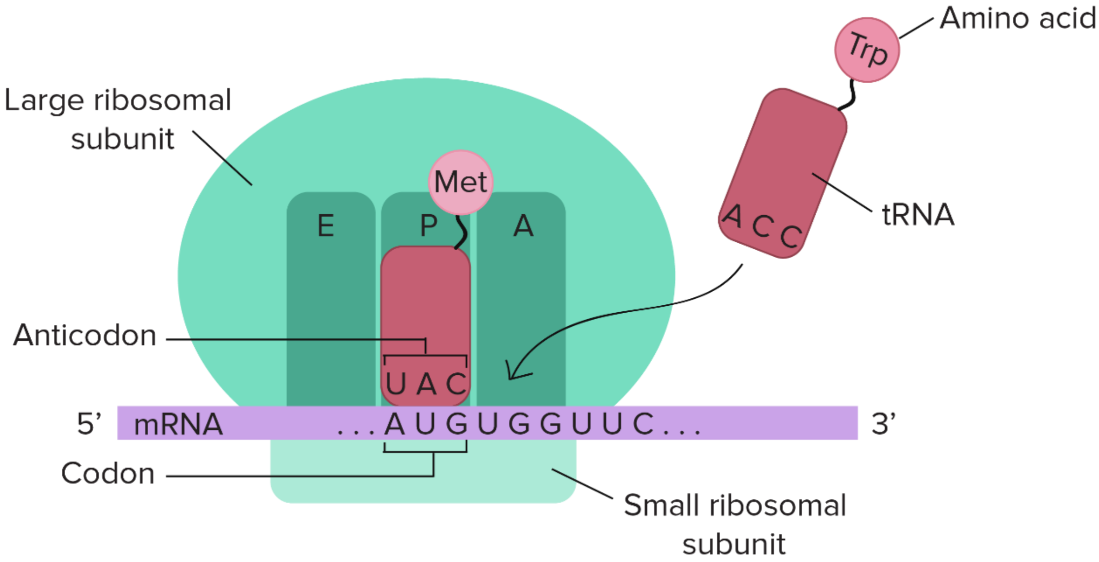
One codon, AUG, specifies the amino acid methionine and also acts as a **start codon** to signal the start of protein construction.

here are three more codons that do *not* specify amino acids. These **stop codons**, UAA, UAG, and UGA, tell the cell when a polypeptide is complete.



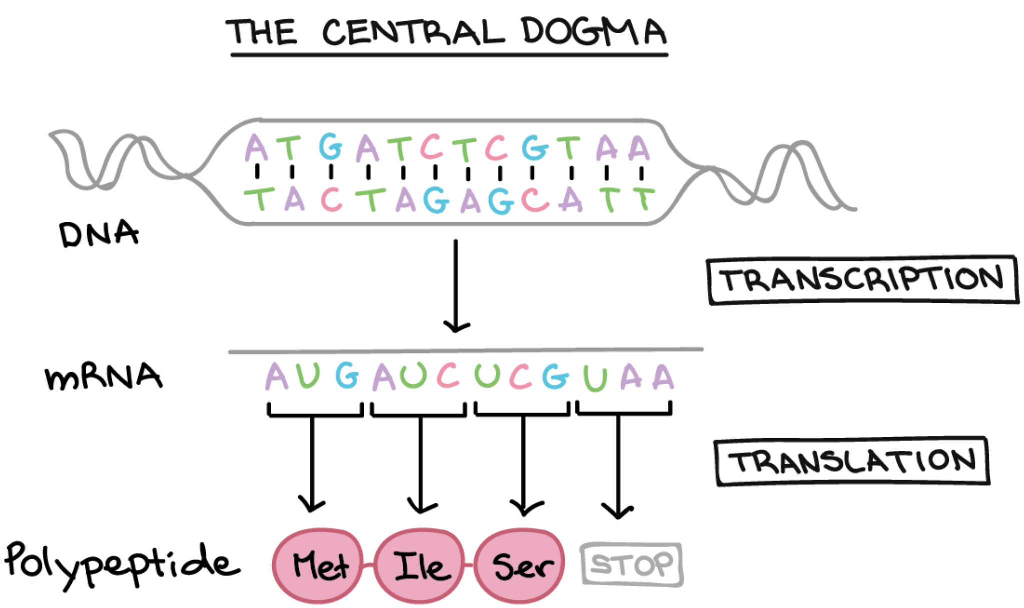
Transfer RNAs, or **tRNAs**, are molecular "bridges" that connect mRNA codons to the amino acids they encode. One end of each tRNA has a sequence of three nucleotides called an **anticodon**, which can bind to specific mRNA codons. The other end of the tRNA carries the amino acid specified by the codons.

There are many different types of tRNAs. Each type reads one or a few codons and brings the right amino acid matching those codons.



Central Dogma

DNA → RNA → protein



- **Retroviruses** violate this order using reverse transcriptase to convert their RNA genome into DNA

VIDEO →Click here to go more in-depth (DNA & Replication)

Questions?! :D

Please Scan & Complete A feedback survey (Tell these people I tried)

Want access to this information & videos at home?

SCAN ME