Pearson & MINISTRY OF EDUCATION AND TECHNICAL EDUCATION

est EGYPTIAN SCHOLASTIC TEST

EST II BIOLOGY

LEVEL UP

2024 EDITION

STRATEGIES

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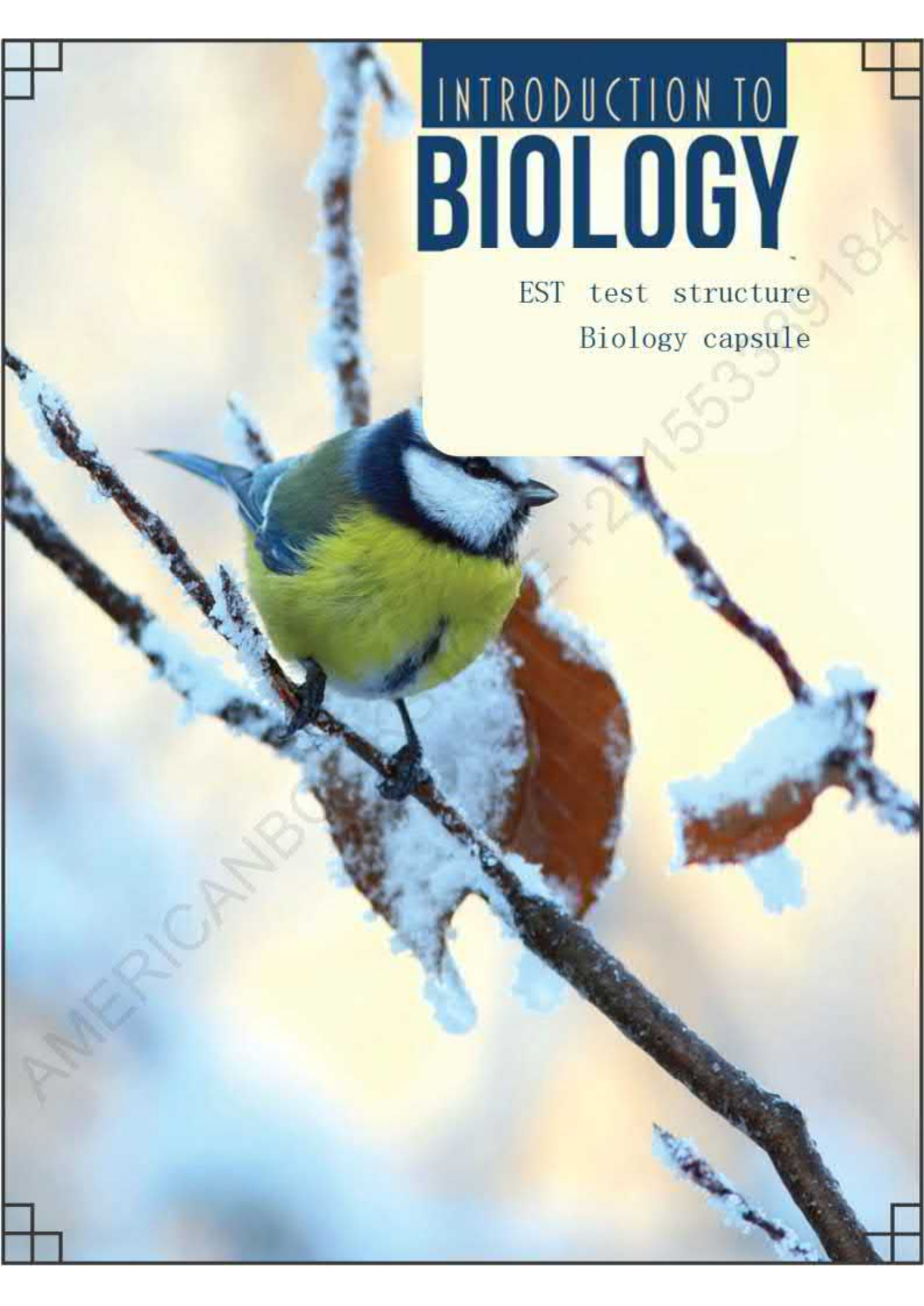


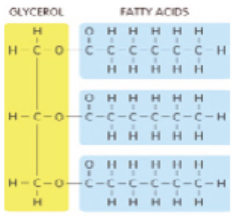
Discover BIOLOGY

BIOCHEMISTRY

THE BUILDING BLOCKS OF LIFE

Four types of **macromolecules** (large, carbon-based organic molecules) are found in living organisms. Most are **polymers**—chains of molecules that form through **dehydration synthesis** (the loss of a water molecule).

A. Carbohydrates: Energy-storing molecules containing carbon, hydrogen, and oxygen in a 1:2:1 ratio. **Monosaccharides**, such as glucose ($C_6H_{12}O_6$), are single-sugar subunits often found as rings. **Disaccharides** have two monosaccharide subunits. **Polysaccharides**, such as starch, glycogen, and cellulose, are long chains of sugars.

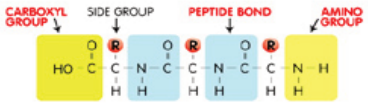


A TRIGLYCERIDE MOLECULE

B. Lipids: Hydrocarbon-based molecules that are **hydrophobic**—insoluble in water. There are three primary families of lipids:

1. **Fats:** Large, energy-storing molecules, each built from two components:
   a. One molecule of **glycerol**, a three-carbon alcohol.
   b. Three **fatty acids**, long hydrocarbon chains that attach to the glycerol backbone. (Hence, fats are also called **triglycerides**.)
2. **Steroids:** Four fused-hydrocarbon rings, such as cholesterol.
3. **Phospholipids:** Glycerol with two fatty acids and a phosphate group attached (found in membranes).

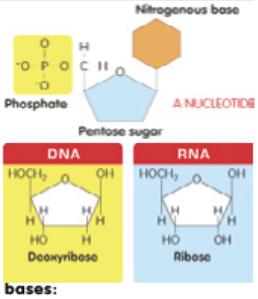
C. Proteins: Long polymer chains called **polypeptides** built from **amino acid** subunits linked by **peptide bonds**. Every amino acid contains a central carbon with an amino group (NH_2), a carboxyl group (COOH), hydrogen (H), and one of 20 side groups (R) that define the attributes of the amino acid.



A POLYPEPTIDE CHAIN

D. Nucleic acids: Polymers of **nucleotides** that encode genetic information. There are two forms: **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**. Individual nucleotides are linked by phosphodiester bonds and contain three basic parts:

1. **Phosphate group**
2. **Five-carbon sugar:** deoxyribose in DNA, ribose in RNA.
3. One of four **nitrogenous bases:**
   a. **Adenine** and **guanine**, double-ringed **purines**.
   b. **Thymine** and **cytosine** single-ringed **pyrimidines**.
   c. RNA contains the pyrimidine **uracil** instead of thymine.



THERMODYNAMICS

The **first law of thermodynamics** states that energy is never created or destroyed, only transformed. The **second law of thermodynamics** states that entropy, or randomness, is always increasing. Every transformation of energy creates greater disorder. Biological life survives by relying upon high-yield energy sources (such as solar radiation) to fuel life processes before releasing that same energy as simpler, low-yield end products (such as heat).

FREE ENERGY CHANGE

All chemical reactions involve a **change in free energy**, ΔG. **Exergonic** reactions release free energy (ΔG is negative) and are spontaneous. **Endergonic** reactions absorb free energy (ΔG is positive) and are non-spontaneous. The **activation energy** of a reaction refers to the energy required to initiate the reaction.

ENZYMES

Enzymes are biological catalysts, proteins capable of speeding chemical reactions without being consumed. Enzymes lower the activation energy of a reaction (but do not affect ΔG, the free energy change). The **substrate** binds to the enzyme's **active site** in an induced fit, in which the enzyme changes its shape to wrap itself around the substrate. Enzymatic activity can be activated or inhibited by other molecules.

A. Cofactors: Some enzymes require inorganic cofactors or organic coenzymes to react.
B. Competitive inhibitors: Non-substrate molecules that block the enzyme's active site.
C. Noncompetitive inhibitors: Bind to an **allosteric site** (receptor site away from the active site) and change the enzyme's **conformational shape** so that it no longer accepts the substrate.
D. Activators: Fit into an allosteric site and open the enzyme's active site.
E. Feedback inhibition: Halts enzymatic activity by an end product that allosterically inhibits formation of an intermediate product.
F. Cooperativity: Occurs when a substrate binds to an active site, opening additional active sites.

CELLS

Every living organism is made up of **cells**, which are the lowest level of structure capable of performing all the activities of life. All cells arise from preexisting cells.

CELLULAR PRECURSORS

Conditions on the early Earth allowed for the **spontaneous abiotic synthesis** of organic compounds. This synthesis would have required an **absence of atmospheric oxygen**, because oxygen naturally breaks down compounds and because the ozone (O_3) layer today blocks the intense UV radiation that fueled such synthesis.

A. Protobionts (collections of abiotically synthesized organic compounds) formed spontaneously as the precursors to cells. Protobionts such as **coacervates** (collections of macromolecules that assemble spontaneously when shaken in water), **microspheres** (collections of protenoids), and **liposomes** (molecules within a lipid bilayer) can combine into larger cells or bud into smaller ones, and can use enzymes to catalyze reactions.
B. The genesis of **RNA**, with its capacity to act as both a catalyst and a heredity blueprint, would have paved the way for the first real cells.

CELL STRUCTURE

A. Cell membrane: Serves as an external barrier and encloses **organelles**.
1. The basic unit is a **phospholipid molecule**, with a polar phosphate group as its hydrophilic head and two nonpolar fatty acid chains as hydrophobic tails.
2. Individual phospholipids form a fluid **phospholipid bilayer**, with hydrophilic heads facing out and hydrophobic tails facing in to form a nonpolar zone that separates the watery cell interior from the extracellular environment.
3. Cell membranes are **semipermeable**, allowing passage of gases, lipids, and small polar molecules but *not* charged molecules (ions and proteins) or large polar molecules.

B. Membrane proteins: Protein molecules embedded in the bilayer that *transport* molecules unable to cross the membrane independently, *assist* in biologically important reactions, and *interact* with membranes of neighboring cells.
C. Cytoplasm: Semifluid medium called **cytosol** and all the organelles inside the plasma membrane but outside the nucleus.
D. Cytoskeleton: A system of protein filaments in the cytoplasm, including **microtubules** and **microfilaments**, that gives the cell shape and helps direct movement.
E. Ribosomes: Proteins that work with RNA to synthesize polypeptides.
F. Cholesterol: Type of **steroid** (lipid with a carbon skeleton of four fused rings) that acts as precursor to many animal hormones. It stabilizes the lipid bilayer of animal cells, preventing solidification at low temperatures and fluidity at high temperatures.

TYPES OF CELLS

CELLS OF EUKARYOTES

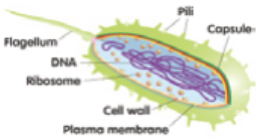
Eukaryotes include multicellular plants and animals and some unicellular protists. Their cells contain membrane-bound **organelles**, each of which performs specific functions and increases efficiency:

A. Nucleus: Membrane-bound storage site of genetic information that determines heredity and directs the activities of a cell.
B. Mitochondria: Double-membraned power plant of the cell and the location of aerobic respiration.
C. Smooth/rough endoplasmic reticulum (SER/RER): Network of membranes where lipids and proteins are synthesized. Rough ER is covered with ribosomes.
D. Golgi apparatus: Organelle that packages and exports proteins and lipids produced in the ER.
E. Vesicles: Sacs in which substances are transported or stored.
F. Lysosomes: Vesicles of digestive enzymes that degrade old cellular components.
G. Plant cells contain several additional components:
1. **Chloroplasts:** Sites of photosynthesis. Contain chlorophyll (a green pigment) and have a double membrane.
2. **Vacuole:** Vesicle used to store water, proteins, and wastes.
3. **Cell wall:** Rigid cellulose layer around the cell membrane.

CELLS OF PROKARYOTES

Prokaryotes include the simplest unicellular organisms and earliest cells to evolve (**bacteria**). Major differences from eukaryotes:

A. Genetic material floats in the cytoplasm in a concentrated but unbounded region called the **nucleoid**.
B. There are no membrane-bound organelles.



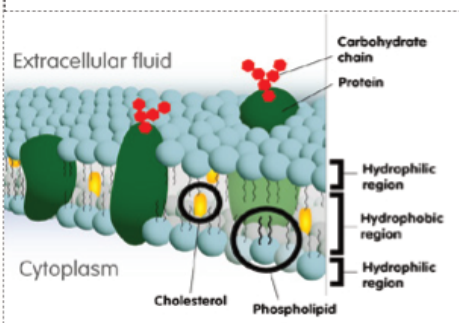
CELL TRANSPORT

PASSIVE MECHANISMS (REQUIRE NO ENERGY)

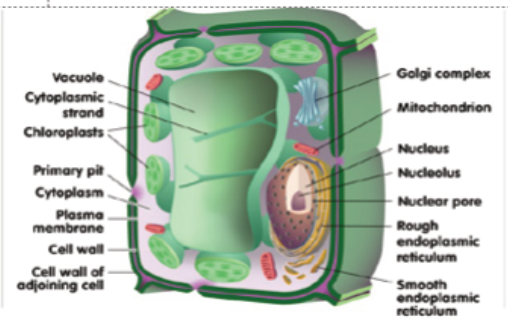
A. Diffusion: Molecules move freely across a membrane to balance a concentration gradient, from regions of high to low concentration. Diffusion of water is called **osmosis**.
B. Facilitated diffusion: Molecules cross an impermeable or semipermeable membrane down their concentration gradient but must do so via special channels.

ACTIVE MECHANISMS (REQUIRE ENERGY)

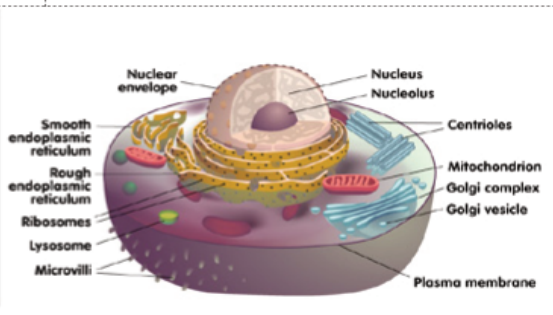
A. Active transport: Transport of molecules from low to high concentrations across a membrane using an energy-dependent transport protein.
B. Endocytosis: Enveloping of an exterior substance within a membranous vesicle for admission to the cell interior.
1. **Pinocytosis:** Endocytosis of dissolved liquid molecules.
2. **Phagocytosis:** Endocytosis of undissolved solid matter.
C. Exocytosis: Extrusion of material from a cell by discharge from vesicles at the cell surface.



CELL MEMBRANE



PLANT CELL



ANIMAL CELL

Discover BIOLOGY

CELLS (continued)

CELLULAR RESPIRATION

Cellular respiration is the cellular process of oxidizing glucose to obtain energy in the form of **adenosine triphosphate (ATP)**.

GLYCOLYSIS

Glycolysis is the oldest metabolic pathway, used by all cells, and a precursor to both the aerobic and anaerobic respiratory pathways. Glycolysis occurs in the cytoplasm. The six-carbon sugar **glucose** is degraded to form two molecules of three-carbon pyruvate, resulting in two NADH and two net ATP.

FERMENTATION

In the absence of oxygen, respiration relies on glycolysis to produce ATP in an anerobic process called **fermentation**. This process uses an organic molecule to accept the electron from NADH and reform NAD^+ for glycolysis to run again. Much energy remains in bonds of end-products, such as ethanol or lactic acid. There are three types of fermentation:

A. Homolactic: Bacteria converts pyruvate into lactic acid.

B. Alcoholic: Yeast and bacteria convert pyruvate into ethanol and CO_2.

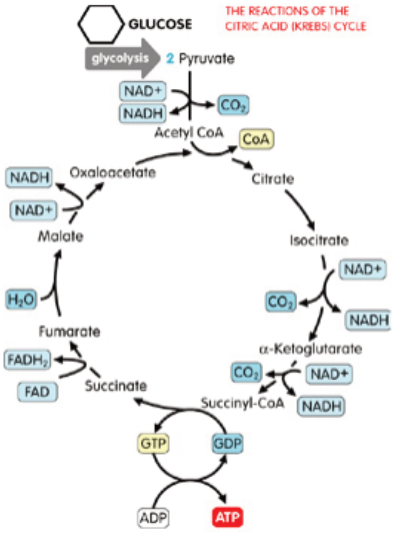
C. Heterolactic: Organisms produce lactic acid as well as other acids and alcohols.

OXIDATIVE RESPIRATION

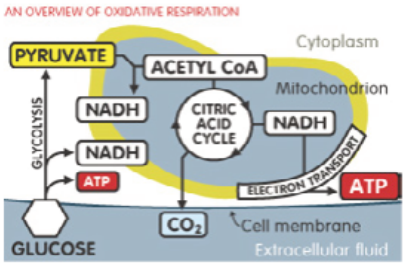
If oxygen is present, glycolysis leads to **aerobic respiration**, which produces a net total of 36 ATP per molecule of glucose.

A. Oxidation of pyruvate: Carbon dioxide splits off from pyruvate to produce acetyl-CoA and NADH.

B. Citric acid cycle (Krebs cycle): Begins with acetyl-CoA joining oxaloacetic acid to form citric acid, which is oxidized to CO_2, yielding ATP, NADH, and $FADH_2$. Oxaloacetic acid is regenerated for another cycle. Occurs in the mitochondria of eukaryotes and the cytoplasm of aerobic prokaryotes.



C. Chemiosmotic (oxidative) phosphorylation: In mitochondria, electrons from NADH and $FADH_2$ flow through an **electron transport chain** from high to low energy states through energy-releasing steps, establishing an electrochemical proton gradient across the inner membrane of mitochondria. O_2 accepts the electrons to form water. ATP is synthesized when H^+ ions diffuse back across the membrane through embedded proteins.



CELL REPRODUCTION

DNA is the cell's genetic material; **chromosomes** are the carriers of this genetic information. In prokaryotes, the chromosome is a single circle of DNA. In eukaryotes, each chromosome is a complex of DNA and histone proteins found in the nucleus.

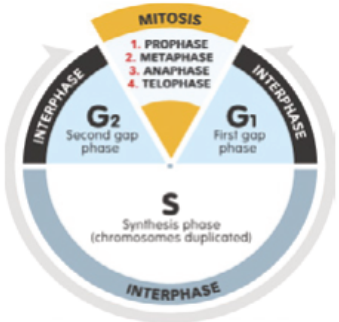
BINARY FISSION

Prokaryotic cells reproduce via **binary fission**. In this process, DNA is replicated, and the cell splits in two roughly equal parts, each with a copy of the cell's DNA.

EUKARYOTIC CELL CYCLE

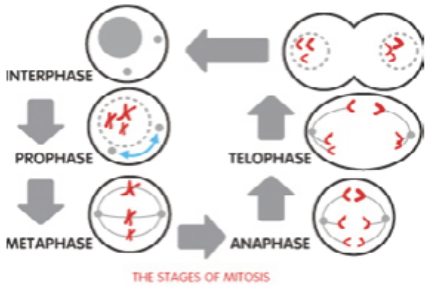
Eukaryotic cells reproduce via the creation of two identical diploid cells from one **diploid** cell. Diploid (2N) refers to the total number of chromosomes in autosomal (nonsexual) cells.

A. Interphase: The period between mitotic divisions during which chromosomes are not visible; comprised of three phases:



1. **G_1 phase:** Major period of cell growth.
2. **S phase:** Chromosome replication takes place, producing pairs of sister chromatids (identical chromosomes) that are each connected by a centromere.
3. **G_2 phase:** Synthesis of cell machinery in preparation for cell division.

B. Mitosis (M) phase: The division of genetic material and cellular contents.



1. **Prophase:** Replicated chromosomes condense. **Spindle** forms along cell equator. Nuclear envelope breaks down; spindle microtubules enter nuclear region, eventually attaching to centromeres of chromosomes.
2. **Metaphase:** Chromosomes align along cell equator called the **metaphase plate** but do not yet segregate to opposite poles. Centromeres divide, freeing sister chromatids.
3. **Anaphase:** Sister chromatids separate to opposite poles.
4. **Telophase:** Chromosomes uncoil at opposite ends and become enclosed by a reformed nuclear envelope.

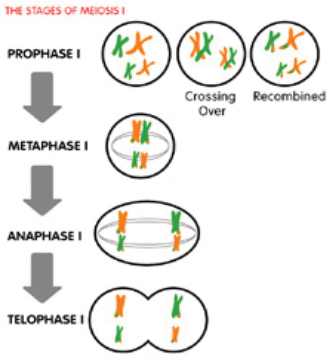
C. Cytokinesis: Physical division of the cytoplasm into two daughter cells.

MEIOSIS

Meiosis produces four **haploid** nuclei called **gametes** from a single diploid cell. Haploid (N) is half of the diploid number. In **interphase**, chromosomes are replicated and align in **homologous pairs**. Each pair contains a maternal and paternal homologue inherited from the previous generation. An important consequence of meiosis is that the **genomes** are **mixed** and **recombined**.

A. Meiosis I:

1. **Prophase I: Crossing-over** occurs, an overlap between homologous chromosomes at x-shaped junctures called **chiasmata** and a resultant exchange of material.
2. **Metaphase I:** Spindle forms; joined homologous pairs line up at the center of the cell.
3. **Anaphase I:** Spindle shortens; chiasmata break apart, maternal/paternal chromosomes dragged to opposite poles.
4. **Telophase I:** Chromosomes are set up at each pole; new haploid nuclei form.



B. Meiosis II: Proceeds as a mitotic division, with each daughter cell from meiosis I splitting into two haploid gametes.

CELL CYCLE REGULATION

Cells divide in order to maintain a **surface-to-volume ratio** so that the cell has enough surface area to absorb nutrients and expel wastes relative to its volume.

A. The cell cycle is regulated internally by **checkpoints** at the G_1, G_2, and M phases. The checkpoints halt cell division until overridden (e.g., when the M checkpoint halts anaphase until the sister chromatids are properly aligned).

1. **Cyclin-dependent kinases** (enzymatic complexes that activate enzymes responsible for cell division) regulate the checkpoints, activating enzymes by phosphorylating them (changing their shape and opening their active sites).
2. The kinases are in turn regulated by **cyclin**, a protein present in the cells at variable (cycling) concentrations.

B. External signals can also regulate cell division.

1. **Growth factors** are proteins that originate in one cell type and promote division in another cell type.
2. **Density-dependent inhibition** stops cells from dividing once they reach a certain density over a given surface area.
3. **Anchorage dependence** prevents cells from dividing unless they attach to specific surfaces.

C. Cancer cells are cells that ignore cell cycle regulations and divide unchecked.

MENDELIAN GENETICS

Genetics is the study of the heredity of organisms. A **gene** is the basic unit of heredity; an **allele** is one of two or more alternative forms of a specific gene.

INTRODUCTION

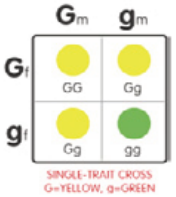
A. Until the 20th century, scientists believed that traits from the parents would blend in the offspring (e.g., a tall father and short mother results in a child of medium height). Eventually, all members of a species would look the same.

B. Gregor Mendel, by crossing different strains of garden peas and analyzing the results, created the genetic theory still used today.

MENDEL'S FIRST LAW (LAW OF SEGREGATION)

A. Single-trait crosses: Mendel took two different strains of true-breeding pea plants, one with green peas and one with yellow peas, and crossed them. In modern terms, this **monohybrid cross** used **homozygous** plants, having the same allele inherited from each parent.

1. The first-generation plants, F_1, were **heterozygous** (having inherited two different alleles of a gene) but showed only one trait. This occurred because the **dominant allele** determines the phenotype in heterozygotes by masking the **recessive allele**.
2. Then, Mendel crossed two F_1 plants. 3/4 of the plants in F_2, the second generation of pea plants, showed the dominant trait; 1/4 showed the recessive.



B. From these results, Mendel came up with three postulates:

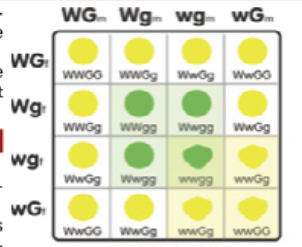
1. Alternative forms of a trait are controlled by *different alleles* of the gene responsible for that trait.
2. When **gametes** (haploid reproductive cells) form in diploid individuals, the two alternative alleles for a gene *segregate* from each other.
3. Every gamete has an *equal chance* of receiving either member of an allele pair.

MENDELIAN GENETICS (continued)

MENDEL'S SECOND LAW (LAW OF INDEPENDENT ASSORTMENT)

A. Mendel also conducted several multi-trait (**dihybrid**) crosses, in which he crossed peas that were heterozygous for two genes.

B. In each case, he observed a 9:3:3:1 phenotype ratio and concluded that genes located on different chromosomes *assort independently* of one another.



MULTI-TRAIT CROSS
G=YELLOW, g=GREEN, W=SMOOTH, w=WRINKLED

GENETICS

A. Genotype: The genes an individual has.

B. Phenotype: The physical appearance of an individual.

B. Incomplete dominance: sometimes heterozygous genotypes result in phenotypes that do not precisely resemble one parent.

1. Phenotype is intermediate between the two parental phenotypes (**incomplete dominance**).
2. Phenotype resembles homozygous dominant, but is still distinguishable from it (**partial dominance**).
3. Both parental phenotypes can be identified in the offspring (**codominance**).

C. Pleiotropy: Instance when a gene produces more than one phenotypic effect.

D. Sex chromosomes: Specific chromosomes that dictate the sex of certain organisms (the remaining chromosomes are called **autosomes**).

1. In humans, there are two sex chromosomes, **X** and **Y**.
   a. **Males** possess one each of X and Y chromosomes.
   b. **Females** possess two X chromosomes.
2. **Sex-linked inheritance:** In humans, a male expresses all traits unique to the X chromosome he inherits from his mother. Males are afflicted with **X-linked disorders** because there is no counterpart on the Y chromosome to express the functional allele.

MOLECULAR GENETICS

NUCLEIC ACIDS

A. DNA occurs most often as a **double helix,** a spiral staircase–shaped molecule composed of two nucleotide chains hydrogen-bonded to each other.

1. One of these chains always ends with a free 3′-OH group, while the other always ends with a free 5′-phosphate group.
2. The chains bind in opposing directions: the 5′ end of one chain is hydrogen-bonded to the 3′ end of its partner.

B. In double-stranded DNA, adenine hydrogen-bonds to thymine, and guanine hydrogen-bonds to cytosine.

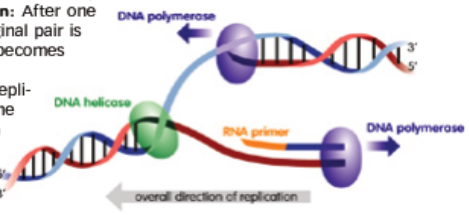
1. Therefore, the proportion in DNA of adenine is always equal to that of thymine, and the proportion of guanine is always equal to that of cytosine: **A = T, G = C**.
2. There is always an equal proportion of purines (A, G) and pyrimidines (C, T).

DNA REPLICATION

A. Complementarity: The base sequence of one chain of DNA completely determines the sequence of its partner in the double helix. Each chain is a complementary mirror image of the other (e.g., the chain AGCCTAT must pair with the chain TCGGATA).

B. Semiconservative replication: After one round of replication, the original pair is not conserved. Each strand becomes part of a new duplex.

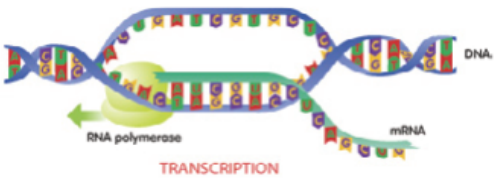
1. When a DNA molecule replicates, it separates at one end to form a **replication fork.** Each strand serves as a template for synthesis of a new strand.
2. **DNA polymerase** is the enzyme that catalyzes the replication process. It moves along each DNA strand from the 5′ to 3′ direction, so new strands are synthesized 5′ end first, 3′ end last.
3. The leading DNA strand is synthesized continuously.
4. The lagging DNA strand is synthesized discontinuously in segments of nucleotides called Okazaki fragments, which later join together with the help of DNA ligase.



GENE EXPRESSION (PROTEIN SYNTHESIS)

A. RNA transcription

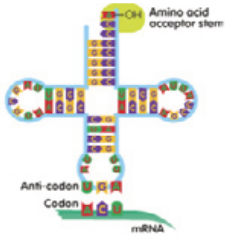
1. The region of DNA encoding the desired gene is unzipped, and the enzyme **RNA polymerase** copies the nucleotide sequence to make a strand of messenger (m)RNA. Though the two strands of DNA are complementary, only one strand (the **template strand**) is transcribed into mRNA.
2. Noncoding sequences of mRNA called **introns** are removed, and the remaining sequences, called **exons,** are spliced together.
3. The mRNA leaves the nucleus.



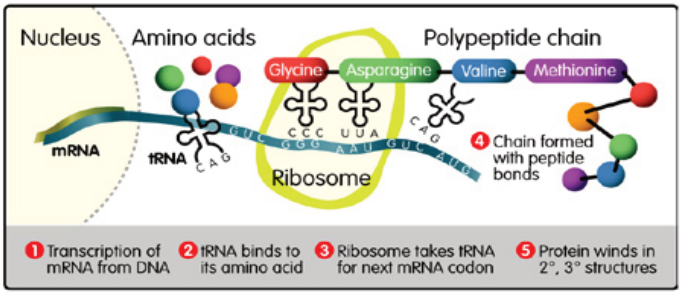
TRANSCRIPTION

B. Translation

1. A ribosome (a complex of ribosomal (r)RNA and protein) binds to an mRNA transcript and reads a triplet of nucleotides, called a **codon.**
2. The ribosome binds the matching **anticodon** of a transfer **(t)RNA** molecule, which is attached to a specific amino acid, into the ribosome's **A-site.**
3. Sequential mRNA codons call new tRNA–amino acids into the A-site, shifting previous tRNA–amino acids to the **P-site,** where they link to form a polypeptide chain until a "stop" codon is reached.



STRUCTURE OF A tRNA MOLECULE



AN OVERVIEW OF PROTEIN SYNTHESIS

THE CENTRAL DOGMA

The process of gene expression/protein synthesis follows a specific order:

A. DNA is transcribed into mRNA.

B. mRNA is then translated into protein.

GENE REGULATION

Gene regulation in prokaryotes: Prokaryotes have genes organized in an **operon** containing all the genes in a metabolic pathway, a promoter, and an **operator** (on-off switch). The operator controls whether RNA polymerase will bind to the promoter and transcribe RNA. The operator can be controlled by both negative and positive gene regulation.

A. Negative gene regulation:

1. **Repressible operons** are regulated by **repressor proteins** (encoded elsewhere than the operon). These proteins bind to the operator and prevent genetic transcription. **Corepressors** regulate the repressor proteins by binding onto an allosteric site.
   a. Repressible operons function in anabolic pathways that synthesize end products from starter reactants.
   b. The end product itself can act as the corepressor, so that once enough products are synthesized the machinery shuts off.
2. **Inducible operons** are also controlled by repressor proteins, but an **inducer** binds to an allosteric site on the repressor protein and inactivates it, triggering transcription.
   a. Inducible operons function in catabolic pathways that break down nutrients.
   b. The nutrient itself sometimes acts as the inducer, such that enzymes are only created when they will be used.

B. Positive gene regulation:

1. An activator protein binds to an operator and helps RNA polymerase attach to the promoter.
2. Molecules can control the activator by binding to an allosteric site and opening its active site, allowing the activator to bind onto the operator

Gene regulation in eukaryotes: Eukaryotic gene regulation occurs at several levels.

A. Modifications on chromatin: Chromatin is a tightly packed form of DNA. Modifications on chromatin can prevent or promote transcription by allowing or barring access to individual genes.

1. **DNA methylation** (the attachment of a CH_3 methyl group to DNA bases) inhibits genetic expression.
2. **Histone acetylation** (the addition of a $COCH_3$ acetyl group to the DNA-binding histone proteins) loosens the grip of histones on chromatin and allows transcription.

B. Control elements: Distal control elements ("enhancers") and proximal control elements are both proteins that bind to DNA at specific (non-coding) DNA binding domains. Control elements activate transcription by attaching to RNA polymerase and forming a transcription initiation complex along the promoter.

C. Steroid hormones: Steroid hormones coordinate expression of multiple related genes by binding to specific receptors that activate transcription in those genes.

D. Regulatory proteins: Regulatory proteins can control the rate of degradation of mRNA and can block mRNA translation by preventing ribosomes from binding to mRNA. **Proteastomes** are protein complexes that can recognize and degrade proteins, thereby curtailing their activity.

MUTATION

A. Point mutations: Mutations that affect single genes through a base-pair substitution, deletion, or insertion.

1. Deletions or insertions that are *not* in a multiple of three cause a **frameshift mutation,** in which all downstream codons are altered.
2. Point mutations may have no effect, may improve or damage the protein, may create a novel protein, or may create a nonfunctional one.

B. Chromosomal mutations: Mutations that affect an entire organism.

1. **Nondisjunction:** An error in chromosomal distribution during meiosis, which results in **aneuploidy,** or gametes with an abnormal chromosome count.
2. **Polyploidy:** A mutation in which gametes contain more than two full sets of chromosomes. Polyploidy is generally less fatal (or altering) than aneuploidy.
3. Mutations can also occur on individual chromosomes. These include:
   a. **Deletion:** A chromosomal fragment gets detached during cell division;
   b. **Duplication:** That same fragment joins its homologous chromosome;
   c. **Inversion:** That fragment gets reinserted backward; or
   d. **Translocation:** That fragment gets attached to a nonhomologous chromosome.
4. The effects of chromosomal mutation are often fatal or can result in genetic disease but in rare cases may improve an organism's fitness.

CONTINUED ON OTHER SIDE

VIRUSES

Viruses are intracellular parasites made up of a genome of double- or single-stranded DNA (or RNA) within a **capsid**, or protein coat. Some viruses have **viral envelopes**, lipid membranes that encase the capsid and assist in invading a **host**.

VIRUS REPLICATION

Viruses cannot **replicate** without a **host**. The **host range** refers to the specific cell type (bacterial, plant, or animal) that each type of virus may infect. Viruses generally replicate via one of two modes, both of which are best understood in bacterial viruses (or **phages**).

A. Lytic cycle:
1. The phage enters the host's cell, releases its DNA from the capsid, and then uses the host's cellular equipment to replicate.
2. The virus's genetic material is transcribed, and viral proteins (such as the capsid proteins) are translated from a viral RNA template.
3. Once the virus replicates and reassembles itself, the host cell lyses, releasing the phage copies. The cycle repeats.

B. Lysogenic cycle:
1. The phage enters the host and incorporates its genome into the host's genome at certain chromosomal locations.
2. The viral genome lies dormant and is replicated each time that the host itself replicates (with every cell division).
3. Environmental cues cause the phage genome to extricate itself from the host's DNA and begin the lytic cycle.

RETROVIRUSES

Retroviruses are animal viruses that reproduce in a manner similar to a phage lysogenic cycle aside from the fact that that the viral genome is **RNA-based**. Reverse transcriptase transcribes the RNA genome into a DNA template that is incorporated into the host's genome at specific sites.

DNA TECHNOLOGY

PLASMIDS

Plasmids are self-replicating rings of bacterial DNA. A plasmid can be used as a **cloning vector**, in which a gene of interest is spliced into that plasmid and reintroduced into the bacteria for mass replication.

A. Restriction enzymes (enzymes that cut DNA at specific sequences) cut open the plasmid and excise the gene of interest from its host DNA.
B. DNA ligase glues the cut fragments in solution with phosphodiester bonds, creating a piece of **recombinant DNA** containing both the gene and the plasmid.
C. Transformation of the plasmid reintroduces the recombinant DNA into bacteria by **electroporation**, an electric shock that temporarily makes the bacteria's plasma membrane permeable.
D. Bacterial growth in culture replicates the gene (within the plasmid). The recombinant plasmid DNA is isolated from the bacteria, and the cloned gene is re-excised using restriction enzymes.

POLYMERASE CHAIN REACTION

A **PCR (polymerase chain reaction)** can be used to clone DNA in vitro.

A. Heating the gene of interest separates it into single strands.
B. Cooling the solution allows the gene to bind with primers that are complimentary to the ends of the target gene.
C. DNA polymerase adds new nucleotides to the primers, creating new copies of the target gene.
D. Reheating the products continues in cycles such that new DNA is created in mass.

GEL ELECTROPHORESIS

Gel electrophoresis is used to isolate DNA fragments by size.

A. DNA cut with restriction enzymes is placed in wells at the end of a gel, and this gel is bathed in an aqueous solution.
B. An **electrical charge** is passed through the gel, pulling the polar DNA molecules through the gel.
C. Variations in size among DNA fragments make the fragments migrate at differential rates: shorter fragments travel farther down the gel than longer ones do.
D. A **DNA ladder** is run in one of the wells, containing fragments of benchmark sizes used to identify the sizes of the other fragments.
E. The gel is **dyed** with a solution that binds to DNA and makes it glow under ultraviolet light. The DNA glows pink under the light and can be physically cut from the gel and isolated.

BLOTTING

Southern blotting, an extension of electrophoresis, pulls DNA fragments from an electrophoresis gel onto a piece of nitrocellulose paper by the capillary action of an alkaline solution. The paper is removed, and a radioactive probe of single-stranded DNA binds to the target DNA. The radioactive DNA shows up on a piece of film placed onto the paper.

Northern blotting is similar to Southern blotting except for the fact that it analyzes whole molecules of mRNA rather than fragments of DNA cut by restriction enzyme digest.

EVOLUTION AND DIVERSITY

Evolution is the process by which species change gradually over time. It arises from processes of **selection** that favor individuals having certain favorable traits over those lacking those favorable traits.

NEO-DARWINIAN THEORY

A. Principle of variation: Variations in morphology, physiology, and behavior occur among individuals in any given population.
B. Principle of heredity: Offspring resemble parents more than they resemble other members of the population.
C. Principle of selection: Individuals with certain traits more successfully survive and reproduce, passing those traits to the next generation.

EVOLUTIONARY FACTORS

A. Mutation: A permanent change in a cell's DNA, causing diversity among individuals.
B. Genetic drift: A random change in the frequency of alleles. Two instances of genetic drift cause individuals' genes to be unnaturally overexpressed:
1. **Founder effect:** Only a few individuals of a species start a new population.
2. **Bottleneck effect:** Only a few individuals of a species survive a disaster.

C. Gene flow: Movement of genes from one population to another through migration of individuals between populations and/or mating between separate populations.

TYPES OF SELECTION

A. Natural selection: Individuals produce more offspring than can survive. Because individuals compete for limited resources, those with favorable variations and traits are more successful at passing on those traits to succeeding generations. Over time, those traits become prevalent, while disadvantageous traits occur with decreased frequency.
1. **Directional selection:** Selection favors an extreme phenotype, the frequency of which increases over time.
2. **Stabilizing selection:** Selection acts to eliminate both extreme phenotypes. The frequency of the intermediate phenotype increases over time.
3. **Disruptive selection:** Selection acts to eliminate the intermediate phenotype from a population, favoring the extremes.

B. Sexual selection: Individuals with traits that appeal to sexual partners are more likely to pass on those traits to succeeding generations. Various traits may be preserved not because they enhance survivorship but because they increase reproductive success.
C. Artificial selection: Humans intentionally breed animals to enhance specific traits.

COEVOLUTION

Coevolution is the long-term evolutionary adjustment of one group of organisms to another.

A. Predator-prey interactions: Both plants and animals develop special defenses when they interact competitively with other organisms.
B. Symbiosis: A relationship in which two kinds of organisms consistently live together.
1. **Commensalism:** A relationship in which one individual is closely associated with another and benefits without doing harm to the host.
2. **Mutualism:** A relationship that benefits both organisms involved.
3. **Parasitism:** A type of predation in which one organism lives in or on a host and benefits while harming the host.

POPULATION GENETICS

Population genetics is the study of the properties of genes in populations (as opposed to in individuals).

POPULATIONS

A. Size: Small populations are more likely to go extinct because **random events** or disturbances may affect the population disproportionately. Also, **inbreeding** may eliminate the genetic diversity necessary for the population to thrive.
B. Dispersion: Widely spaced populations may not thrive because individuals may not interact often enough to reproduce sufficiently.

POPULATION GROWTH

A. Biotic potential: $dN/dt = r_iN$; the rate at which a population increases when there are no limits on its rate of growth. N is the population size; dN/dt is the rate of change in population size over time; and r_i is the population's capacity for growth.
B. Carrying capacity: $dN/dt = rN[(K - N)/K]$; the size at which a population stabilizes in a particular environment, based on available resources, predation, competition, and niche.

HARDY-WEINBERG PRINCIPLE

In the absence of mutation, migration, genetic drift, and nonrandom selection, allele and genotype frequencies remain constant in a random-mating population. Dominant alleles do not replace recessive ones because the frequencies do not change. Mathematically:

If the frequency of allele *a* is *p*, and the frequency of allele *b* is *q*, then the genotype frequencies after one generation of random mating are represented by:

$$p^2(a) + 2pq(ab) + q^2(b) = 1$$

or

$$1 = (p + q)^2 = p^2 + 2pq + q^2$$

CLASSIFYING ORGANISMS: THE THREE-DOMAIN SYSTEM

The **five-kingdom system** of classifying organisms has given way to a **three-domain system** that better reflects current evolutionary research. **Domain Bacteria** and **Domain Archaea** are offshoots of what was once Kingdom Monera. **Domain Eukarya** contains all four other kingdoms but subdivides what was once Kingdom Protista into five separate kingdoms: Archaezoa, Euglenozoa, Alveolata, Stramenopila, and Rhodophyta.

DOMAIN ARCHAEA

Consists of those **prokaryotes** that inhabit the harshest environments. Believed to be the ancestors of Kingdom Eukarya.

A. Methanogens: Strict anaerobes (oxygen is fatal to them) that live in swamps and convert CO_2 to methane (CH_4).
B. Extreme halophiles: Live in lakes saltier than the ocean.
C. Extreme thermophiles: Live in hot deep-sea vents and sulfur springs.

DOMAIN BACTERIA

Consists of all other **prokaryotes**.

DOMAIN EUKARYA

Arose from prokaryotes through two evolutionary steps:

A. An **internal membranous system** (including a nuclear envelope) derived from infoldings of the plasma membrane.
B. Symbiosis with prokaryotes that later became mitochondria and chloroplasts.

KINGDOM ARCHAEZOA

Perhaps the oldest Eukarya; **lack mitochondria**, are flagellated, have dual nuclei and a simple cytoskeleton. **Example:** *Giardia*, a protist found in water.

KINGDOM EUGLENOZOA

Flagellated unicellular protists **with mitochondria**. **Examples:** 1. *Euglena* (which has a flagella coming from an anterior folding); 2. kinetoplastids (which have a kinetoplast, a unique organelle that houses genetic material outside the nucleus).

KINGDOM ALVEOLATA

Characterized by **alveoli** (vesicles below the plasma membrane). **Examples:** 1. dinoflagellates (photosynthetic phytoplankton that cause algal blooms known as red tides); 2. *Apicomplexa* (animal parasites such as *Plasmodium*, which causes malaria); 3. ciliates (unicellular ciliated cells capable of binary fission or conjugation, such as *Paramecium*).

KINGDOM STRAMENOPILA

Characterized by **flagella that have hairlike protrusions**. Autotrophic stramenopila have chloroplasts that more closely resemble the original prokaryotic symbionts. **Examples:** 1. diatoms (unicellular protists with silicated exoskeletons); 2. brown and golden algae.

KINGDOM RHODOPHYTA

Protists that evolved to lose their flagella. **Example:** red algae.

KINGDOM FUNGI

Decomposing organisms characterized by **absorptive nutrition**. Includes yeasts, which are unicellular, but also multicellular fungi that have the following features: 1. tubular units

CLASSIFYING ORGANISMS: THE THREE-DOMAIN SYSTEM (continued)

called **hyphae** with cell walls made of chitin, a plasma membrane, and eukaryotic organelles; 2. divisions between hyphae called **septa**, which separate hyphae into cells but also allow the passage of organelles from cell to cell; 3. multiple hyphae organized into a network called a **mycelium**.

- **Zygomycota:** Terrestrial decomposers that have spores resistant to harsh environmental changes. **Examples:** 1. bread mold; 2. mycorrhizae (symbiosis between a fungus and the roots of plants, in which the fungus absorbs minerals that it passes to the roots in exchange for sugars from the plant).
- **Ascomycota:** Terrestrial and aquatic decomposers that form spores in **asci** (which look like sacs) and have large fruiting bodies called **ascocarps** that release the asci. **Examples:** 1. truffles; 2. fruit molds; 3. lichens (symbiosis between a fungus and an algae); 4. some yeasts and also some mycorrhizae.
- **Basidiomycota:** Club-shaped, sexually-reproducing decomposers that have large fruiting bodies called **basidiocarps**. **Examples:** 1. mushrooms; 2. some yeasts.

KINGDOM PLANTAE

Multicellular eukaryotes characterized (with some exceptions) by **photosynthetic nutrition**. *For classification, see* Plants, *next page.*

KINGDOM ANIMALIA

Multicellular eukaryotes characterized by **ingestive nutrition**; generally reproduce sexually. All animals are believed to have originated from a single progenitor.

Major criteria for animal classification

A. Parazoa vs. eumetazoa

1. **Parazoa** lack true tissues; each cell is basically modular.
2. **Eumetazoa** have true tissues (i.e., specialization of cells by function).

B. Radiata vs. bilateria

1. **Radiata** have **radial symmetry**, i.e., have a top and a bottom, but bodies are shaped like circles without a front or a back end. Have only **two germ layers** (embryonic cell layers that go on to constitute adult tissues): an ectoderm and an endoderm.
2. **Bilateria** have **bilateral symmetry**, i.e., have dorsal (top), ventral (bottom), anterior (front), and posterior (back) sides. Are characterized by **cephalization** (sensory organs face the anterior end). Have **three germ layers** (including a mesoderm between the ectoderm and endoderm).

C. Acoelomates vs. pseudocoelomates vs. coelomates

1. **Acoelomates** have **no body cavity** separating the digestive tract from the rest of the body.
2. **Pseudocoelomates** have a **simple body cavity**, but it is not completely lined by mesodermal tissue.
3. **Coelomates** have a **body cavity** completely lined with mesodermal tissue that suspends the digestive tract and internal organs in fluid.

D. Protostomes vs. deuterostomes

1. **Protostomes** have embryonic cells that divide in pattern known as **spiral cleavage**. Cells are **determinate** (i.e., each dividing cell has a specific fate in forming the adult body). During embryonic cleavage, the **mouth** is formed from the **blastospore** (embryonic cellular infolding).
2. **Deuterostome** embryonic cells divide in pattern of **radial cleavage**. Cells are **indeterminate** (i.e., each cell, if separated, could form its own embryo). During embryonic cleavage, the **anus** is formed from the blastopore.

Animal phyla

- **Phylum Porifera (sponges):** **Sessile** (attached by a base) suspension feeders with no true tissues or organs. **Spongocoel** (central cavity) draws in water through **osculum** (large hole); food is siphoned out. **Amoebocytes** digest food, carry nutrients to other cells.
- **Phylum Cnidaria (sea anemones, jellyfish):** Have a saclike body plan with a single opening as both mouth and anus. **Polyps** are sessile with mouths facing up; **medusas** are free-floating with mouths facing down. Both have **cnidae**, organelles that shoot off **nematocysts** (stinging barbs).
- **Phylum Ctenophora (comb jellies):** Similar in appearance to cnidarians; named for comblike plates of cilia used for motion. Tentacles have **colloblasts** (sticky threads for capturing food).
- **Phylum Platyhelminthes (flatworms):** Can be terrestrial or marine; some are parasitic. Have true muscle tissue but, like radiata, have only one digestive tract opening that serves as both mouth and anus. **Examples:** planaria, tapeworms.
- **Phylum Rotifera (rotifers):** Tiny multicellular organisms with a digestive tract that has two openings (mouth and anus). Have a wheel-like crown of cilia at the mouth, used to suck in water.
- **Phylum Nematoda (roundworms):** Worms without segments. Covered with a protective cuticle. Reproduce sexually, with internal fertilization of eggs. No circulatory system, so nutrients transported through fluid of the pseudocoelom.
- **Phylum Nemertea (proboscis or ribbon worms):** Acoelomate but have a full digestive tract and closed circulatory system. Capture prey using a fluid-filled sac that operates a proboscis.
- **Phyla Bryozoa, Phoronida, Brachiopoda (lophophorates):** Sessile aquatic suspension feeders with lophophores, fold of ciliated tentacles that draw water into the mouth. No true head. **Bryozoans** look like mosses; their hard exoskeletons create reefs. **Phoronids** are aquatic worms that build hard chitinous tubes. **Brachiopods** are sessile marine creatures that look like clams and live like Bryozoa.
- **Phylum Mollusca (mollusks):** Have a three-part body: a **muscular foot** (for moving), a **visceral mass** (containing the organs), and a **mantle** (tissue covering the visceral mass that may produce a shell). Many feed using a **radula**, a scraping organ that drags for nutrients. **Examples:** 1. snails (gastropoda); 2. clams, mussels (bivalvia); 3. squids, octopus (cephalopoda).
- **Phylum Annelida (segmented worms):** True coelomates; have a digestive tract with specialized regions, nerves, and a closed circulatory system. Each segment has **metanephridia**, excretory tubes that remove wastes. **Examples:** 1. earthworms (oligochaeta); 2. leeches (hirudinea).
- **Phylum Arthropoda (arthropods):** Have a chitinous **exoskeleton**, specialized **appendages** with joints, and segmented bodies, and grow by **molting** their exoskeletons to form increasingly larger ones. Have an open circulatory system with a heart, and sensory organs for touch, smell, and sight.
  - **Subphylum Chelicerata (scorpions and spiders):** Feed with clawlike **chelicerae**. Most have simple rather than compound eyes. **Spiders** (arachnids) have **book lungs**, stacks of organs that carry out gas exchange.
  - **Subphylum Uniramia (centipedes, millipedes, insects):** Have compound rather than simple eyes. Have antennae and feed with jawlike mandibles. **Insects** (Insecta) have a **three-part body** with a head, thorax, and abdomen. Remove waste with **Malpighian tubules** and breathe using a tracheal system that lets oxygen directly into cells. Many insects can fly and also undergo **metamorphosis**, a changing of the body from a larval to an adult stage.
  - **Subphylum Crustacea (crabs, shrimp, lobsters, barnacles):** Have jawlike mandibles (as opposed to chelicerae) and two pairs of antennae. Have many pairs of appendages on the abdomen (unlike insects, which have appendages on the thorax), and can regenerate appendages.
- **Phylum Echinodermata (echinoderms):** Marine organisms radially symmetrical in adult form but bilaterally symmetrical in larval form. Endoskeletons derive from the mesoderm. Water vascular system powers **tube feet** used in movement and feeding. **Examples:** 1. sea stars (Asteroidea); 2. sea urchins, sand dollars (Echinoidea); 3. sea cucumbers (Holothuroidea).
- **Phylum Chordata (chordates):** Have an embryonic **notochord** for skeletal support and a **hollow dorsal nerve cord** (all other animals have solid ventral nerve cords) that develops into a brain and spinal chord. **Pharyngeal slits** filter out water without its continuing through the entire digestive tract: in aquatic vertebrates, these have evolved toward gas exchange; in higher animals, used for jaw support and auditory sensation. Have a **postanal tail** originally used for aquatic propulsion (other animals' digestive tracts extend throughout the body).

Vertebrate classes

- **Superclass Agnatha:** Jawless vertebrates lacking paired appendages. Skeleton made of cartilage; notochord exists throughout life. **Examples:** hagfishes, lampreys.
- **Superclass Gnathostomata:** All other vertebrates. Have hinged **jaws** and **vertebrae** that replace the notochord. Are divided between the **fish** and the **tetrapods** ("four feet").
  - **Class Chondrichthyes (cartilaginous fishes):** Have **cartilage** skeletons, jaws. Breathe using **gills** derived from the pharyngeal slits. Fertilization is internal. Lateral line system is a sensory system that detects changes in pressure or vibrations in the water. **Examples:** sharks, rays.
  - **Class Osteichthyes (bony fishes):** Have **bone** skeletons. Breathe through **gills** that are covered with a protective layer called the **operculum**. Fertilization is internal. Stay afloat via air-filled swim bladders. **Examples:** tuna, salmon.
  - **Class Amphibia (amphibians):** Oldest tetrapods; most live close to water, Have **damp skin** used in gas exchange and **shell-less eggs** that must be laid in water. Frogs undergo **metamorphosis** between an aquatic larval stage and a terrestrial adult stage. The adult stage marks the loss of gills and of the lateral line system. **Examples:** 1. frogs, toads (Anura); 2. salamanders (Urodela); 3. caecilians (Apoda).
  - **Class Reptilia (reptiles):** Eggs are **amniotic**, with a protective water-filled sac (**amnion**) in which the embryo grows alongside a repository of nutrients (**yolk**). Eggs have leathery shells and are laid on land. Have protective keratinized **scales** for skin, breathe using lungs, and are **ectothermic** (control temperature via behavioral or environmental rather than metabolic regulations). **Examples:** 1. turtles, tortoises (Chelonia); 2. lizards, snakes (Squamata); 3. crocodiles, alligators (Crocodilia).
  - **Class Aves (birds):** Evolved from reptiles. Have **wings**, specialized bones; beaks, feathers made of keratin; no teeth; instead grind food in a **gizzard**. Lay amniotic eggs with hard shells. Four-chambered heart. **Endothermic** (regulate temperature metabolically). **Examples:** pigeons, eagles.
  - **Class Mammalia (mammals):** Also evolved from reptiles. **Endothermic**; have **hair** made of keratin and make milk from **mammary glands**. Have large brains, specialized teeth, and an inner ear derived from the pharyngeal slits.
    - **Subclass Monotremata (monotremes):** Hatch from eggs. **Examples:** platypuses, echidnas.
    - **Subclass Marsupialia (marsupials):** Fertilization is internal; embryo develops inside the uterus. The embryo continues to develop after birth, as the fledgling organism nurses inside the mother's external protective pouch. **Examples:** koalas, kangaroos.
    - **Subclass Placentalia (placental mammals):** Fertilization is internal; embryo develops inside the uterus. A protective and nurturing complex called the **placenta** forms around the embryo, which develops fully inside the uterus before birth. **Examples:** mice, dogs, cats, horses, whales, humans.

HUMAN ORGAN SYSTEMS

SKELETAL AND MUSCULAR SYSTEMS

Humans have an **endoskeleton** (as opposed to an exterior exoskeleton) that supports, protects, and allows for movement at the **joints**. There are three types of muscle. **Skeletal (striated) muscle** attaches to bones and coordinates movement. The basic unit of a skeletal muscle is the **sarcomere**, where thin **actin** filaments are interspersed with thick **myosin** filaments. When the filaments slide alongside each other, the muscles contract. **Cardiac muscle**, found only in the heart, is structured like skeletal muscle but can trigger its own contraction independently of the nervous system. Also, the entire heart contracts as one unit whenever an action potential is generated in any one part of the heart. Filaments in **smooth muscle** are organized in a pattern that allows for less overall tension than in skeletal muscle but for contraction over greater lengths. Smooth muscle is found in vessels, such as the arteries and the digestive tract, that carry fluids over long distances.

NERVOUS SYSTEM

The nervous system controls sensory input and motor output. The basic unit of the nervous system is a **neuron**, each of which contains: 1. a **cell body** containing the nucleus and organelles; 2. **dendrites**, a fibrous network that receives messages; 3. an **axon**, a fibrous body that sends messages. The axon is insulated by a **myelin sheath**. The gap between the dendrites of one neuron and the axon of another neuron is called a **synapse**; messages flow through the synapse either electrically or chemically. **Sensory neurons** convey sensory input to the central nervous system, **interneurons** coordinate sensory information with motor output, and **motor neurons** convey instructions to the body. The **central nervous system (CNS)** consists of the **brain** and **spinal cord**; the **peripheral nervous system (PNS)** consists of the cranial nerves, spinal nerves, and ganglia. The **cranial nerves** connect the brain to the organs of the upper body, while **spinal nerves** connect the spinal cord to the rest of the body. **Ganglia** are clusters of nerves that are related in function. The PNS has a sensory (afferent) division responsible for incorporating outside stimuli and a motor (efferent) division responsible for responding to those stimuli. Within the motor division, the **somatic nervous system** controls voluntary functions (e.g., movement) and the **autonomic nervous system** controls involuntary functions (e.g., digestion or cardiovascular activity). The autonomic nervous system is further divided between the **parasympathetic nervous system** (which conserves energy in the body) and the **sympathetic nervous system** (which readies the body for action).

CIRCULATORY SYSTEM

Deoxygenated blood passes through the superior and inferior **vena cava** into the right atrium of the **heart**. Blood then flows into the right ventricle, which pumps it to the lungs via the **pulmonary arteries**. Oxygenated in the lungs, blood flows through the **pulmonary veins** back into the left atrium of the heart, then into the left ventricle, from which it is pumped to the entire body via the **aorta**. **Arteries** carry blood away from the heart, breaking down into a network of **arterioles**. **Veins** arise from a network of **venules** to bring blood back toward the heart. Between arterioles and venules are **capillaries**, tiny vessels where cellular exchange (gases, nutrients, wastes) occurs. The **lymphatic system** returns lost fluid to the blood. Lymph fluid can intermingle with blood along **lymph capillaries**, which run alongside circulatory capillaries. **Lymph nodes** filter the lymph fluid by the action of **white blood cells**, protective cells that sequester and isolate foreign bodies.

RESPIRATORY SYSTEM

The **larynx** controls the descent of food into the digestive system and air into the respiratory system. Air passes through the larynx into the **trachea**, where it splits into two **bronchi** that lead to the **lungs**. The bronchi branch into **bronchioles**, which have buds at the ends called **alveoli** that are the surface of respiratory exchange. In the capillaries surrouding the alveoli, carbon dioxide in the blood is exchanged for oxygen. The **diaphragm**, a wide, flat muscle at the base of the chest cavity, controls inhalation and exhalation of air in the lungs.

DIGESTIVE SYSTEM

Food passes through the **pharynx** (throat) into the **esophagus**, a long tube that brings food into the **stomach** by **paristalsis**, a rhythmic motion. The stomach breaks down food into **chyme**, a nutrient fluid. Food passes from the stomach into the **small intestine**, where enzymes further break down chyme. The small intestine is lined with **villi**, tiny projections that absorb nutrients and put them into the bloodstream. The food then passes to the **large intestine**, where water is reclaimed. Waste matter is stored in the **rectum** until excreted from the **anus**.

EXCRETORY SYSTEM

The **liver** converts toxic **nitrogen waste** (ammonia) to less toxic **urea**. The renal arteries carry urea to the **kidneys**, which filter urea out of the bloodstream and control reabsorption of impor-

HUMAN ORGAN SYSTEMS (continued)

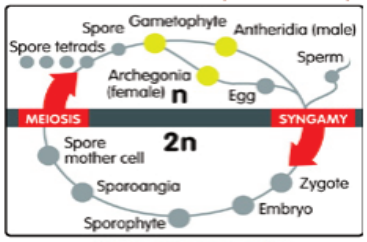
tant nutrients and secretion of toxic solutes. The functional unit of a kidney is the **nephron**. Blood enters the nephron in a mass of capillaries called the **glomerulus**, which filters molecules out of the blood and into the **Bowman's capsule**. The filtered material then passes through the **loop of Henle**, the site of secretion and reabsorption. The filtered blood collectively exits the kidney through the renal veins; wastes proceed to a collecting duct at each nephron. These ducts pass the urine into the **ureters**, tubes that exit the kidney and store urine in the **bladder**, where it waits to be excreted.

REPRODUCTIVE SYSTEM

The male **testes** are contained in the scrotum, a sac outside the body wall where temperatures are cooler than the internal body. **Sperm** form in the testes and pass to the **epididymis**, a tube in which the sperm become capable of fertilization and mobility. Sperm exit the epididymis through the **vas deferens**, a tube that joins with the **seminal vesicles**. The seminal vesicles contribute secretions that create **semen**, a nutrient- and enzyme-rich fluid containing the sperm. Semen exits through the **ejaculatory duct** and past the male **urethra** and into the female **vagina**. Each egg grows in the female **ovaries** within a **follicle**, a nourishing cell. Every month, one egg cell exits the follicle and can be fertilized by a male sperm cell. The follicle tissue forms a mass in the ovary called the **corpus luteum**, which secretes the hormones that line the uterus during pregnancy. The egg passes through the **oviduct**, a tube that leads to the **uterus**. The egg then lodges itself within the walls of the uterus. A **placenta** forms, which connects the fetus with the mother through an **umbilical cord** and allows for direct nourishment, gas exchange, and waste removal between the fetus and the mother's bloodstream.

PLANTS

Plants are **autotrophs**, able to synthesize their own organic nutrients (primarily via **photosynthesis**). The **plant life cycle** alternates between the diploid (**sporophyte**) and haploid (**gametophyte**) generations. The sporophyte produces spores via meiotic division; the gametophyte, formed from the spore, gives rise to haploid gametes. Reproduction occurs both sexually and asexually.



THE LIFE CYCLE OF A PLANT

PHOTOSYNTHESIS

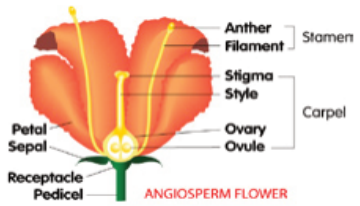
A. Plants use **chlorophyll**, **photopigments** to capture energy from sunlight. Formula: $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$

B. Photosynthesis involves the following chemical processes:

1. **Light reactions:** Transfer of light energy to electrons. Occurs on photosynthetic membranes in chloroplasts. In **primary photoevent**, pigment captures photons of light, exciting electrons within pigment. Energy breaks H_2O to release O_2 and drives **inward transport** of hydrogen ions across membrane for **chemiosmotic synthesis** of ATP.
2. **Dark reactions (Calvin Cycle):** Enzyme-catalyzed reactions use ATP and NADPH from the light reactions to drive formation of organic molecules using CO_2. Electrons return to the pigment.

MAJOR PLANT CLASSIFICATIONS

- **Chlorophyta (green algae):** Aquatic green algae.
- **Bryophyta (nonvascular plants):** Lack vascular system to transport water and nutrients, so remain small and require moist environments. **Examples:** mosses, liverworts.
- **Tracheophyta (vascular plants):** Have highly developed vascular system to transport water and nutrients. **Xylem** carries water and dissolved materials up from roots; **phloem** distributes products of photosynthesis. **Roots** use **mycorrhizae** (symbiotic fungus) to draw water and minerals from soil and store the plant's organic nutrients. **Primary growth** (vertical) occurs due to ongoing mitosis at **apical meristem** (tip) of roots and shoots. **Secondary growth** (thickness) results as new xylem pushes old xylem inward, new phloem pushes old phloem outward.
  - **Filicopsida (ferns):** Least evolved vascular plants; reproduce by spores. Depend on moist environments.
  - **Spermatopsida (seed-bearing plants):** Reproduce by seeds.
    - **Gymnosperms (conifers):** Gametes found in **cones**; pollen grains spread by wind, which carries nonflagellated sperm. Not dependent on moisture to reproduce.
    - **Angiosperms (flowering plants):** Have nonflagellated sperm not dependent on water for dispersal. Gametes generally distributed by wind or animals. More specialized vascular network than in gymnosperms. **Stamen** (pollen-producing part of flower) consists of anther and filament; **pistil** (egg-producing central part of flower) consists of ovary, style, and stigma.

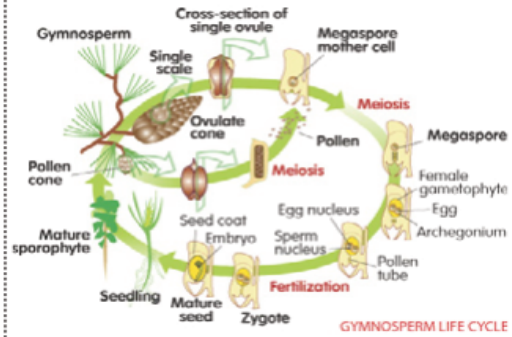


ANGIOSPERM FLOWER

- **Monocots:** A **single cotyledon** (seed leaf) forms during embryonic development. Leaf veins are **parallel**. Flower parts occur in multiples of **three**. Vascular tissue **scattered** throughout stem. **Fibrous root** system. **Examples:** grasses, grains, spring-flowering bulbs.
- **Dicots:** **Two cotyledons** form during embryonic development. Leaf veins in **network** pattern. Flower parts occur in multiples of **four** or **five**. Vascular tissue arranged in **tubular** pattern in stem. **Taproot** system. **Examples:** roses, sunflowers, most trees.

GYMNOSPERM LIFE CYCLE

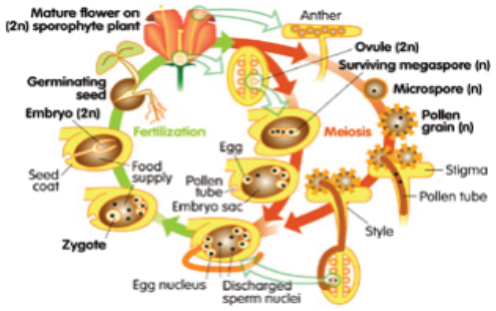
Diploid sporophyte is dominant. Males make **microspores**; females make **megaspores**. Spores give rise to gametophytes, which produce gametes.



GYMNOSPERM LIFE CYCLE

ANGIOSPERM LIFE CYCLE

Diploid sporophyte dominant. Diploid plant produces male and female haploid spores, which give rise to gametophytes (**flowers**) that produce gametes. Gametes form a diploid zygote via **self-pollination** or **cross-pollination**.



ANGIOSPERM LIFE CYCLE

C4 AND CAM PLANTS

Photorespiration occurs when a plant avoids water loss by closing **stomata** on hot, dry days. The plant, unable to take in airborne CO_2 for the **Calvin cycle**, instead incorporates internal O_2—reducing efficiency of photosynthesis by creating energetically useless compounds. C4 and CAM plants resist photorespiration.

- **C4 plants:** Named for tendency to fix carbon into a 4-carbon compound rather than 3-carbon compound of most (C3) plants. **Fixation** occurs in loosely placed mesophyll cells beneath leaf surface, using an enzyme (PEP carboxylase) that is more efficient at fixing carbon than the C3 plant enzyme (rubisco). Calvin cycle occurs in tightly packed bundle sheath cells beneath mesophyll, where 4-carbon compound releases carbon as CO_2. By localizing Calvin cycle in bundle sheath cells and by saturating those cells with CO_2, C4 plants prevent photorespiration. **Example:** corn.
- **CAM (crassulacean acid metabolism) plants:** Resist water loss by closing stomata during day, opening at night. At night, take in CO_2, convert to organic acids that are stored until daytime. Acids release CO_2 for Calvin cycle (powered by ATP generated in light reactions of photosynthesis). **Example:** cacti.

PLANT TROPISMS

Plants respond to various stimuli by a differential growth of cells on one side of the plant or the other such that the plant moves toward or away from the stimulus.

A. Phototropism: Plant shoots grow toward a source of light.
B. Gravitropism: Roots grow downward, shoots grow upward in response to gravity.
C. Thigmotropism: Plant grows in response to touch (e.g., climbing plants that coil around support structures).

ECOLOGY AND THE BIOSPHERE

ECOSYSTEMS AND BIOMES

A. Population: An interbreeding group of the same species.
1. Every species has a **niche** defined by its lifestyle factors (e.g., behavior, habitat, predation).
2. Overlap of niches results in **competition** until competitors are eliminated or displaced into a different niche.

B. Community: All the populations (biotic factors) in an area.
C. Ecosystem: All the biotic *and* abiotic factors in an area.
D. Biome: A large region with distinct plant and animal life.
1. **Tropical rain forest:** Infertile soil but heavy rainfall; dense vegetation. Greatest biodiversity of any biome.
2. **Savanna:** Open grassland with scattered trees; transitional between rain forest and desert; found primarily in Africa.
3. **Desert:** Sparse, arid; large daily fluctuation in temperature.
4. **Chaparral:** Coastal area with short evergreen shrubs; mild, rainy winter; hot, dry summer.
5. **Temperate grassland:** Rich soils, abundant precipitation, agriculturally productive; covers much of the Americas.
6. **Temperate deciduous forest:** Deciduous trees (drop leaves every winter); warm, rainy summer; cool winter.
7. **Taiga:** Northern coniferous forest with long, cold winter.
8. **Tundra:** Cold; little precipitation or vegetation; permafrost exists near the surface; covers ~20% of Earth's land area.
9. **Marine:** Salt water; covers ~75% of Earth's surface; home to 10% of living species. Divided into zones:
   a. **Intertidal/littoral zone:** Shorelines and coasts; subject to periods of wet and dry.
   b. **Neritic zone:** Shallow waters to the continental shelf.
   c. **Oceanic/pelagic zone:** Surface layers of the open ocean.
   d. **Aphotic/abyssal zone:** Deep-water areas; no sunlight.
10. **Freshwater:** Ponds, lakes, rivers; tied closely to terrestrial habitats. Lakes in temperate regions see thermal stratification. <3% of the Earth's surface.

ECOLOGICAL SUCCESSION

Communities change through an orderly process of **succession**.
A. Pioneer organisms move into an uninhabited area.
B. With succession, the community's biomass, complexity, species diversity, and capacity to process nutrients all increase.
C. The result is a stable **climax community**.

ENERGY FLOW

Energy in an ecosystem flows among organisms of different **trophic levels**. **Primary producers** (plants, chemosynthetic bacteria) have the most biomass, followed by **primary consumers** (herbivores) and **secondary and tertiary consumers** (carnivores, omnivores). Finally, **decomposers (saprophytes)** break down organic remains and excretions. Only 10% of a trophic level's energy flows to the next; the rest is lost to respiration, heat, and so on.

CYCLES IN THE ENVIRONMENT

- **Water cycle:** Solar energy causes water to **evaporate** from oceans into atmosphere. Plants **transpire**, also sending water into atmosphere as vapor. Water vapor **condenses** into clouds and **precipitates** into rain. Rain falls back to Earth, collects on land as **runoff** or **groundwater**, and runs back into oceans.
- **Carbon cycle:** Plants incorporate **airborne CO_2** into organic compounds. Primary consumers eat plants. When organisms die, their carbon is locked into **fossil fuels** or decomposed by microbes. **Burning** of fossil fuels, **decomposition** of organisms, and **cellular respiration** all release CO_2 back into the air.
- **Nitrogen cycle:** **Nitrogen-fixing bacteria** convert atmospheric N_2 gas into ammonium (NH_4^+). **Nitrifying bacteria** convert ammonium into nitrites (NO_2^-) and nitrates (NO_3^-), which are assimilated by plants, which are then eaten by animals. After plant or animal death, **decomposers** (bacteria, fungi) convert nitrogen back to ammonium (NH_4^+). **Denitrifying bacteria** process nitrogenous compounds back into atmospheric N_2 gas.
- **Phosphorous cycle:** **Phosphorous-containing rocks** weather into soil; plants take up phosphates (PO_4^{3-}) from soil. Animals eat plants; **decomposers** break down dead plants and animals, returning phosphates to soil. **Leaching** removes phosphates from soil via water that runs into lakes and streams. **Sedimentation** forms new phosphorous-containing rocks.

Biochemistry

1

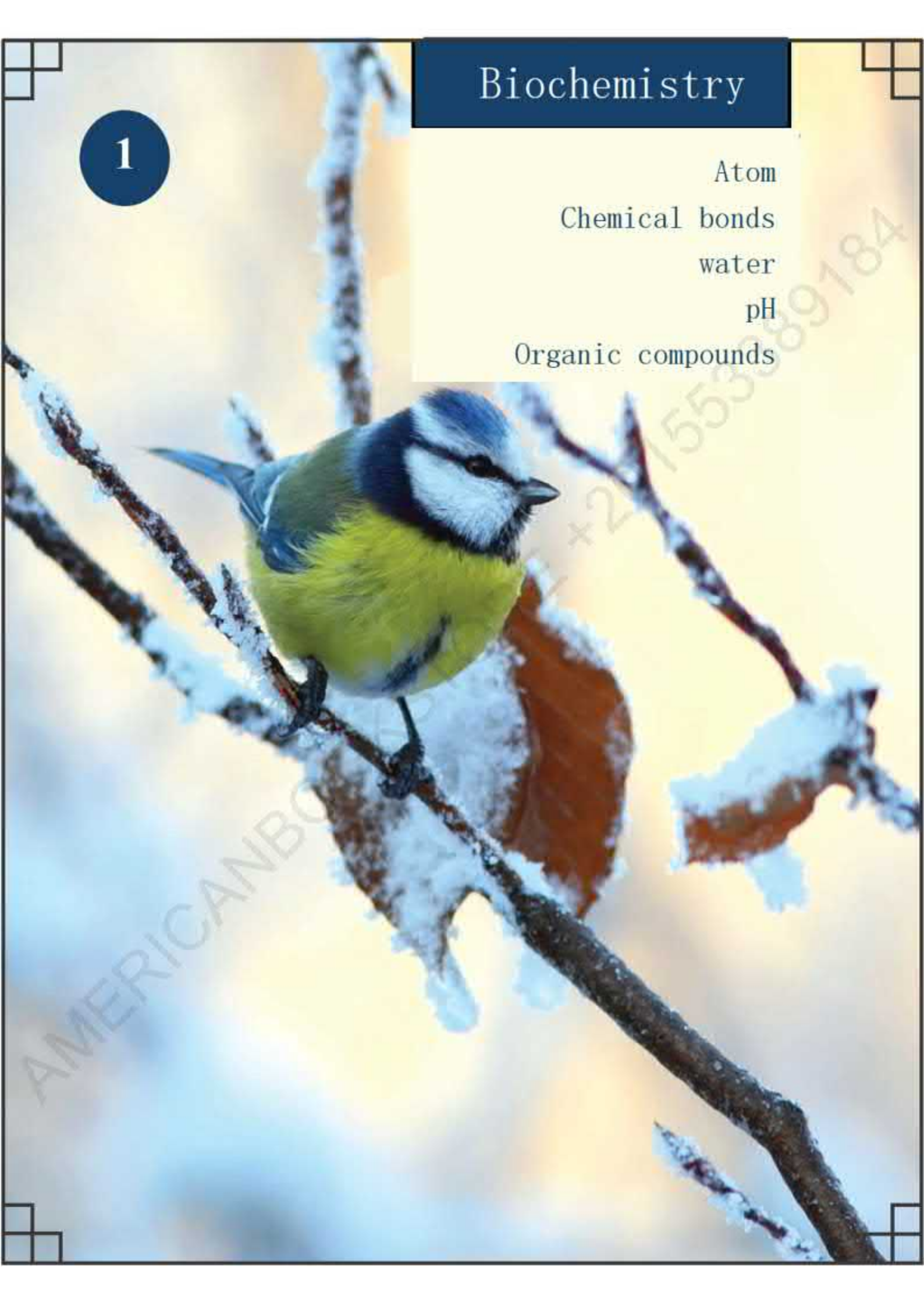
Atom

Chemical bonds

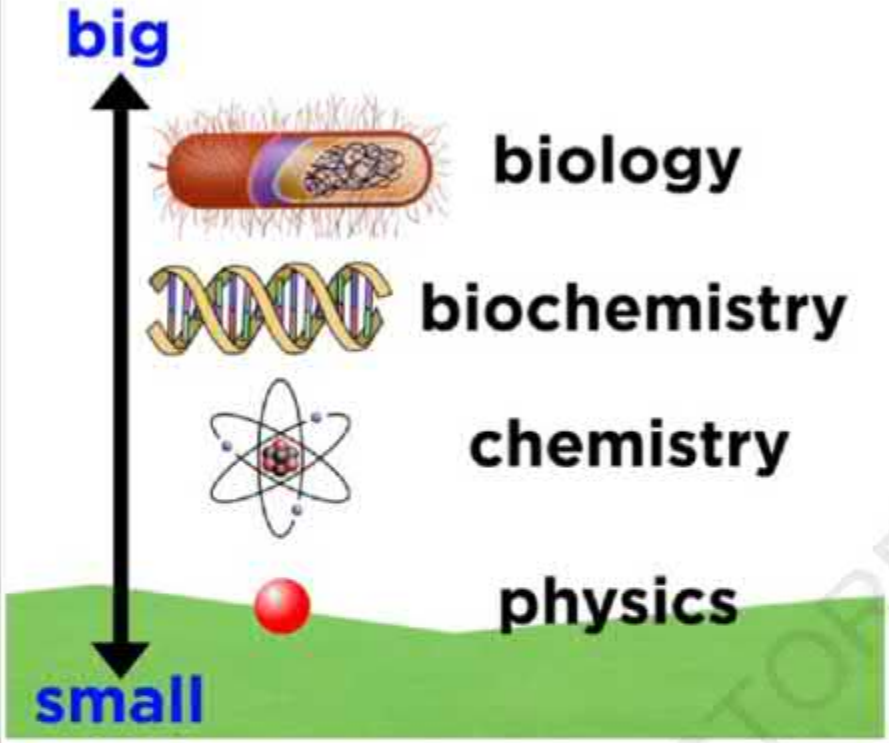
water

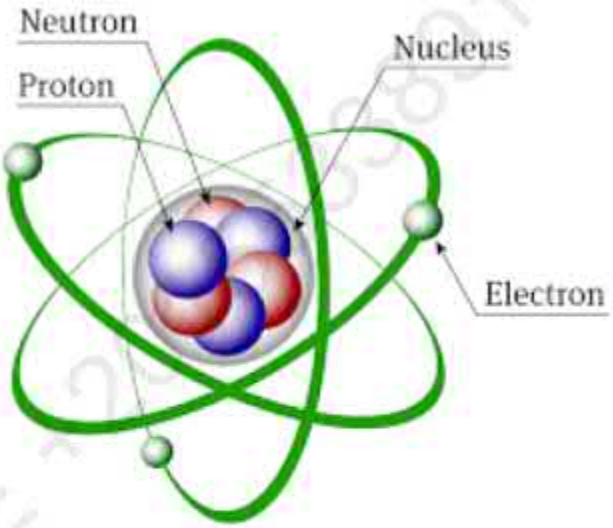
pH

Organic compounds



BIOCHEMISTRY



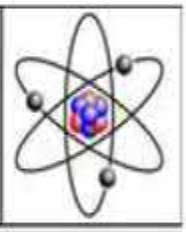


Atomic structure

- Electrons in the lowest available energy level are said to be in the ground state.
- When an atom absorbs energy, its electrons move to a higher energy level. The atom is then said to be in the excited state.

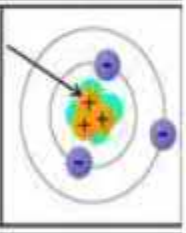
Atom

The smallest unit of matter that can't be broken down chemically



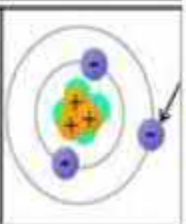
Proton

A positively charged subatomic particle



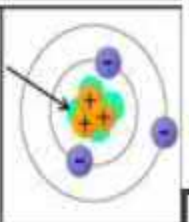
Electron

A negatively charged subatomic particle



Neutron

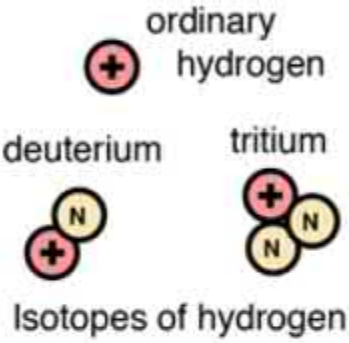
A subatomic particle with no charge



Isotopes

- They are atoms of one element that vary only in the number of neutrons in the nucleus.

Chemically, all isotopes of the same element are identical because they have the same number of PROTONS



Isotopes of hydrogen

$^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$

Notation for the different isotopes of the chemical element carbon.

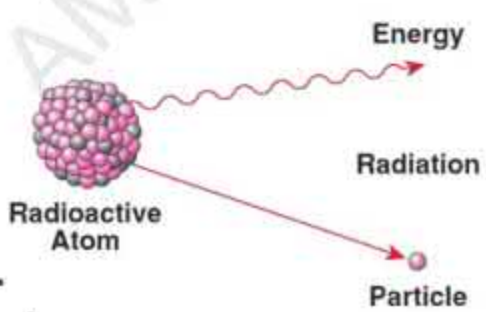
There are about 400 stable isotopes.

Radioactive Isotopes: (radioisotopes)

Radioactive Isotopes: (radioisotopes)

- The nuclei of radioisotopes emit particles and decay at a known rate called a half-life. Knowing the half-life enables us to measure the age of fossils or to estimate the age of Earth. (**C-14** is used to measure Age of Fossils).

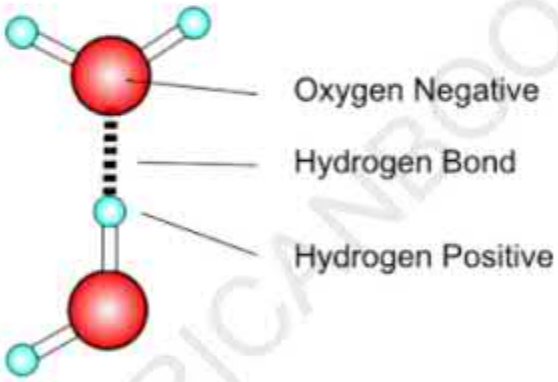
- **Iodine (I-131)** Used for treatment of thyroid gland (hyperthyroidism) and in diagnosis of some diseases.
- Radioactive carbon can be used as a tracer, incorporated into molecules of carbon dioxide, and used to track metabolic pathways.

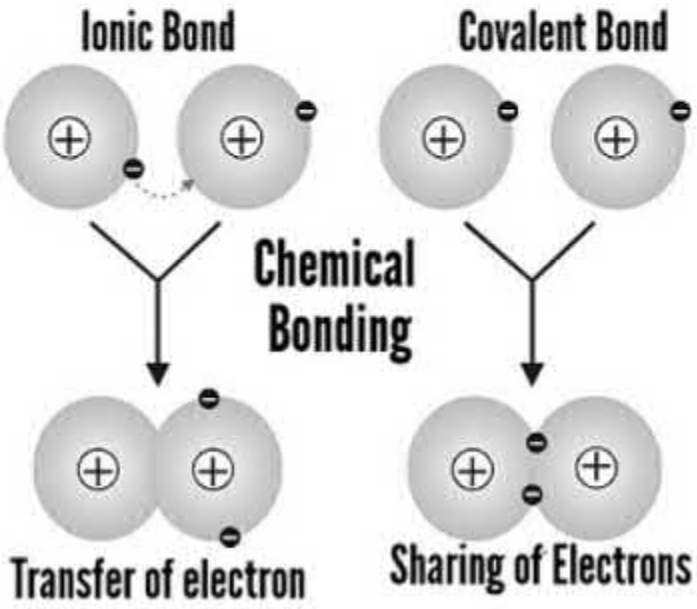


Parent Isotope	Daughter Isotope	Half Life (years)
Carbon-14	Nitrogen-14	5730
Uranium-235	Lead-207	710 million
Potassium-40	Argon-40	1.25 billion

Chemical Bonds

- Chemical Bonding refers to the attraction between atoms which initiates the formation of chemical substances containing more than one atom.
- The two most important cases of chemical bonding are: Co-valent Bond and Ionic Bond.
- **Covalent bond** refers to the bond in which two atoms share one or more pairs of electrons.
- **Ionic Bond** refers to the one in which one or more electrons form one atom usually are removed and attached to another atom.
- **Hydrogen bonds** are strong intermolecular forces created when a **hydrogen** atom bonded to an electronegative atom approaches a nearby electronegative atom.





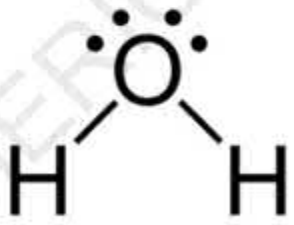
Water

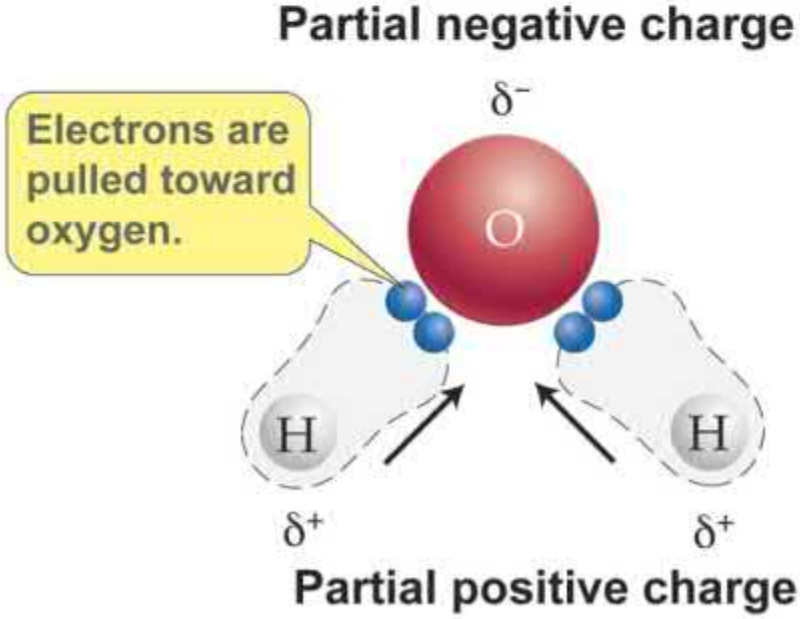
- A water molecule consists of two hydrogen atoms bonded to an oxygen atom, and its overall structure is bent. This is because the oxygen atom, in addition to forming bonds with the hydrogen atoms, also carries two pairs of unshared electrons. All of the electron pairs - shared and unshared - repel each other.

- Water is classified as a dipolar molecule because of its **polar covalent bonds** and its bent shape.

Dipolar molecule: A molecule that is positive at one end and negative at the other

- Thanks to their polarity, water molecules happily attract each other. The plus end of one - a hydrogen atom - associates with the minus end of another - an oxygen atom.





Water properties

1- **Water has a high specific heat**: This means that amount of heat needed to change water temp by 1℃ is high so resist changes in temperature.

Biological importance:

- Keeps the rate of metabolic reactions in the cells constant
- Helps the aquatic organisms to survive

2- **Water has a high heat of vaporization** : a relatively great amount of heat is needed to evaporate water.

Biological importance:

- Homeostasis (Body temperature control)

3- **Water has high adhesion properties:** Attraction force between water and other substances

Biological importance:

- It helps water flow up from the roots of a plant to the leaves.

4- **Water is the universal solvent:** Because water is a highly polar molecule,

Biological importance:

- It dissolves most of organic substances. (Lipids are exception)

5- **Strong cohesion tension**: This means that molecules of water tend to stick to each other.

Biological importance:

- Transpirational-pull cohesion tension.
- Also causes the **Surface Tension.**

6- **Density:** Ice floats because it is less dense than water

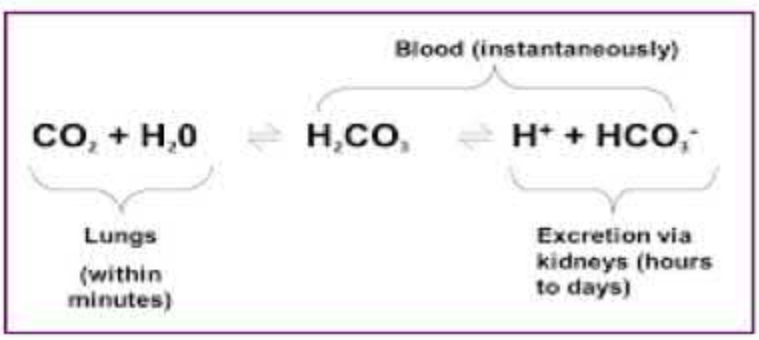
Biological importance:

That's why Fish can live in frozen ponds.

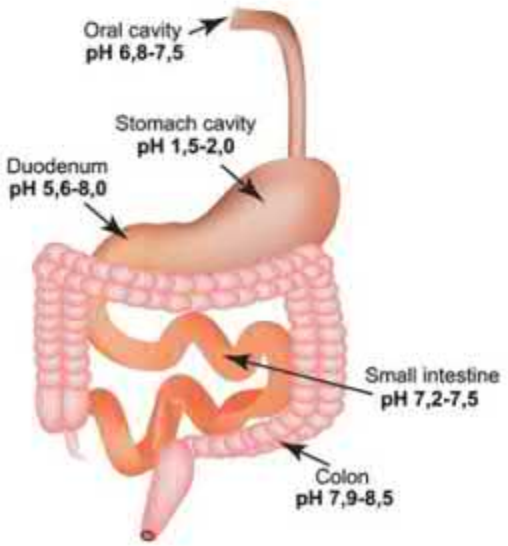
pH "power of hydrogen"

- It is a figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral,
- lower values are more acid and higher values more alkaline. The pH = −log [H^+], means it equals minus log the hydrogen ion concentration in moles per liter.

- A solution of pH 1 is 10 times more acidic than a solution with a pH of 2, and 100 times more acidic than a solution with a pH of 3.
- The internal pH of most living cells is close to (7). Even a slight change can be harmful.
- NB. Gastric juice is most acidic body secretions
- Biological systems regulate their pH through the presence of **buffers**, substances that resist change in pH.
- A buffer works by absorbing excess hydrogen ions or donating hydrogen ions when there are too few.
- The most important buffer in human blood is the **bicarbonate ion** (HCO_3^-).



pH of the gastrointestinal tract



Organic Compounds

- Organic compounds are compounds that contain carbon. There are four classes of organic compounds: **carbohydrates, lipids, proteins, and nucleic acids.**

Carbohydrates

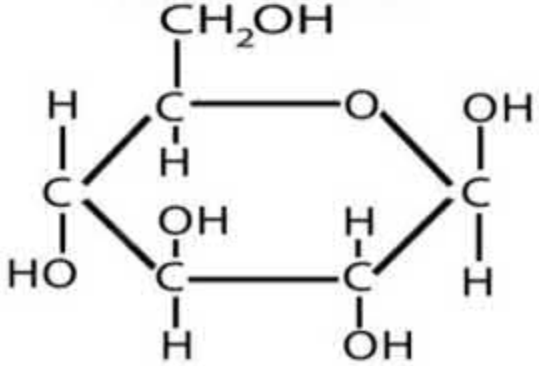
Components	Function	Sources	Classification
• Carbon • "The most abundant element – by weight – in living organisms" • Hydrogen • Oxygen	♦ Supply Energy **1gm = 4 calories** Main source of energy ♦ Store Energy ♦ Enter in some cellular structure	Rice Potato Bread Fruits	**Sugar** 1. monosaccharides 2. disaccharides **Non sugar** polysaccharides.

MONOSACCHARIDES ($C_6H_{12}O_6$)

All monosaccharides have a chemical formula of ($C_6H_{12}O_6$) Examples are **glucose, galactose, and fructose**, which are all isomers of each other.

Isomers they are compounds with the same molecular formula, but with different structures. Therefore, **they have different physical and chemical properties.**

Glucose



NB. Molasses is a source of: sucrose (29%), glucose (12%)

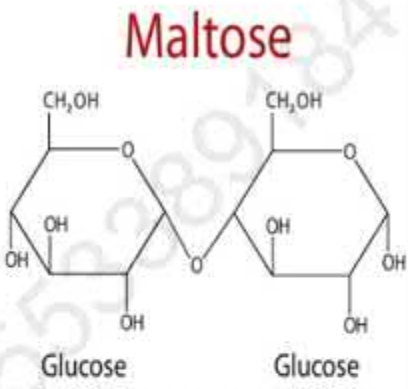
DISACCHARIDES ($C_{12}H_{22}O_{11}$)

All disaccharides have the chemical formula $C_{12}H_{22}O_{11}$. They consist of two monosaccharides joined by a process known as dehydration synthesis. Examples are **maltose, lactose, and sucrose.**

Dehydration Synthesis of Monosaccharides

Monosaccharides + Monosaccharide → Disaccharide + Water

$C_6H_{12}O_6$	+	$C_6H_{12}O_6$	→	$C_{12}H_{22}O_{11}$	+	H_2O
Glucose	+	Glucose	→	Maltose	+	Water
Glucose	+	Galactose	→	Lactose	+	Water
Glucose	+	Fructose	→	Sucrose	+	Water



Dehydration synthesis*: The monomers combine with each other via covalent bonds to form larger molecules known as polymers. In doing so, monomers release water molecules as byproducts.

*Dehydration also called **Condensation reaction**

*No of water molecules produced due to dehydration = "no of amino acids-1"

- **Hydrolysis** is the opposite of dehydration synthesis. It is the breakdown of a compound with the addition of water. It is what occurs during digestion and is the reverse of dehydration synthesis. **Sucrose + Water → Glucose + Fructose**

POLYSACCHARIDES

Polysaccharides are polymers of carbohydrates. They form as many monosaccharides are joined together by dehydration synthesis. Examples are cellulose, starch, chitin, and glycogen.

Found in plants	**Cellulose**	**Starch**
	Makes up plant cell walls	Storage of carbohydrates
Found in animals	**Chitin**	**Glycogen**
	Makes up the exoskeleton in arthropods	Storage of carbohydrates in the liver & skeletal muscle

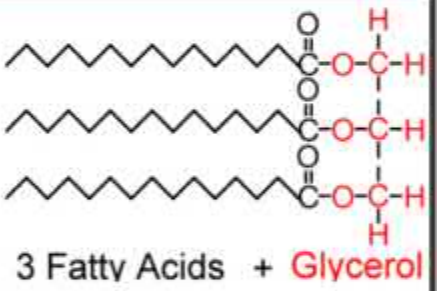
Lipids

They are biological macromolecules which are composed of carbon, oxygen and hydrogen. They divided into

- Simple lipids (fats, waxes, oil)
- Complex lipids (phospholipids)
- Derivative lipids (steroids) "Hydrophobic hormones"

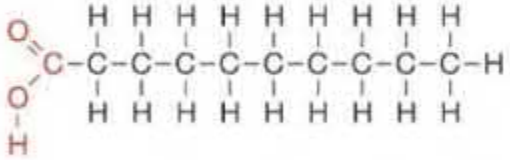
Components	Function	Resources	Classification
• Carbon • Hydrogen • Oxygen	- Supply Energy "The highest organic matter to provide energy but not the main source" **1gm = 9 calories** - Store Energy (Most effective way" - Structural (cell membrane) - Endocrine (steroid hormones) - Insulation (Thermal, electrical & mechanical)	Meat Milk Plants Oils	Saturated fats Unsaturated fats

- Lipids are formed from 3 fatty acids bound to a glycerol molecule
- Glycerol is an alcohol having 3 hydroxyl OH groups

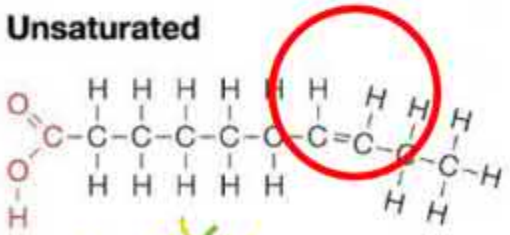


Fats	Oils
Found in animals	Found in plants
Saturated FA	Non saturated FA
Solid in room temp	liquid
May cause heart disease	More safe
Ex. butter	EX. Sunflower oil

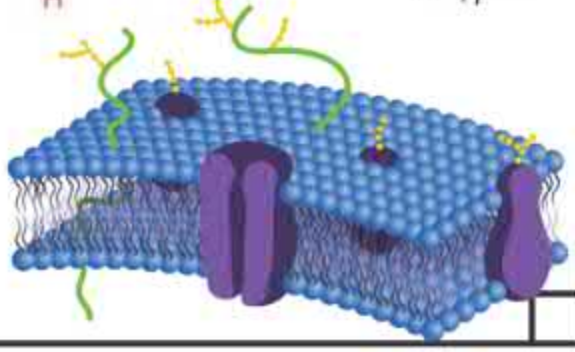
Saturated



Unsaturated



Phospholipid bilayer in cell membrane



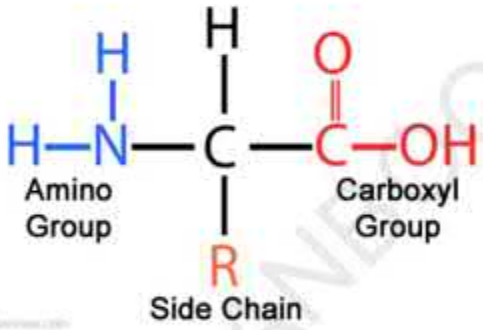
Protein

- Proteins are polymers or polypeptides consisting of repeating units called amino acids "monomer" joined by peptide bonds.

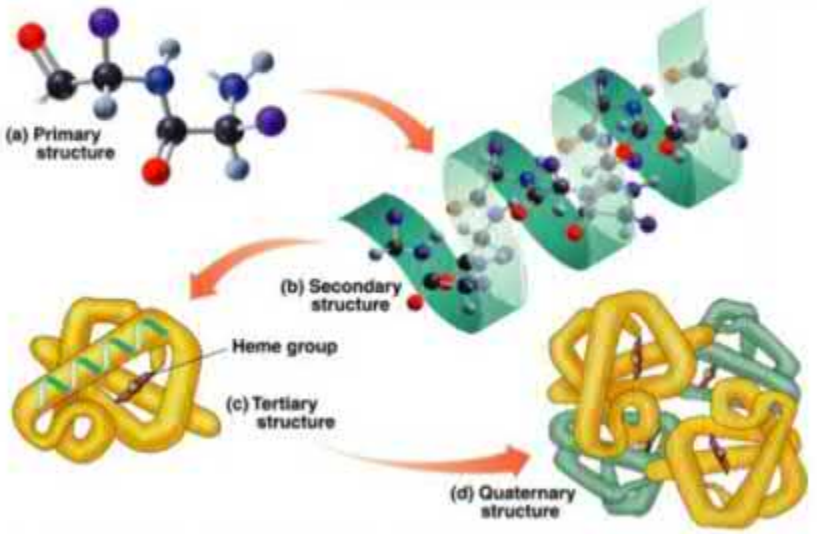
- Amino acids consist of a carboxyl group, an amine group, and a variable (R), all attached to a central carbon atom. The R group, or variable, differs with each amino acid.

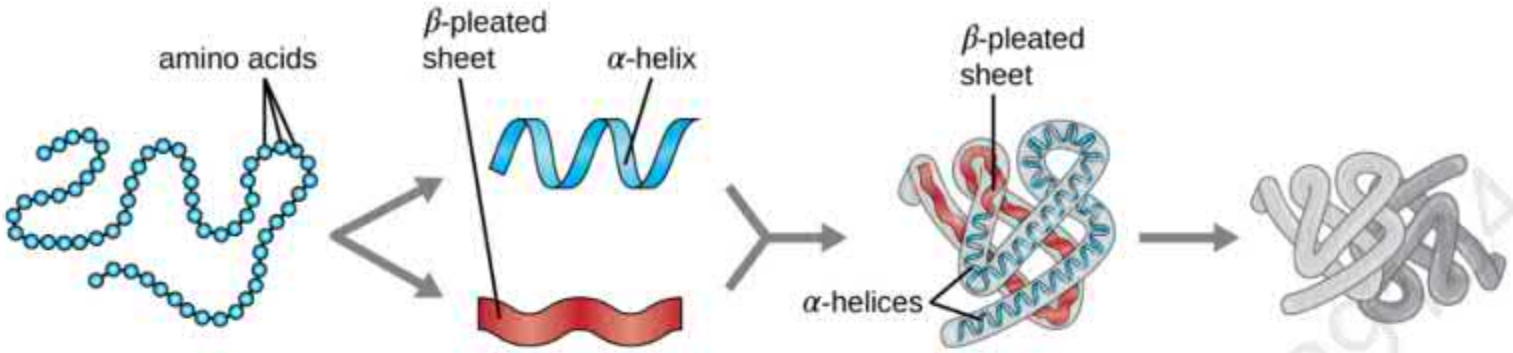
Components	Function	Resources	Classification
Carboxyl group Amine group R Group contains C, O, H, and S, P, N	♦ Growth ♦ Repair ♦ Act as enzymes ♦ Hormones ♦ Membrane channel "depends on their shape"	Fish Meat Poultry Some plants (beans)	20 types of amino acids

Amino Acid Structure



Summary of Protein Structures





Primary Protein Structure Sequence of a chain of amino acids	**Secondary Protein Structure** Local folding of the polypeptide chain into helices or sheets	**Tertiary Protein Structure** three-dimensional folding pattern of a protein due to side chain interactions	**Quaternary Protein Structure** protein consisting of more than one amino acid chain
-Amino acids arranged in a chain -By Peptide bond 2AA= Dipeptide 3:10AA= Oligopeptide More than 10 = poly-peptide	-Folding of polypep-tide chin -By Hydrogen bond	-Further folding to gain 3D shape -Holding by : -Hydrogen bond -Electrostatic inter-action -Disulfide bond	-More than one poly peptide chain -Holding by electrostatic interaction alone

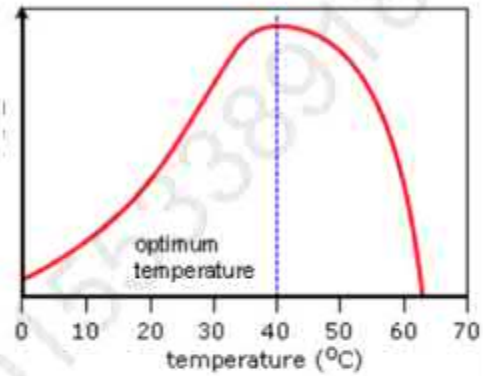
The shape of a protein, in is the result of four levels of structure: primary, second-ary, tertiary, and quaternary.

hemoglobin

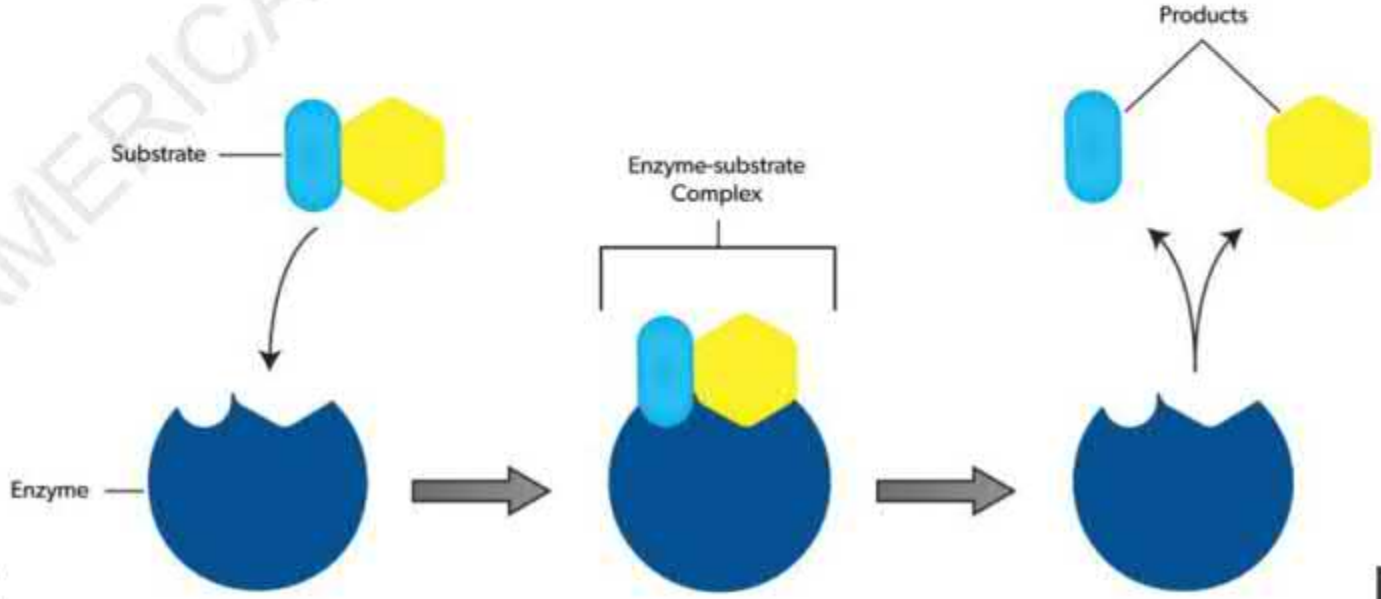
four separate polypeptide subunits

Enzymes

- Enzymes are large proteins (Tertiary type)work as **catalyst**
- **Enzymes speed up reactions by lowering the energy of activation for the reaction.**
- The chemical that an enzyme works on is called a **substrate.**
- Enzymes are specific.
- Enzymes denature (lose their natural shape) in high temperatures or adverse pH.

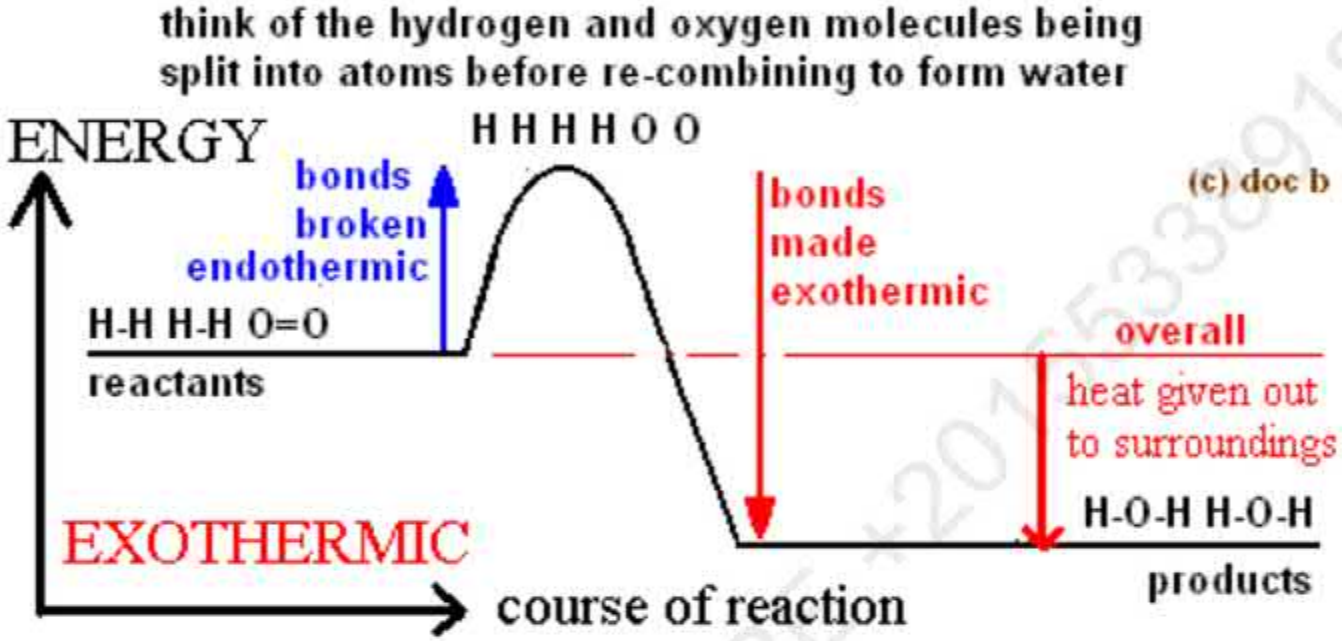


- When a protein/enzyme denatures, it cannot function because its tertiary structure has been altered beyond repair.
- The **induced-fit model** describes how enzymes work. As the substrate enters the active site, it induces the enzyme to alter its shape slightly so the substrate fits better. (The old **"lock and key"** model was abandoned because it implied that the enzyme never changes.)
- Enzymes are not degraded during a reaction and are reused.
- Enzymes are named after their substrate, and the name ends in the suffix "ase" For example, sucrase is the name of the enzyme that hydrolyzes sucrose, and lactase is the name of the enzyme that hydrolyzes lactose.
- Enzymes function with the assistance from cofactors (minerals) or coenzymes (vitamins).



Enzymes

Energy profile of a chemical reaction



energy is taken in to break bonds (endothermic)
energy is released on forming bonds (exothermic)
the difference between them gives the net energy released

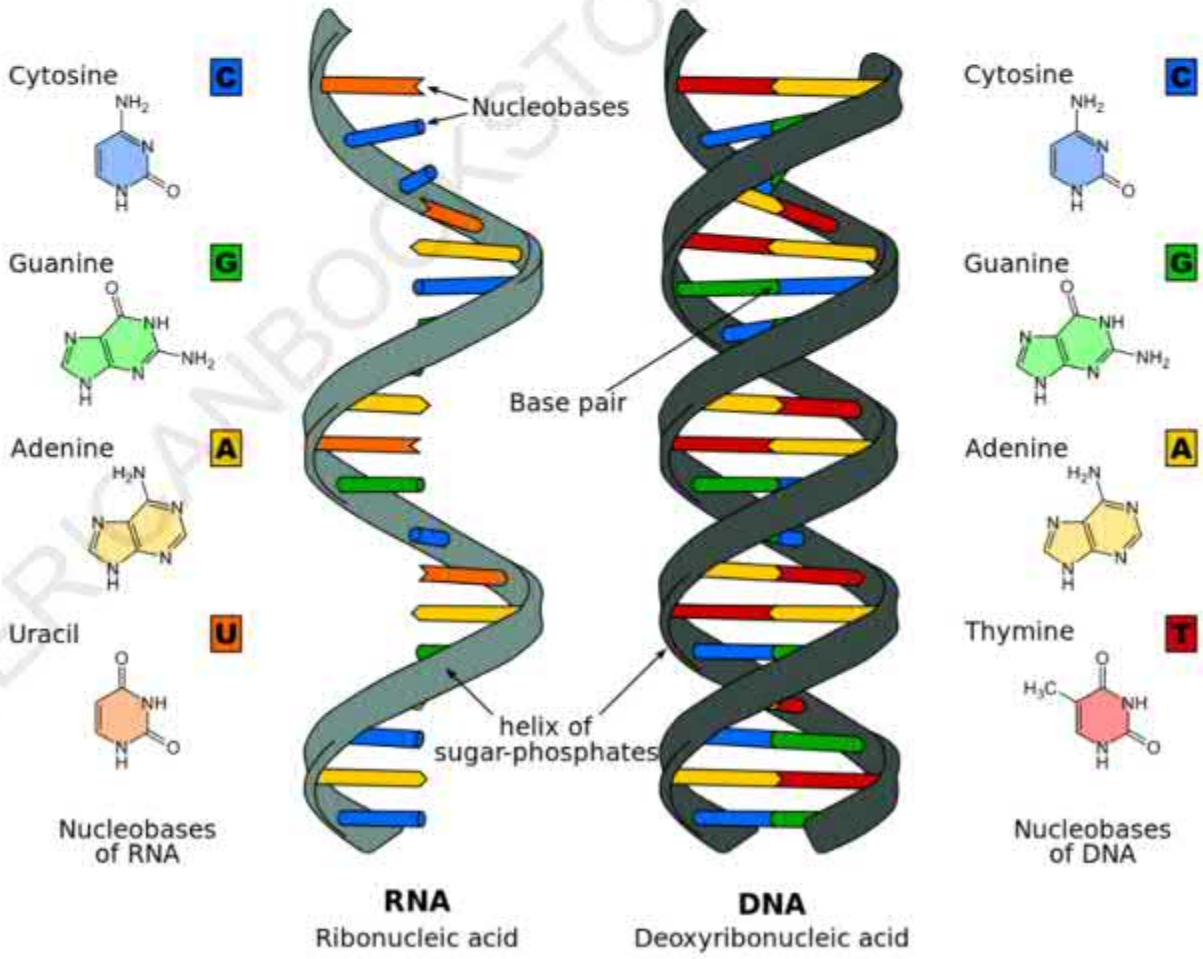
NB: Enzymes force the reaction to proceed only in one direction

Prions

Prions are infectious proteins that cause several brain diseases, including mad cow disease. A prion is a misfolded version of a protein normally found in the brains of mammals. If a prion gets into a normal brain, it causes all the normal proteins to misfold in the same way.

Nucleic Acid

Components	Function	Resources	Classification
Nucleotides • Phosphate (phosphoric acid) - 5 carbon sugar - Nitrogenous base	♦ Carry genetic material ♦ regulating the expression of genetic information ♦ Protein synthesis	DNA is Inherited	DNA RNA



"Will be discussed in details later"

The Cell

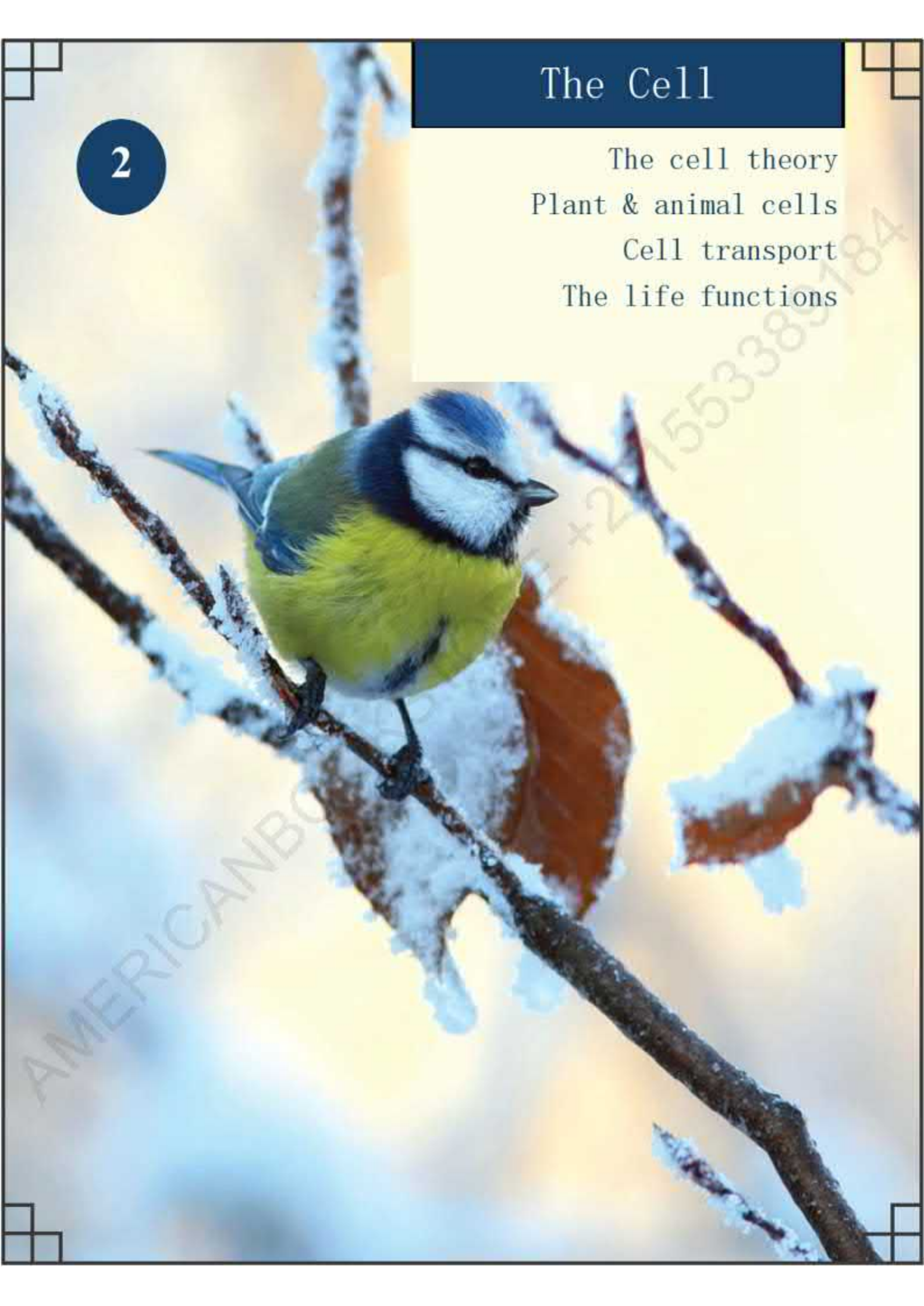
2

The cell theory

Plant & animal cells

Cell transport

The life functions



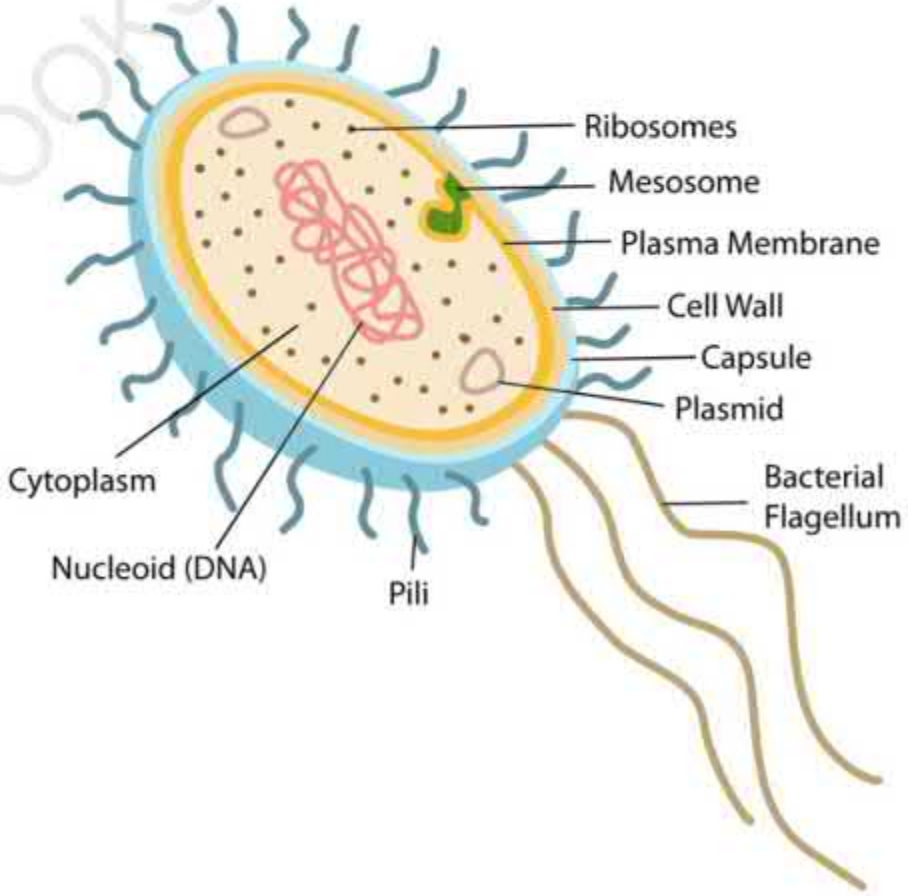
THE CELL

Modern cell theory states:

- All living things are composed of cells.
- Cells are the basic unit of all organisms.
- All cells arise from preexisting cells.

- Cells sized from 8-100 micrometers (μm) in the human body.
- Cells are divided into two varieties:

- **Prokaryotes** have no nucleus or other internal membranes. Example Bacteria.
- **Eukaryotes** have a nucleus and are more complex cells. They make up every form of life other than bacteria. Human cells are eukaryotic cells.



Prokaryotes	Eukaryotes
No membrane-bound organelles such as a nucleus	Contain distinct organelles surrounded by membranes, such as nucleus and mitochondria
Contains a single, circular chromosome	Chromosomes are linear; human body cells contain 46 chromosomes in each nucleus
Can contain plasmids	Does not contain plasmids
Respiration can be either aerobic or anaerobic	Respiration is mostly aerobic
Cytoskeletal elements, such as microfilaments, are absent	Cytoskeletal elements, like microfilaments and microtubules, are present
Most are unicellular	Some, like euglena and paramecium, are single, many are multicellular with specialized cell types, such as muscle, blood, and skin cells
Very small: 1-10 μm	Larger: 10-100 μm
Most have tough external cell walls	Most (except plant cells and protists) are surrounded by only a cell membrane
Example: Bacteria	Animal cell, plant cells, Fungi, Protists

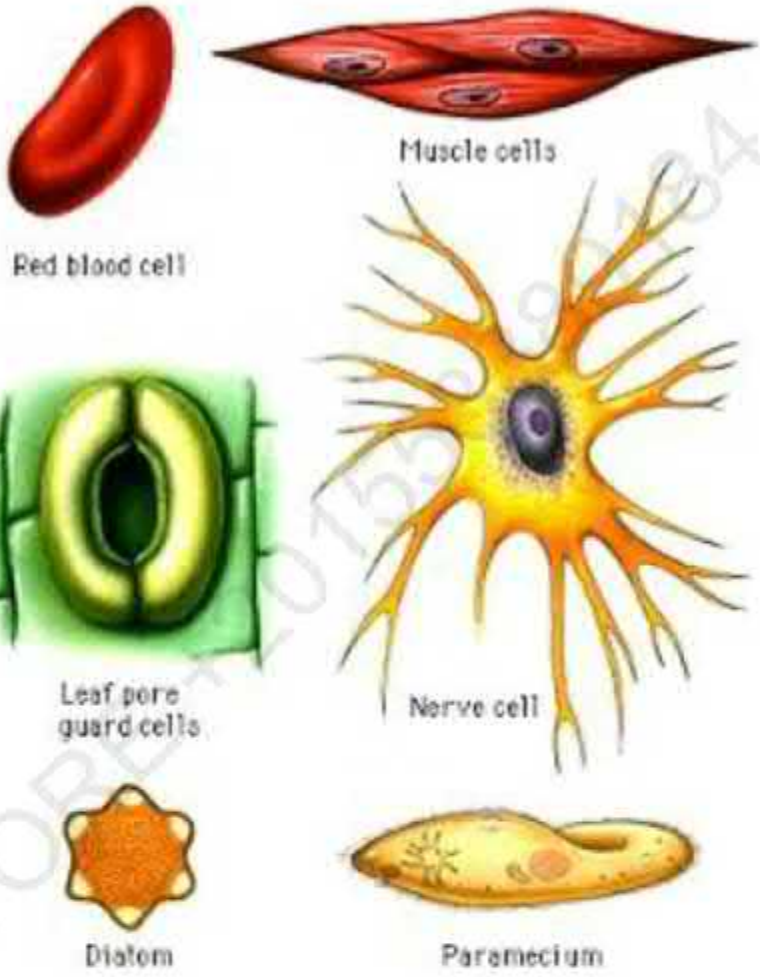
Common properties between prokaryotic and eukaryotic cells:

Cell membrane, Cytoplasm, Cell organelles*, Hereditary material

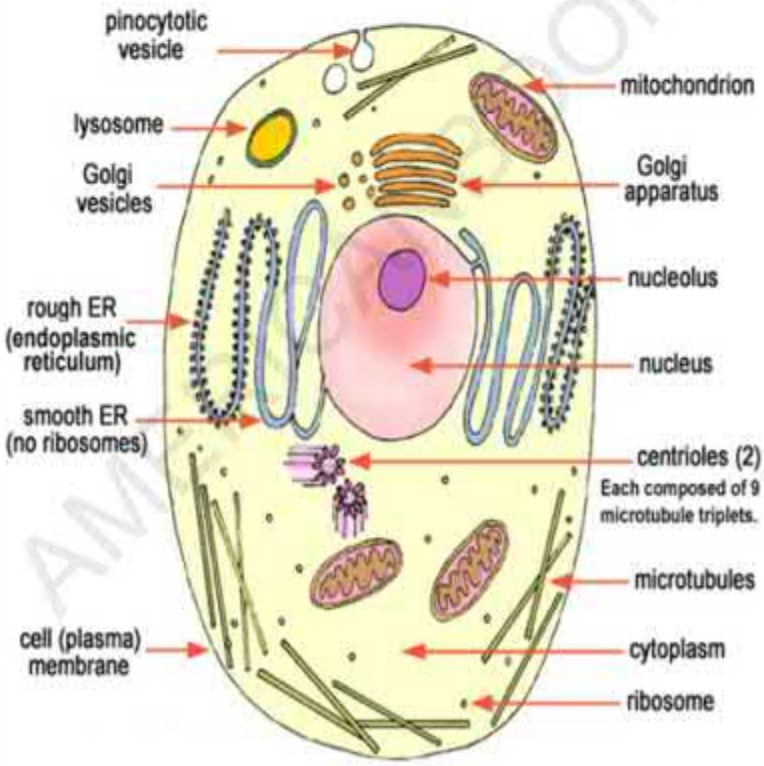
- All organisms on Earth are believed to have descended from a common ancestral prokaryotic cell about 3.5 billion years ago.
- According to the theory of **endosymbiosis** "eukaryotic cells containing organelles like mitochondria and chloroplasts evolved when free-living prokaryotes took up permanent residence inside other larger prokaryotic cells, about 2 billion years ago. This was the origin of a complex eukaryotic cell with internal membranes that compartmentalized the cell, making it very efficient and leading to the evolution of all multi-celled organisms.

The human body is made of approximately two hundred different eukaryotic cell types, each with a different function. Therefore, each cell type has a different form.

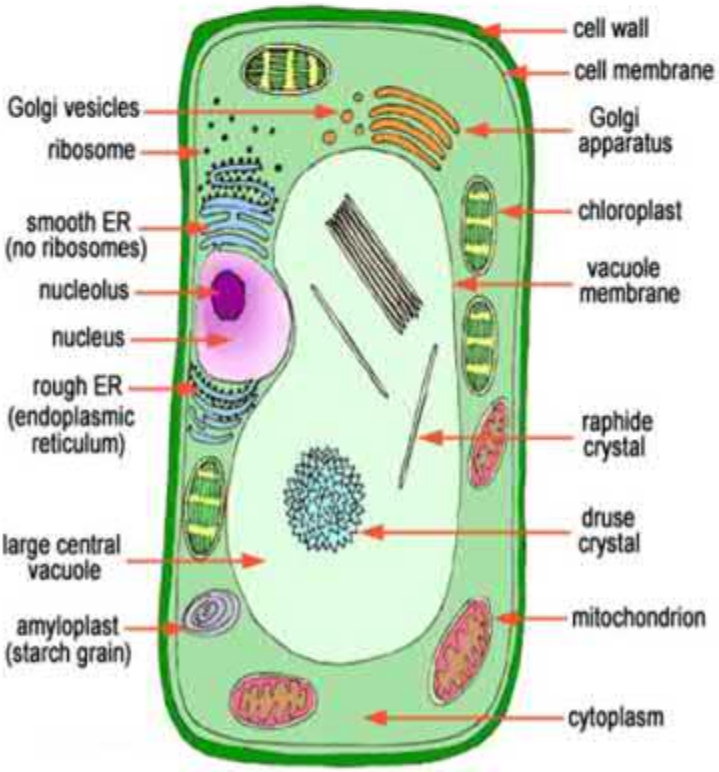
Although different cell types have different functions and appearances, they all contain the same organelles.



Eukaryotic cells



ANIMAL CELL



PLANT CELL

STRUCTURES OF PLANT AND ANIMAL CELLS

- Cell is composed of a **protoplasmic** substance surrounded by cell membrane.
- **Protoplasm** consists of **cytoplasm** and **nucleus.**
- **Eukaryotic** cell may contain:

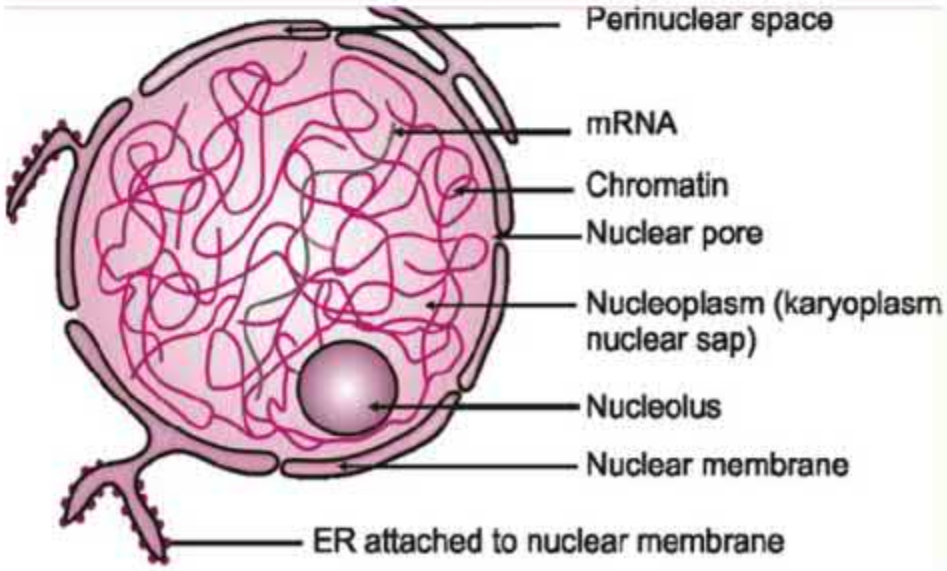
1. **Cell Wall.**
2. **Plasma membrane (cell membrane).**
3. **Cytoplasm.**
4. **Nucleus.**
5. **Cell organelles.**

An Organelle is a cell component that performs a specific function in that cell, It may be membranous "enclosed inside a membrane" or not.

Nucleus

The nucleus contains chromosomes made of DNA that is wrapped with special proteins called histones into a chromatin network. The nucleus is surrounded by a double membrane or envelope.

Function: Storage of genetic material, play an important role in cell division



Nucleolus

- The nucleolus is a prominent region inside the nucleus of "non dividing cell".
- One or two nucleoli are commonly visible in a nondividing cell

Function: The main function of the nucleolus is to make ribosomal RNA (rRNA)

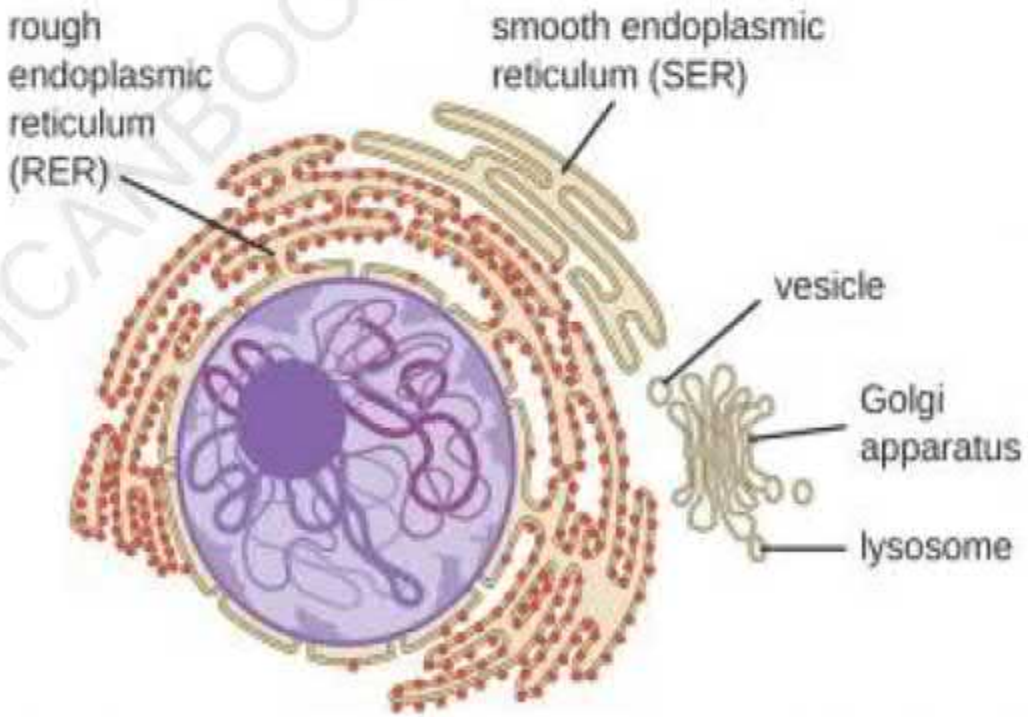
Ribosome

Ribosomes are particles made of ribosomal RNA and protein. They are suspended freely in the cytoplasm or bound to endoplasmic reticulum.

Function: Protein synthesis

Endoplasmic Reticulum

The endoplasmic reticulum (ER) is a system of membrane channels that traverse the cytoplasm.



- The ER is like a factory for the production of proteins and lipids. It also forms a network of tubes that carry substances around the cell. There are two types of ER

  1. **The rough ER** is called "rough" because it is studded ribosomes while the smooth ER is called "smooth" because it lacks ribosomes.

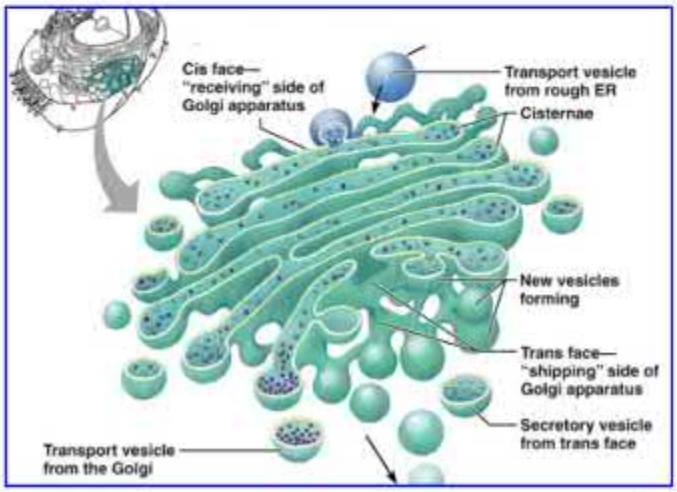
- **The Smooth ER** contains enzymes that are involved in the **creation of lipids.** Other enzymes in the smooth ER **help in the detoxification of drugs and alcohol.** And other enzymes for **changing carbohydrates into glycogen.**

- Ribosomes attached to the Rough ER are responsible for **protein synthesis.** These ribosomes assemble amino acids into polypeptides. When synthesis is complete the ER packages the polypeptides in special vesicles and sends them to the Golgi apparatus where they will be packaged and "shipped".

Golgi Apparatus

The Golgi apparatus lies near the nucleus and consists of flattened sacs of membranes stacked next to each other (like a stack of pancakes) and surrounded by vesicles.

Function: They **modify, store**, and **package** substances produced in the rough endoplasmic reticulum. The Golgi apparatus also **secretes** these substances to other parts of the cell and to the cell surface for export to other cells.

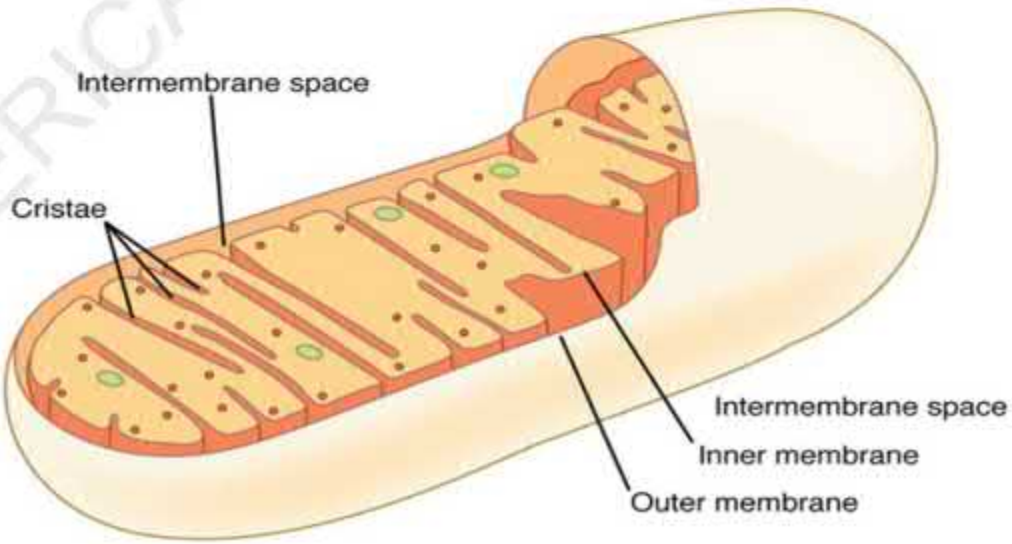


Lysosome

- Lysosomes are **digestive sacs** that contain enzymes to **break down cellular waste or debris** from outside the cell into new building material.
- Lysosomes break down big macro molecules into smaller molecules which can be used to nourish the cell. They also **break down damaged organelles** and **destroy foreign invaders** such as bacteria.
- Lysosomes are formed by Golgi bodies.
- White blood cells (WBCs) use Lysosomes in killing microbes.
- Plant cells do not usually have lysosomes.

Mitochondria

- The mitochondrion (plural, mitochondria) is the site of cellular respiration.
- All cells have many mitochondria.
- A very active cell could have about 2,500 of them.
- Mitochondria consist of an outer double membrane and folded inner membranes called cristae.
- Enzymes that are important to cellular respiration are embedded in the cristae membrane.
- Mitochondria contain their own DNA and can self-replicate.

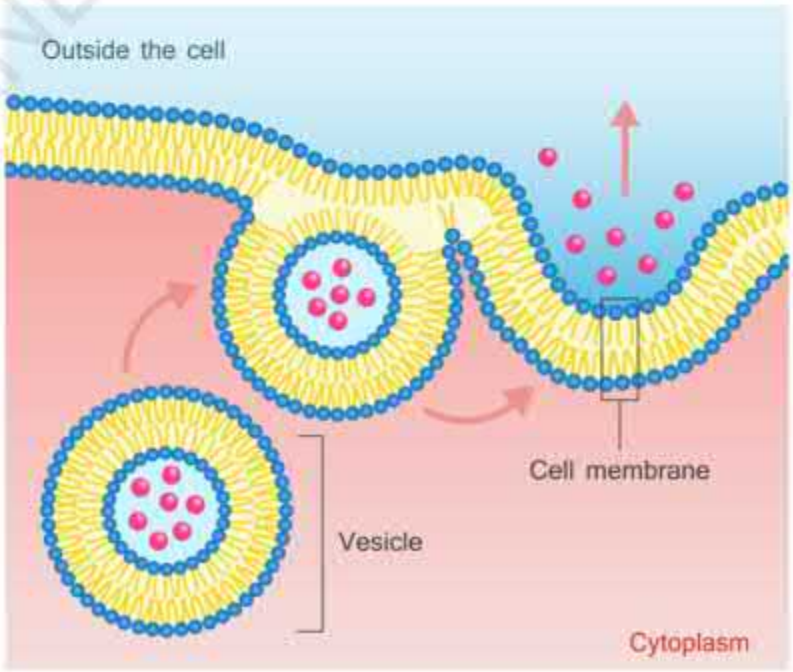


Vacuole

- Vacuoles are membrane-bound structures that store substances for the cell.
- Freshwater protista, like paramecium and amoeba, have **contractile vacuoles** that pump excess water out of the cell.
- Plant cells and human fat (adipose) cells have large central vacuoles for storage.
- The vacuoles in animal cells are generally smaller than that in plant cells.
- Animal cells can have multiple small vacuoles while plant cells usually have a single large vacuole.

Vesicle

Vesicles are **tiny vacuoles**. They are found in many places in cells, including the axon of a neuron, where they release neurotransmitter into a synapse.



Plastids

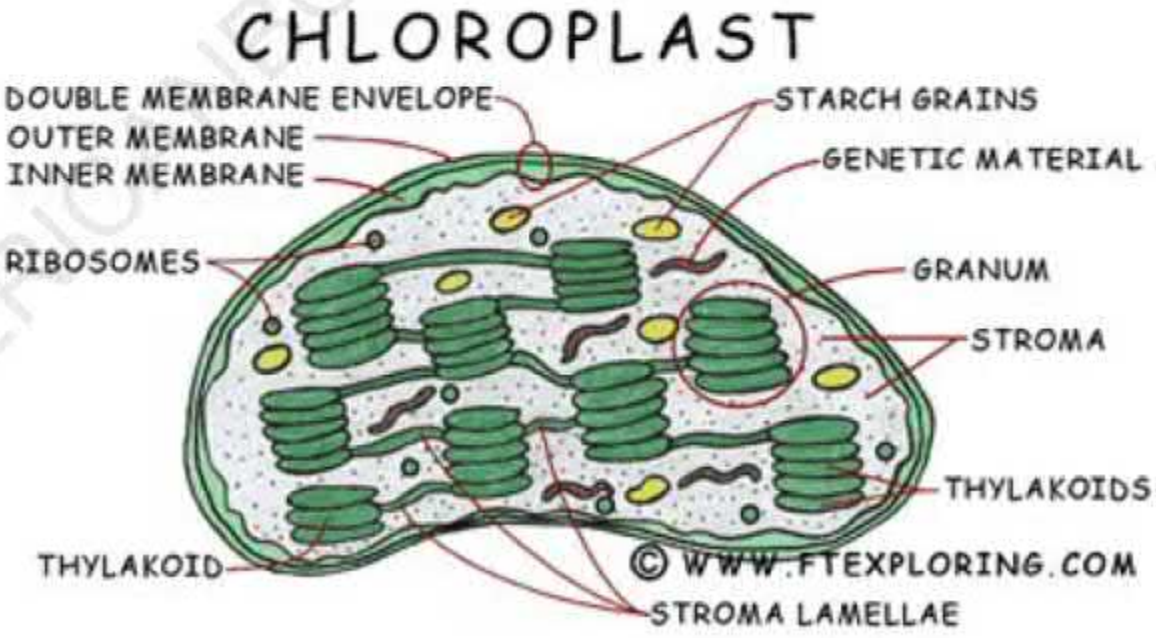
Plastids have a double membrane and are found only in plants and algae. There are three types.

1. **Chloroplasts** are green because they contain chlorophyll. They are the sites of **photosynthesis**. In addition to a double outer membrane, they have an inner one that forms a series of structures called grana. The grana lie in the stroma.

Chloroplasts, like mitochondria, contain their own nuclear material and can self-replicate.

2. **Leucoplasts** are colorless and **store starch**. They are found in roots, like turnips, or in tubers, like potatoes.

3. **Chromoplasts** store carotenoid pigments and are responsible for the red- orange-yellow coloring of carrots, tomatoes, daffodils, and many other plants. These bright pigments in petals **attract pollinating insects** to flowers.

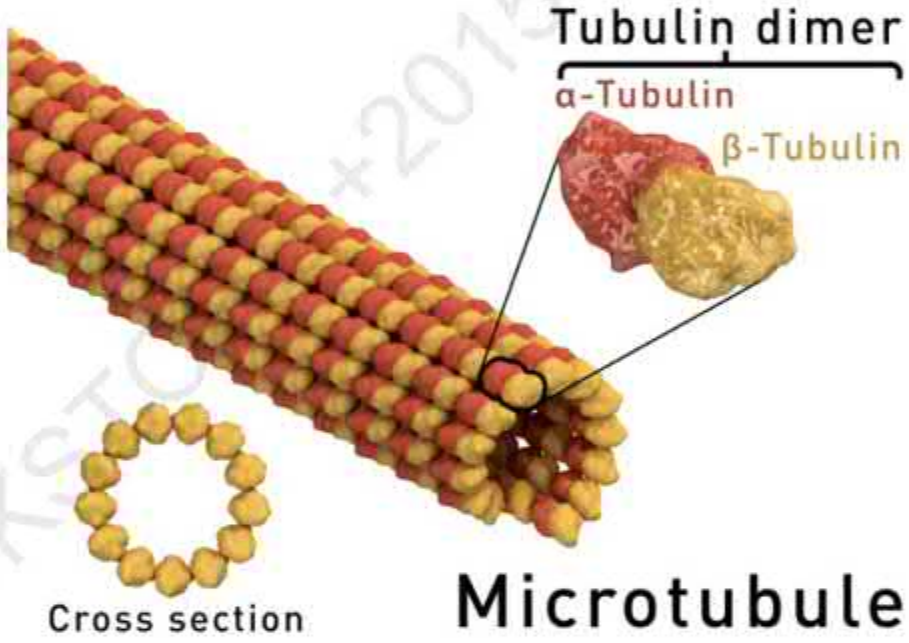


Cytoskeleton

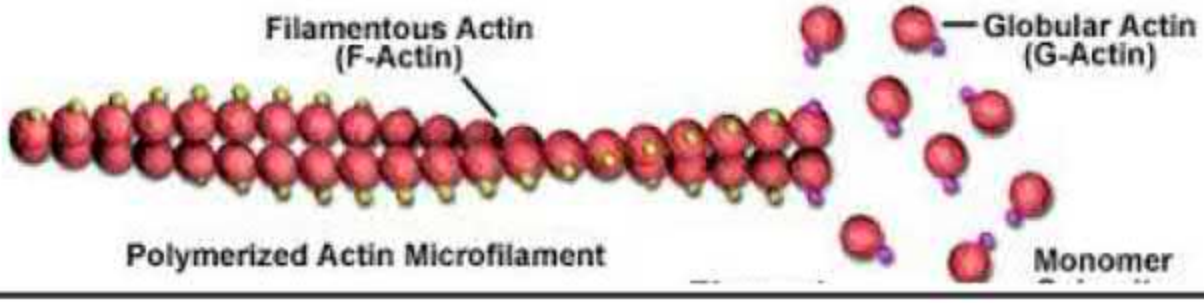
The cytoskeleton of a cell is a complex network of protein filaments that extends throughout the cytoplasm and gives the cell its shape and enables it to move.

The cytoskeleton includes two types of structures.

1. **Microtubules** are thick hollow tubes that make up the cilia, flagella, and spindle fibers. They are formed from the protein tubulin.

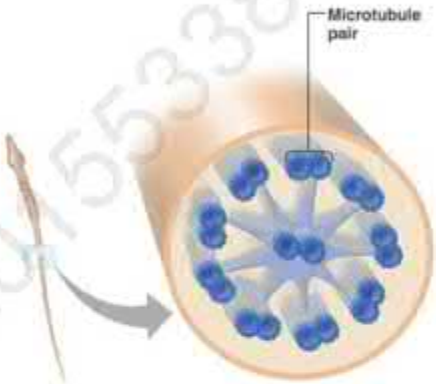


2. **Microfilaments** are made of the protein actin and help support the shape of the cell. They enable:
   - Animal cells to form a cleavage furrow during cell division
   - Amoeba to move by sending out pseudopods
   - Skeletal muscles to contract by sliding along myosin filaments



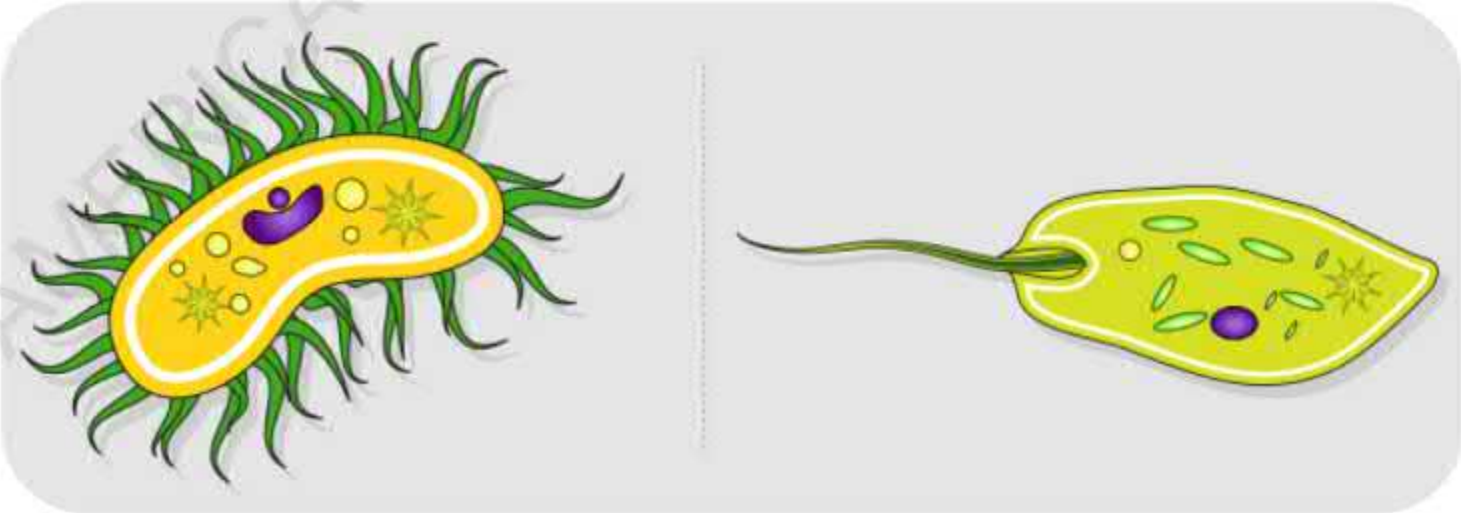
Centrioles and Centrosomes

- Centrioles and centrosomes lie outside the nuclear membrane and organize the spindle fibers required for cell division.
- **Only animal cells** have centrioles and centrosomes. Plant cells have microtubule organizing regions instead.
- Two centrioles make up one centrosome.
- Centrioles and spindle fibers have the same structure. they consist of 9 triplets of microtubules arranged in a circle (9+2)
- Nerve cells do not contain centrosomes so they are not able to divide.



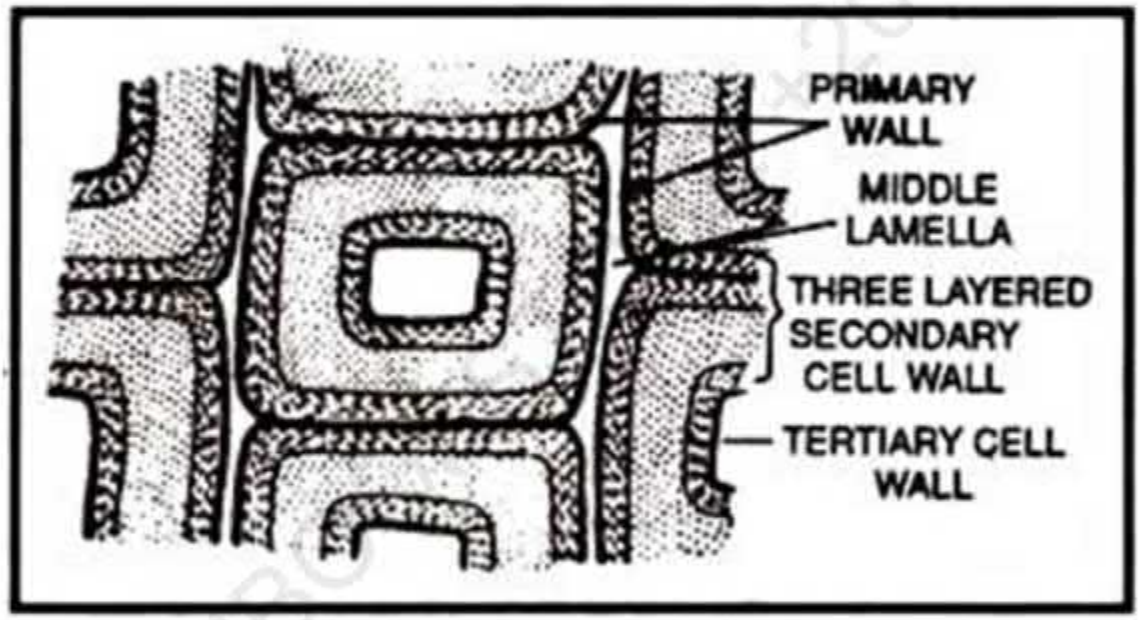
Cilia and Flagella

- Cilia and flagella have the same internal structure; both are made of microtubules.
- Cilia are short, and flagella are long.
- Both consist of 9 pairs of microtubules organized around 2 singlet microtubules.
- Function: Movement.



Cell Wall

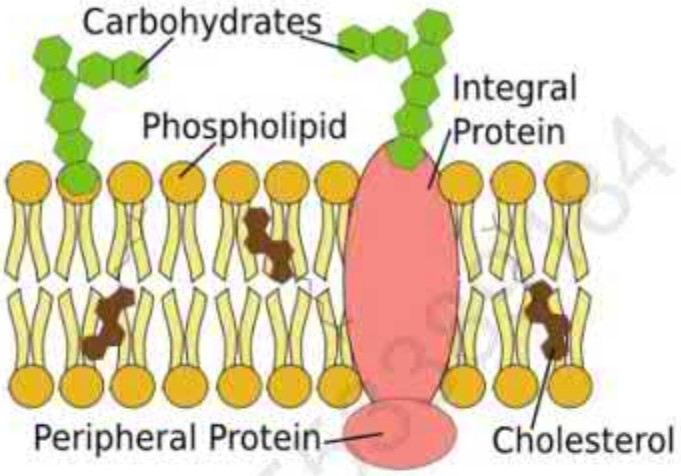
- The cell wall is one structure **not found in animal cells.**
- Cell walls of fungi consist of **chitin**, while plants and algae have cell walls made of **cellulose.**
- In plant cells, the primary cell wall is located immediately outside the plasma membrane. Some cells produce a second cell wall underneath the primary cell wall.
- When a plant cell divides, a thin gluey layer is formed between the two cell walls, which becomes the middle lamella and which keeps the two daughter cells attached.



Cytoplasm

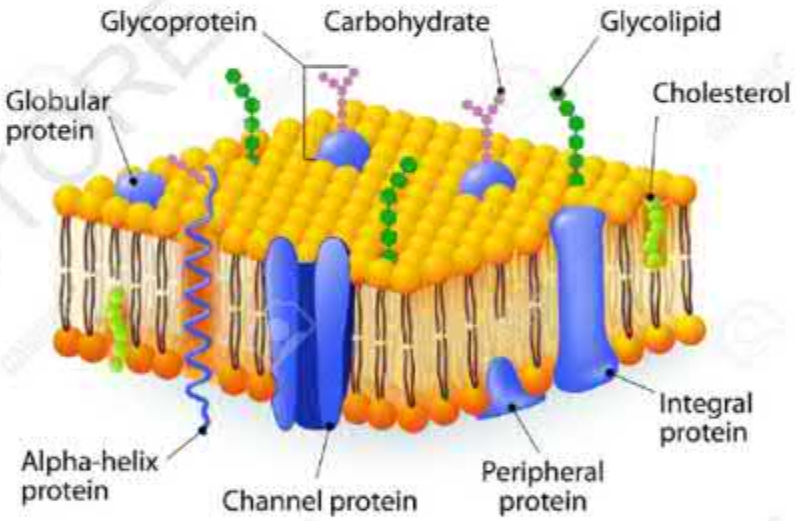
- A semi-fluid substance filling the space between the nucleus and cell membrane. It's composed of water and other organic and inorganic substances.

Cell or Plasma Membrane



- The cell or plasma membrane is a selectively permeable membrane that controls what enters and leaves the cell.

- It is described as a "**fluid mosaic**" because it is made of many small particles that are able to move around in order to control what enters and leaves the cell.



- The plasma membrane consists of a phospholipid bilayer with proteins dispersed throughout. Molecules of cholesterol are embedded within the membrane, making it less fluid and more stable.

- The external surface of the plasma membrane has carbohydrate chains attached to it that are important for cell-to-cell recognition.
- An average cell membrane consists of about 60 percent protein.
- These proteins provide a wide range of functions for the cell.
- Some membrane proteins, like ATP synthetase , act as an enzyme.
- Some, like those involved in the sodium-potassium pump, transport ions into and out of cells.

TRANSPORT INTO AND OUT OF THE CELL

Important Definitions

1. **Selectively permeable**: A characteristic of a living membrane. The substances that pass through a selectively permeable membrane change with the needs of a cell.

2. **Solvent**: The substance that does the dissolving.

3. **Solute**: The substance that dissolves.

4. **Hypertonic**: Having a greater concentration of solute than another solution.

5. **Hypotonic**: Having a lower concentration of solute than another solution.

6. **Isotonic**: Two solutions containing equal concentrations of solute.

7. **Passive Transport**: The movement of molecules down a concentration gradient from a region of higher concentration to a region of lower concentration. Passive transport NEVER requires energy. It occurs either by diffusion (**simple diffusion** or **facilitated diffusion**) or by **osmosis**.)

8. **Active transport** is the movement of molecules against a gradient, which requires energy, usually in the form of ATP.

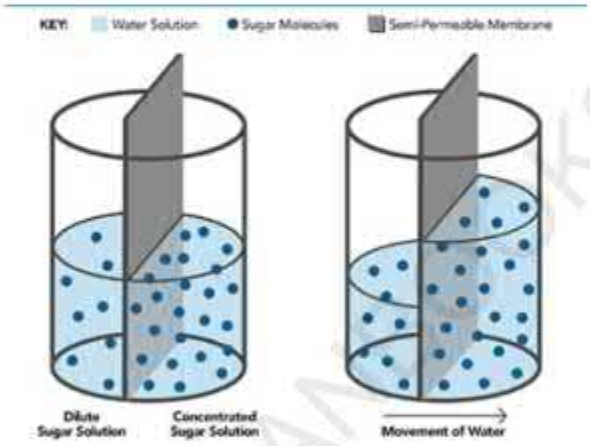
9. **Exocytosis** is the active release of molecules from a cell.

10. **Pinocytosis**, also called cell drinking, is the uptake of large, dissolved molecules.

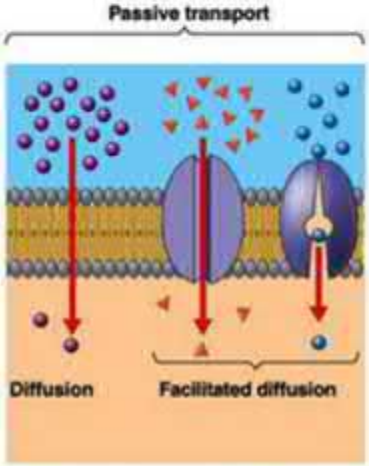
Types of transport

Passive transport

- Movement down a concentration gradient.
- Do not consume energy
- **Simple diffusion** is merely the movement of particles from a higher concentration to a lower concentration.
- **Facilitated diffusion** relies on special protein membrane channels to assist in transporting specific substances across a membrane.



- **Osmosis** is the diffusion of *water* across a *membrane*. Water flows down a gradient toward a region with high solute concentration.

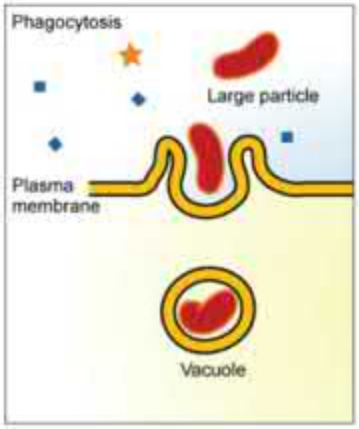


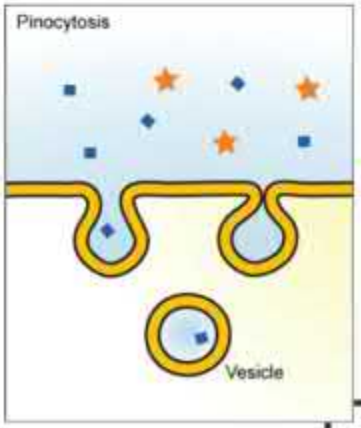
Active transport

- Movement against gradient
- Consume energy
- **Exocytosis** is the active release of molecules from a cell. Example is found in the synapse of nerve cells. Vesicles containing a neurotransmitter such as acetylcholine (ACh) release their contents into the synapse in order to pass an impulse to another cell.
- **Endocytosis**

1. Pinocytosis, also called cell drinking, is the uptake of large, dissolved molecules. The plasma membrane invaginates around tiny particles and encloses them in a vesicle.

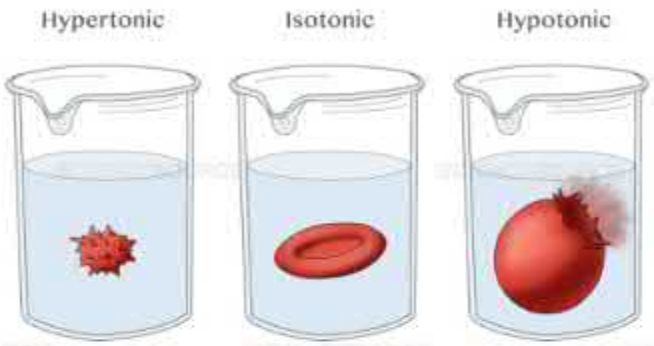
2. Phagocytosis is the engulfing of large particles or even small organisms by pseudopods.





Types of transport

Passive transport



Cell in a hypertonic solution. Water will leave the cell, causing the cell to shrink. This cell shrinking is known as **plasmolysis**. a cell in a hypotonic solution. Water flows into the cell. This causes an animal cell to burst.

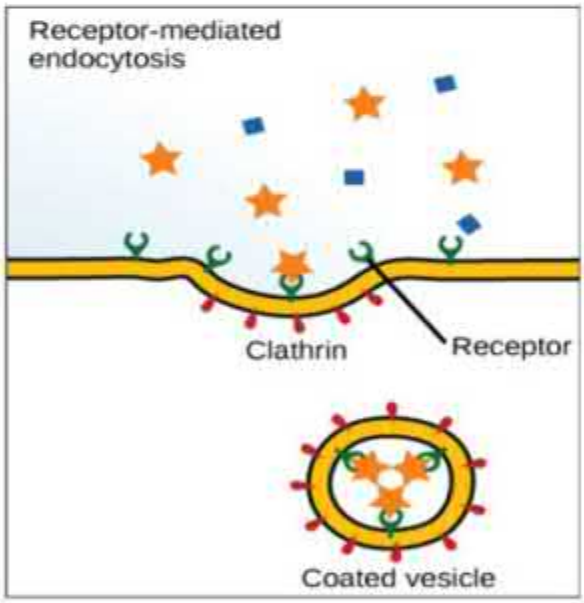
Factors favoring diffusion:

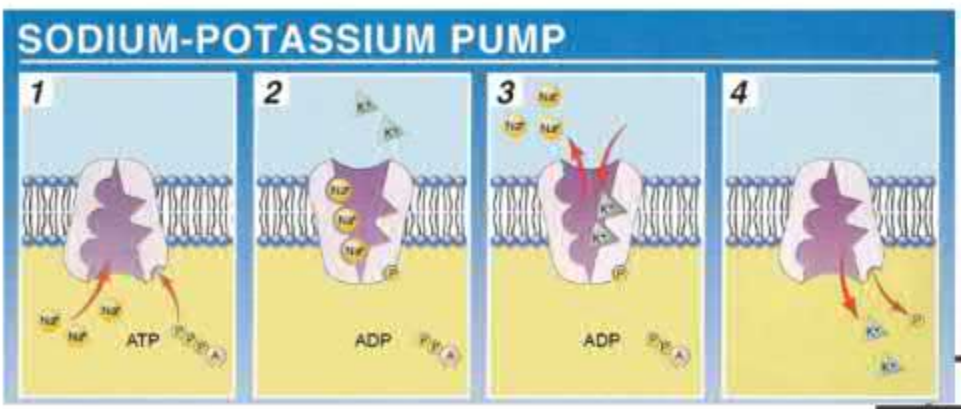
1. **Distance** (the shorter the better)
2. **Concentration gradient** (the bigger the better).
3. **Size of the molecules** (the smaller the better).
4. **Surface area for diffusion** (the larger the better).
5. **Temperature** (molecules have more kinetic energy at higher temperature).

Active transport

3. Receptor-mediated endocytosis enables a cell to take up large quantities of very specific substances. Extracellular substances bind to specific receptors on the cell membrane and are drawn into the cell into vesicles.

- This is the way in which body cells take up cholesterol from the blood. Another example is sodium, potassium pump





The life functions

"Life is a list of characteristics cell must posses to be considered living". This characteristics include:

1. **Ingestion.** Nutrients intake

2. **Digestion.** Enzymatic breakdown, hydrolysis, of food so it is small enough to be assimilated by the body

3. **Respiration.** Metabolic processes that produce energy (ATP) from food (glucose) for all the life processes

4. **Transport.** Distribution of molecules from one part of a cell to another or from one cell to another

5. **Regulation.** Ability to maintain internal stability, homeostasis

6. **Synthesis.** Combining of small molecules or substances into larger, more complex ones

7. **Excretion.** Removal of metabolic wastes

8. **Egestion.** Removal of undigested waste

9. **Reproduction.** Ability to generate offspring

10. **Irritability.** Ability to respond to stimuli

11. **Locomotion.** Moving from place to place (animal cells only)

12. **Metabolism.** Sum total of all the life functions

The life functions

Irritability

Metabolism

Respiration

Reproduction

Synthesis

Excretion

Transport

Growth

Regulation

I'M MR. STRANGER

Ingestion

Nutrition

Ambulation

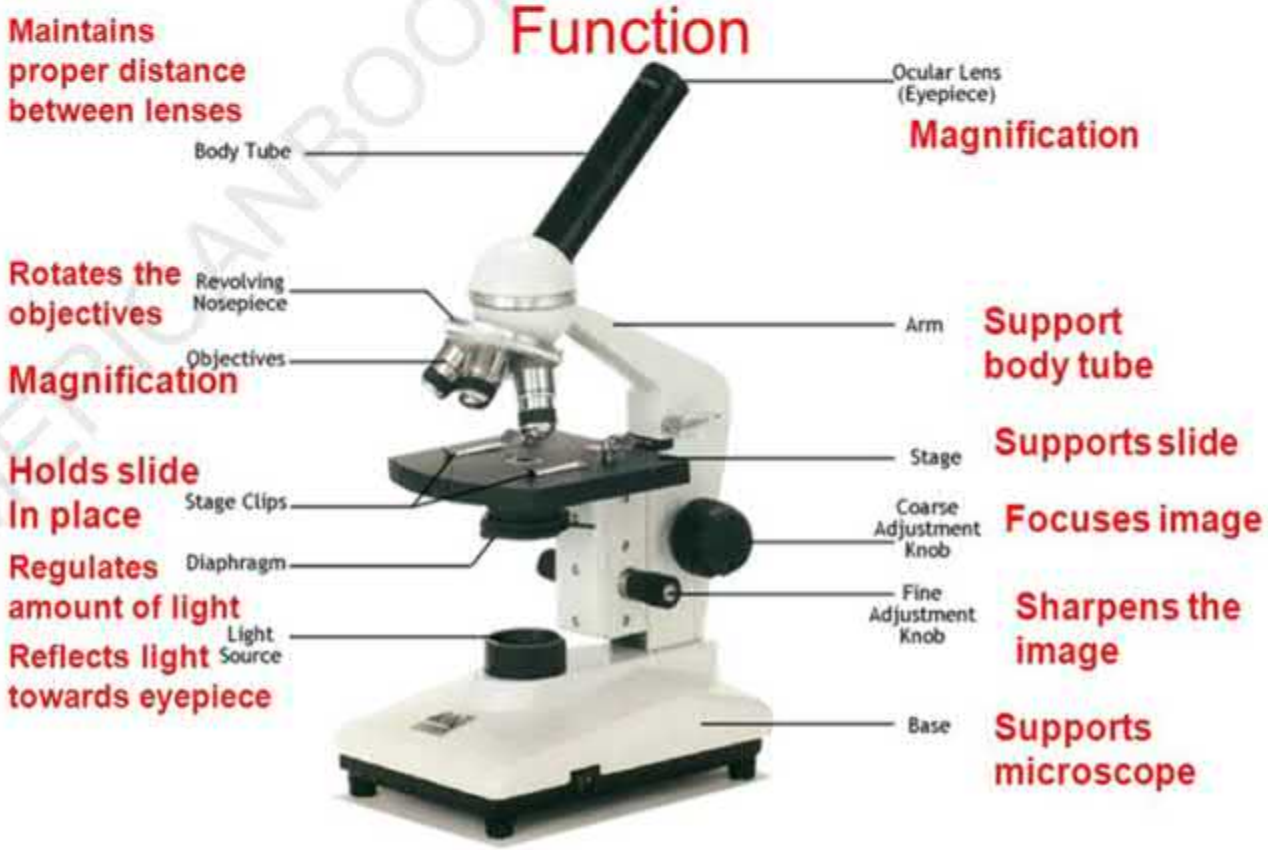
Digestion

Egestion

TOOLS AND TECHNIQUES TO STUDY CELLS

- The main tool for studying cell structure is the **compound microscope**
- Good microscopes have both high magnification and excellent resolution (image clarity)
- **Anton van Leeuwenhoek** developed the first microscope in the seventeenth century
- Microscope magnification equals Magnification power of eyepiece x Magnification power of objective lens
- When you use the microscope, remember that the image is upside-down and backward from the actual specimen you placed onto the slide.
- **Different types of microscopes:**
  1. Phase-contrast microscope
  2. Transmission electron microscope
  3. Scanning electron microscope

The Parts of the Microscope and Their Function



- **A phase-contrast microscope** is a light microscope that enhances contrast. It is useful in examining living, unstained cells.

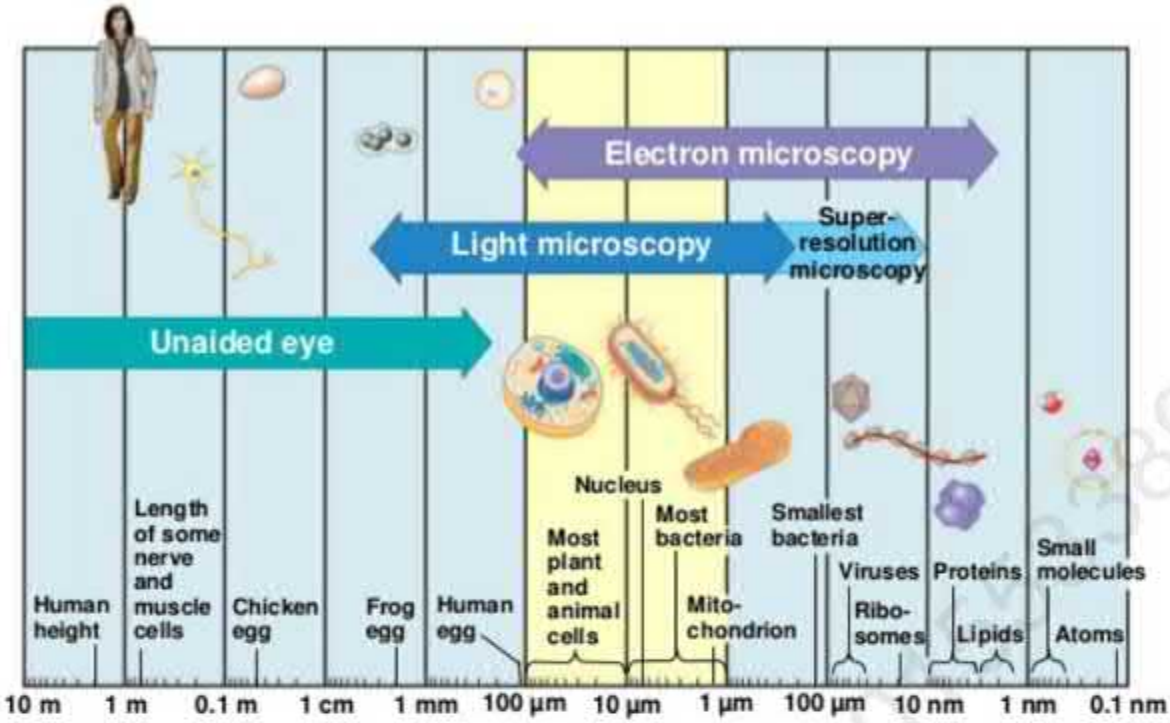
- **Electron microscopes** use a beam of electrons, instead of a beam of light, to produce superior resolving power as well as magnification over 100,000×.

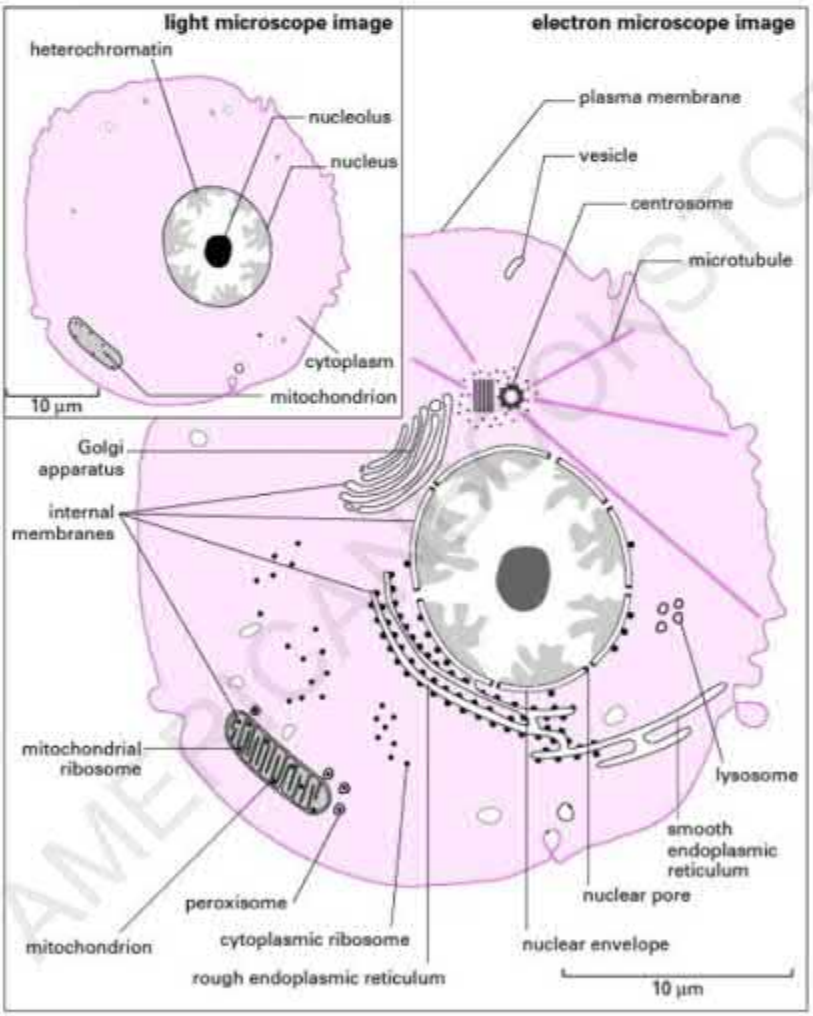
1. **The transmission electron microscope (TEM)** is useful for studying the interior of cells. The source of electrons is a tungsten filament within a vacuum column.

Drawbacks of EM:

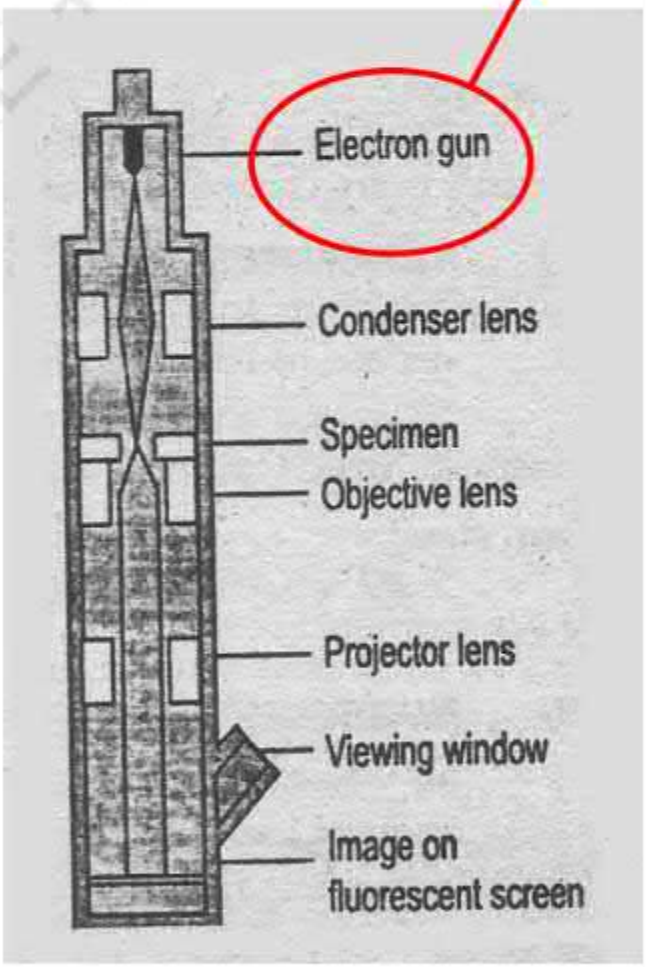
- The tissue is no longer alive after processing.
- Preparation of specimens is elaborate. Tissue must be fixed, dehydrated, and sectioned on a special machine, a process that requires many hours and much expertise.
- The EM is a delicate machine and requires special engineers to maintain it.
- Specimens must be sliced so thin that only a small portion of a tissue sample can be studied at one time.
- The machine costs hundreds of thousands of dollars.
- Need large space

2. **The scanning electron microscope (SEM)** is useful for studying the surface of cells. The resulting images have a three dimensional appearance. Once again, specimens are examined only after an elaborate process that kills the tissue.





Power source



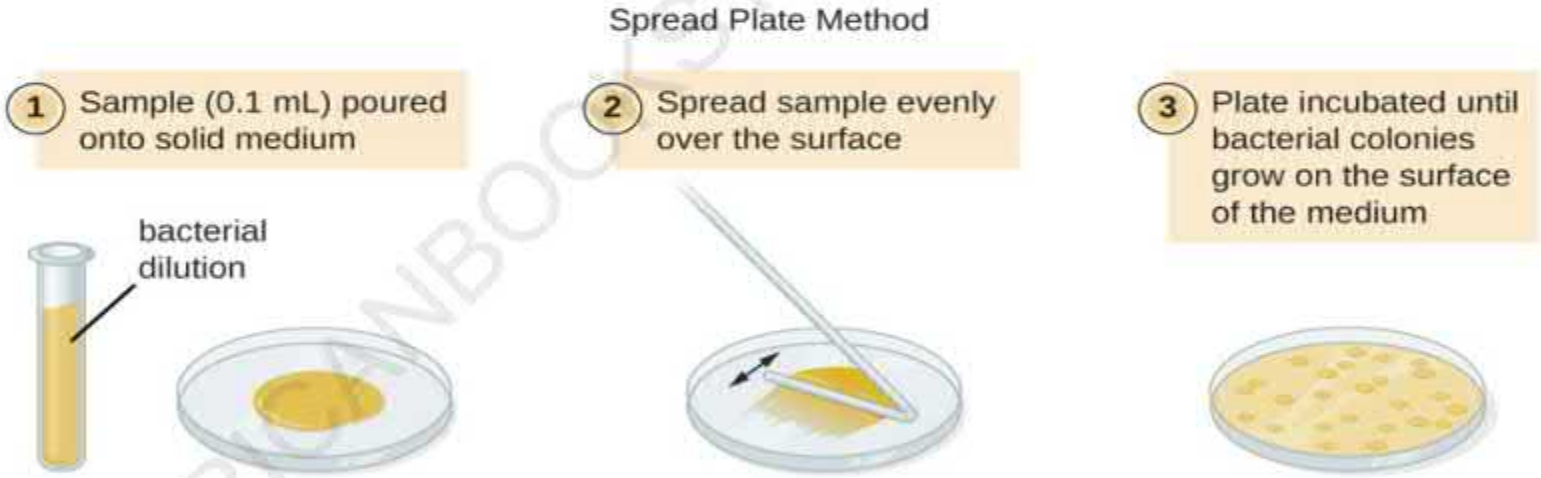
Other tools for studying cells

- Ultracentrifugation
- Freeze fracture
- Tissue culture

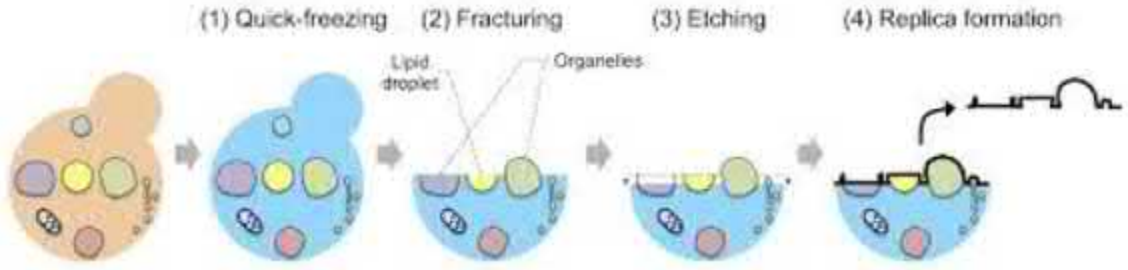
Ultracentrifugation It used to separate and isolate specific component of the cell by **cell fractioning**

1. First, tissue is mashed in a blender
2. Resulting liquid, is spun at high speed in an ultracentrifuge and separated into layers based on differences in density
3. Nuclei are forced to the bottom first, followed by mitochondria and then ribosomes with clear liquid above the organelles

Tissue culture



Freeze fracture



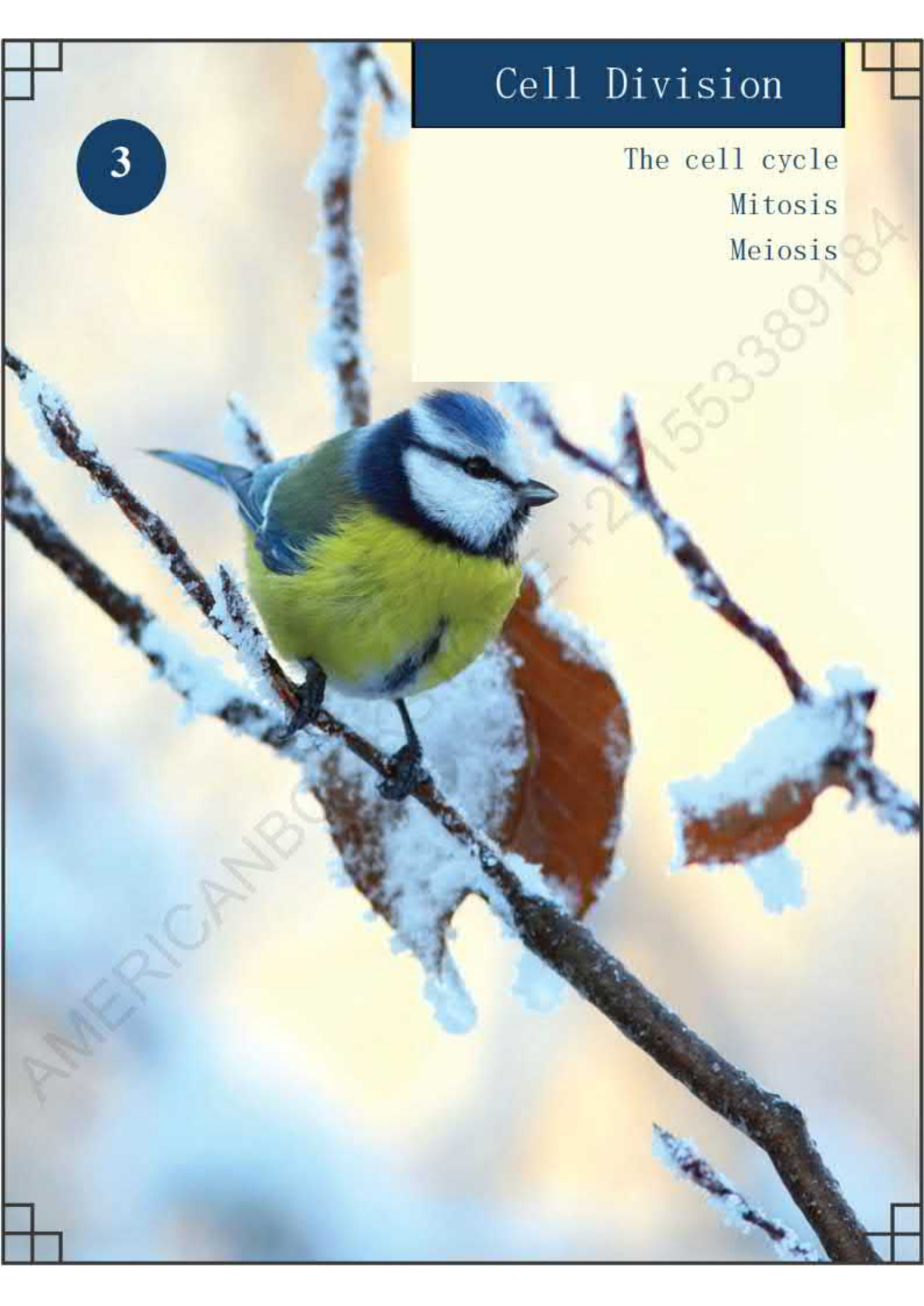
Cell Division

3

The cell cycle

Mitosis

Meiosis



- There are two types of cell division, mitosis and meiosis.

Mitosis

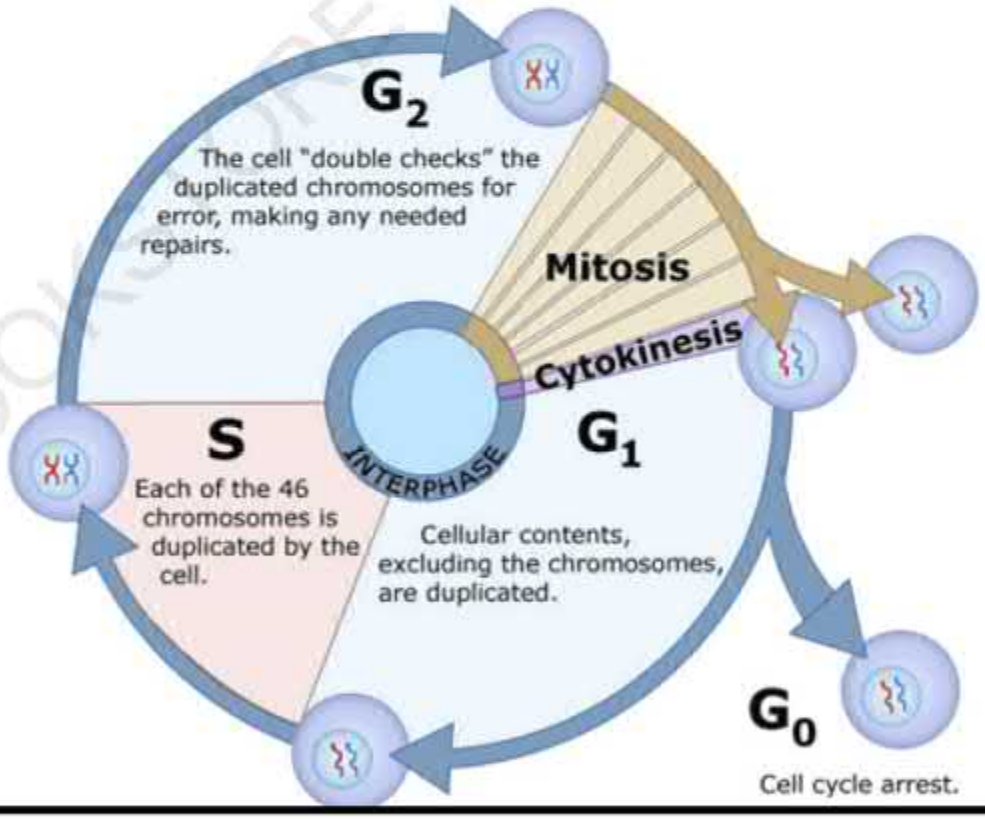
Functions in the growth and repair of body cells. It produces two genetically identical daughter cells with the same chromosome number as the parent cell. Each daughter cell is diploid (2n), just like its parent cell.

Meiosis

Occurs only in sexually reproducing organisms. It produces gametes (sperm and ova) with half the chromosome number of the parent cell. Each resulting cell is haploid (n).

THE CELL CYCLE

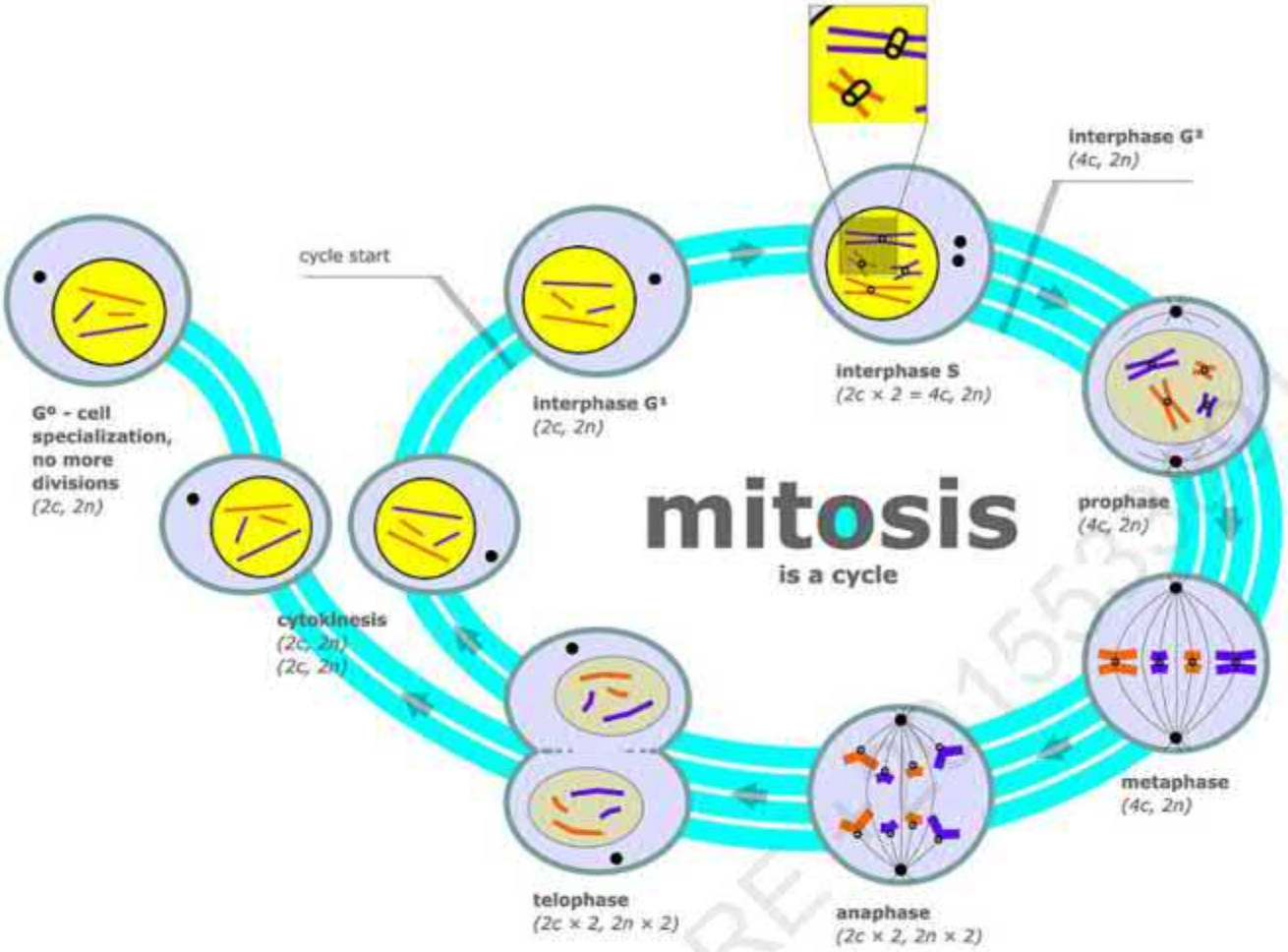
Living and dividing cells pass through a regular sequence of growth and division called the cell cycle. The cell cycle consists of five major stages: G1,S, G2 (which together make up interphase), mitosis, and cytokinesis.



Interphase

More than 90% of the life of a cell is spent in interphase.
During interphase

1. chromosomes replicate in preparation for cell division.
2. One or more nucleoli become visible within the nucleus
3. The nuclear membrane remains intact.



Prophase

Chromosomes begin to condense and become visible

The nucleoli disappear, Centrioles begin to migrate to the poles.

Spindle fibers begin to form in the cytoplasm, extending from one centrosome to the other.

The nuclear membrane begins to disintegrate.

Metaphase

Chromosomes line up single file located on the equator or metaphase plate

Centrosomes are at opposite poles of the cell

Spindle fibers run from centrosomes to the centromeres

Anaphase

The centromeres of each chromosome separate, and spindle fibers begin to pull the sister chromosomes apart

Anaphase is the shortest phase of mitosis

Telophase.

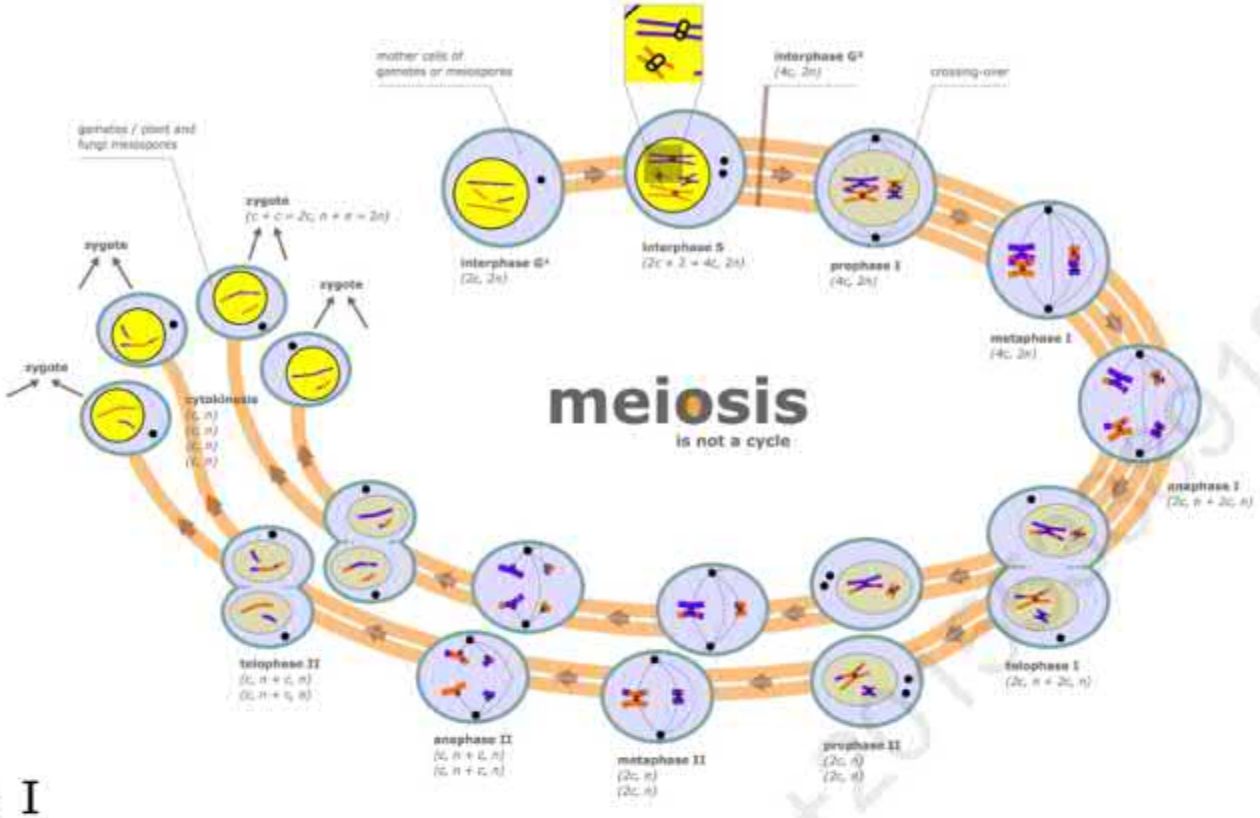
Chromosomes cluster at opposite ends of the cell, and the nuclear membrane re-forms.

Supercoiled chromosomes begin to unravel and to return to their pre-cell division condition as long, threadlike strands

The nuclear membrane re-forms

Cytokinesis

Cytokinesis is division of the cytoplasm. In animal cells, a cleavage furrow forms down the middle of the cell and the two daughter cells separate from each other. In plant cells, a cell plate forms down the middle of the cell, a sticky middle lamella cements adjacent cells together



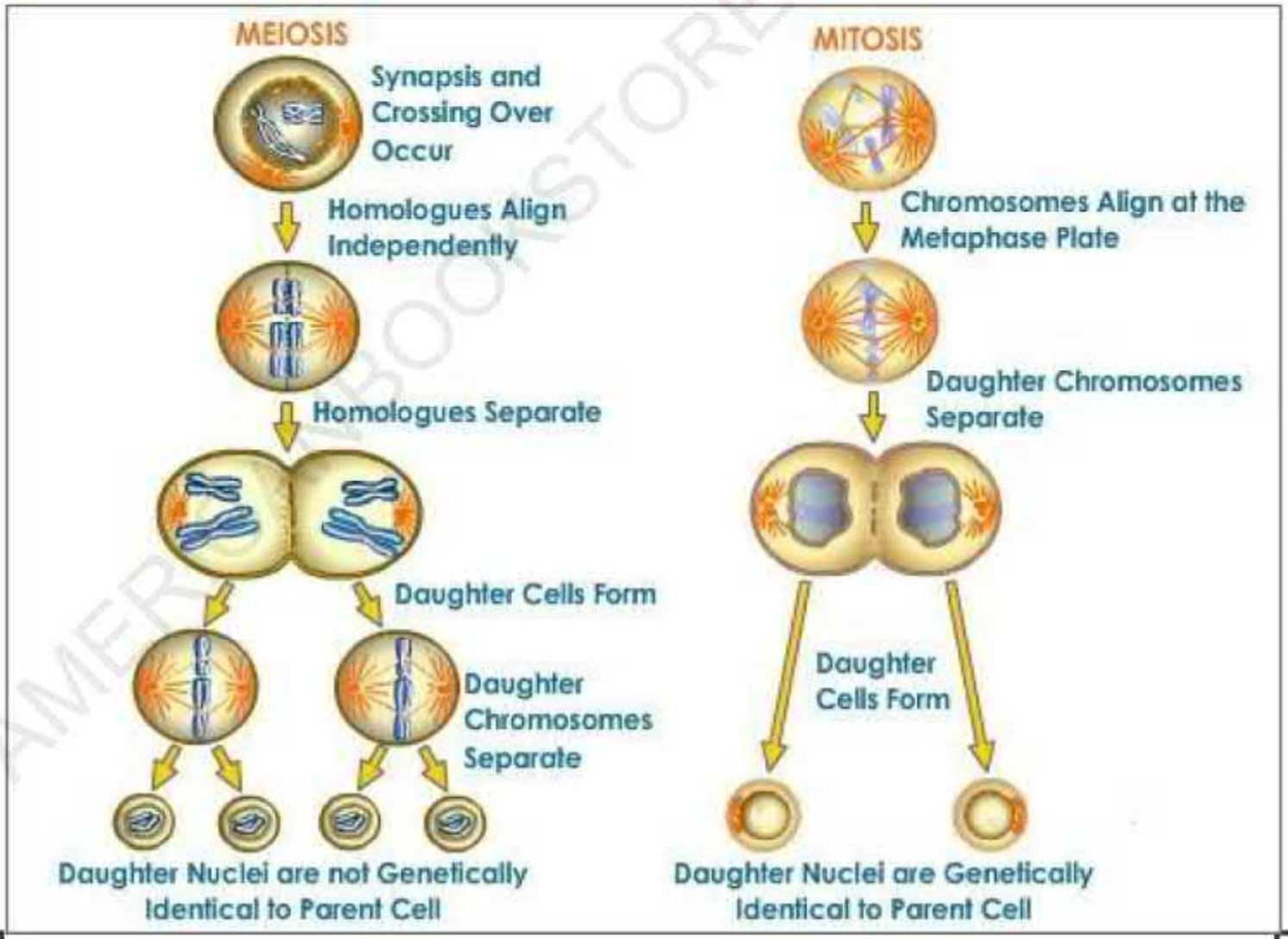
Meiosis I

1. This stage is also called reduction division.
2. Synapsis and crossing-over occur. During synapsis, chromosomes pair up precisely with their homologue so that crossing-over can occur. Crossing- over is the process in which homologous chromatids exchange genetic material. Crossing-over is important because it ensures greater variety in the gametes.
3. Homologous chromosomes separate.
4. Next, chromosomes line up randomly on the equatorial plate and separate independently. This means that how one pair of chromosomes lines up and separates has no effect on how any other pair of chromosomes lines up and separates.
5. Each resulting gamete is genetically unique.

Meiosis II

1. This stage is similar to mitosis
2. Sister chromatids separate.
3. This division maintains the haploid number of chromosomes.
4. This phase completes the goal of meiosis— producing four genetically unique cells from one original mother cell.

Property	Mitosis	Meiosis
DNA Replication	Occurs during interphase before mitosis begins.	Occurs during interphase before meiosis begins.
Number of divisions	One	Two
Synapsis of homologous chromosomes	Does not occur.	Occurs along with crossing over between non-sister chromatids in prophase I.
Number of daughter cells and genetic composition	Two diploid (2n) daughter cells that are genetically identical to the parent cell.	4 haploid (n) daughter cells, each containing half as many chromosomes as the parent cell. Daughter cells are genetically different from the parent cell and each other.
Role in the animal body	Produces cells for growth and repair.	Produces gametes and assures genetic diversity in sexual reproduction.



Cell Respiration

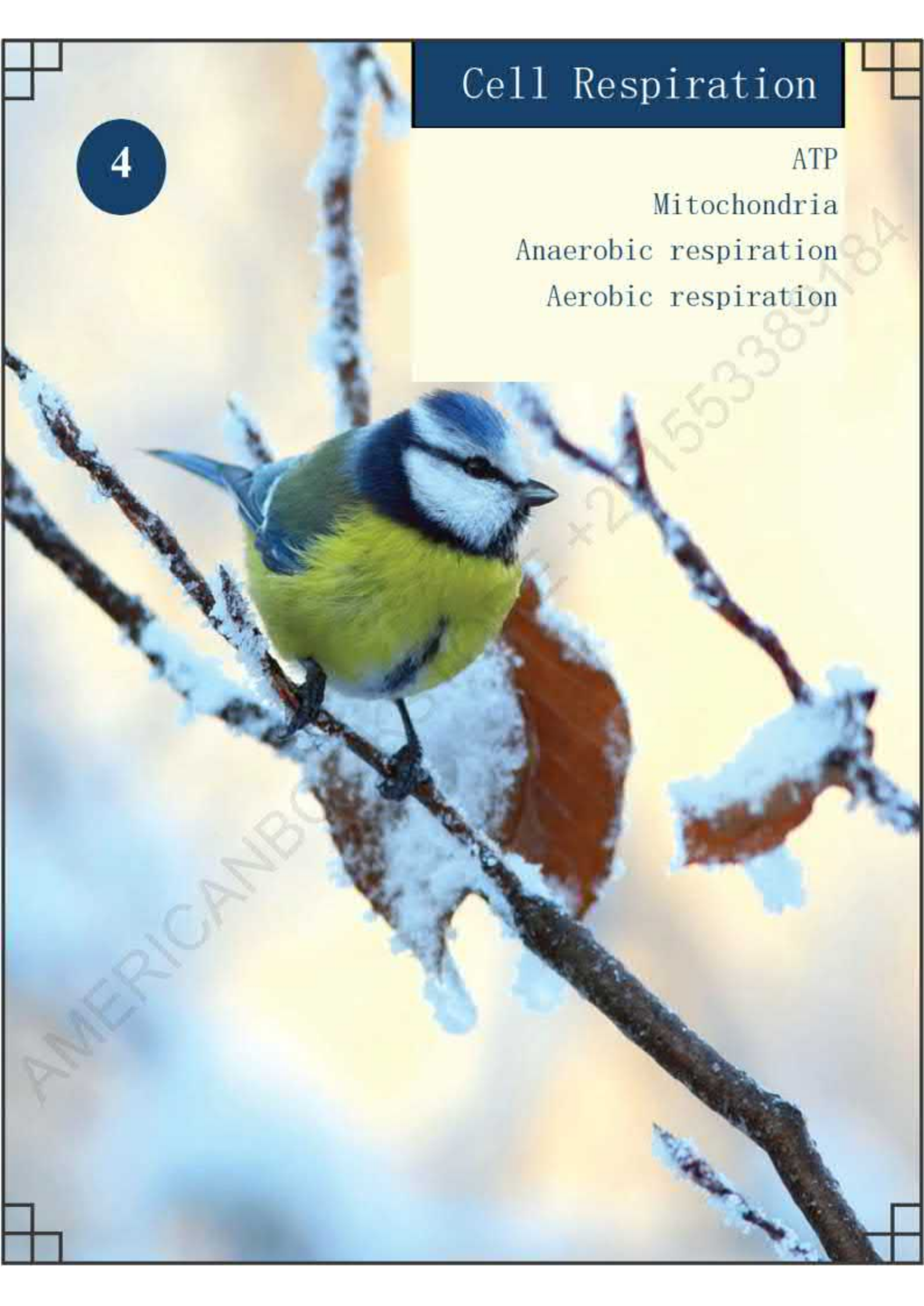
4

ATP

Mitochondria

Anaerobic respiration

Aerobic respiration



Cell respiration

- It is the way to cell to get energy
- Cells release energy from glucose & transfer it to ATP .
- Energy stored in ATP is immediately available for cellular activities
- It consists of series of **oxidative reactions**

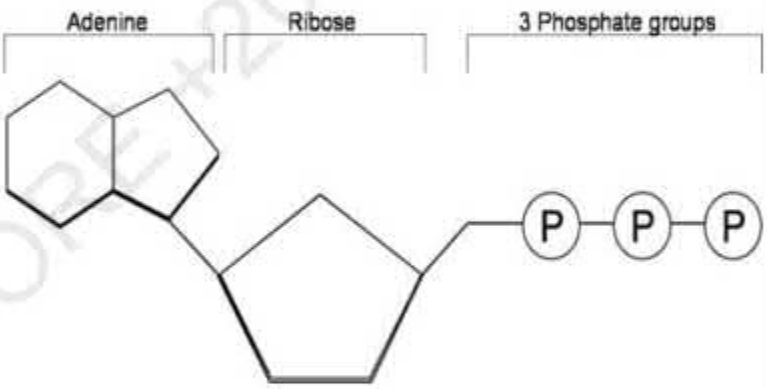
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

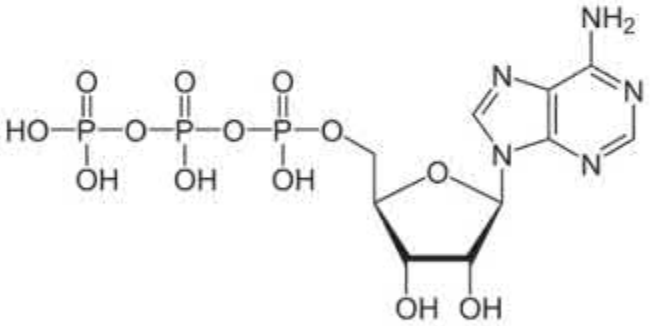
ATP (ADENOSINE TRIPHOSPHATE)

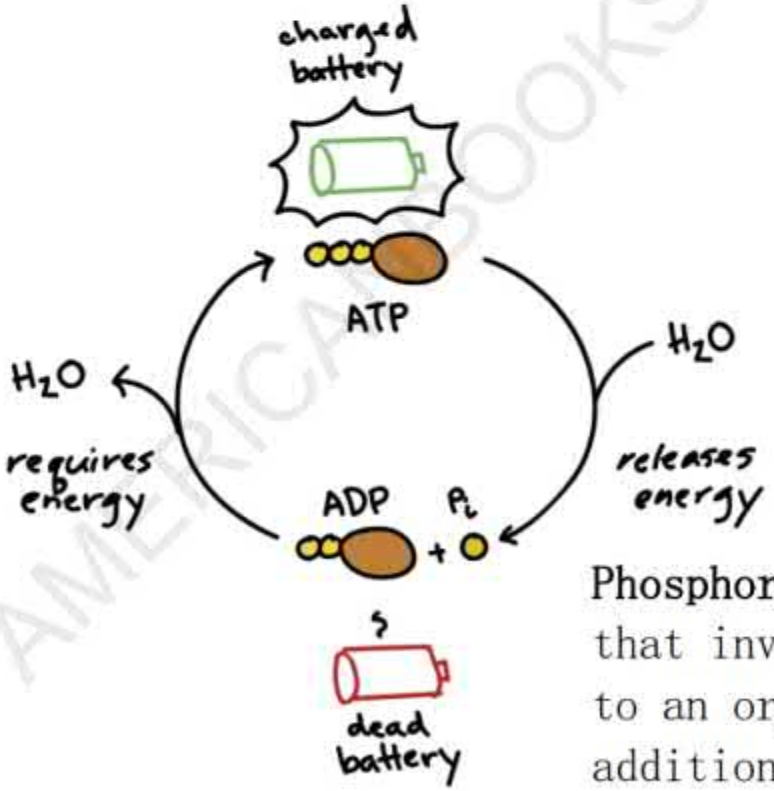
- ATP is the special high-energy molecule that stores energy for immediate use in the cell.
- It consists of:
  1. **Adenosine**

(the nucleotide adenine + ribose)

  2. **Three phosphates.**



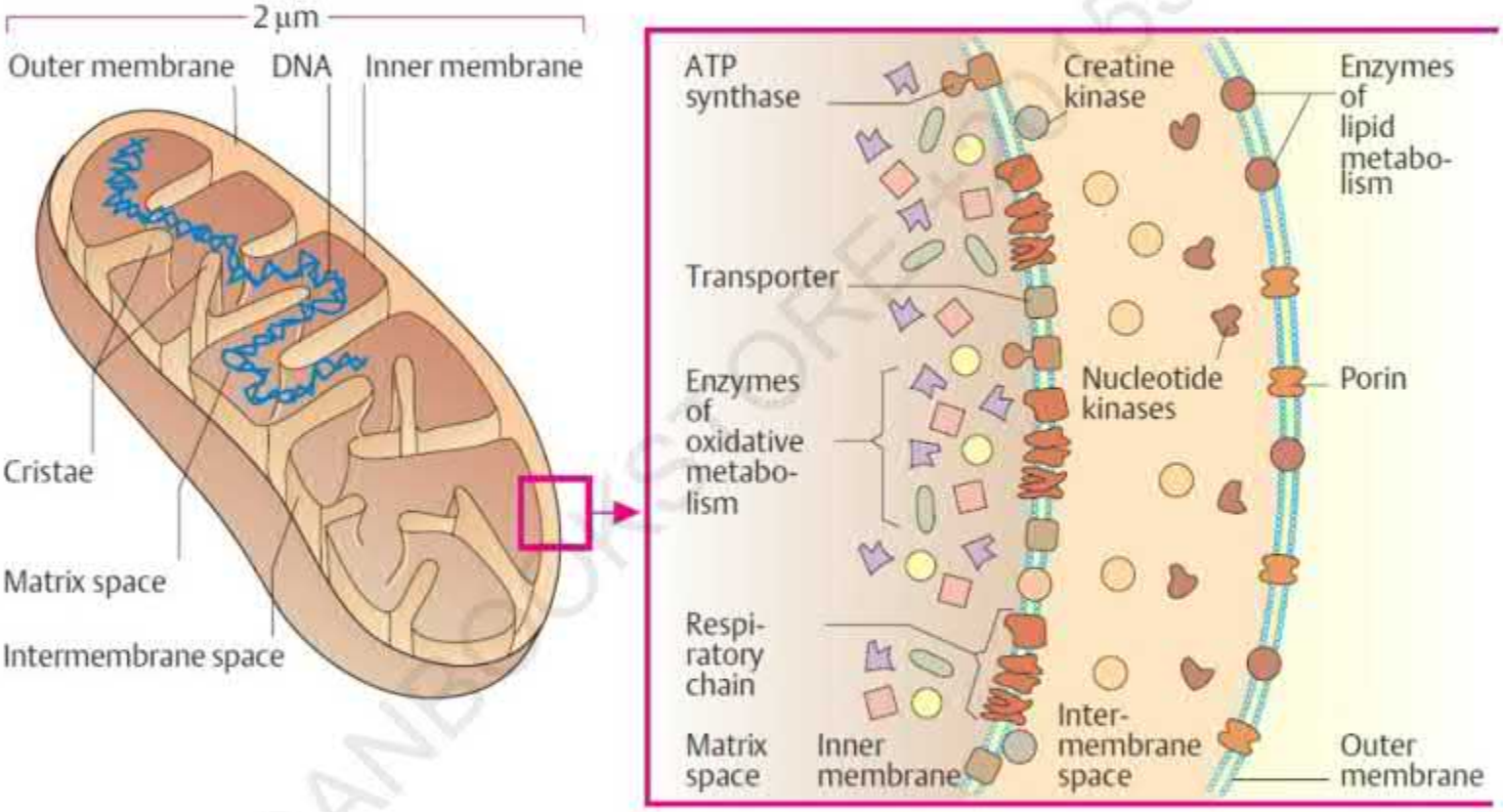




Phosphorylation: A biochemical process that involves the addition of phosphate to an organic compound. Examples the addition of phosphate to adenosine di-phosphate (ADP) to form adenosine tri-phosphate (ATP).

Mitochondrion

- The mitochondrion (plural, mitochondria) is the site of cellular respiration.
- All cells have many mitochondria.
- Mitochondria consist of an outer double membrane and folded inner membranes called cristae.
- This inner membrane divides the mitochondria into two internal compartments, the **outer compartment and the matrix.**

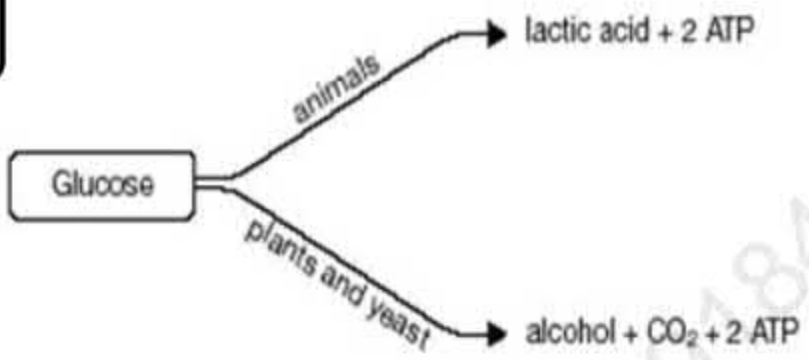


- The Krebs cycle takes place in the matrix; the electron transport chain takes place in the cristae membrane.

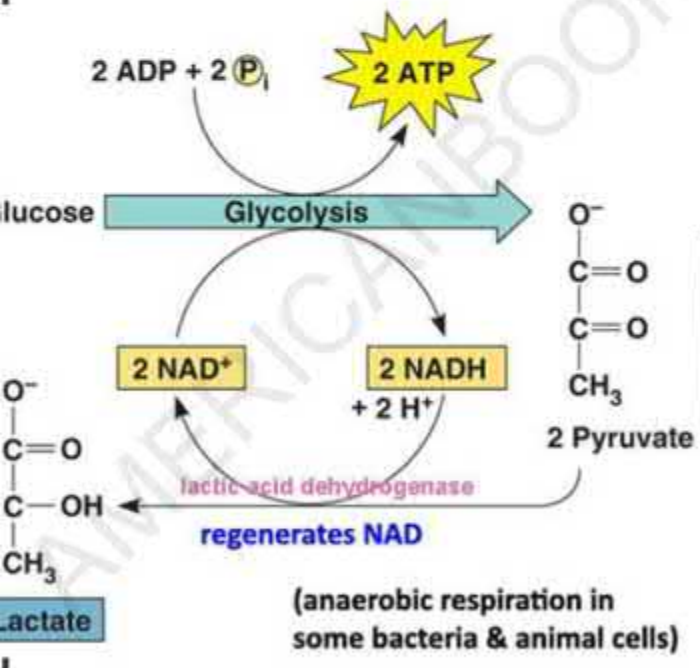
- Cell respiration has two phases: anaerobic and aerobic. If oxygen is not present (anaerobic), glycolysis is followed by alcohol fermentation or lactic acid fermentation.

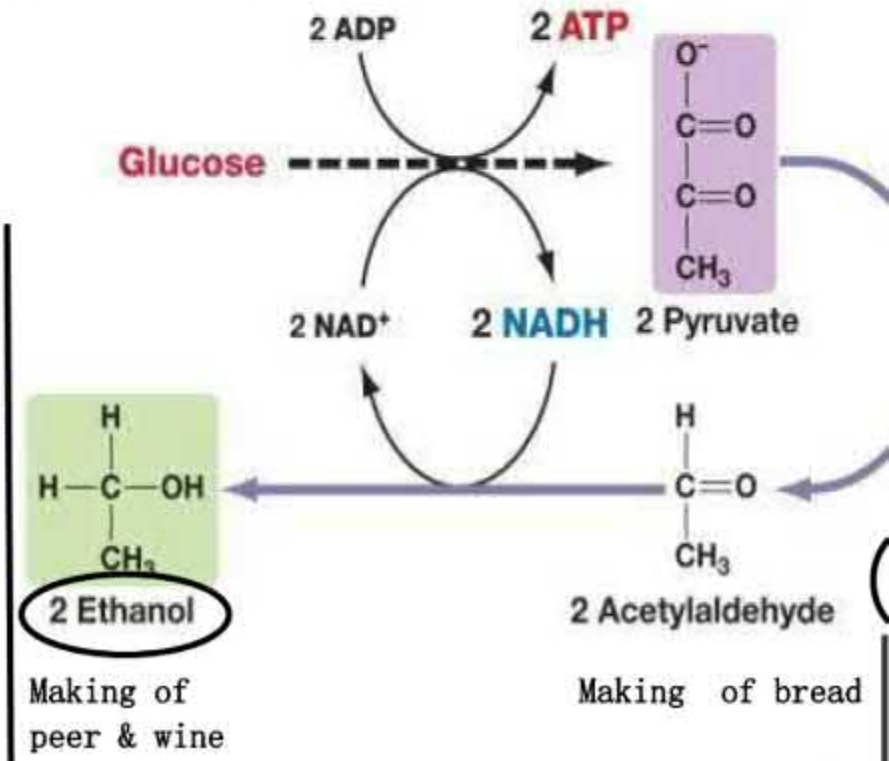
- If oxygen is present (aerobic), glycolysis is followed by the Krebs cycle, the electron transport chain, and chemiosmosis.

ANAEROBIC RESPIRATION



- 1 Glucose + 2 ATP → 2 Pyruvate + 4 ATP + 2 NADH
- In the absence of Oxygen
- Net gain 2 ATP
- Consists of 2 stages: Glycolysis plus lactic acid fermentation (animals, bacteria) or alcohol fermentation (in yeast)
- Alcohol fermentation used in various industrial uses
- Lactic acid fermentation happens in skeletal muscles during severe Exercise, Because oxygen is not sufficient causing muscle fatigue and burning.
- When the blood brings more oxygen , regular respiration starts and lactic acid Carried to liver to change into pyruvate again



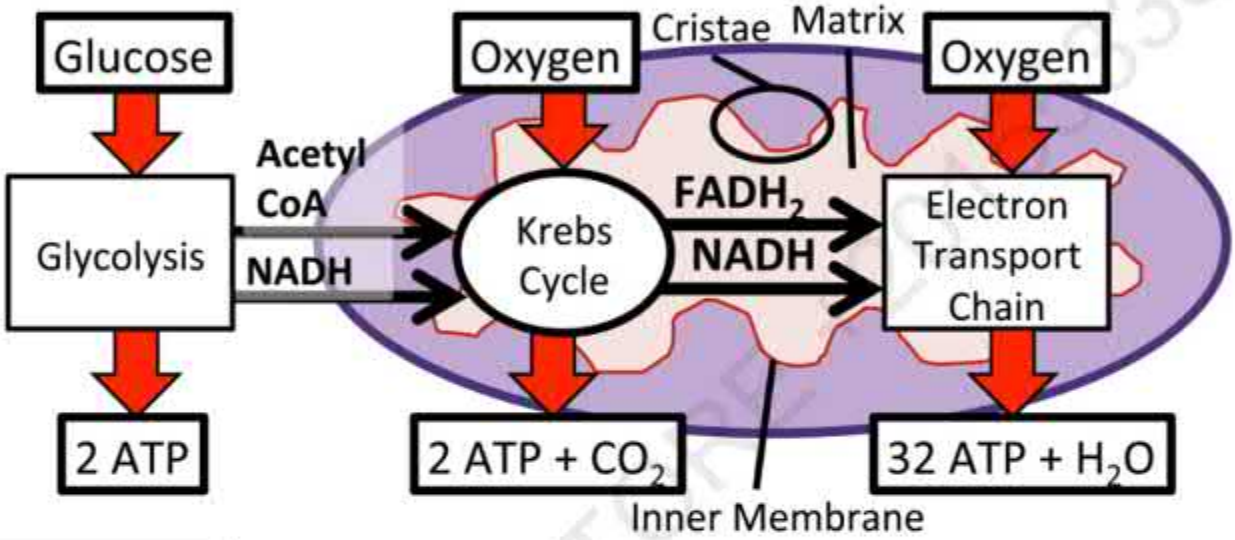


AEROBIC RESPIRATION

Aerobic respiration consists of three processes:

1. Glycolysis
2. Krebs cycle
3. Electron transport chain.

$$O_2 + C_6H_{12}0_6 \rightarrow CO_2 + H_2O + Energy$$



Glycolysis

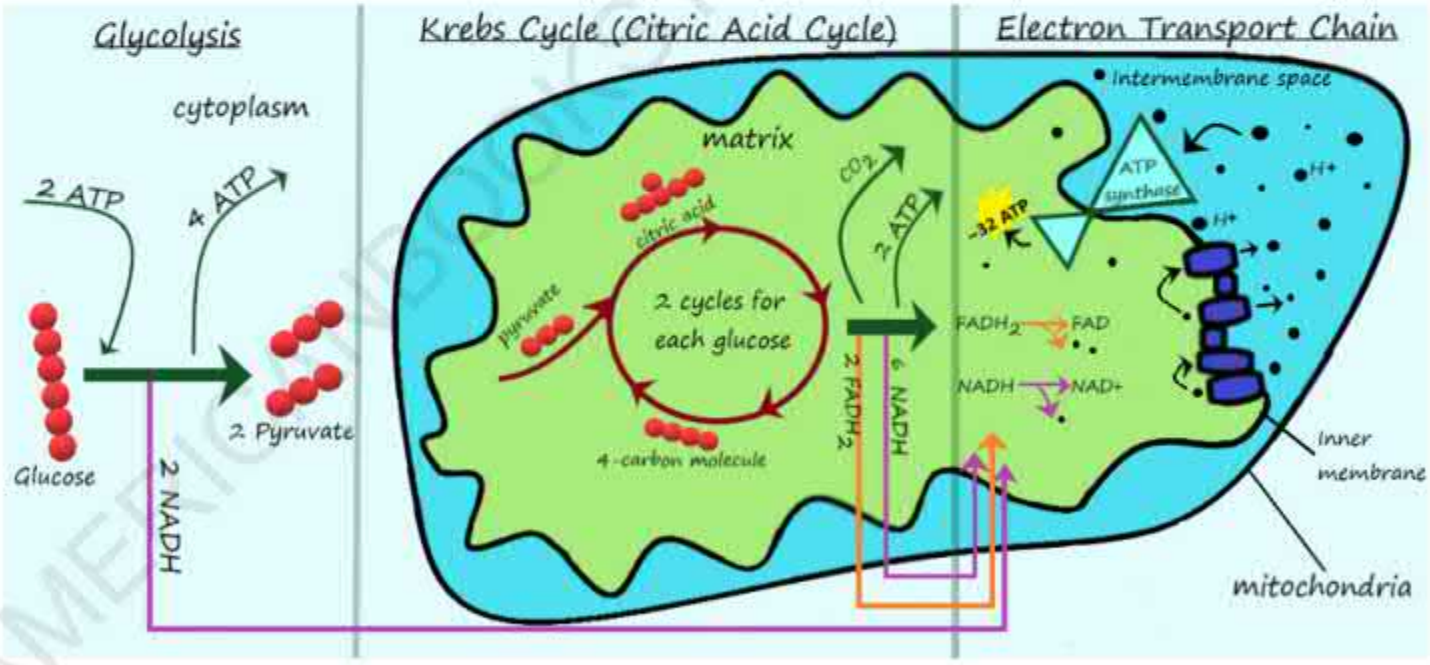
- Glycolysis is the anaerobic phase of aerobic respiration.
- One molecule of glucose breaks apart into two molecules of pyruvate.
- Pyruvate, or pyruvic acid, is essentially one-half a glucose molecule and is the raw material for the next step in respiration, the Krebs cycle.
- Glycolysis occurs in the cytoplasm.
- Glycolysis is a complex, multi-step process, each step of which is controlled by a different enzyme.
- Two molecules of ATP supply the energy of activation, the energy needed to begin the reaction.
- Glycolysis releases 4 ATP molecules, resulting in a net gain of 2 ATP

1 Glucose + 2 ATP → 2 Pyruvate + 4 ATP + 2 NADH
(net gain 2 ATP)

The Krebs cycle *(citric acid cycle)*

- Pyruvic acid (from glycolysis) combines with coenzyme A (a vitamin A derivative) to form **Acetyl-CoA**, which enters the Krebs cycle.
- This occurs in the matrix of the mitochondria.
- Each turn of the Krebs cycle produces 1 molecule of both ATP and FADH 2 plus 3 molecules of NADH.
- The by-product is CO2, which is exhaled.
- he function of Krebs cycle is to produce high energy molecules (NADH and FADH2) to carry protons (H+) to electron transport chain
- The Krebs cycle produces
    - **Small amount of ATP (2)**
    - **Carbon dioxide**
    - **NADH (6) and FADH2 (2)**

2 Pyruvate + coenzyme A → 2 Acetyl co A → 6NADH + 2 $FADH_2$ + 2 ATP



NADH and FADH2

- They are *coenzymes* that shuttle protons and electrons from glycolysis and the Krebs cycle to the electron transport chain.

Electron transport chain

- The electron transport chain creates a gradient across the cristae membrane.
- This gradient is then used to produce ATP through a process called **chemiosmosis** or **oxidative phosphorylation.**
- Almost all the ATP produced during aerobic cell respiration is produced by chemiosmosis.

PART I: A PROTON GRADIENT

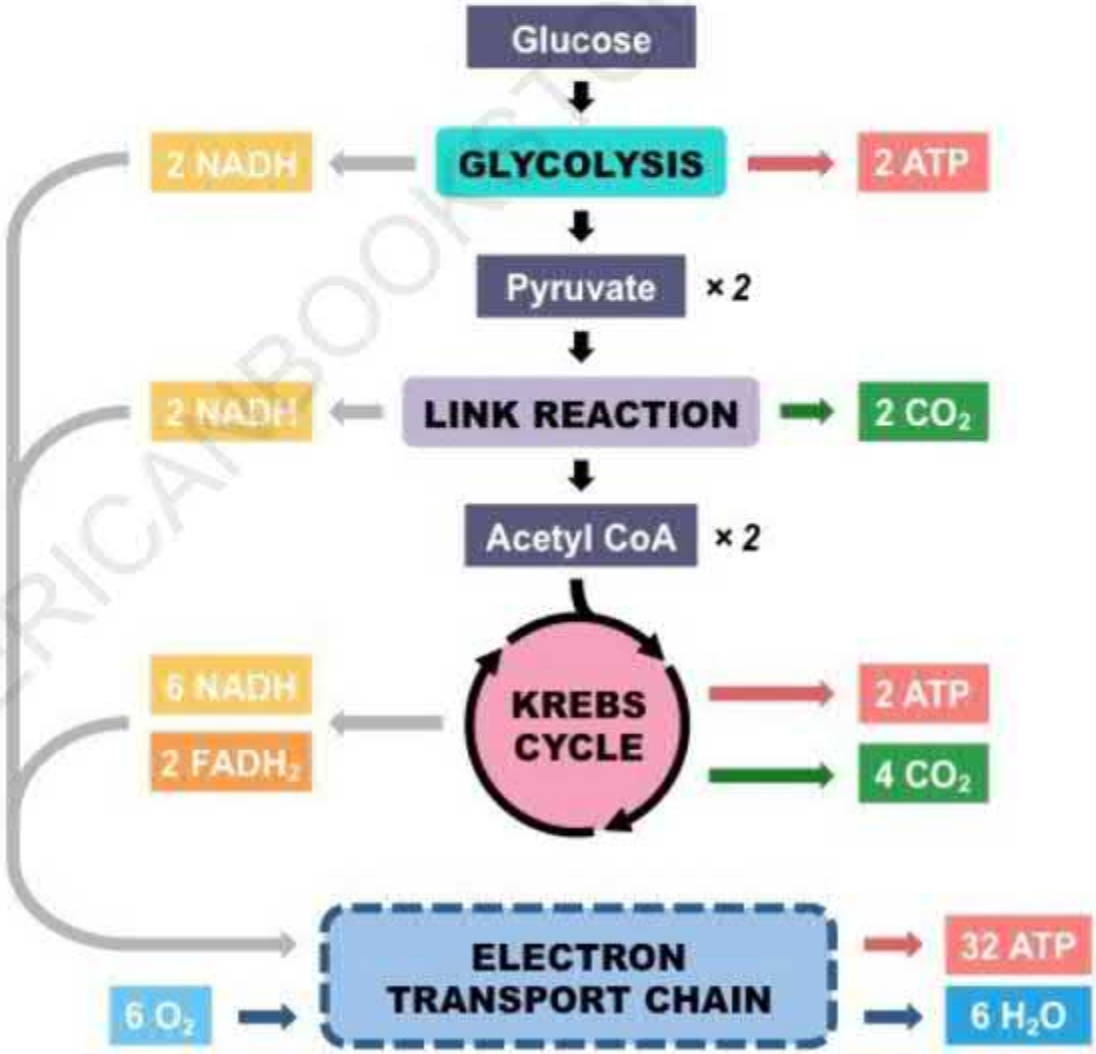
- **NADH and FADH2** carry high-energy electrons from the Krebs cycle and glycolysis to the electron transport chain (ETC)
- As these electrons are pulled along the ETC, they release energy
- This energy is used to pump protons (H+) across the cristae membrane
- This gradient represents stored or **potential energy** that can be used to do work

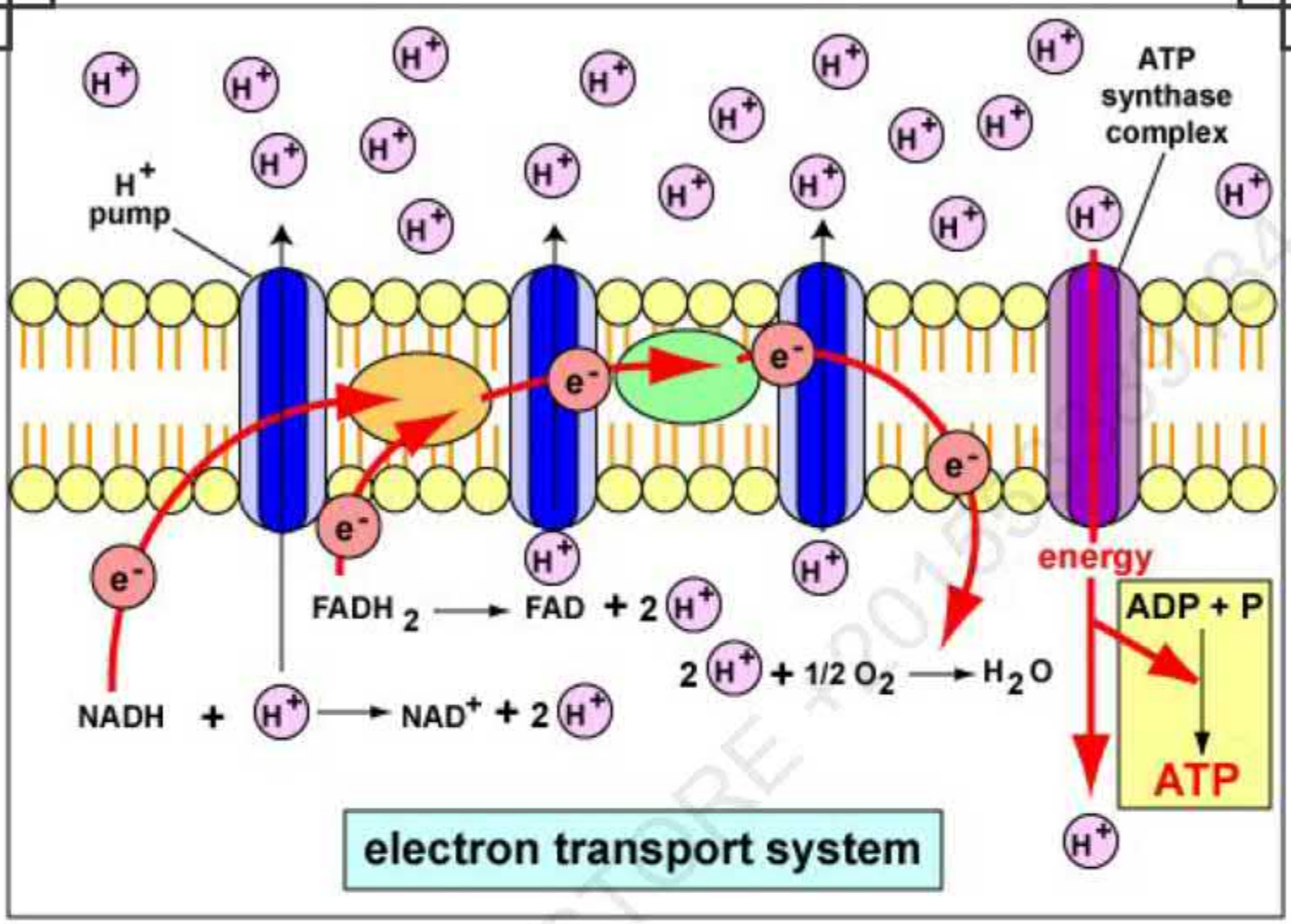
PART II: CHEMIOSMOSIS

- It uses the energy stored in the proton gradient to power the synthesis of ATP
- It depends on a very special molecule located within the cristae membrane called ATP synthase.
- This molecule is actually a proton channel structure that can spin like a turbine.
- As protons pour through the ATP synthase channel, part of the molecule turns and attaches phosphates to ADP molecules, forming molecules of ATP.

Electron transport chain

- Oxygen serves as the final electron and proton acceptor in the ETC.
- When oxygen combines with protons and electrons at the end of the ETC, water is formed as a waste product. This is the water vapor we constantly exhale.
- Water is produced as a waste product as oxygen combines with protons and electrons that flow down the ETC. $\frac{1}{2} O_2 + H_2 \rightarrow H_2O$
- Protons cross the cristae membrane Only through the ATP synthase
- Each proton carried by an **NAD** molecule produces **3 ATP**
- Each proton carried by an **FAD** molecule produces **2 ATP**



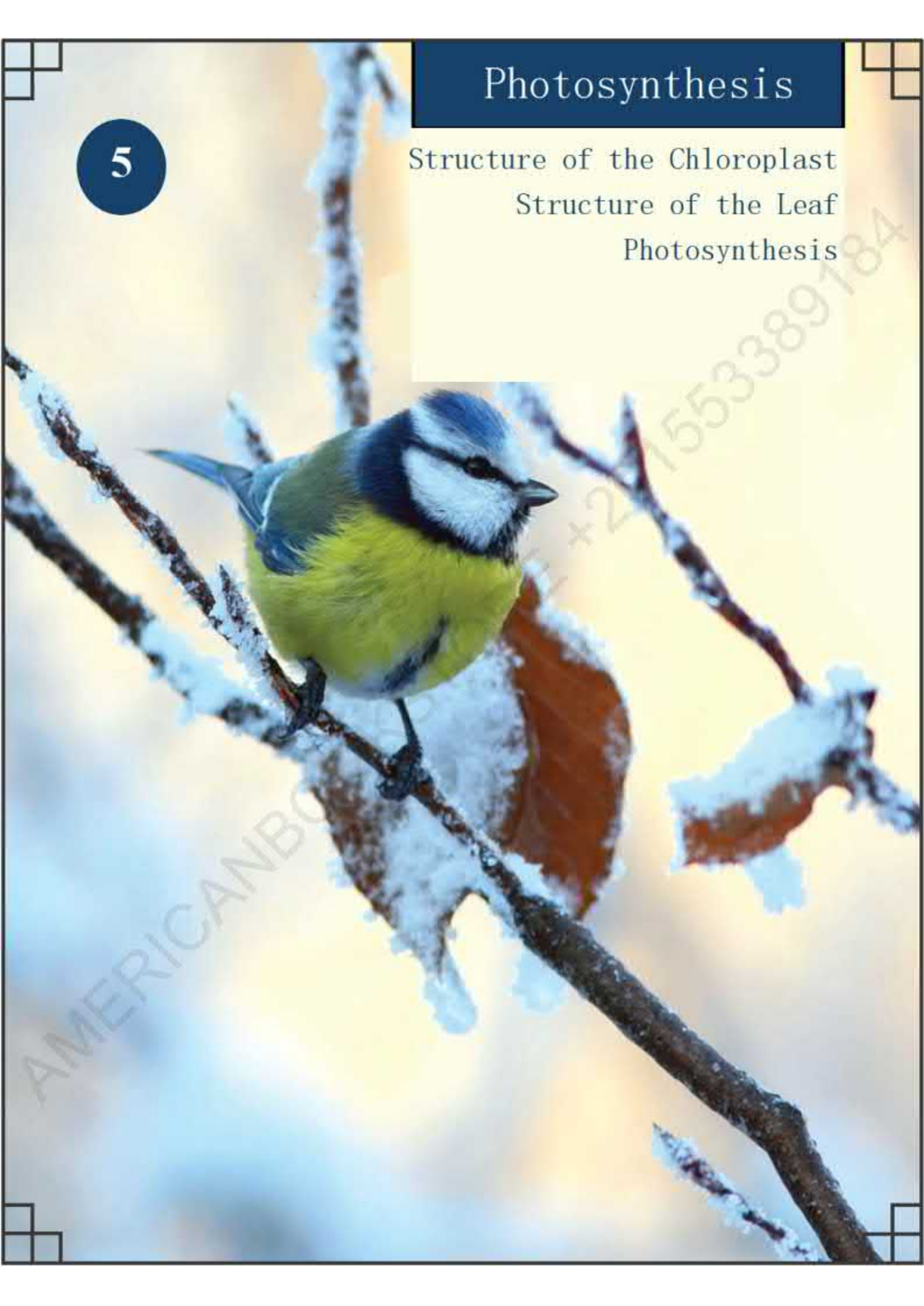


5 Photosynthesis

Structure of the Chloroplast

Structure of the Leaf

Photosynthesis



Photosynthesis

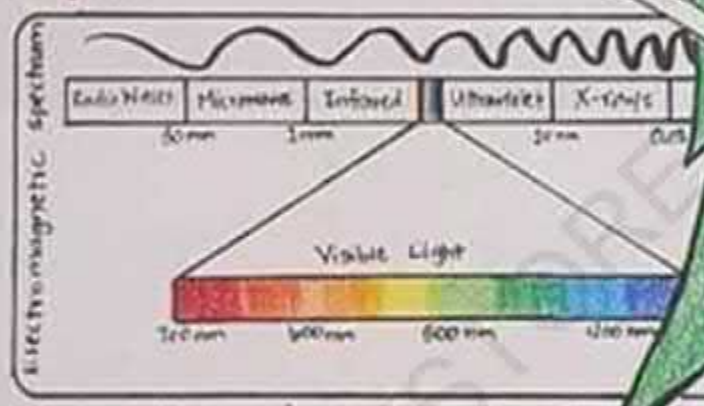
Sun

Definition: A process that captures and transforms light energy from the sun and store it in high-energy sugar molecules.

Different types of chlorophyll absorb different wavelengths of light. Unabsorbed wavelengths get reflected.

Light is a form of energy called electromagnetic radiation. Electromagnetic radiation travels in waves of various wavelengths.

Light & Photosynthesis



Helps regulate Earth's environment. Produces the O_2 we breathe, and it removes CO_2 from Earth's atmosphere.

Light absorption and photosynthesis take place inside an organelle called a chloroplast.

Light-dependent

Light-independent

light energy

H_2O

O_2

Takes place in the thylakoids.

Main function is to capture and transfer light energy.

"photo" part

NADP+

ADP

Calvin Cycle

The "synthesis" part. Take place in stroma.

CO_2

Sugar

P

ATP

energy stored in bonds

H^+

e^- e^-

NADPH

energy-carrying molecules

Thylakoids contain pigment molecules called chlorophyll.

Stroma

thylakoid

chloroplast

Stages of Photosynthesis

light

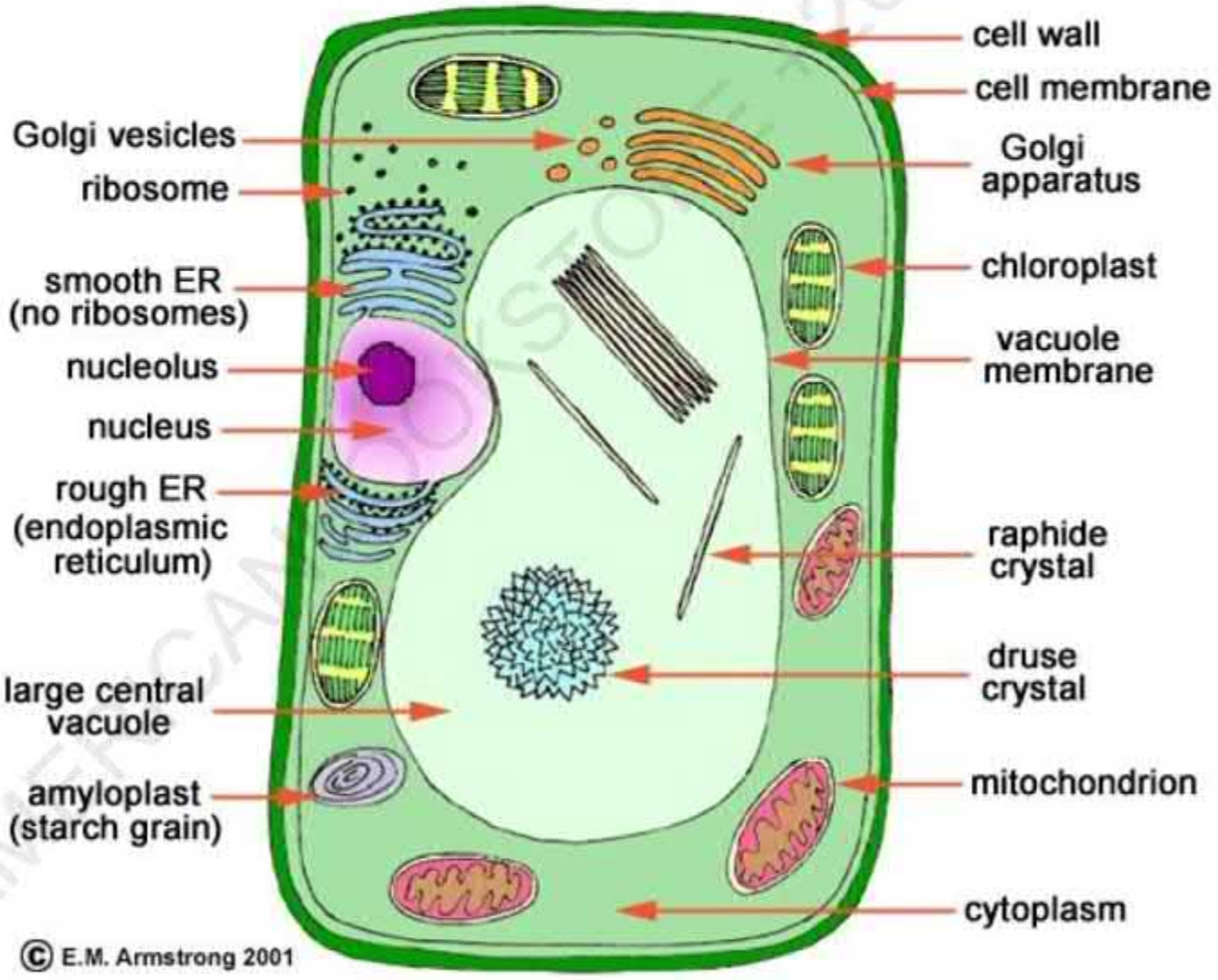
$$6CO_2 + 6H_2O \rightarrow\rightarrow\rightarrow 6O_2 + C_6H_{12}O_6$$

(glucose)

PLANTS

Photosynthesis

- **Photosynthesis**, the process by which **green plants** and certain other organisms transform light energy into chemical energy. During photosynthesis in green plants, light energy is captured and used to convert water, carbon dioxide, and minerals into oxygen and energy-rich organic compounds.



Plant cell structure

The formula for photosynthesis is :

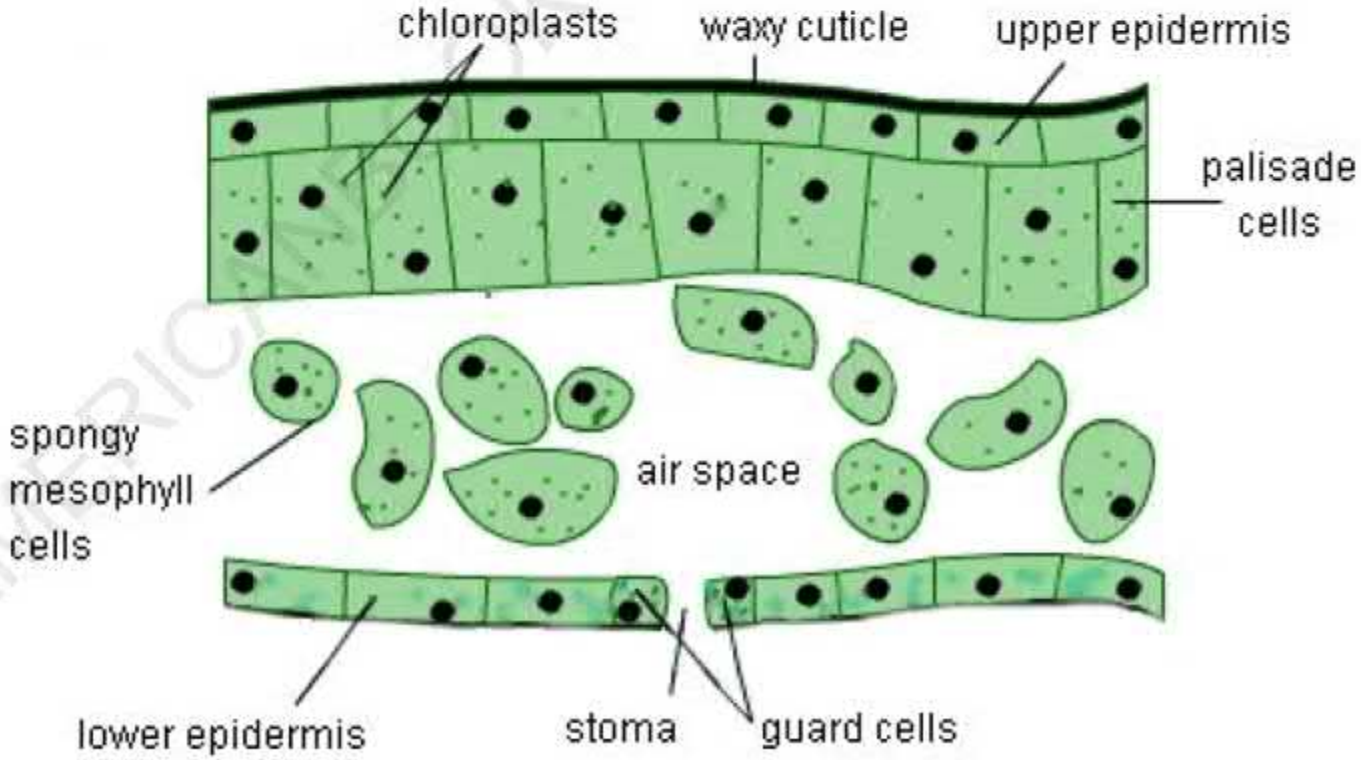
Photosynthesis

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

carbon dioxide + water ⟶ glucose + oxygen

NB This is a reduction reaction (Carbon dioxide gain electron from the hydrogen in water).

- Organisms that make there own food called **Autotrophs.**
- Photosynthesis process takes place in **chloroplasts** inside plant leaf.
- most photosynthesis takes place in the **palisade** layer, which lies just under the leaf surface.
- The **spongy cells** beneath the palisade layer also carry out photosynthesis, but this layer is more important for gas exchange.



Leaf structure

- The outer cell layer of a leaf, both top and bottom, is called **epidermis** (just as it is in skin).
- The epidermis has a layer of wax on it called the **cuticle**. The job of the cuticle is:
  (1) to protect the leaf from attack by things like fungi.
  (2) to keep water from escaping the leaf.
- The cuticle is always found on the top surface of a leaf and is often found on the bottom surface as well.

Structure of the chloroplast

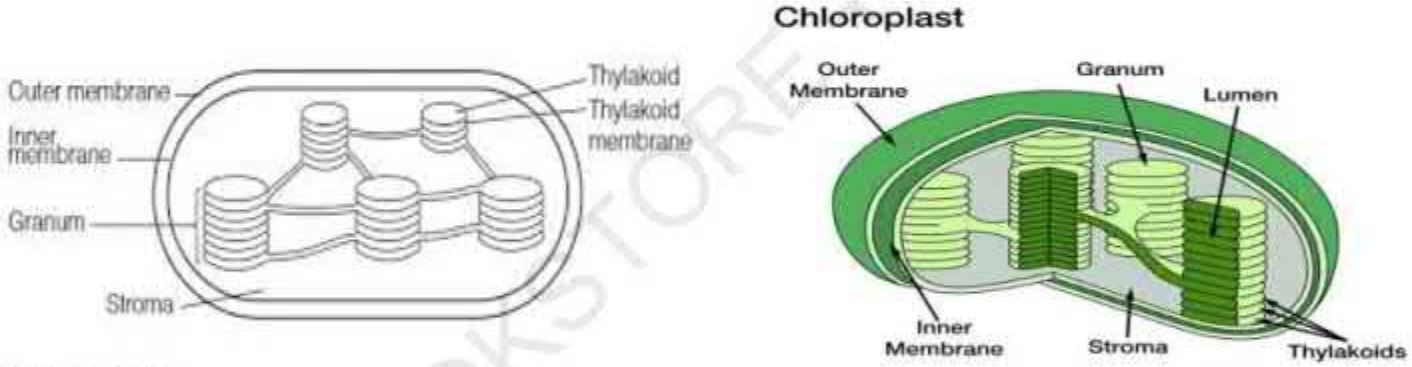
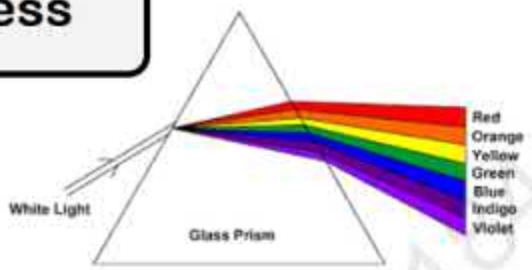


Fig. 1. Chloroplast structure.

- The chloroplast is a double-membraned organelle.
- The inner fluid of the chloroplast is the **stroma**.
- Inside the stroma are flattened membrane structures called **thylakoids**.
- The inner space of the thylakoid is simply called the **thylakoid space**, and thylakoids themselves are found in stacks called **grana**.
- The membranes of the thylakoids are filled with green pigments called "**chlorophyll**".
- This is what gives plants their green color.

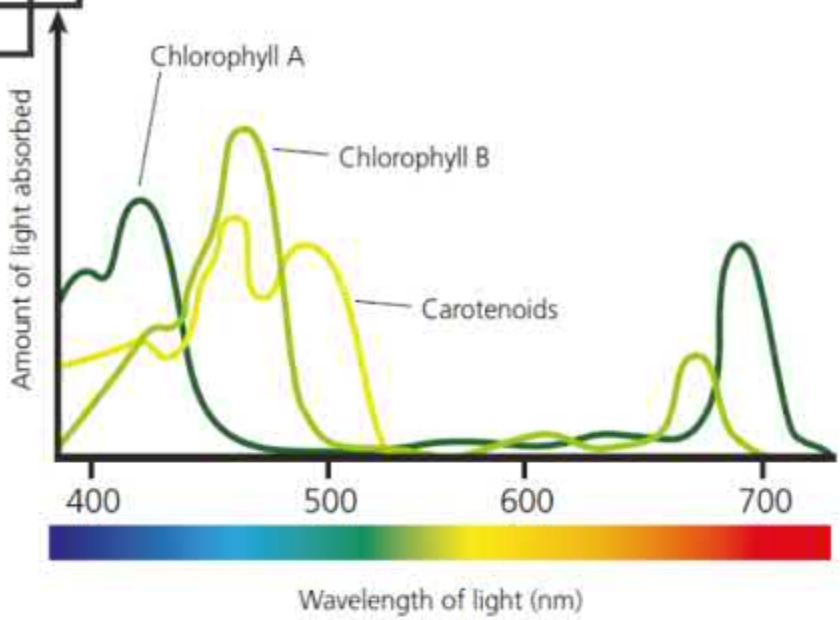
Photosynthesis process

Light and photosynthetic pigments



- When light strike object it could be (Reflected, transmitted or absorbed).
- Something appear red reflect red light and absorb all other colors of light.
- Different pigments absorb light of different wave length.
- In plants **photosynthetic pigments** absorb light energy to perform photosynthesis process.
- Only the green **chlorophyll a** can participate directly in the light- dependent reaction.
- Other pigments (called **accessory pigments**) absorb light and pass light photons to **chlorophyll a.**

Accessory Pigment	Color	location
Chlorophyll b	Green	Green parts
Carotenoids	Yellow Orange Red	carrots
Phycobilins	Red	Red Algae

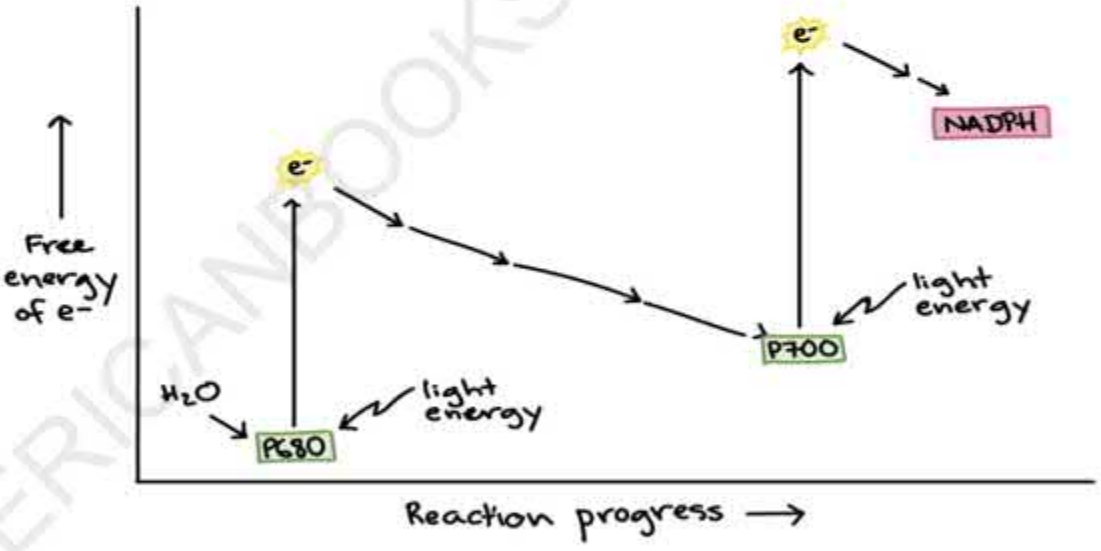


The absorption spectra of extracted chlorophyll and carotenoids (accessory pigments). The primary light harvesting chlorophylls absorb light in the blue and red regions. Carotenoids absorb in the blue and green regions.

Stages of photosynthesis

- Photosynthesis is a two stage process:

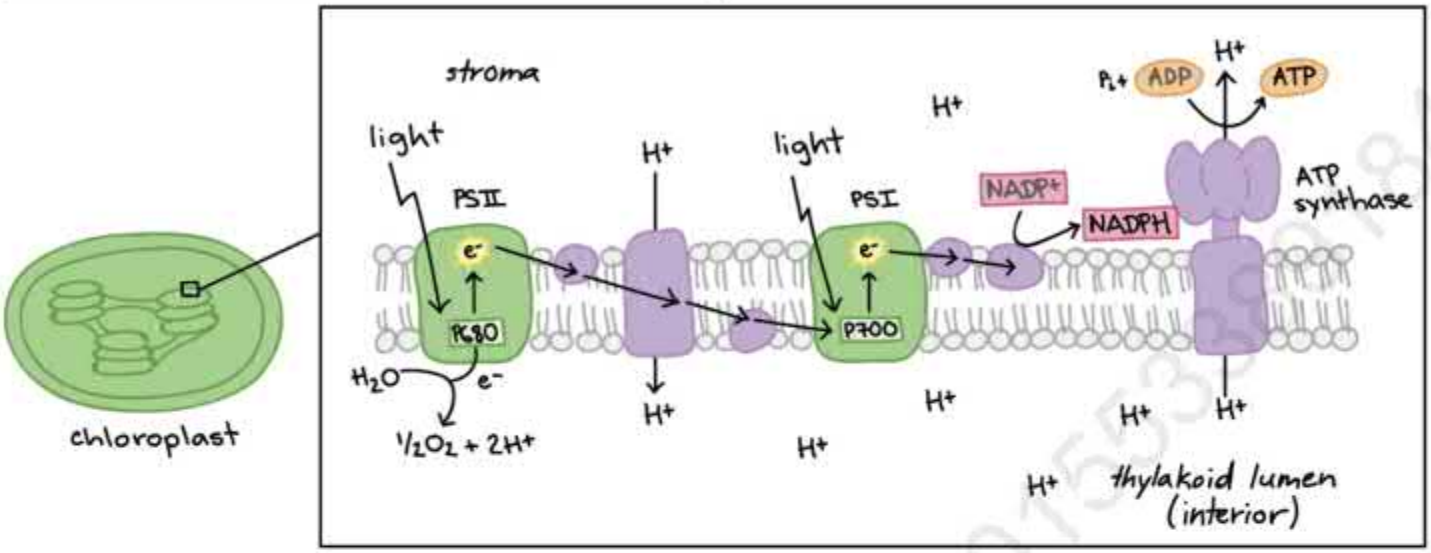
1. **The Light dependent reactions,** a light-dependent series of reactions which occur in the **grana**, and require the direct energy of light to make energy-carrier molecules (ATP & Proton) that are used in the second process.



2. **The light-independent reactions,**

A light-independent series of reactions which occur in the **stroma** of the chloroplasts, when the products of the light reaction are used to make carbohydrates (sugar) from carbon dioxide (reduction).

The Light dependent reactions



Photosystems, large complexes of proteins and pigments (light-absorbing molecules) that are optimized to harvest light, play a key role in the light reactions. There are two types of photosystems: **photosystem I (PSI) and photosystem II (PSII).**

Both photosystems contain many pigments that help collect light energy, as well as a special pair of chlorophyll molecules found at the core (reaction center) of the photosystem.

The special pair of photosystem I is called **P700**, while the special pair of photosystem II is called **P680**.

In a process called non-cyclic photophosphorylation (the "standard" form of the light-dependent reactions), electrons are removed from water and passed through PSII and PSI before ending up in NADPH. This process requires light to be absorbed twice, once in each photosystem, and it makes ATP . In fact, it's called photophosphorylation because it involves using light energy (photo) to make ATP from ADP (phosphorylation). Here are the basic steps:

1. **Light absorption in PSII.** When light is absorbed by one of the many pigments in photosystem II, energy is passed inward from pigment to pigment until it reaches the reaction center. There, energy is transferred to P680, boosting an electron to a high energy level. The high energy electron is passed to an acceptor molecule and replaced with an electron from water. This splitting of water releases the Oxygen we breathe.

2. **ATP synthesis.** The high-energy electron travels down an electron transport chain **(ETC),** losing energy as it goes. Some of the released energy drives pumping of H^+ ions from the stroma into the thylakoid interior, building a gradient. H^+ ions from the splitting of water also add to the gradient.) As H^+ ions flow down their gradient and into the stroma, they pass through ATP synthase, driving ATP production in a process known as **chemiosmosis.**

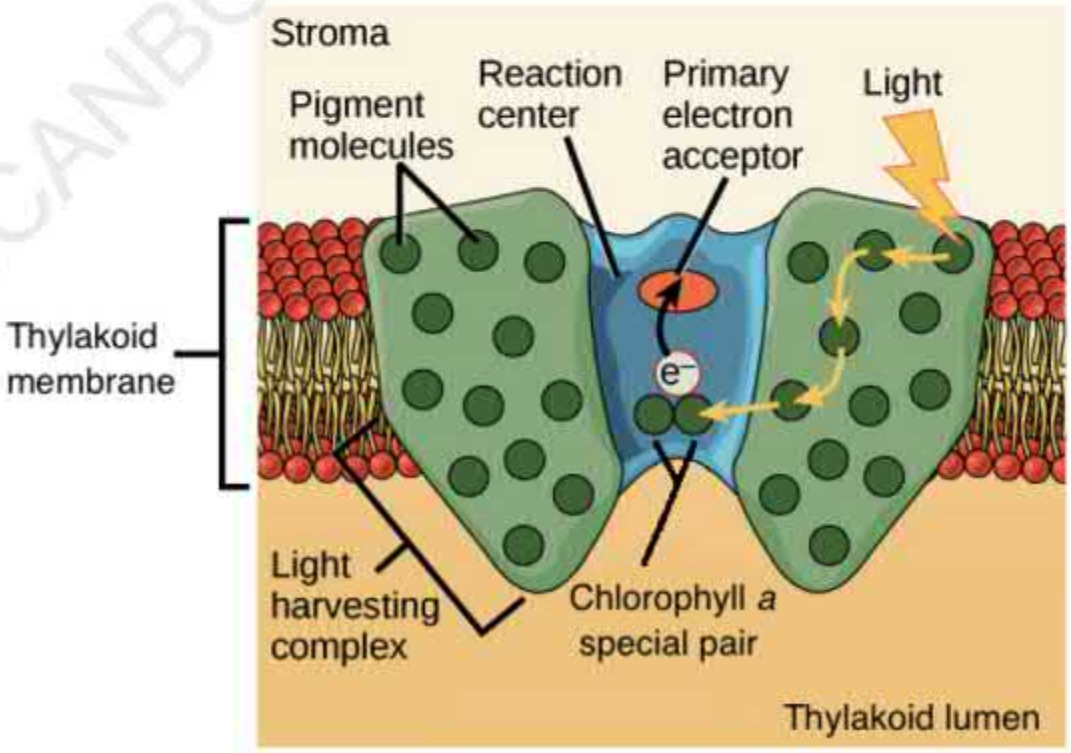
3. **Light absorption in PSI.** The electron arrives at photosystem I and joins the P700 special pair of chlorophylls in the reaction center. When light energy is absorbed by pigments and passed inward to the reaction center, the electron in P700 is boosted to a very high energy level and transferred to an acceptor molecule. The special pair's missing electron is replaced by a new electron from PSII (arriving via the electron transport chain).

4. **NADPH formation.** The high-energy electron travels down a short second leg of the electron transport chain. At the end of the chain, the electron is passed to $NADP^+$ (along with a second electron from the same pathway) to make NADPH.

What is a photosystem?

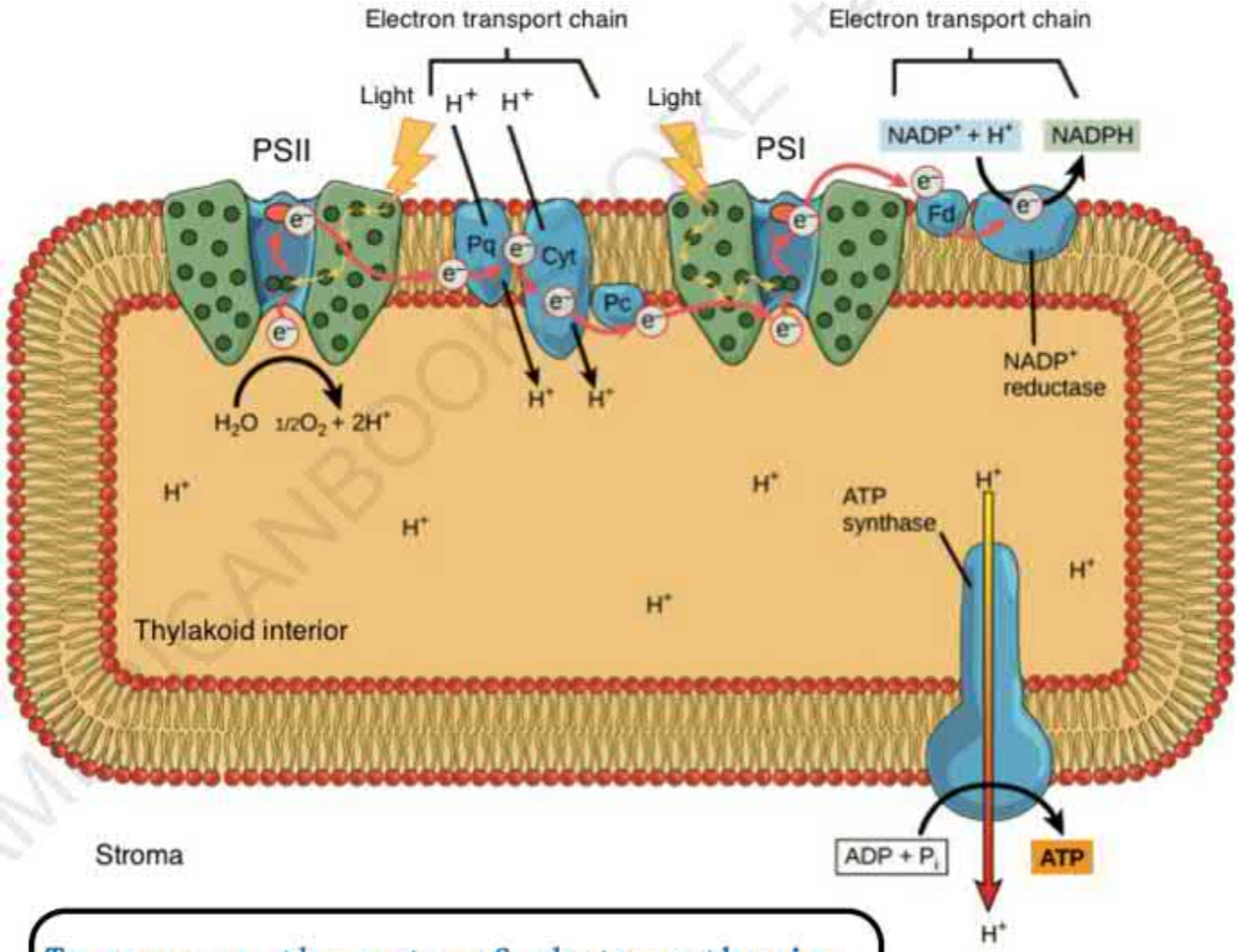
- Photosynthetic pigments, such as **chlorophyll a, chlorophyll b, and carotenoids**, are light-harvesting molecules found in the thylakoid membranes of chloroplasts. Each photosystem has light-harvesting complexes that contain proteins, 300-400 chlorophylls, and other pigments. When a pigment absorbs a photon, it is raised to an excited state, meaning that one of its electrons is boosted to a higher-energy orbital .
- Most of the pigments in a photosystem act as an energy funnel, passing energy inward to a main reaction center. When one of these pigments is excited by light, it transfers energy to a neighboring pigment through direct electromagnetic interactions in a process called resonance energy transfer. The neighbor pigment, in turn, can transfer energy to one of its own neighbors, with the process repeating multiple times.

- Collectively, the pigment molecules collect energy and transfer it towards a central part of the photosystem called the **reaction center.**



- The reaction center of a photosystem contains a unique pair of chlorophyll *a* molecules, often called **special pair**. Once energy reaches the special pair, it will no longer be passed on to other pigments . Instead, passing it to another molecule in the complex called the **primary electron acceptor**. With this transfer, the electron will begin its journey through an electron transport chain.

- There are two types of photosystems in the light-dependent reactions, (PSII) and (PSI). PSII comes first in the path of electron flow, but it is named as second because it was discovered after PSI.



To measure the rate of photosynthesis:

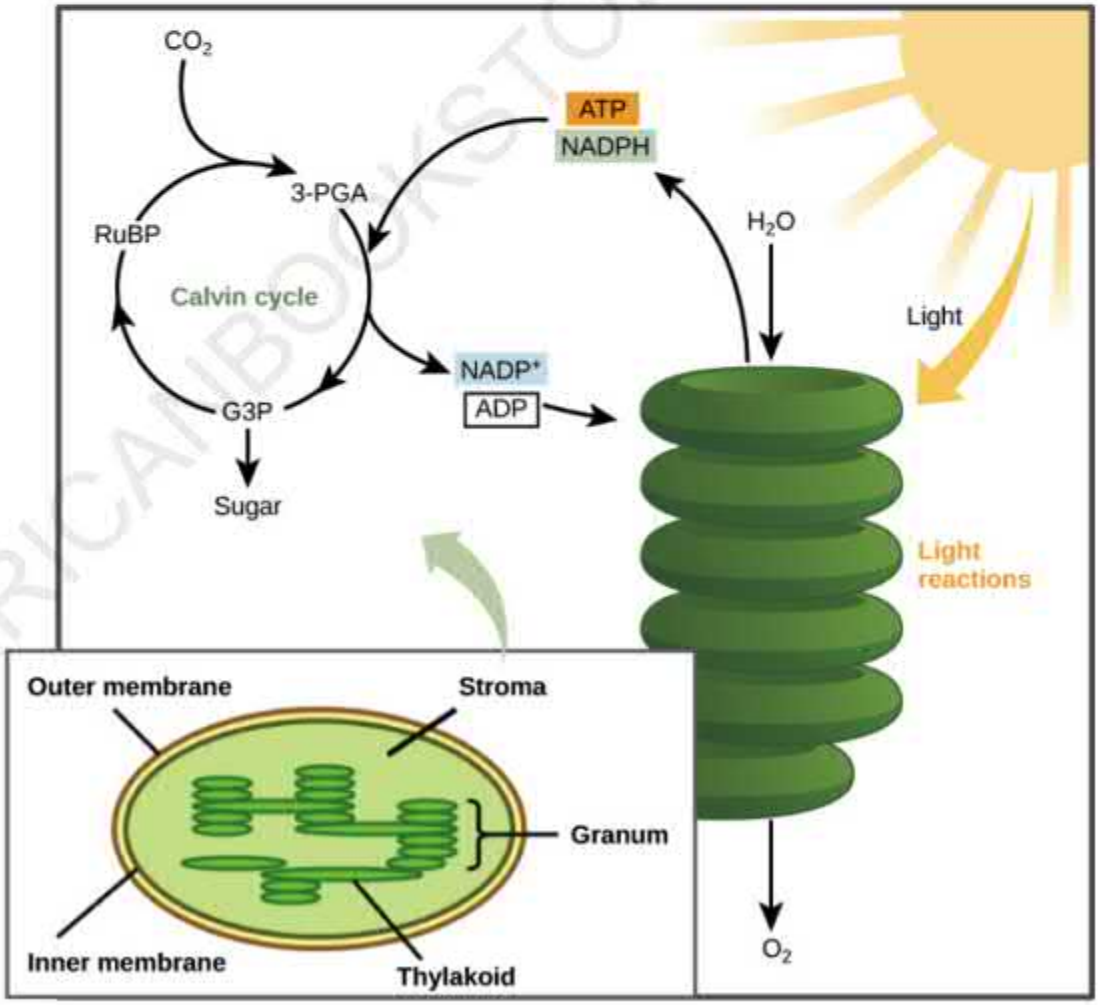
1- rate of o_2 production

2- rate of Co_2 consumption

The Light independent reactions

- In plants, carbon dioxide (CO_2) enters the interior of a leaf via pores called stomata and diffuses into the stroma of the chloroplast— the site of the **Calvin cycle** reactions, where sugar is synthesized. These reactions are also called the **light-independent** reactions because they are not directly driven by light.

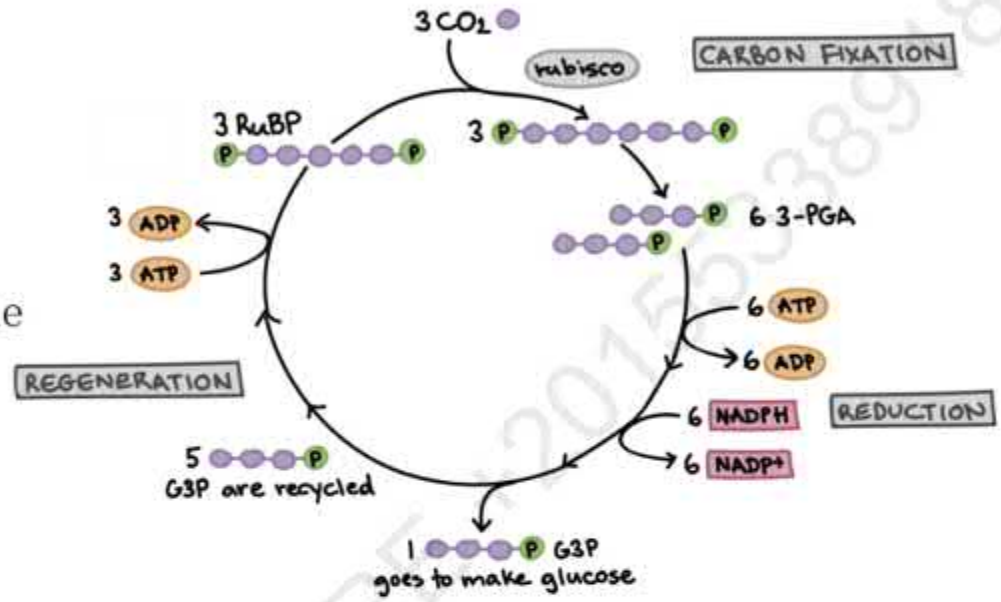
- In the Calvin cycle, carbon atoms from (CO_2) are fixed (incorporated into organic molecules) and used to build three-carbon sugars. This process is fueled by, and dependent on, ATP and NADPH from the light reactions. This takes place in the stroma (the inner space of chloroplasts).



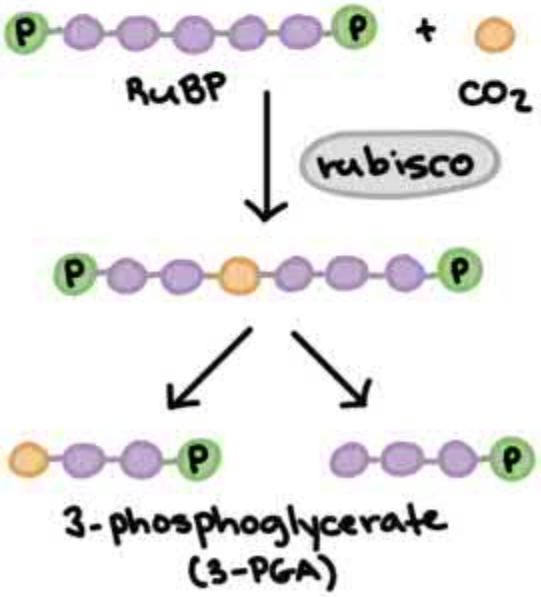
Reactions of the Calvin cycle

The Calvin cycle reactions can be divided into three main stages:

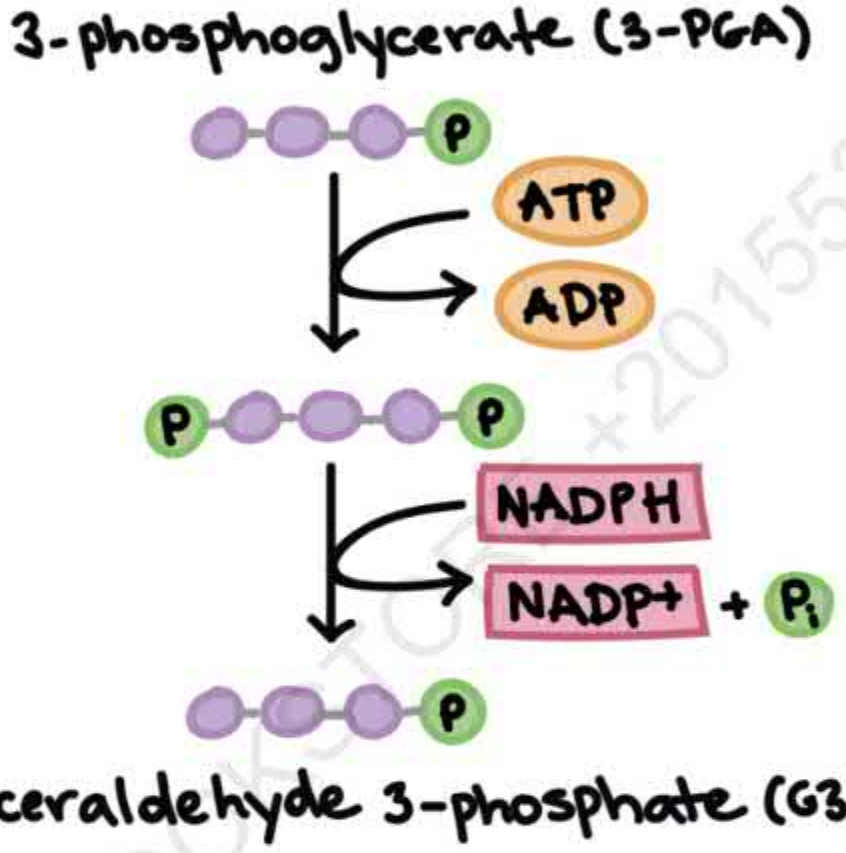
1. carbon fixation
2. Reduction
3. regeneration of the starting molecule

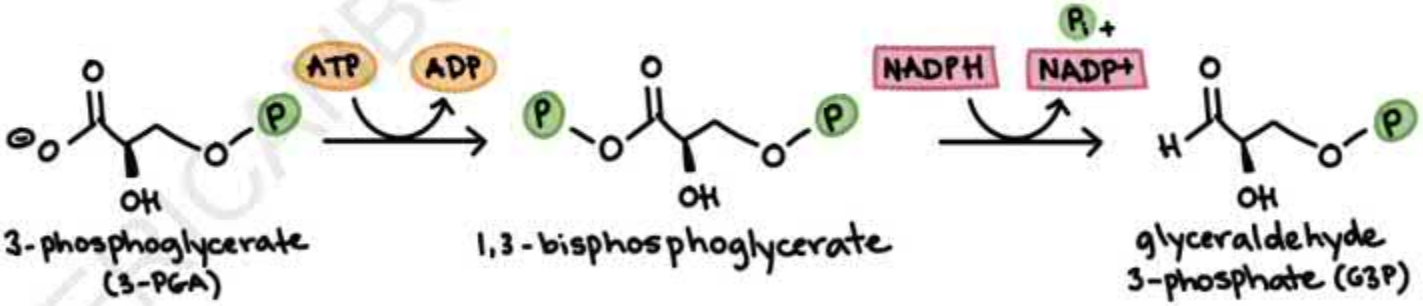


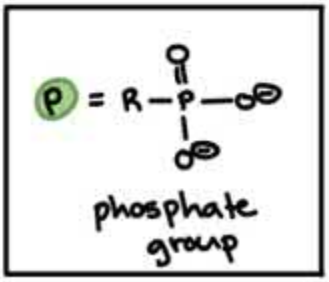
Carbon fixation. A (CO_2) molecule combines with a five-carbon acceptor molecule, ribulose-1,5-bisphosphate (**RuBP**). This step makes a six-carbon compound that splits into two molecules of a three-carbon compound, 3-phosphoglyceric acid (3-PGA). This reaction is catalyzed by the enzyme RuBP carboxylase/oxygenase, or **rubisco.**



Reduction. In the second stage, ATP and NADPH are used to convert the 3-PGA molecules into molecules of a three-carbon sugar, glyceraldehyde-3-phosphate (G3P). This stage gets its name because NADPH donates electrons to, or **reduces**, a three-carbon intermediate to make G3P.







Regeneration. Some G3P molecules go to make glucose, while others must be recycled to regenerate the RuBP acceptor. Regeneration requires ATP and involves a complex network of reactions, which called the "**carbohydrate scramble**".

In order for one G3P to exit the cycle (and go towards glucose synthesis), three (CO_2) molecules must enter the cycle, providing three new atoms of fixed carbon. When three (CO_2) molecules enter the cycle, six G3P molecules are made. One exits the cycle and is used to make glucose, while the other five must be recycled to regenerate three molecules of the RuBP acceptor.

- Three turns of the Calvin cycle are needed to make one G3P molecule that can exit the cycle and go towards making glucose.
- Let's summarize the quantities of key molecules that enter and exit the Calvin cycle as one net G3P is made. In three turns of the Calvin cycle:

Summary of Calvin cycle reactants and products

Carbon	**3**	CO_2 from air	combine with 3 RuBP acceptors, making 6 molecules of (G3P)
ATP	**9**	From light dependent reaction	6 during the fixation step, 3 during the regeneration step
NADPH	**6**	From light dependent reaction	during the reduction step

6

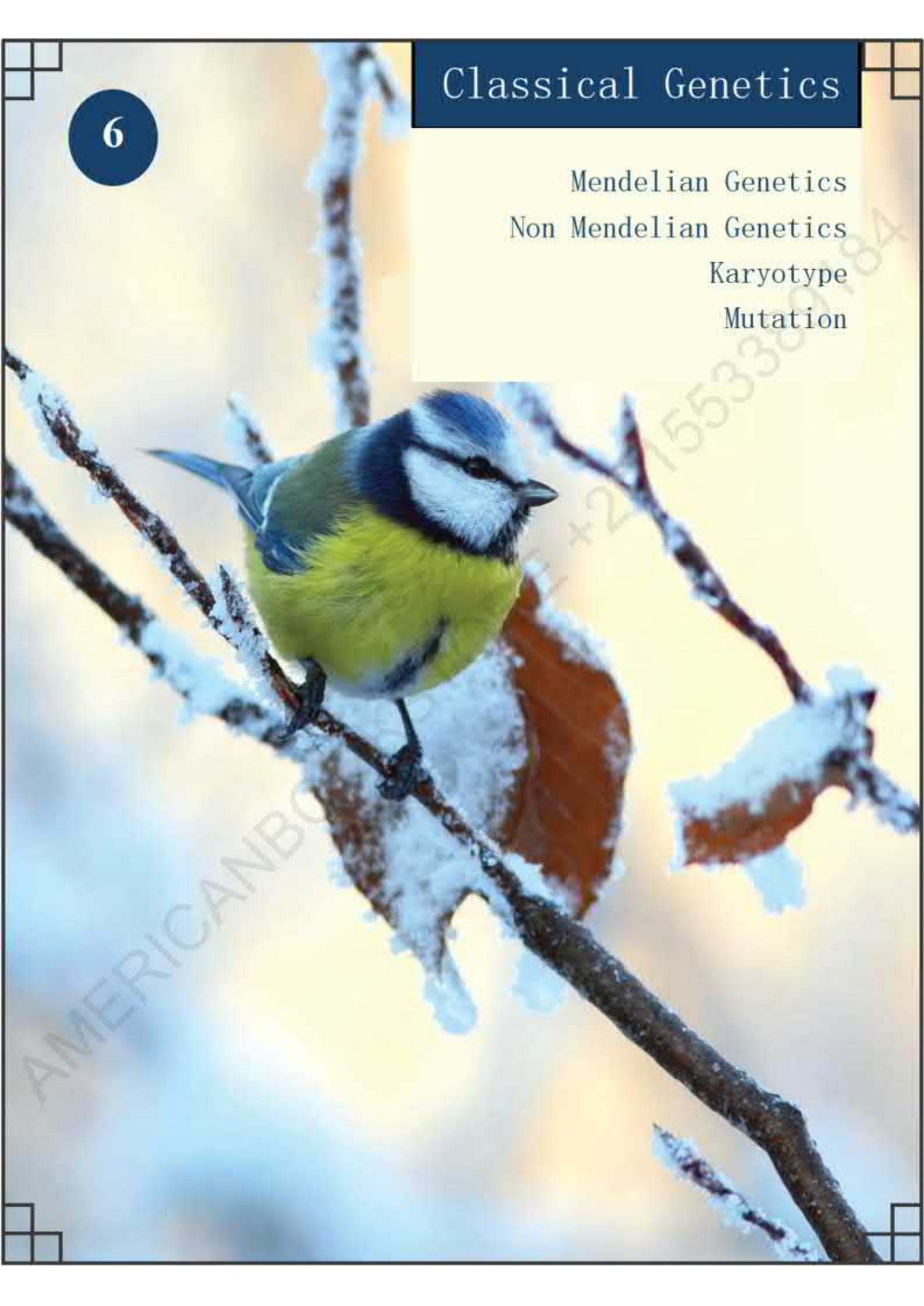
Classical Genetics

Mendelian Genetics

Non Mendelian Genetics

Karyotype

Mutation



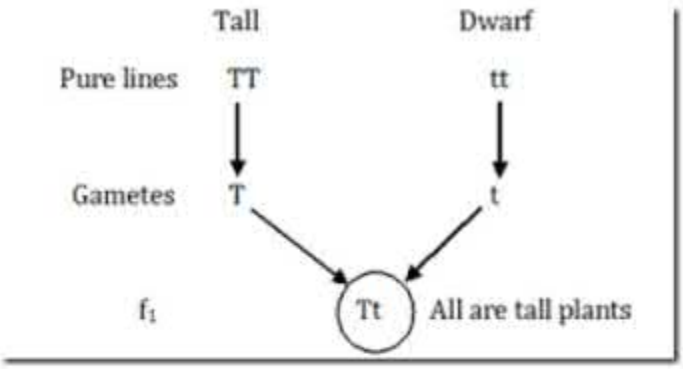
Important Definitions

- **Allele:** Variant form of a giving gene, different alleles can result in different phenotypic traits.
- **Dominant:** Allele that is phenotypically expressed over another allele.
- **Recessive:** Allele that is only expressed in absence of a dominant allele.
- **Pure (homozygous):** Having two identical alleles for a particular gene.
- **Hybrid (Heterozygous):** Having two different alleles for a particular gene.
- **Genotype:** The genetic makeup of an organism (ex: TT)
- **Phenotype:** The physical characteristics of an organism (ex: tall)
- **Monohybrid cross:** Cross between two organisms that are each hybrid for a single trait (Tt * Tt)
- **Autosomal trait:** Trait that is located on an autosome (non-sex chromosome)
- **Sex-linked trait:** Trait that is located on one of the two sex chromosomes
- **Pedigree:** Chart that shows the presence or absence of a trait within a family across generations.
- **Testcross (backcross)**

A way to determine whether an individual plant or animal showing the dominant trait is homozygous dominant (TT) or heterozygous (Tt).

(the individual of unknown genotype (B_) is crossed with a homozygous recessive individual (bb). If the individual being tested is homozygous dominant (BB), all offspring of the test cross will show the dominant trait and have the hybrid (Bb) genotype. If the individual being tested is actually hybrid (Bb), some individuals, will show the recessive trait.

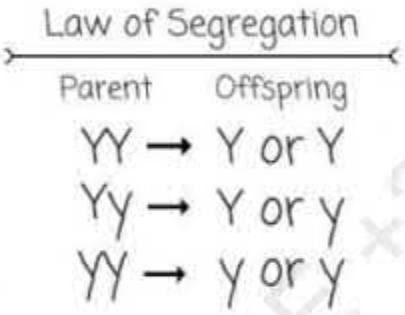
Law of Dominance

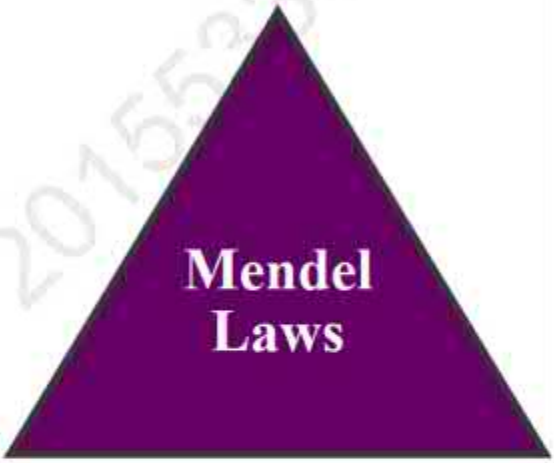


when two organisms, homozygous (pure) for two opposing traits are crossed, the offspring will be hybrid (carry two different alleles) but will exhibit only the dominant trait. The trait that remains hidden is the recessive trait.

Law of Segregation

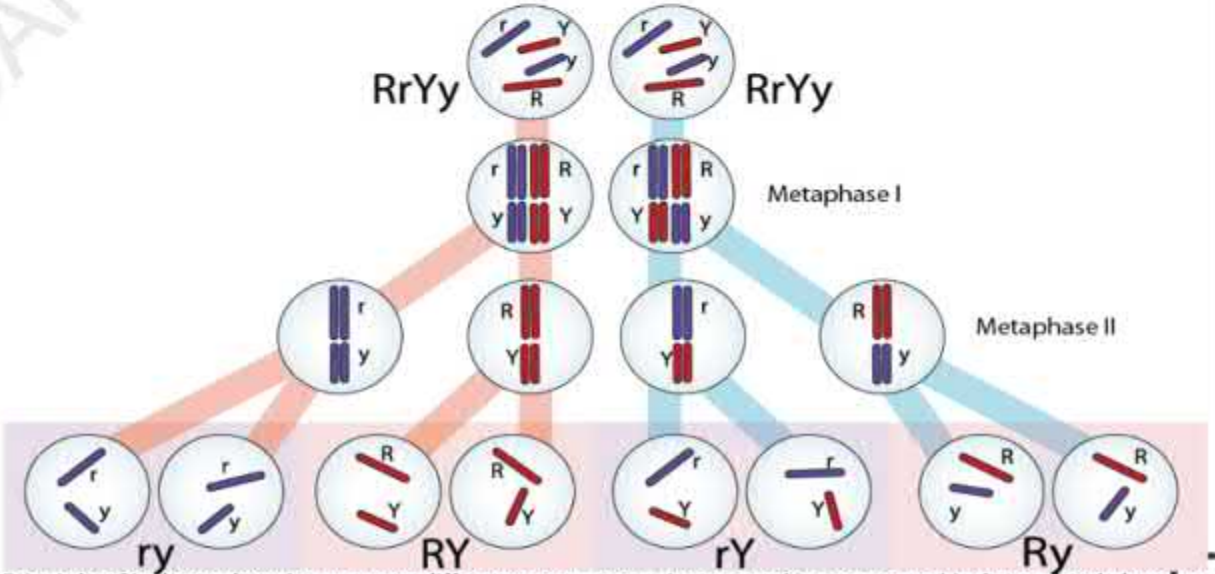
The law of segregation states that during the formation of gametes, the two traits carried by each parent separate.





Law of Independent Assortment

The law of independent assortment applies when a cross is carried out between two individuals that are hybrid for two traits on separate chromosomes. This law states that during gamete formation, the genes for one trait (such as height, T or t) are not inherited along with the genes for another trait (such as seed color, Y or y).



Principle of Independent Assortment: different genes assort (are passed into gametes) independently because they are located on different chromosomes which align randomly at the metaphase plate during meiosis I.

Mendel's laws problems

Inheritance of a single trait

TT (Tall)

tt (short)

	T	T
t	Tt	Tt
t	Tt	Tt

F1 100 % Dominant Hybrid Tt
100% Tall

Tt (Tall)

Tt (Tall)

	T	t
T	TT	Tt
t	Tt	tt

F2 1 DP : 2 DH : 1 R
3 Tall (75%): 1 Short

Inheritance of 2 separate traits

TTPP (Tall, Purple)

tt pp (short, white) **TtPp** (Tall, Purple)

F1 100 % Dominant Hybrid
(for both traits) TtPp

TtPp (Tall, Purple)

TTPP
(Tall, Purple)

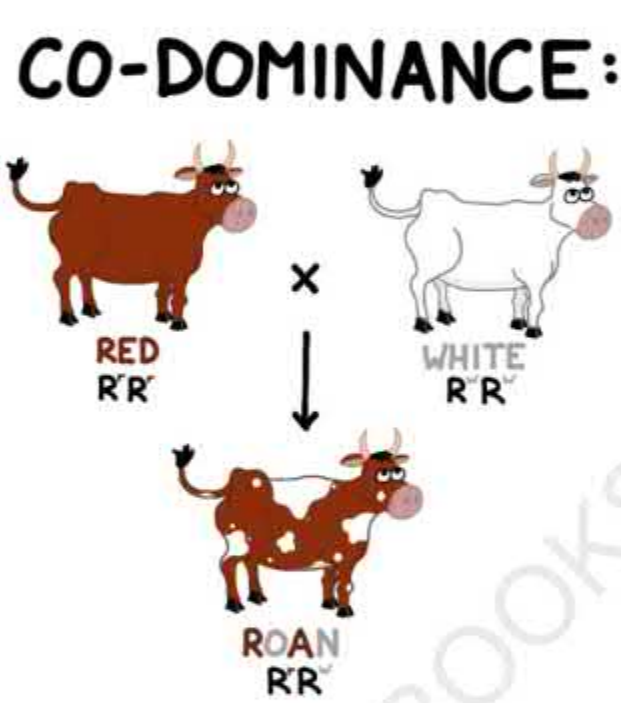
	TP	**Tp**	**tP**	**tp**
TP	TTPP	TTPp	TtPP	TtPp
Tp	TTPp	TTpp	TtPp	Ttpp
tP	TtPP	TtPp	ttPP	ttPp
tp	TtPp	Ttpp	ttPp	ttpp

F2 Phenotype ratio 9:3:3:1
9 Tall, Purple
3 Tall, White
3 Short, Purple
1 Short, white

Non-Mendelian Genetics

Codominance

It is possible, in the case of multiple alleles (i.e., more than two), for two alleles to exhibit codominance. This means that a heterozygote expresses a mixture of the traits of both alleles. This is the case, for example, **blood types** are determined with 3 alleles A,B & O



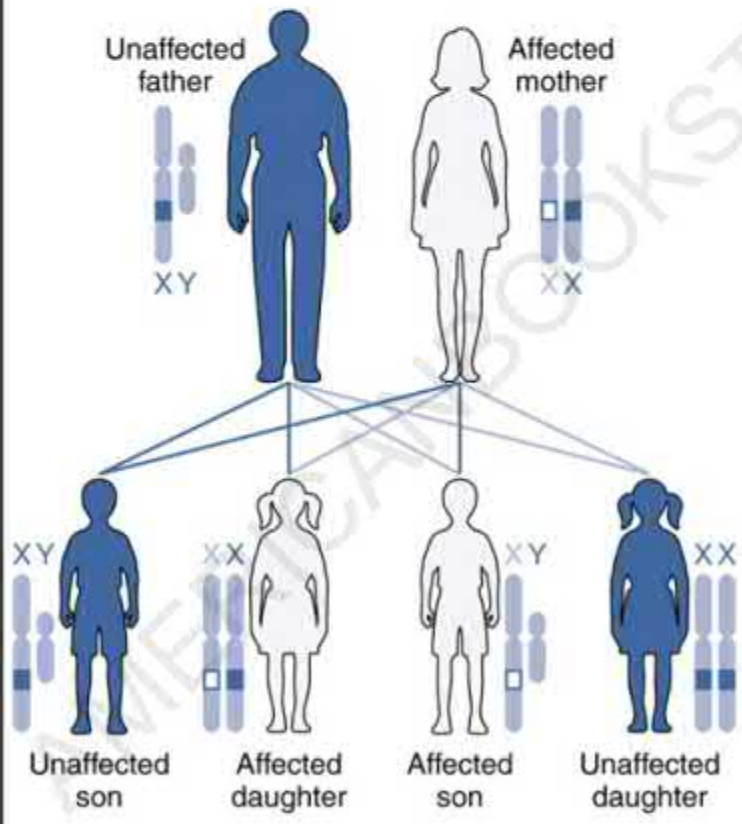
Incomplete dominance

Occurs when the offspring's phenotype is a **blending** of those of the parents. For example, crossing red and white snapdragons produces pink offspring. Pink is a new phenotype, not observed in either parent. Another example: A long watermelon (LL) crossed with a round watermelon (RR) produces all oval watermelons (RL).

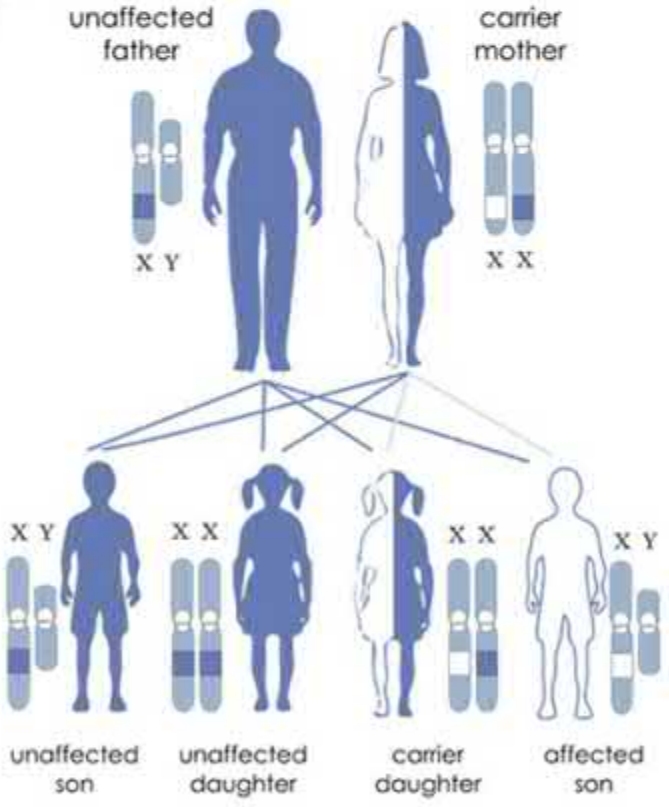
Sex-linked genes

Occur much more often in one gender (usually male) than the other. The gene for a sex- linked trait is located on either the X or the Y chromosome. In most mammals, males have an X and a Y chromosome, while females have two X chromosomes. Because a boy inherits his Y chromosome from his father, he must inherit his single X chromosome from his mother. The Y chromosome is very small and does not have the full set of genes present on the X chromosomes. Therefore, a recessive allele on the X chromosome will be expressed in males. Consider the inheritance of **hemophilia, a blood-clotting disorder** inherited as an X-linked recessive trait.

X-linked Dominant Inheritance



X-linked Recessive Inheritance



Human Blood types

When there are more than two allelic forms of a gene, we refer to that situation as **multiple alleles.** In humans there are **four different blood groups: A, B, AB, and O** determined by the presence of specific molecules on the surface of the red blood cells. These four different blood types are determined by **three alleles, *A, B,* and *O*.** *A* and *B* are codominant and are often written as I^A and I^B. (*I* stands for immunoglobin.)

When both alleles are present, they are both expressed, and the person has AB blood type. In addition, O is a recessive trait and is often written as *i*.
A person can have any one of the six blood genotypes.

Blood Type	Genotype
A	Homozygous A (AA)
A	Hybrid A (Ai)
B	Homozygous B (BB)
B	Hybrid B (Bi)
AB	Heterozygous (AB)
O	Homozygous O (ii)

Polygenic inheritance

Many characteristics such as **skin color, hair color, and height** result from a blending of several separate genes that vary along a continuum. They are controlled by several genes and are called **polygenic**.

Example: (Two parents who are short carry more genes for shortness than for tallness. However, they can have a child who inherits mostly genes for tallness from both parents and who will be taller than his/her parents.)

Sex Influenced inheritance

Genotype	Male	Female
BB	Bald	Bald
Bb	Bald	Not Bald
bb	Not Bald	Not Bald

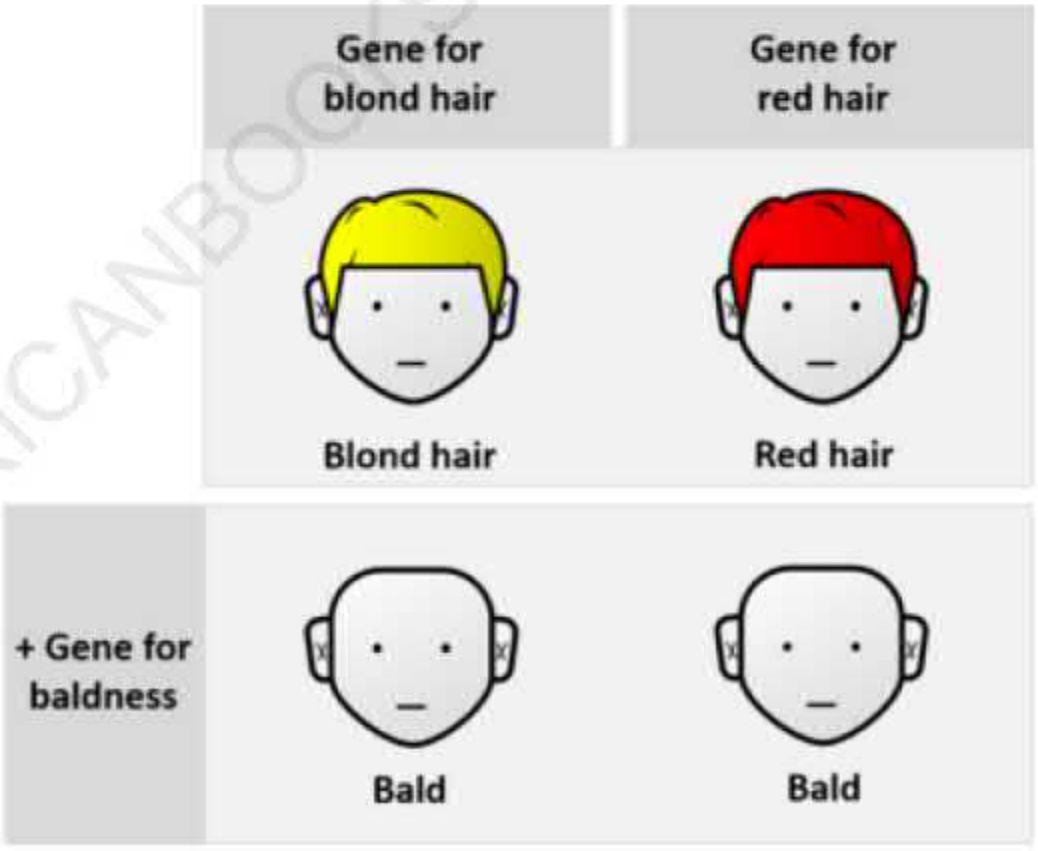
Inheritance can be influenced by the sex of the individual carrying the traits. An example can be seen in male pattern **baldness in humans**, . This is not a sex-linked trait but rather a sex-influenced trait.

Gene linkage

- Gene linkage is a pattern that violates Mendel's law of independent assortment.
- Alleles for two genes that are located close to each other on a chromosome may often "travel together."
- For example, individuals with a condition called "nail-patella syndrome" have a greater chance of also having the B blood type allele (which results in blood types of B or AB).
- These genes occur next to each other, and so certain alleles are inherited together more often.

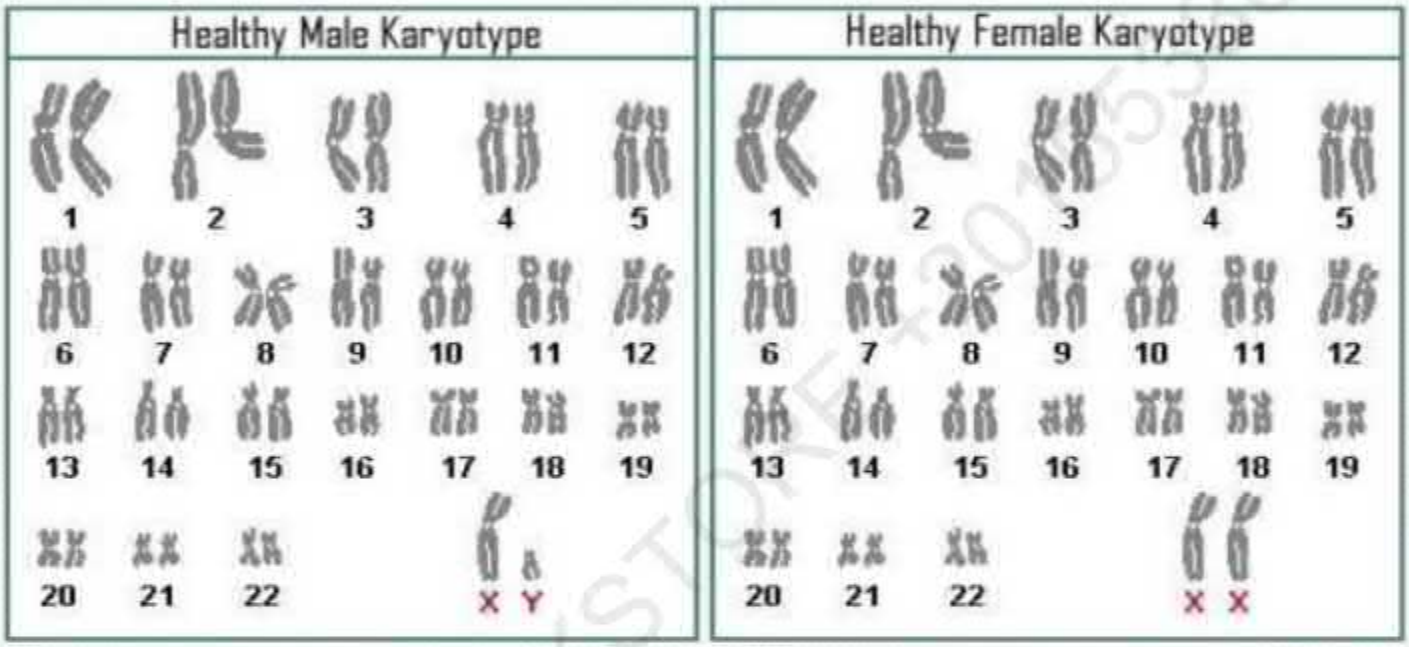
Epistasis

- The term epistasis describes a certain relationship between genes, where an allele of one gene hides or masks the visible output, or phenotype, of another gene.



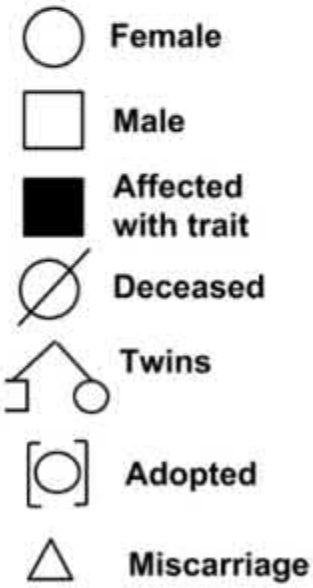
karyotype

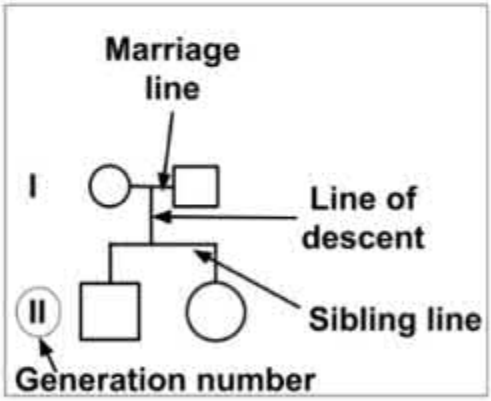
- A karyotype is a laboratory procedure that analyzes the size, shape, and number of chromosomes. Specialists prepare and photograph chromosomes during metaphase of mitosis when they are fully condensed.
- In human, there are 44 (22 pairs) autosomes and 2 sex chromosomes.



The pedigree

- Family tree that indicates the phenotype of one trait being studied for every member of a family.



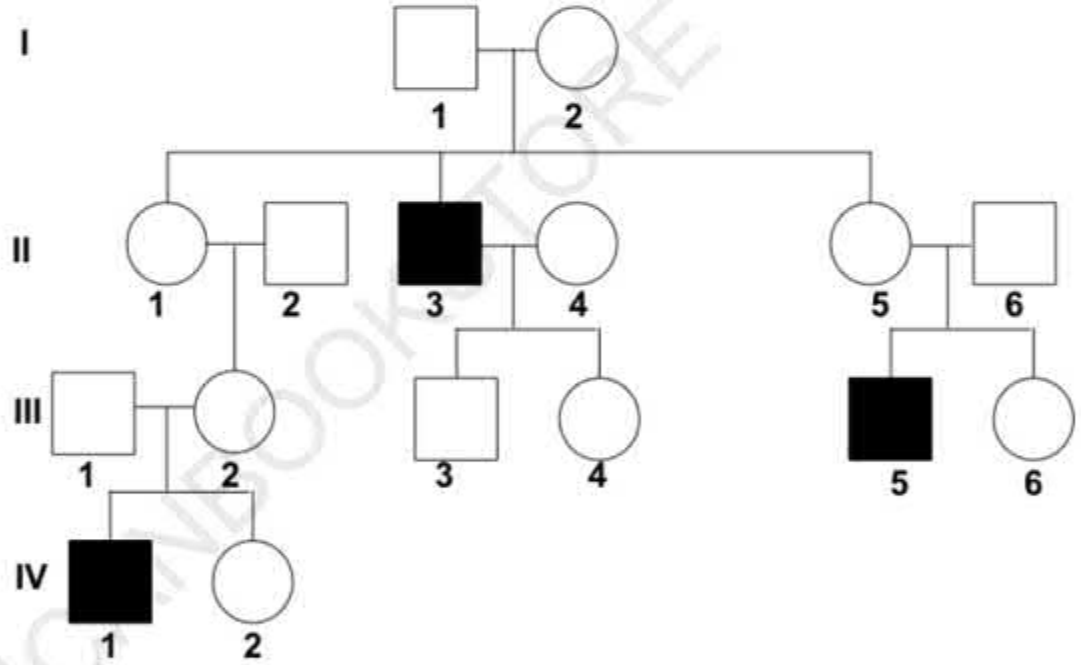


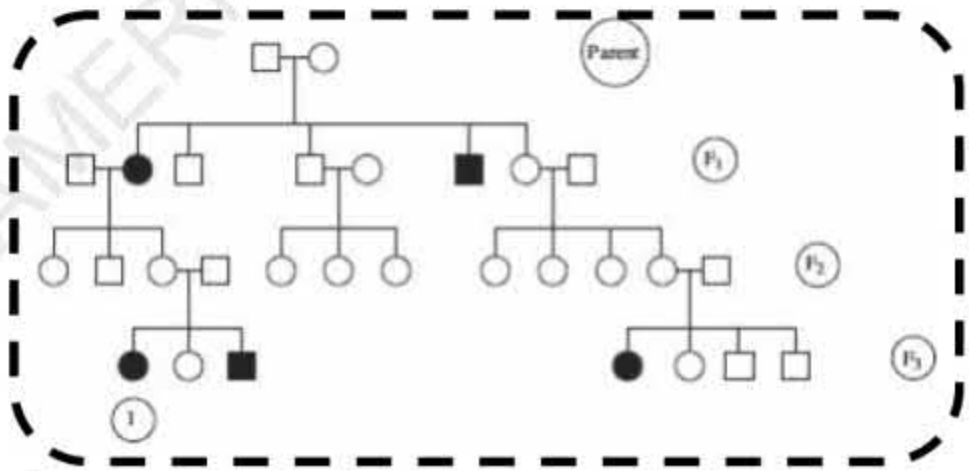
- By analyzing a pedigree, we can:
  - determine genotypes
  - identify phenotypes
  - predict how a trait will be passed on in the future

Reading pedigree

1. Determine whether the trait is **dominant or recessive**. If the trait is dominant, one of the parents must have the trait. Dominant traits will not skip a generation. If the trait is recessive, neither parent is required to have the trait since they can be heterozygous.

2. Determine if the chart shows an **autosomal or sex-linked** (usually X-linked) trait. For example, in X-linked recessive traits, males are much more commonly affected than females. In autosomal traits, both males and females are equally likely to be affected (usually in equal proportions).



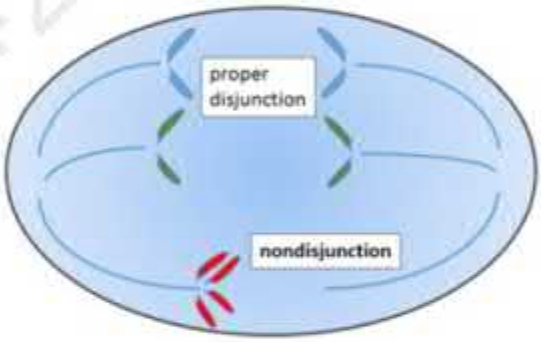


Analyze that ?

Human inherited disorders

- Human genetic defects can be caused by either a gene or a chromosome mutation.
- Chromosomal aberrations include:

1. **Deletion**: A fragment lacking a centromere is lost during cell division.
2. **Inversion**: A chromosomal fragment reattaches to its original chromosome but in the reverse orientation.
3. **Translocation**: A fragment of a chromosome becomes attached to a non homologous chromosome.
4. **Polyploidy**: A cell or organism has extra sets of chromosomes.
5. **Nondisjunction**: Homologous chromosomes fail to separate during meiosis. the resulting zygote will have an abnormal number of chromosomes.



anaphase

- Any abnormal chromosome condition is known as **aneuploidy.**
- If a chromosome is present in triplicate, the condition is known as trisomy.
- People with **Down syndrome** have three #21 chromosomes. The condition is referred to as **trisomy-21.**
- An organism in which the cells have an extra set of chromosomes is referred to as triploid (3n).
- The cells of the endosperm or cotyledon of a seed are triploid.
- An organism with more than 3 sets of chromosomes is referred to as polyploid. Scientists breed plants to be polyploid because they will produce abnormally large flowers and fruit.

Gene and chromosome mutation

Chromosomal Disorder	Pattern of Inheritance	Description
Down syndrome	47 chromosomes with trisomy-21	Characteristic facial features, mental retardation, prone to developing Alzheimer's and leukemia.
Klinefelter's syndrome	XXY 47 Chromosomes "a male with an extra X Chromosome"	Have male genitals, but the testes are abnormally small and these men are sterile

Genetic Disorder	Pattern of Inheritance	Description
Hemophilia	Sex-linked recessive	Caused by the absence of one or more proteins necessary for normal blood clotting.
Huntington's disease	Autosomal dominant	A degenerate disease of the nervous system resulting in certain and early death. Onset is usually in middle age.
Tay-Sachs disease	Autosomal recessive	Onset is early in life and is caused by lack of the enzyme needed to break down lipids necessary for normal brain function. It is common in Ashkenazi Jews and results in seizures, blindness, and early death.
Cystic fibrosis	Autosomal recessive	The most common lethal genetic disease in the U.S. 1 out of 25 Caucasians is a carrier. Characterized by buildup of extracellular fluid in the lungs, digestive tract, etc
Phenylketonuria (PKU)	Autosomal recessive	Inability to break down the amino acid phenylalanine. Requires elimination of phenylalanine from diet; otherwise serious mental retardation will result.

7

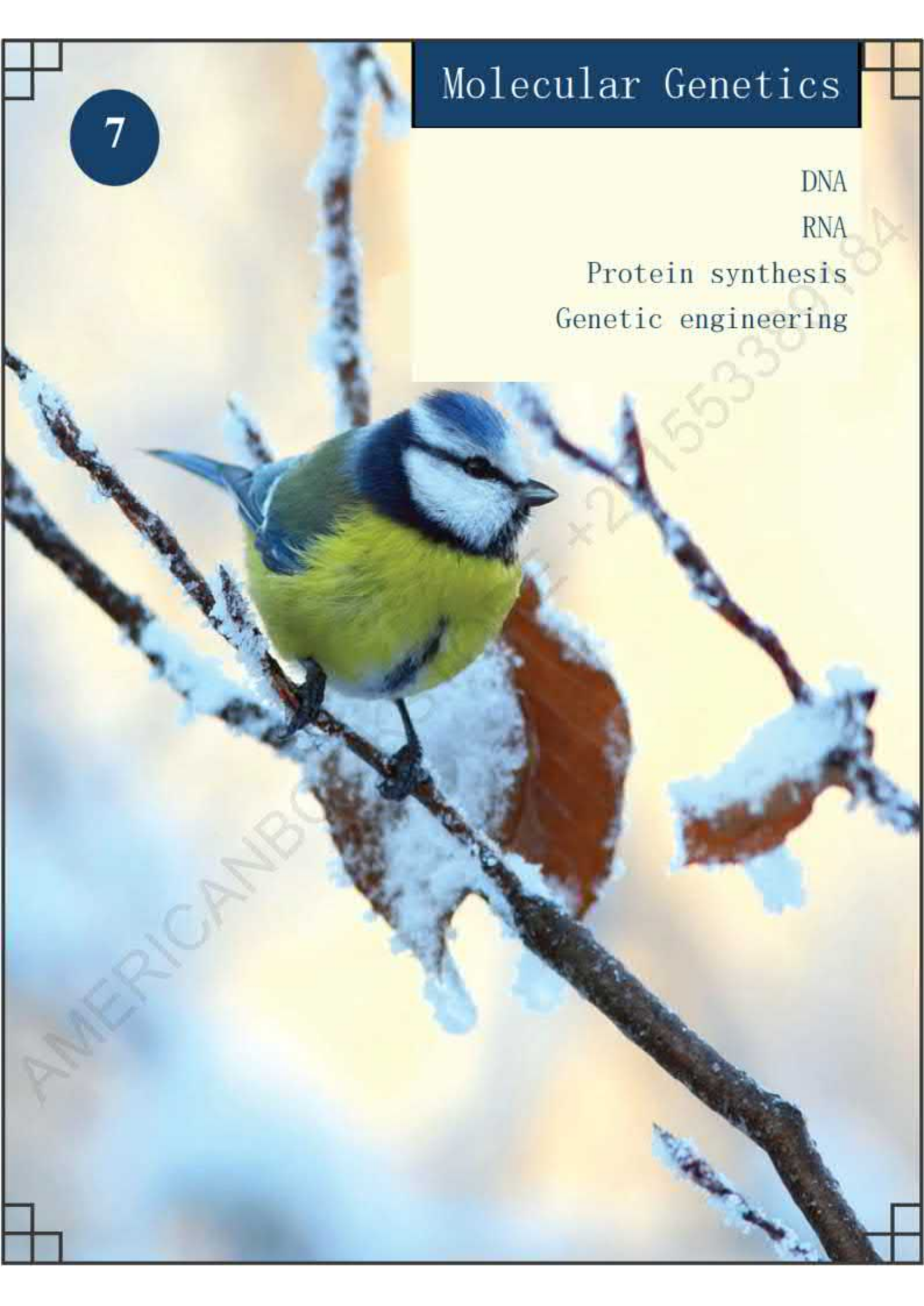
Molecular Genetics

DNA

RNA

Protein synthesis

Genetic engineering

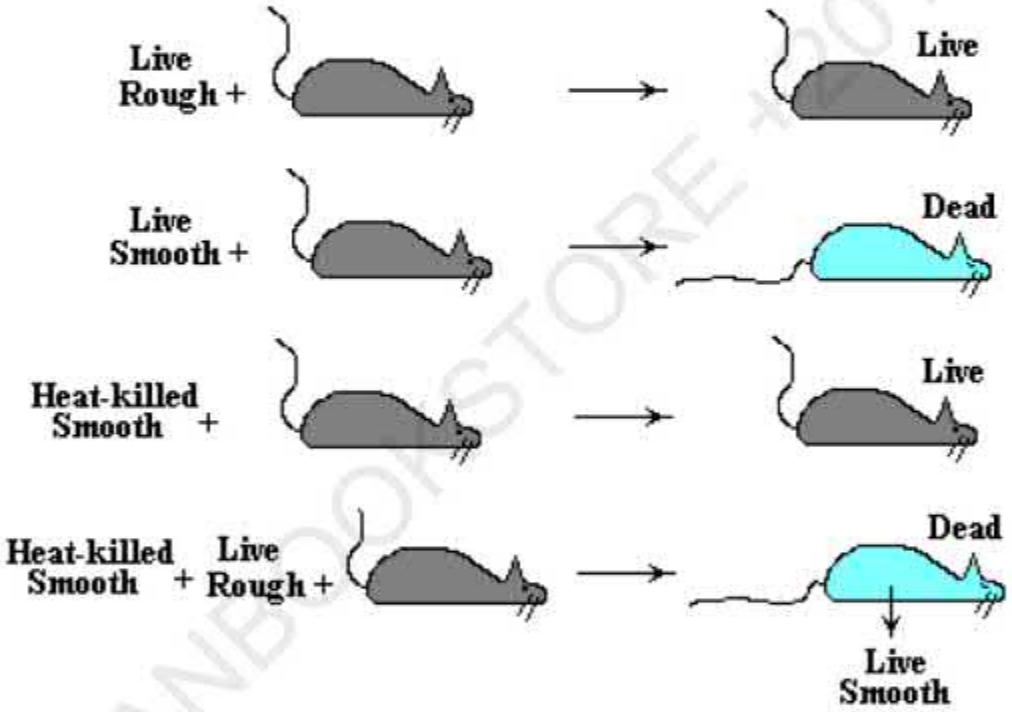


MOLECULAR GENETICS

Determine the genetic material

Griffith 1927
Bacterial transformation

The ability of bacteria to alter their genetic makeup by absorbing foreign DNA molecules from other bacterial cells and incorporating the foreign DNA into their own.

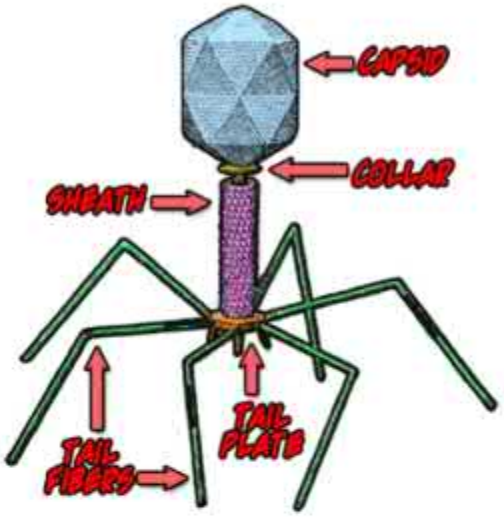


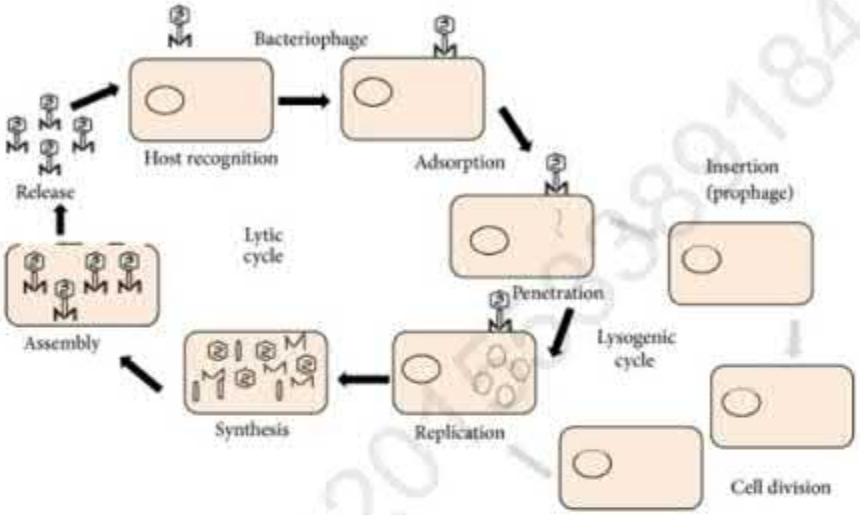
Avery 1944
Bacterial transformation
Factor is DNA

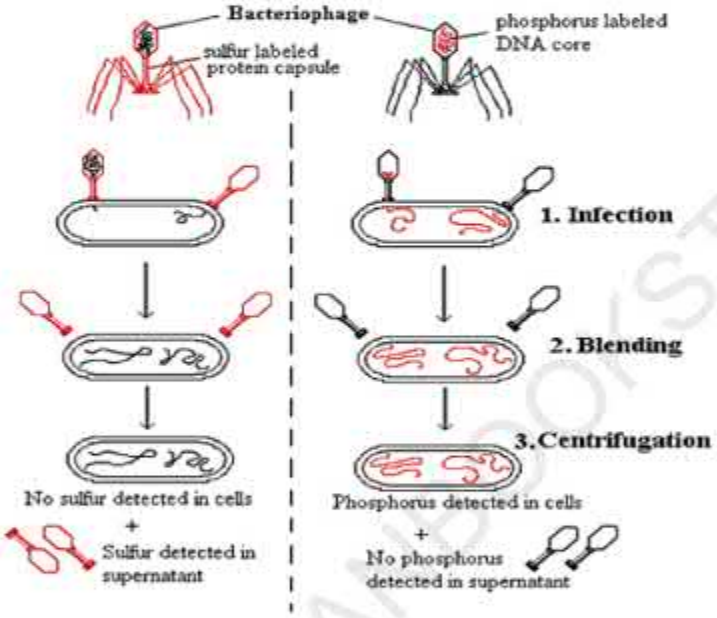
The molecule that Griffith's bacteria were transferring was, in fact, DNA
He conduct:
1. Physical and chemical examination
2. Crucial experiment
(DNAse, Protease)

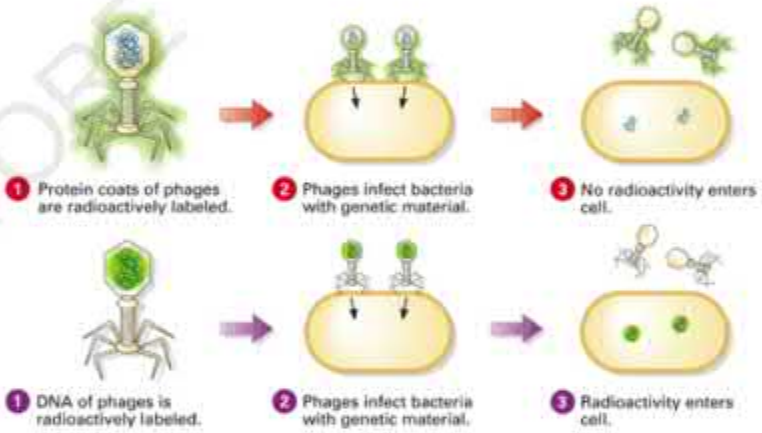
Hershey & Chase 1952 Bacteriophage

DNA, not proteins, is the molecule of inheritance "Using labeled bacteriophages" (P^{32} , S^{35})









Franklin 1950:1953 Diffraction X-Ray

Carried out the X-ray crystallography analysis of DNA that showed DNA to be a helix using "X Ray diffraction"

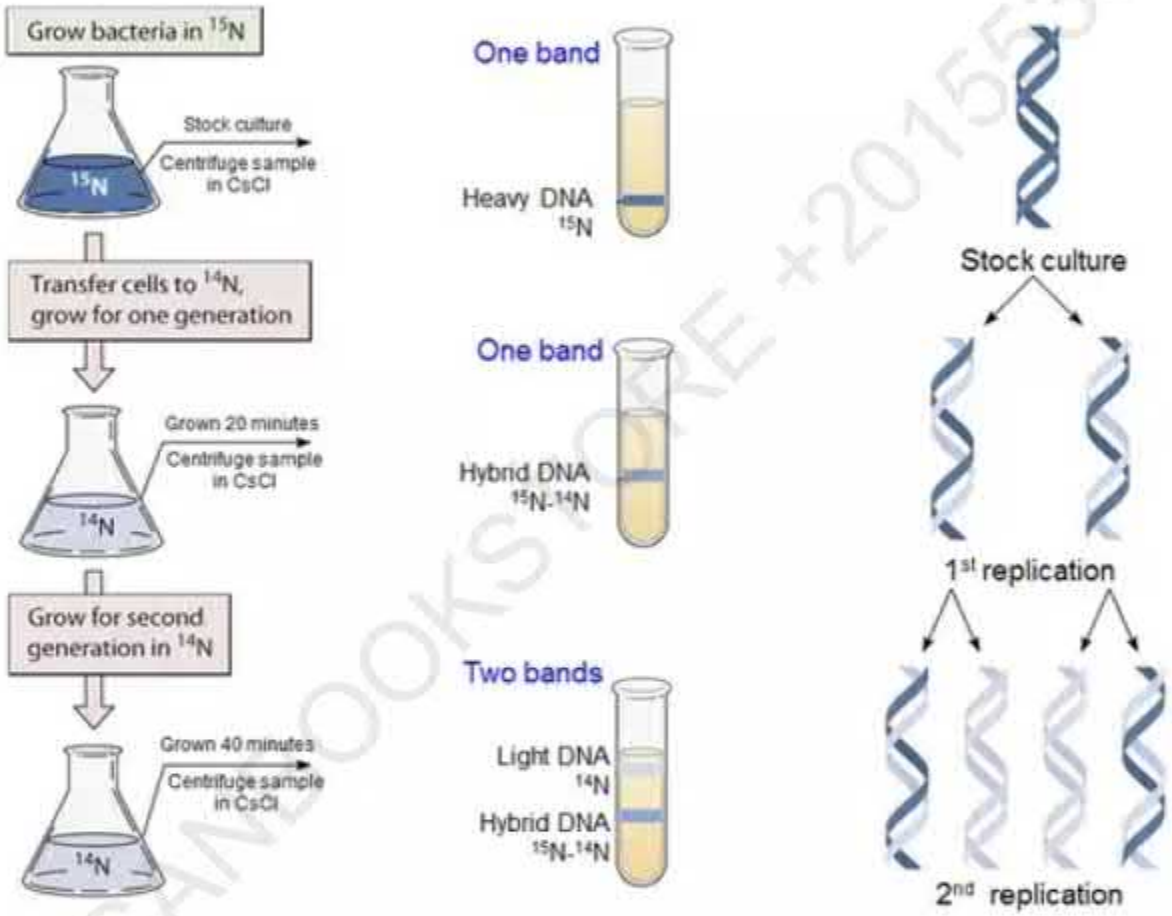
Watson & Crick 1953 DNA 3D Model, Double helix

Received the Nobel Prize in 1962 for correctly describing the structure of DNA as a double helix.

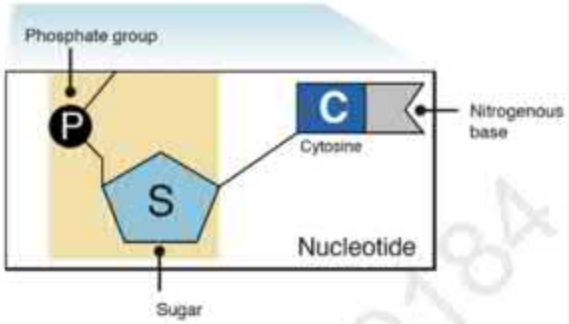
Meselson, Stahl 1953
DNA double helix in bacteria

Proved Watson and Crick's hypothesis

DNA replication is semiconservative

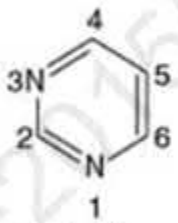


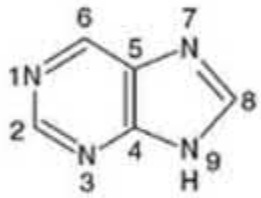
Deoxyribonucleic Acid (DNA)

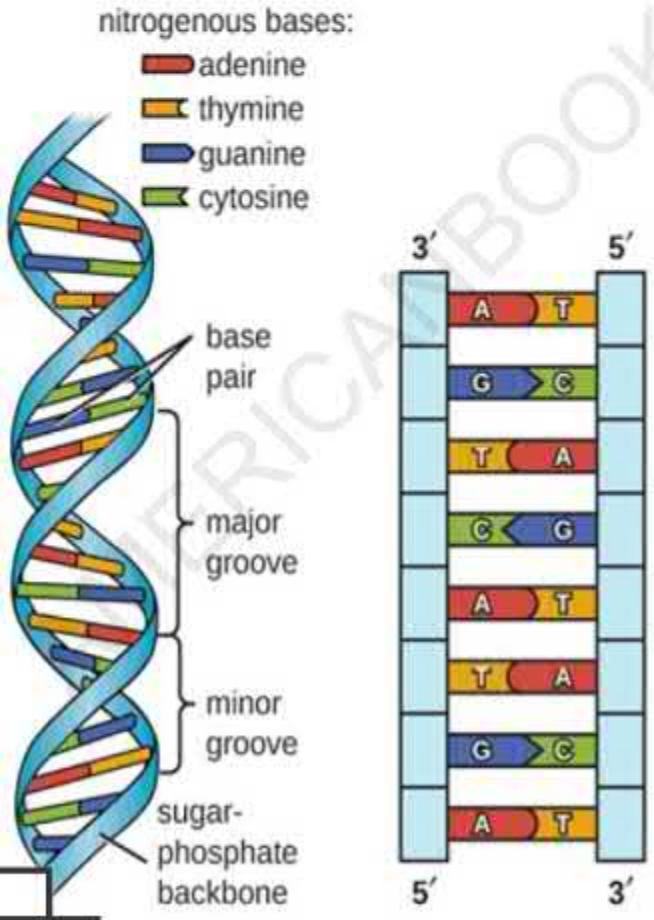


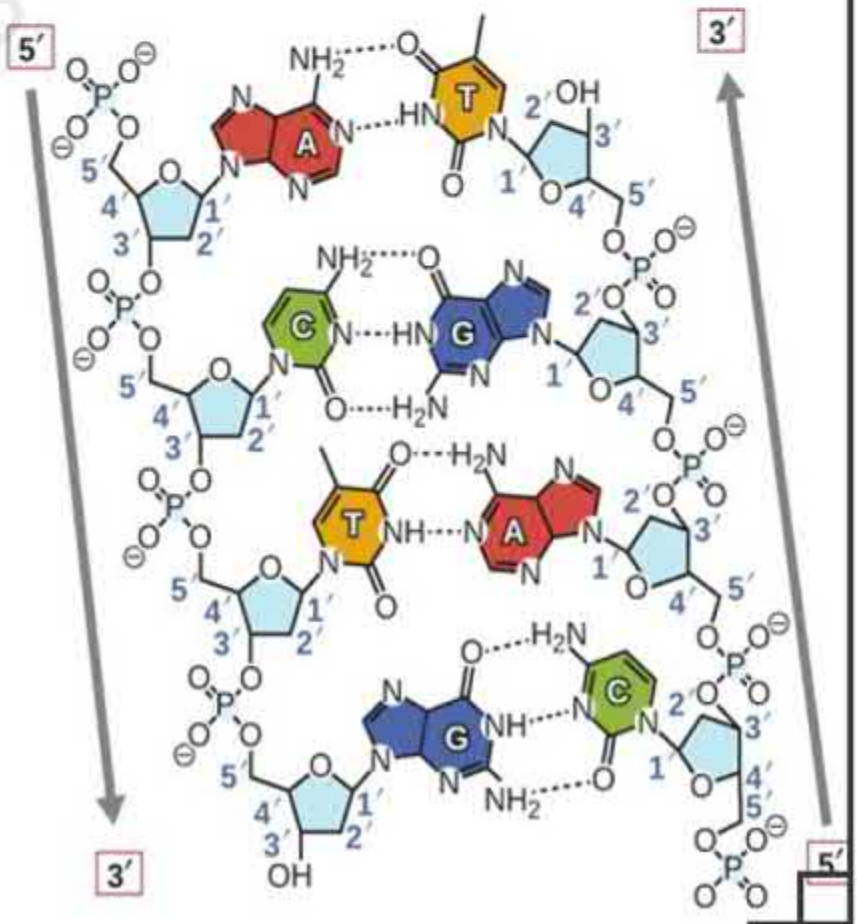
- DNA is a double helix shaped like a twisted ladder.
- DNA consists of two complementary strands running in opposite directions from each other.
- DNA molecule is composed of thousands of smaller units called **nucleotides.**
- Each nucleotide consists of 3 parts:

- **Sugar (5- C deoxyribose)**
- **Phosphate group**
- **Nitrogen base:**
  - a- **purine**: Adenine A, Guanine G
  - b- **pyrimidine**: Cytosine C , Thymine T
- **Base Pairing** G ≡ C A = T
- **Chargaff rule A=T , G=C**

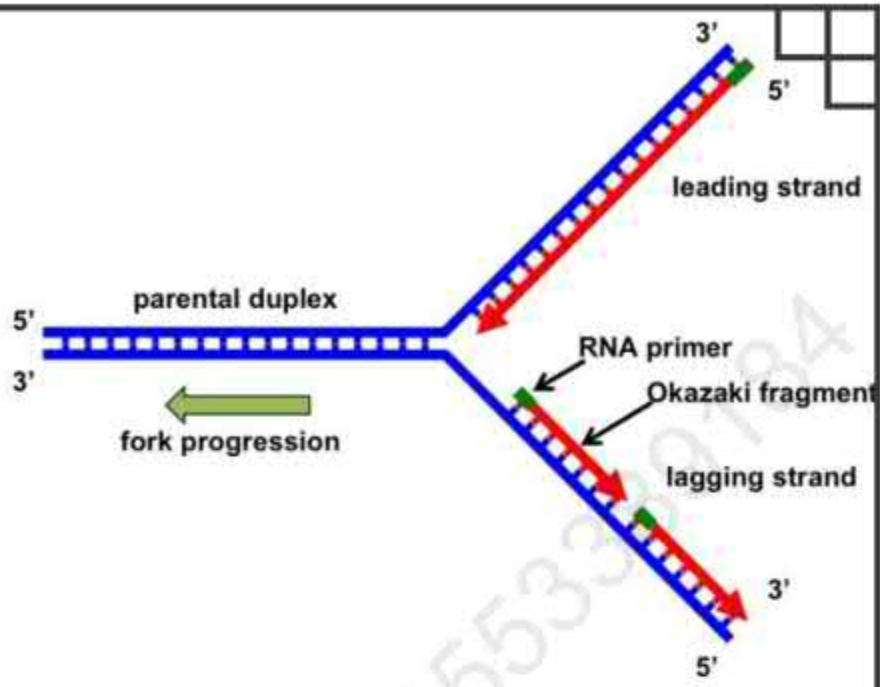








DNA Replication



Objective:

To make an exact copy of DNA

Type:

Semi-conservative replication (Each DNA molecule will consists of one old strand and one new strand)

Time:

S - phase in interphase of cell life cycle.

Steps:

1. The double helix unwinds, and the two strands separate.
2. DNA polymerase lines up nucleotides to form new second strands. according to the base-pairing rules. "Each DNA strand acts as a template for the formation of a new complementary strand."
3. Hydrogen bonds form between the base pairs, forming the new "rungs" of the DNA ladder.
4. The new double-stranded molecules twist up into double helices.

DNA helicase:

DNA helicase is an enzyme that begins the unraveling of the DNA molecule at the sites of the hydrogen bonds.

DNA polymerase:

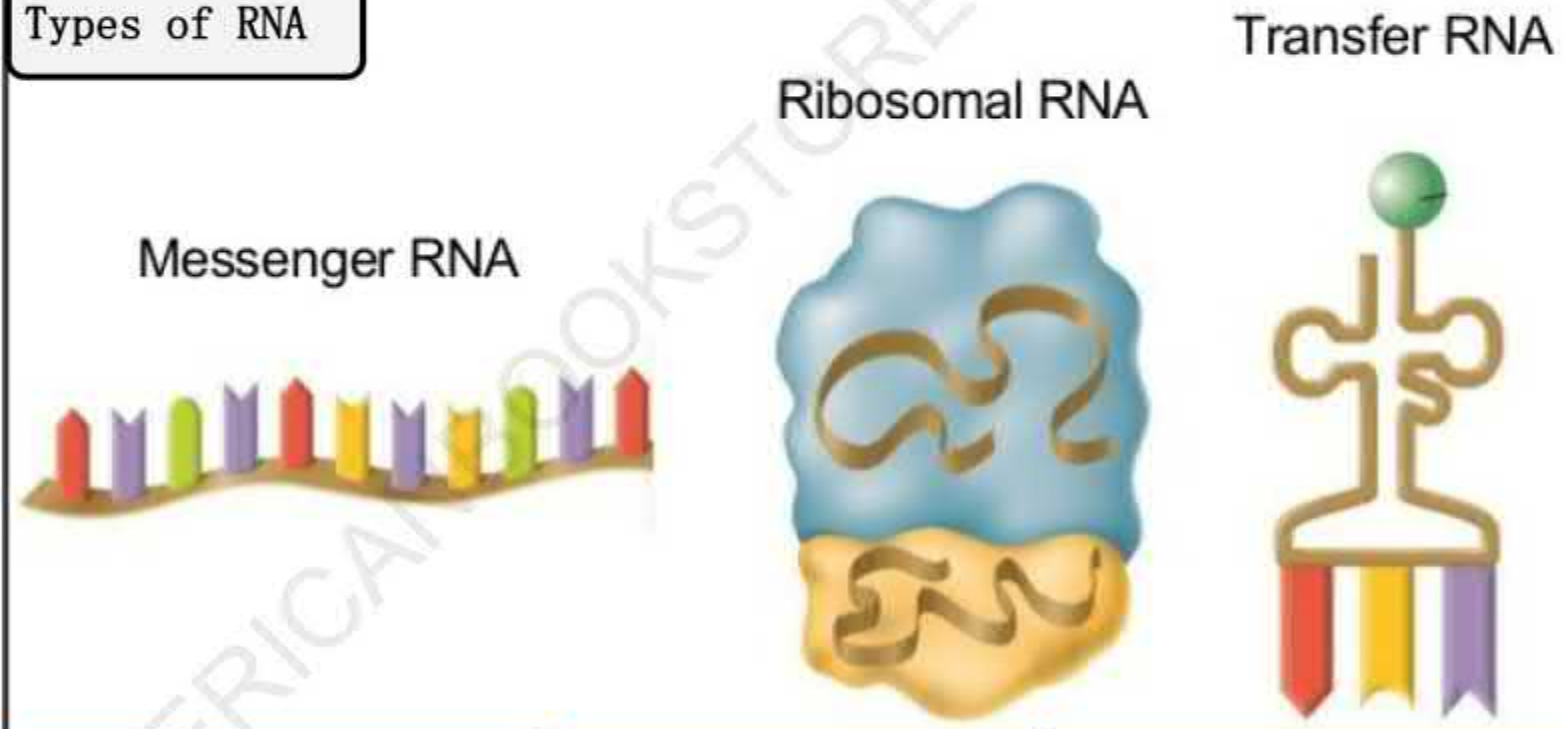
This enzyme arranges the new nucleotides next to their complimentary base to make the new strand of DNA.

Leading strand:
A leading strand is a strand of DNA that starts at the 5 end and is made continuously

Lagging strand:
A strand of DNA that starts at the 38 end. Its production proceeds slower than the leading strand because it is made in pieces that are then bonded by **DNA ligases.**

Telomeres: special noncoding nucleotide sequences at the ends of chromosomes that repeat thousands of times. (To avoid loss of genes during replication)

Types of RNA



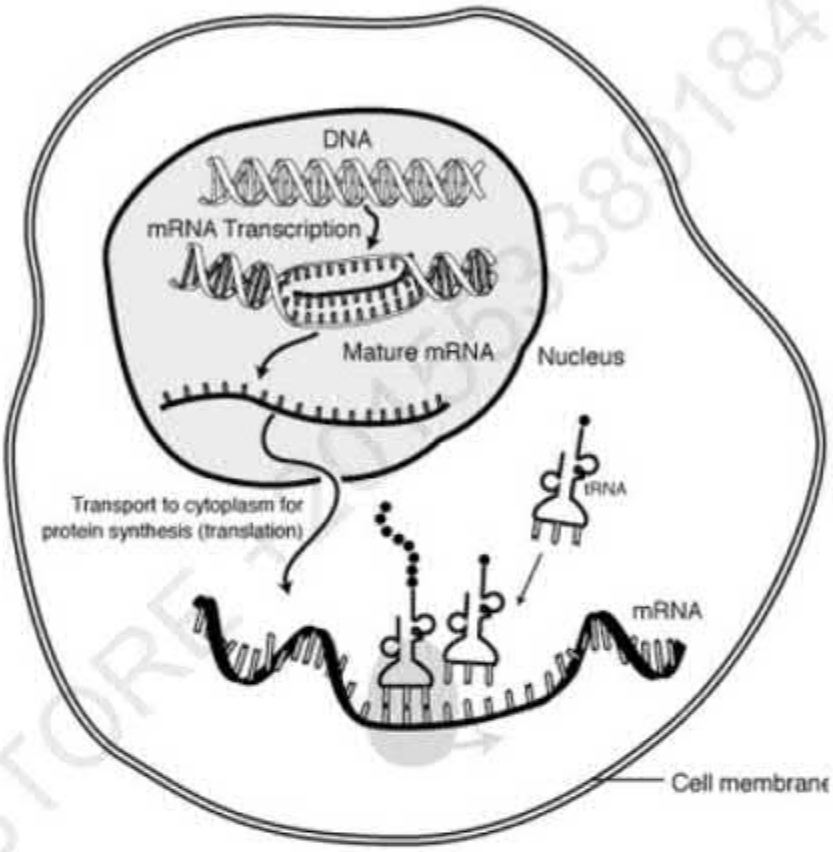
carries messages from DNA in the nucleus to the Ribosome in cytoplasm	Translate mRNA codes "base sequence" to amino acids codes	carries amino acids to the mRNA at the ribosome in order to form a polypeptide

Ribonucleic acid (RNA)

DNA	RNA
DNA stands for Deoxyribonucleic Acid. The sugar portion of DNA is 5-Deoxyribose.	RNA stands for Ribonucleic Acid The sugar portion of RNA is Ribose.
DNA is a double-stranded molecule consisting of a long chain of nucle-otides.	RNA usually is a single-strand helix consisting of shorter chains of nucleotides.
The bases present in DNA are adenine, guanine, cytosine and **thymine. (T)**	The bases present in RNA are adenine, guanine, cytosine and **uracil. (U)**
DNA is self-replicating.	RNA is synthesized from DNA on an as-needed basis.
DNA is susceptible to UV damage.	Compared with DNA, RNA is relatively resistant to UV damage.
DNA is found in the nucleus of a cell and in mitochondria.	Depending on the type of RNA, this molecule is found in a cell's nucle-us, its cytoplasm, and its ribosome.
DNA is only two types: intra nuclear and extra nuclear.	Three different types of RNA: m-RNA, t-RNA and r-RNA.
Its quantity is fixed for cell.	The quantity of RNA of a cell is variable.
It is long lived.	Some RNAs are very short lived while others have somewhat longer life.
Functions: Carry genetic materials	Functions: ♦ Protein synthesis ♦ Carry genetic materials in some organisms

Protein Synthesis

- Protein Synthesis means expression of genes
- There are three main steps in this process:
  1. **Transcription**
  2. **Processing**
  3. **Translation**



Transcription:

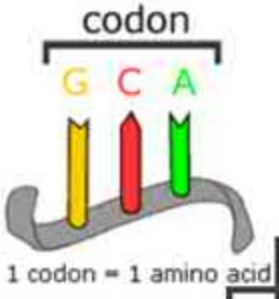
- RNA polymerase binds to promoter
- The complementary nucleotides attach
  G– C / C– G / A– U / T– A
- They joined as a strand

Processing:

- RNA is processed or edited by a series of enzymes.
- The enzymes remove pieces of RNA that do not code for any protein. **(introns)**
- **Exons** (expressed sequences or coding regions), are pieced back together to form the final transcript.

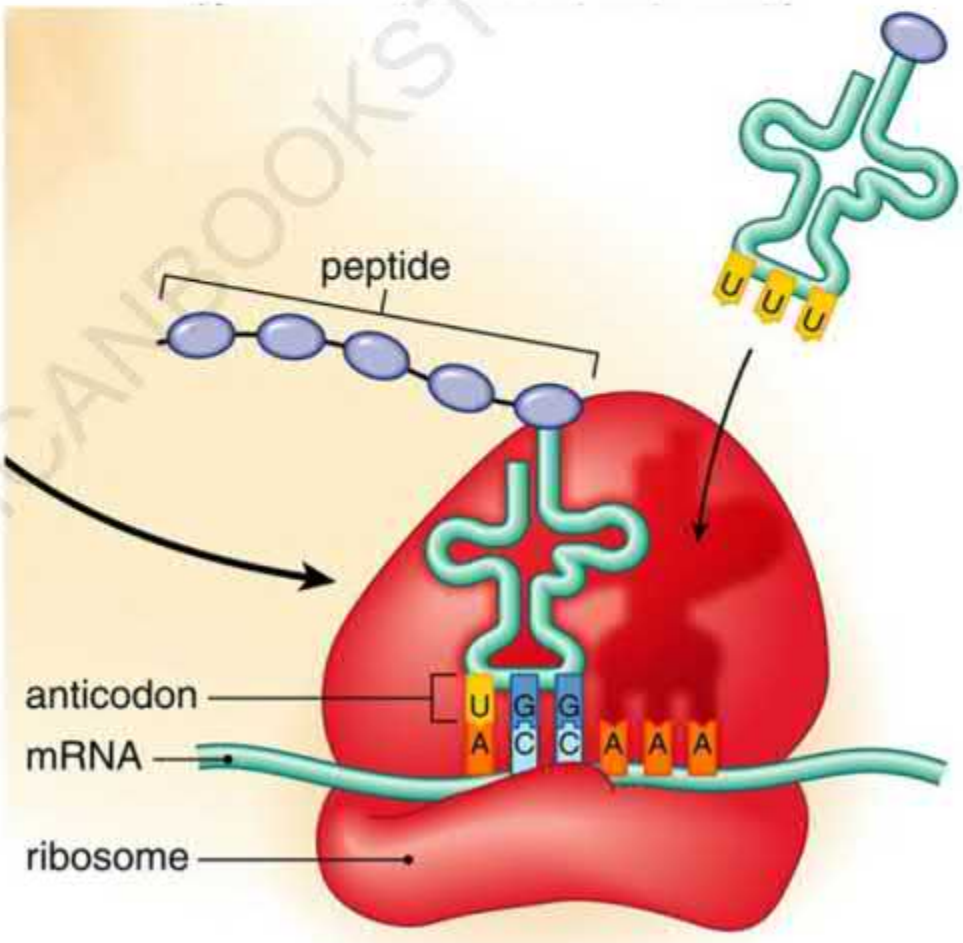
Promoter:- It is the sequence of nucleotides on the DNA that directs RNA polymerase to the strand that will be transcribed and mRNA transcription starts from it.

Codon:- consists of 3 consecutive nucleotides that specify a single amino acid that is to be added to the polypeptide.



Translation:

- Translation is the process by which the mRNA sequence is converted into an amino acid sequence.
- Translation occurs at the ribosome.
- Amino acids present in the cytoplasm are carried by tRNA molecules to the codons of the mRNA strand at the ribosome.
- Each codon has Anti-codon found on the corresponding tRNA.
- Some tRNA molecules can bind to two or more different codons. For example, codons UCU, UCC, UCA, and UCG all code for a single amino acid, serine.
- **Start Codon AUG**: represents the start of translation. (represent amino acid methionine)
- Three **stop codons (UAA- UAG - UGA)** marks the end of translation.
- Gene expression according to the body needs



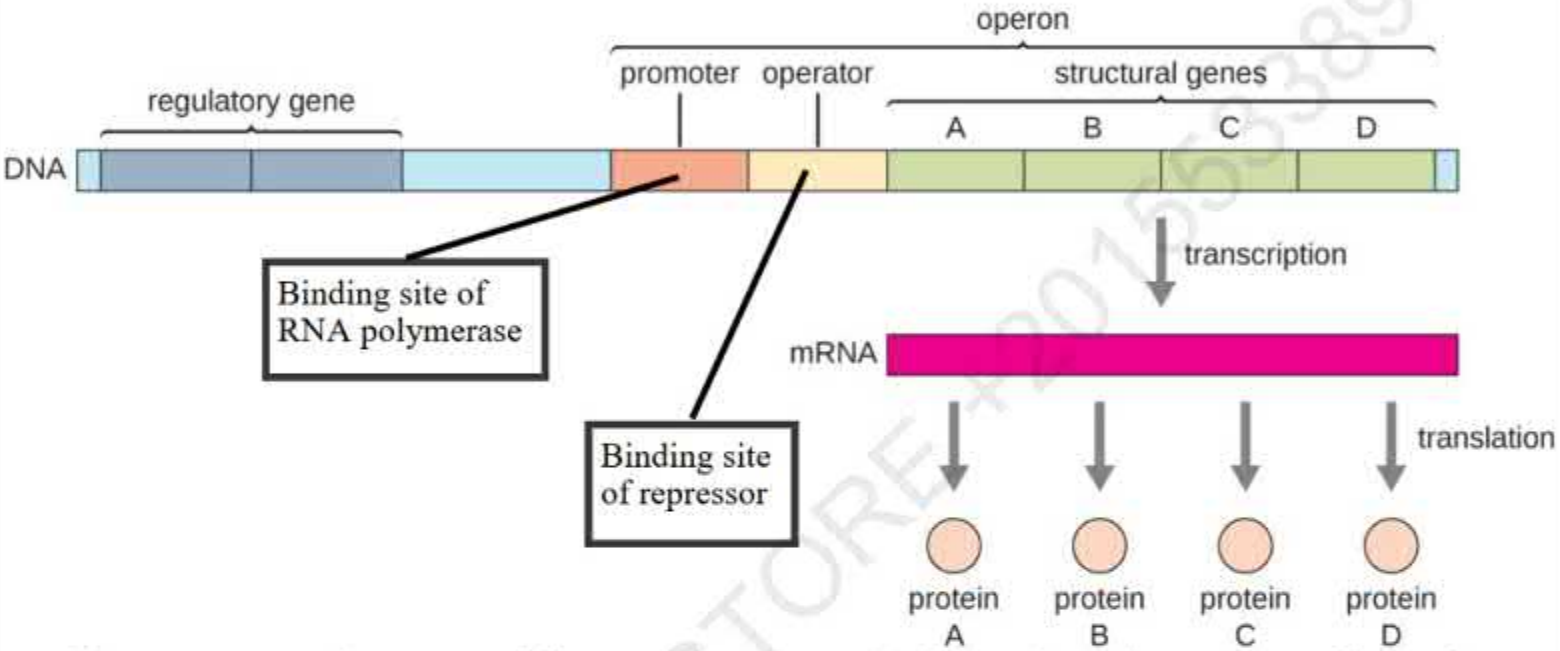
tRNA–amino acid at ribosome

Gene Regulation

- Gene expression according to the body needs

"That means that every gene in a cell is not turned on all the time"

- The regulation mechanism is not will understood in human
- Gene regulation in bacteria (Operon hypothesis)



- The **operon** is actually a cluster of functional genes plus the switches that turn them on and off.
- There are two types of operons. **Lac or inducible operon**, which is normally turned off .The other is the **repressible operon**,
- which is always turned on unless it is actively turned off because it is temporarily not needed.
- The operon contains:

  •**The promoter** is the binding site of RNA polymerase. RNA polymerase must always bind to DNA before transcription can take place. So, the promoter is like an "on" switch.

  •**The operator** is the binding site for the repressor, which turns off the Lac operon.

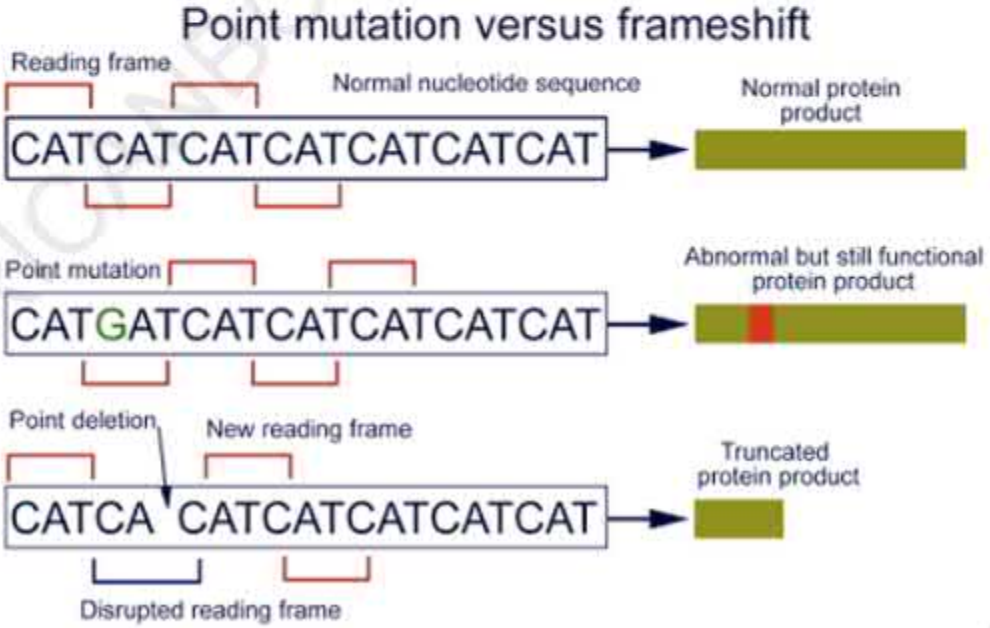
  •**TATA box** (named for its sequences of alternating adenine and thymine), which helps RNA polymerase bind to the promoter.

Mutations

- It is a change in genetic code during DNA replication
- May be inherited (if it happens in gametes) or not if it happened in somatic cells
- It is a source of variation and evolution
- May be harmful or even lethal but some are useful

Gene Mutations

- **Point Mutation:** The simplest mutation is a point mutation. This is a base-pair substitution, where one nucleotide converts to another.
- The inherited genetic disorder sickle cell anemia results from a point mutation in the gene that codes for hemoglobin.
- The abnormal hemoglobin causes red blood cells to sickle when available oxygen is low. When red blood cells sickle, a variety of tissues may be deprived of oxygen and suffer severe and permanent damage.
- **Frameshift Mutation:** results from a single nucleotide insertion or deletion. Both mutations result in a frameshift because the entire reading frame is altered and is unreadable.



Chromosome Mutations

The Human Genome

-The human genome (an organism's genetic material) consists of 3 billion base pairs of DNA and about 20,000 : 30,000 genes.

- 97 percent of our DNA does NOT code for protein product and has often been called **junk**.

- Some of these Junk Are (regulatory sequences - Introns)

GENETIC ENGINEERING AND RECOMBINANT DNA

- **Recombinant DNA** means taking DNA from two sources and combining them in one cell.

- **genetic engineering** : The branch of science that uses recombinant DNA techniques for practical purposes

- **Restriction enzymes** are an important tool for scientists working with DNA. They cut DNA at specific recognition sequences or sites, such as GAATTC, and are sometimes referred to as molecular scissors.

- **Gel electrophoresis** separates large molecules of DNA on the basis of their rate of movement through an agarose gel in an electric field. The smaller the molecule, the faster it runs through the gel.

- **Polymerase chain reaction (PCR)** is a cell-free, automated technique by which a piece of DNA can be rapidly copied or amplified. Billions of copies of a fragment of DNA can be produced in a few hours.

8 Evolution

EVOLUTION

- **Evolution** is the change in the genes of a population on Earth over time.
  - **Microevolution**: Change in one gene pool of population over generation
  - **Macroevolution**: refers to **speciation**, the formation of entire new species.

NB. Evolution is for population not individuals

EVIDENCE OF EVOLUTION

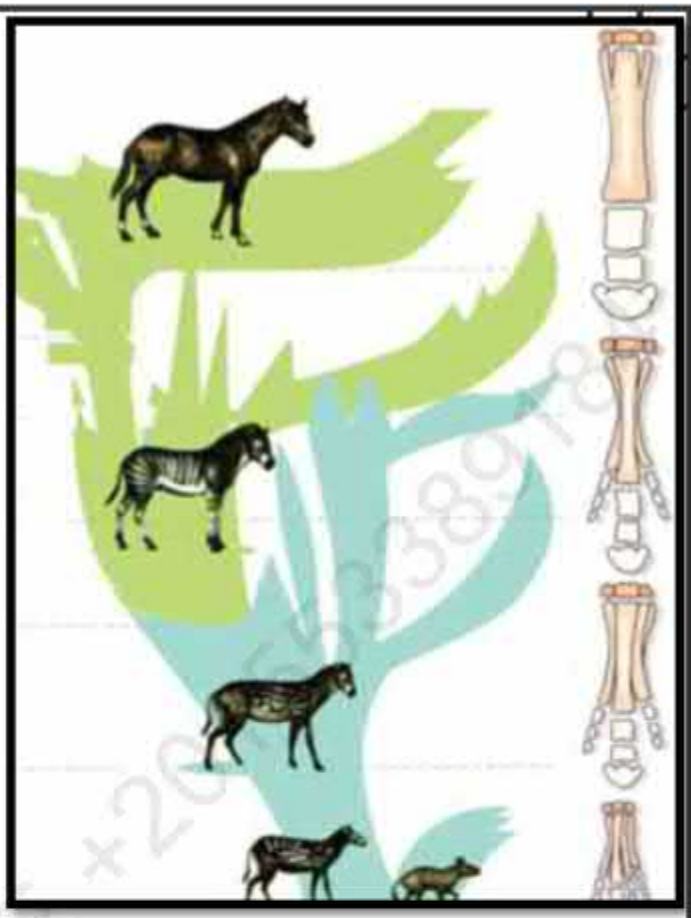
1. Fossil record
2. Comparative anatomy
3. Comparative biochemistry
4. Comparative embryology
5. Molecular biology
6. Biogeography

Fossil Record

- The remains or traces of living organisms which lived in old ages and were buried after their death in sedimentary rock

- **Conditions for fossil formation**

1- The presence of hard skeletons for living organisms
2- Burial of living organisms in sedimentary rocks right after their death
3- The presence of suitable mineral medium which replaces the organic parts of living organisms



- **Fossil Record**: Complete set of fossils which records the evolution of some living organisms during geological ages, such as fossil records of horses and elephants.
- It reveals the existence of species that have become extinct or have evolved into other species.

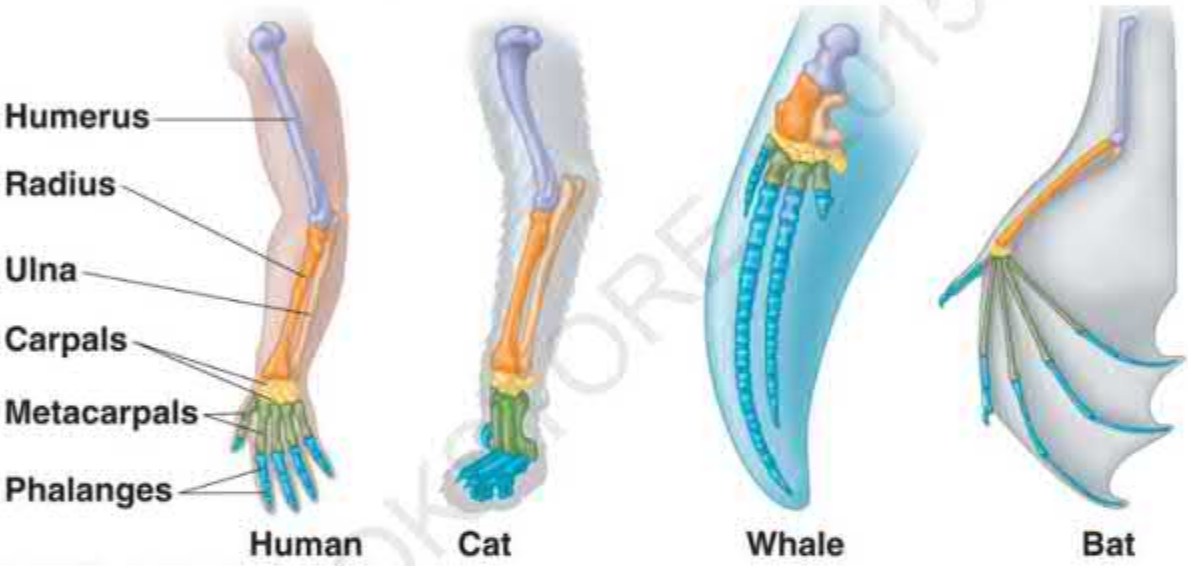
- **The fossil record shows these important facts:**
  - 99% of all organisms that ever lived on Earth are now extinct.
  - Through studies of radioactive dating and half-life, we know that Earth is about 4.6 billion years old.
  - Prokaryotic cells are the oldest fossils and were the first organisms to develop on Earth.

- **Transitional fossils** that link older extinct fossils to modern species. For example, Archaeopteryx is a fossil that shows both reptile and bird characteristics.
- **Index fossil:** Fossil of living organisms on which we depend in the comparison between the layers of sedimentary rocks in order to determine their relative ages

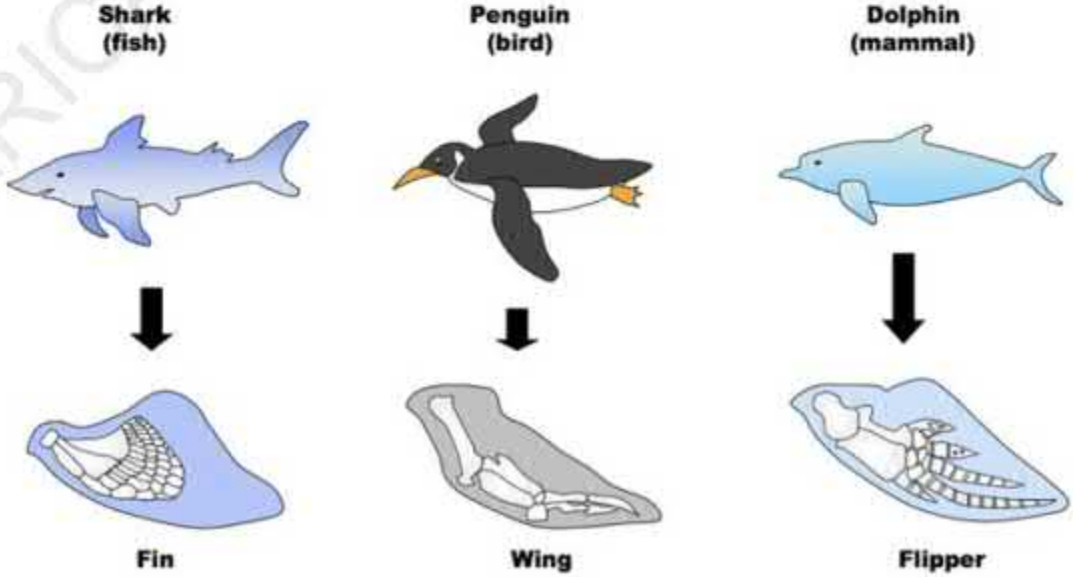
Comparative anatomy

Organisms that have similar anatomical structures are related to each other and share a common ancestor. Example, a comparison of dental structure in chimpanzees and humans demonstrates that we are related and that we both descended from a common ancestor less than 10 million years ago.

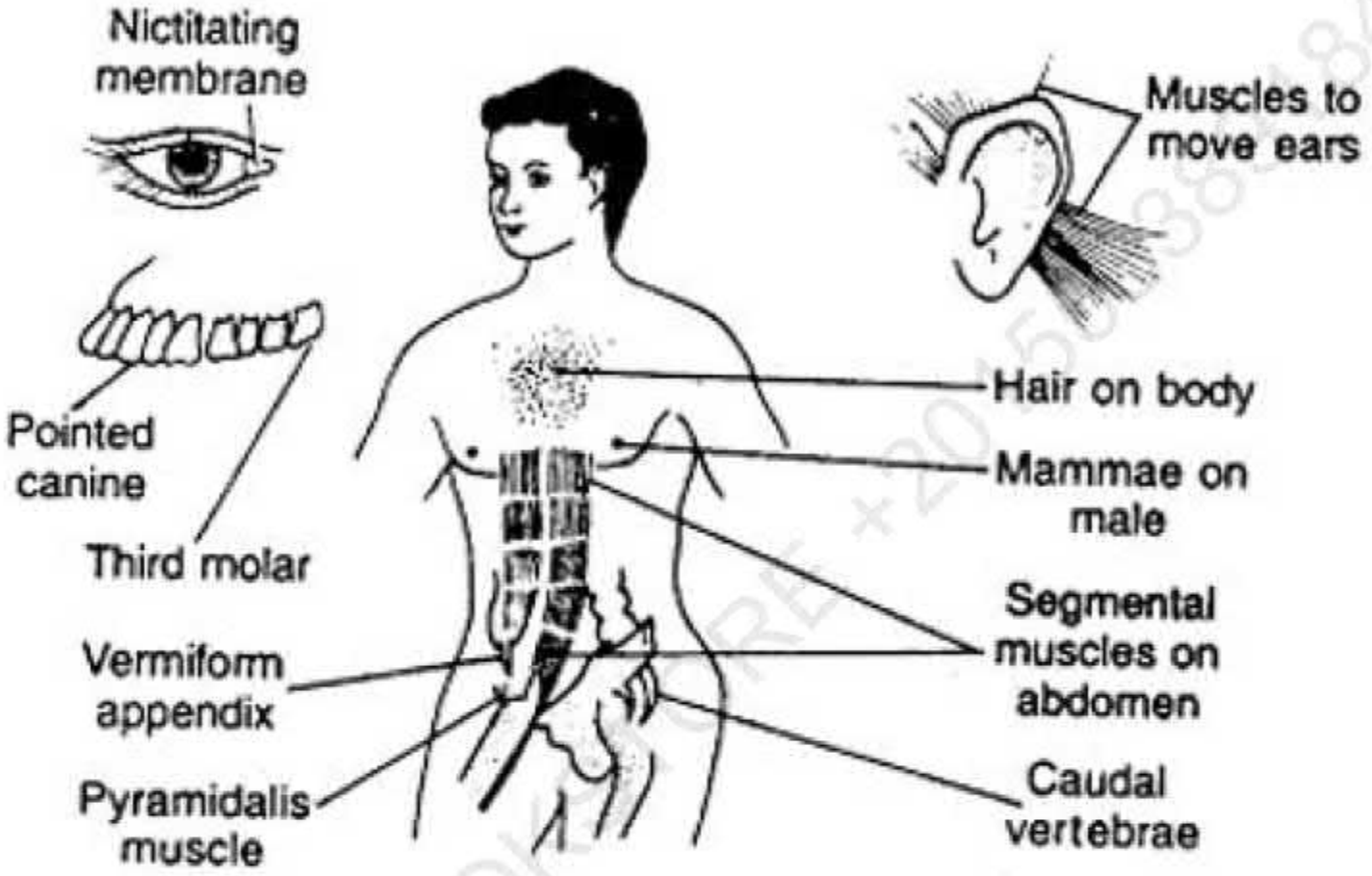
A- **Homologous structures** : Same structure but different functions (Bat wing , Human hand)



B- **Analogous structure**: Different structures , but same function (Not Evidence) Ex: Bat wing and Fly wing.
Analogous structures are evidence of convergent evolution.



C- **Vestigial structure**:- Structures that once had a function and lost the function and reduced with time ex: Human appendix , ostrich wings , and snake hind limbs



Vestigial organs of man

Comparative Biochemistry

- Organisms that have a common ancestor will have common biochemical pathways.
- The more closely related organisms are to each other, the more similar their biochemistry is.
- Researchers can test new medicines on mice because mice and human are both mammals

Comparative Embryology

- Closely related organisms go through similar stages in their embryonic development
- Example all vertebrate embryos have **gill pouches** on the sides of their throats. In fish, the gill pouches develop into **gills**. In humans, they develop into **eustachian tubes** that connect the middle ear with the throat.

Molecular Biology

- All aerobic organisms contain cells that carry out respiration and require electron transport chains,

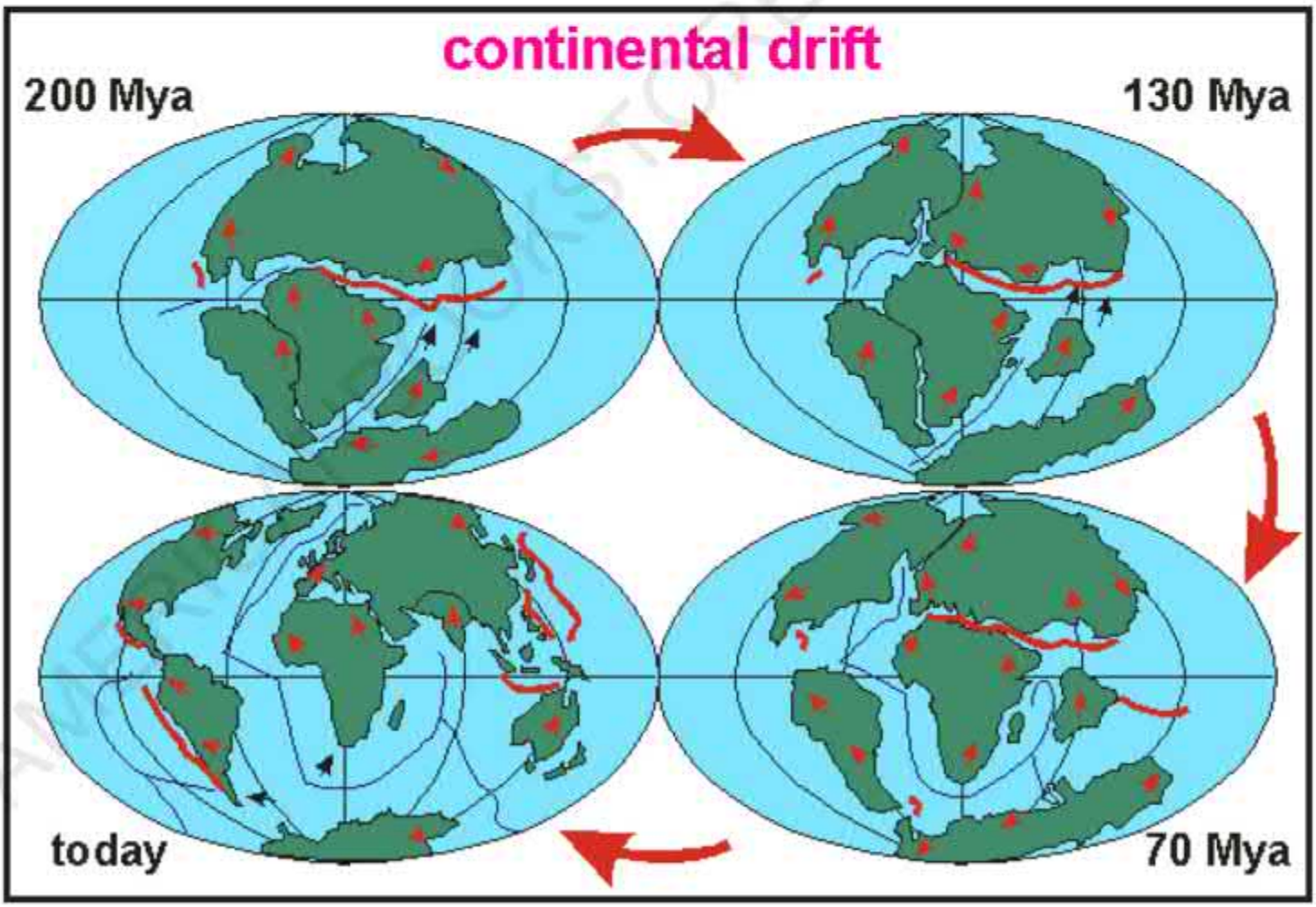
- A comparison of the amino acid sequence of **cytochrome c** among different organisms shows which are most closely related.

  "The cytochrome c in human cells is identical to that of our closest relative, the chimpanzee, but differs somewhat from that of a pig and is vastly different from the cytochrome c found in paramecia or in oak leaves."

Biogeography

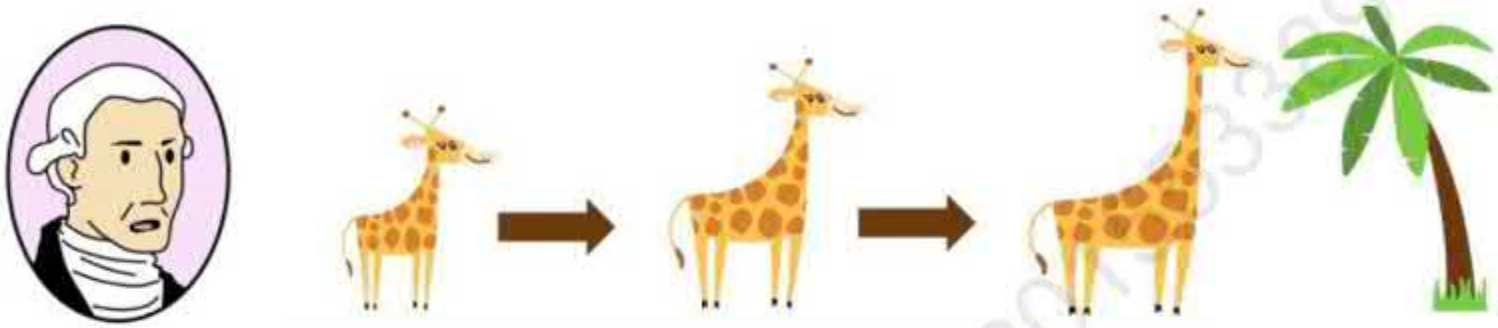
- The theory of continental drift states that about 250 million years ago, the continents were locked together in a single supercontinent known as Pangaea, which slowly separated into seven continents over the course of the next 150 million years.

- Study of the location of the fossils, confirms the theory that **marsupials** migrated by land from South America across Antarctica to Australia before those two became separate continents about 55 million years ago. Today most of the world's marsupials are isolated in Australia.



Lamarck Theory of evolution:

- His theory relied on the ideas of inheritance of acquired characteristics and use and disuse.
- Individual organisms change in response to their environment.
- Example: The giraffe developed a long neck because it ate leaves of the tall trees and had to stretch to reach them.



Jean Baptiste Lamarck – Evolution by *Transformation* (1809)

Long-necked giraffes evolved as generations of giraffes stretched their necks to reach higher leaves

DARWIN'S THEORY OF NATURAL SELECTION

- Populations tend to grow exponentially, to overpopulate, and to exceed their resources.
- Overpopulation results in competition and a struggle for existence.
- There is variation and an unequal ability of individuals to survive and reproduce (but he didn't identify the source of variation)
- Only **the best-fit** individuals survive and get to pass on their traits to offspring. **(survival of the fittest)**
- Evolution occurs as advantageous traits accumulate in a population.

Charles Darwin – Evolution by *Descent with Modification* (1859)

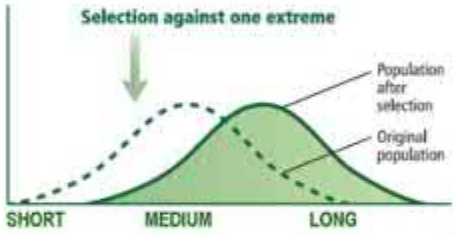
Long-necked giraffes are randomly born and have more offspring due to their competitive advantage

Evolution and Drug Resistance

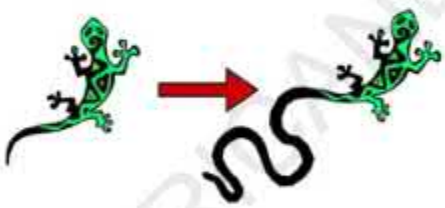
- Not all evolution occurs slowly. Natural selection can produce very rapid shifts in populations.
- For example, a few years after the discovery of antibiotics, bacteria appeared that were resistant to these drugs.
- Antibiotics killed susceptible bacteria only resistant individuals survived to reproduce, the next generation was resistant to the antibiotic they were exposed to.
- An entire population of bacterium can "become" resistant to a particular antibiotic in a matter of **months.**

TYPES OF NATURAL SELECTION

Directional Selection

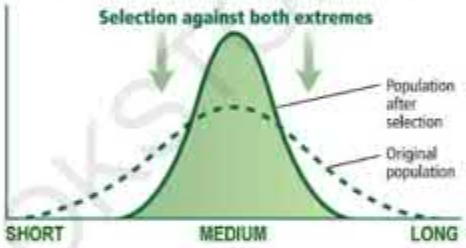


FOR: one extreme trait
AGAINST: the other extreme



EX. Long wiggly tails look like a snake and scare predators. The longer the tail, the more it looks like a snake.

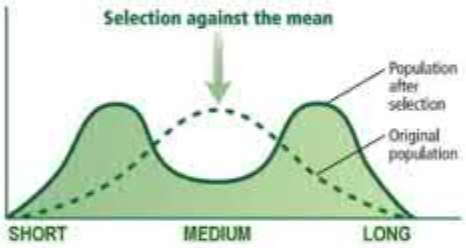
Stabilizing Selection



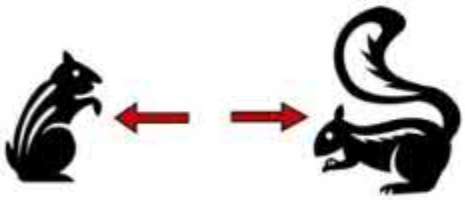
FOR: moderate traits
AGAINST: both extremes

EX. Short tails mess up the cat's balance. Long tails drag on the ground. Medium tails are best.

Disruptive Selection



FOR: both extremes
AGAINST: moderate traits



EX. Short tails help keep predators from catching you on the ground. Long tails are good for balance in the trees. Medium tails don't help.

- The process of natural selection can alter the frequency of inherited traits in a population in three different ways, depending on which phenotypes in a population are favored.

VARIATION WITHIN A POPULATION

- The existence of hundreds of breeds of dogs demonstrates the tremendous potential for variation within a species.
- Dogs such as the Great Dane, Chihuahua, and Beagle, which are all so very different from each other, belong to one species, *Canis familiaris*.
- The sources of variation in a population are **mutation, genetic drift, and gene flow.**

- **Population**: consists of all members of one species in one place at the same time for example, all the lions on the Masai plain in Kenya
- **Population size:** the number of individuals in a population

1- Mutation:-

Mutations are changes in genetic material

2- Genetic Drift:-

Genetic drift is change in the gene pool due to chance.

Examples:

A- **BOTTLENECK EFFECT** Natural disasters such as fire, earthquake, and flood reduce the size of a population non-selectivly .

B- **THE FOUNDER EFFECT** When a small population breaks away from a larger one to colonize a new area.

3- **Gene Flow** :- the movement of alleles into or out of a population. It can occur as a result of the migration of fertile individuals or gametes between populations.

Example: pollen from one valley can be carried by the wind to another valley

POPULATION STABILITY— HARDY-WEINBERG EQUILIBRIUM

- Hardy and Weinberg, two scientists, developed a theorem that described a stable, nonevolving population, that is, one in which allelic frequency does not change.
- For example, if the frequency of an allele for a particular trait is 0.5 and the population is not evolving, then in 1,000 years, the frequency of that allele will still be 0.5.
- This is called Hardy-Weinberg equilibrium.
- The characteristics of a stable population are:
  1) **The population must be very large**
  2) **Isolated from other populations.**
  3) **There must be no mutations in the population.**
  4) **Mating must be random.**
  5) **There must be no natural selection.**

Hardy-Weinberg Equation

$$p + q = 1 \text{ or } p^2 + 2pq + q^2 = 1$$

p to stand for the dominant allele
q to stand for the recessive allele
p2 represents the homozygous dominant individual.
q2 represents the homozygous recessive individual.
2pq Heterozygous

TRY THIS!!

If 9 percent of the population has blue eyes, what percent of the population is hybrid for brown eyes? Homozygous for brown eyes?

SOLUTION

1. The trait for blue eyes is homozygous recessive, bb, and is represented by q^2. In this example, q2 = 9% Convert to a decimal: $q^2 = 0.09$
2. To solve for q, take the square root of 0.09 = 0.3
3. Since p + q = 1 and q = 0.3, then p = 0.7
4. The hybrid condition is represented by 2pq
5. the percent of the population that is hybrid, substitute for 2(p)(q). 2(0.7) (0.3) = 0.42. Convert to a percent: 2pq = 42%
6. Homozygous dominant is represented by p^2.
   $p^2 = (0.7)2 = 0.49$ ……
   Convert to a percent: p2 = 49%

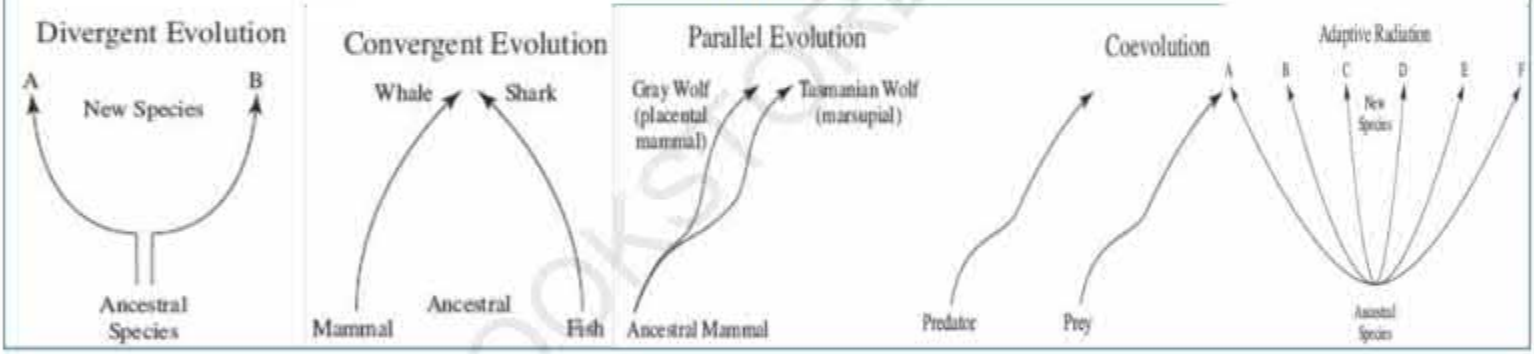
ISOLATION AND NEW SPECIES FORMATION

- A species is a population whose members have the potential to interbreed in nature and produce viable, fertile offspring.
- Anything that fragments a population and isolates small groups of individuals may foster the formation of new species.
- If enough time elapses, the two populations may become so different that, even if they were brought back together, interbreeding would not occur.
- At this point, a new species is said to have come into being.
- **Isolation factors:**

1. **Geographic isolation:** occurs when species are separated by things like Mountain ranges, canyons, rivers, lakes.
2. **Polyploidy:** a type of mutation that results from errors during meiosis instead of being haploid (n) or diploid (2n), polyploid organisms can be tetraploid (4n) or octoploid (8n).
3. **Habitat isolation:** occurs when two organisms live in the same area but encounter each other rarely. "one inhabits the water while the other inhibits the trees".
4. **Behavioral isolation:** occurs when two animals become isolated from each other because of some change in behavior by one member or group
5. **Temporal isolation:** Temporal refers to time. Different plants of one species living in the same area may become functionally separated into two populations because some plants become sexually mature earlier
6. **Reproductive isolation:** Closely related species may be unable to mate because of anatomical incompatibility. Example, a small male dog and a large female dog cannot mate because of the enormous size differences between the two animals.

PATTERNS OF EVOLUTION

Divergent Evolution	Convergent Evolution	Parallel Evolution	Coevolution	Adaptive Radiation:
when a population becomes isolated	When unrelated species occupy the same environment	two related species that have made similar evolutionary adaptations after their divergence	the mutual evolutionary set of adaptations of two interacting species	the emergence of numerous species from a single common ancestor
Homologous structures	Whale (mammal) and shark (fish) both have streamline appearance	gray wolf of North America and the Tasmanian wolf of Australia	Pollinator-plant	finches on Galapagos islands



THEORIES ABOUT EVOLUTION

1. **Gradualism:** It is the theory that organisms descend from a common ancestor gradually, over a long period of time, in a linear or branching fashion. Big changes occur by an accumulation of many small ones.

2. **Punctuated Equilibrium:** This theory proposes that new species appear suddenly after long periods of no change. Most likely, a new species arises in a different place and expands its range, competing with and replacing the ancestral species that becomes extinct

3. **Spontaneous Generation:** It is the theory that living things emerge from nonliving or inanimate objects.

HOW LIFE BEGAN

1. **A. I. Oparin and J. B. S. Haldane**, in the 1920s, hypothesized separately that under the conditions of early Earth, organic molecules could form. They stated that in the absence of corrosively reactive molecular oxygen that would react with and degrade them, organic molecules could form and persist.

2. **Stanley Miller and Harold Urey**, in the 1950s, tested the Oparin-Haldane hypothesis and proved that almost any energy source would have converted inorganic molecules in the early atmosphere into a variety of organic molecules, including amino acids.

3. **Sidney Fox**, He was able to produce membrane-bound, cell-like structures he called **proteinoid microspheres**, which would last for several hours in a laboratory.

The Heterotroph Hypothesis and the Theory of Endosymbiosis

- First cells on Earth were anaerobic heterotrophic prokaryotes.
- The first cell evolved about 3.5 billion years ago.
- Eukaryotic cells with a nucleus and other internal organelles evolved about 1.5 billion years ago from prokaryotic cells , when smaller prokaryotes took up residence inside larger prokaryotic cells and performed important functions for the host cell.
- the first multicellular animals appeared about 565 million years ago.
- **Cambrian explosion:** The 40 million years during which , all the all the different phyla appeared
- Animals moved from the oceans to the land

Several characteristics enabled animals to move to land:

- Lungs
- Skin to keep the animals from drying out
- Limbs to move about
- Mechanisms for internal fertilization and
- Shell to protect their eggs and to keep them from drying out

Several characteristics enabled plants to move to land:

- Roots that anchor them into the soil and absorb water
- Supporting cells to enable them to compete favorably for light
- Vascular tissue to carry water upward
- Waxy molecule (cutin) to protect the leaves from dehydrating
- Seeds, a protective package for the embryo and its food

Human ancestors arose in Africa. How they spread throughout the rest of the world is not agreed upon. However, scientists agree that modern humans, *Homo sapiens*, arose about 150,000 years ago.

IMPORTANT CONCEPTS OF EVOLUTION

1. Evolution is not always a slow process.
2. Evolution does not occur at the same rate in all organisms.
3. Evolution does not always cause organisms to become more complex.
4. Evolution occurs in populations, not individuals.
5. Evolution is directed by changes in the environment.

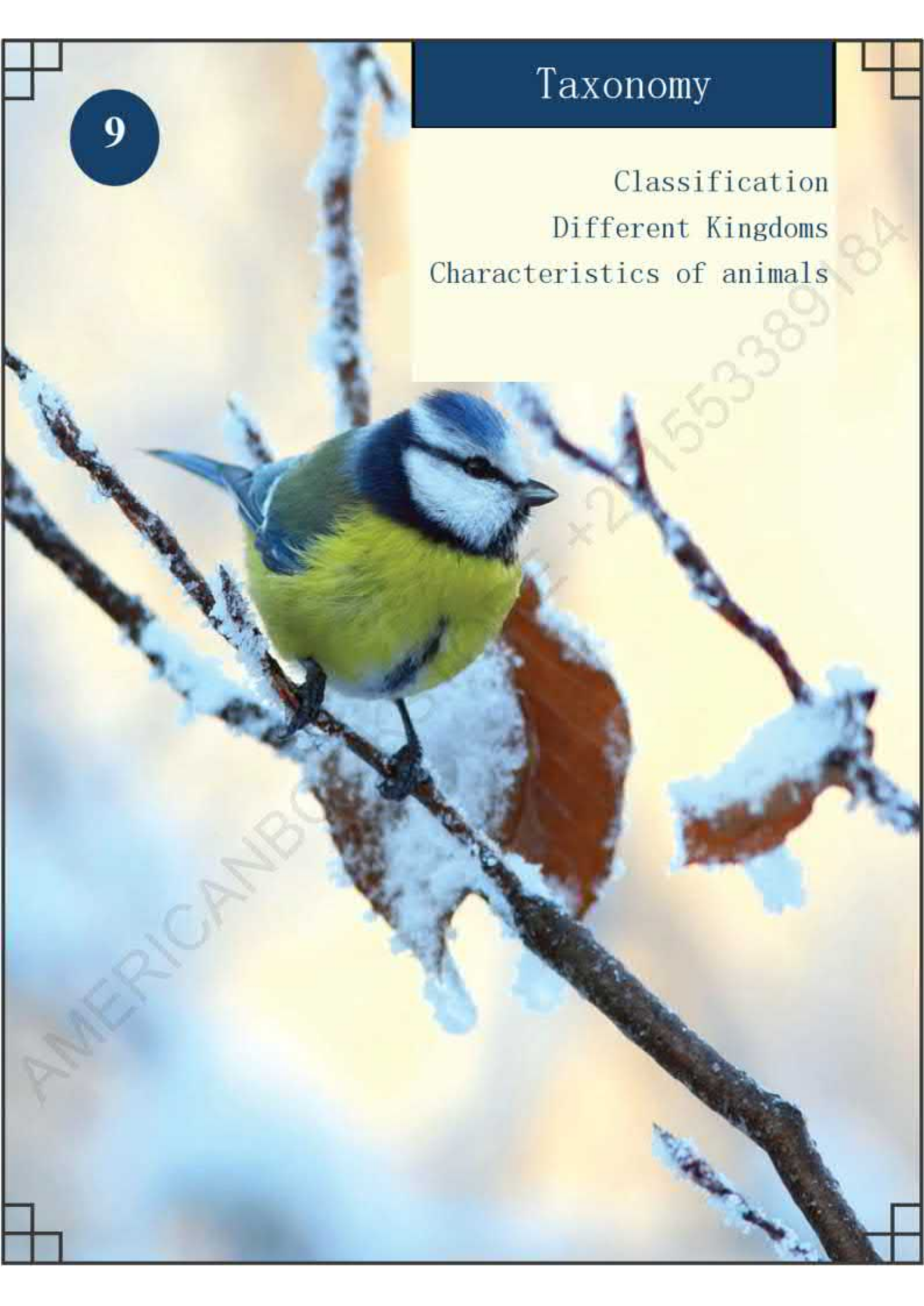
9

Taxonomy

Classification

Different Kingdoms

Characteristics of animals



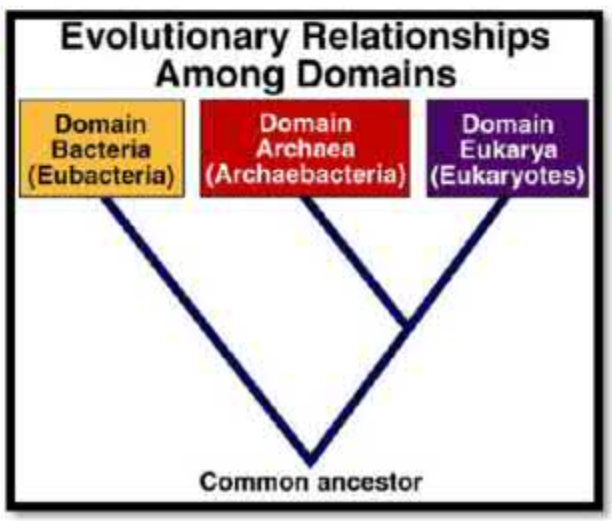
TAXONOMY

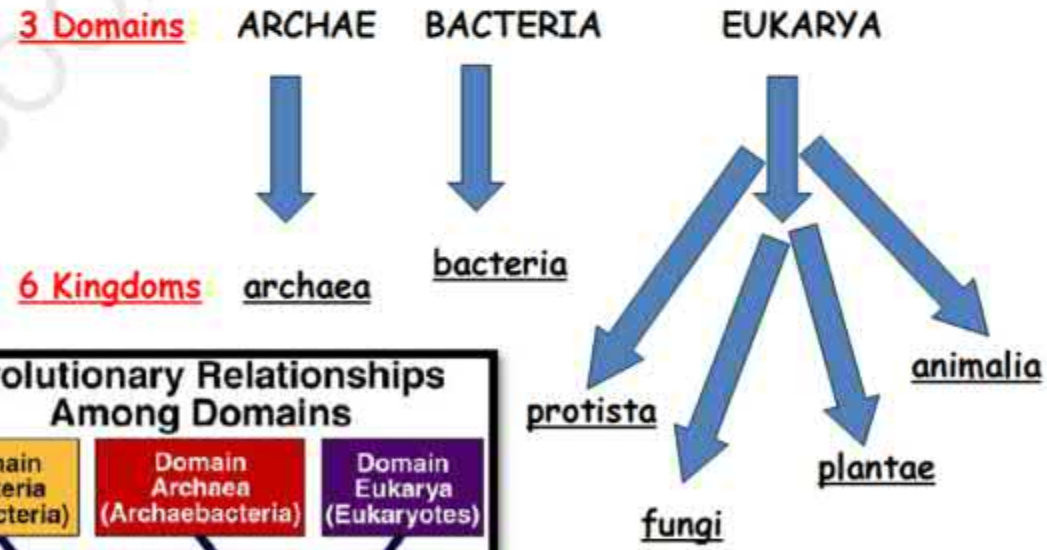
- It is a system by which we name and classify all organisms, living and extinct.
- The classification is based on the shared characteristics
- **Carl Linnaeus** invents two systems:

  1. The Taxonomic hierarchy is the process of arranging various groups, class and other categories into successive levels of the biological classification. Which are **kingdom, phylum, class, order, family, genus , and species.**

  King Philip Come Over For Good Spaghetti

  2. Binomial nomenclature: every organism has a two-part name. For example, human is *Homo sapiens* and lion is *Panthera leo*.
- Now most scientists the **three-domain system**, which is based on DNA analysis. It reflects evolutionary history and the relationships among organisms.





TAXONOMY

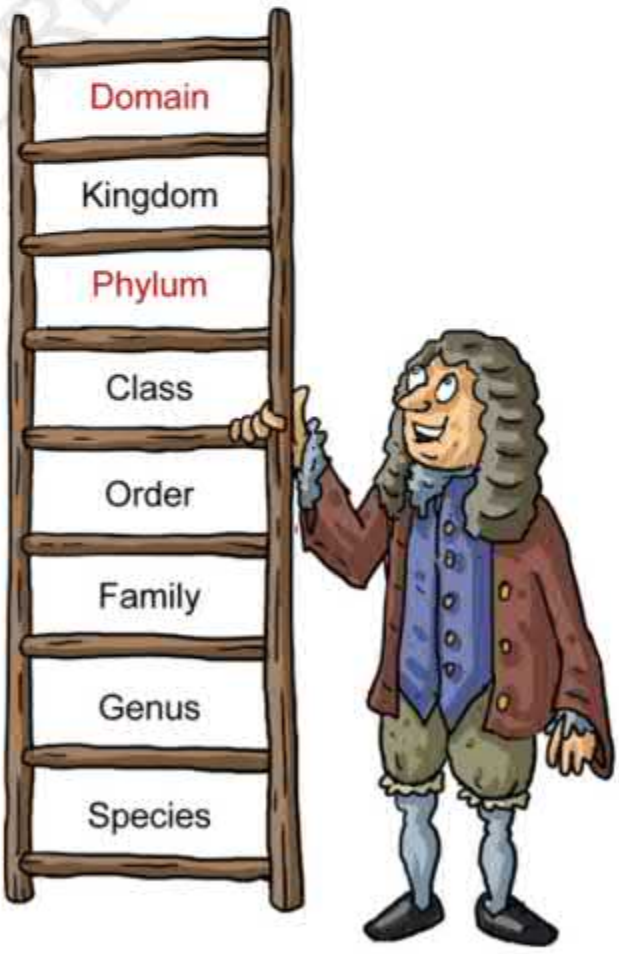
Notes

- **Kingdom Monera** was considered as a kingdom in 5 kingdoms classification but replaced with (Eubacteria and Archaebacteria in 6 kingdoms system later.

- **Algae**

It covers many different organisms capable of producing oxygen through photosynthesis. Some prokaryotes as Cyanobacteria (Blue green algae) and others are Eukaryotes.

Whittaker 1969 5 kingdoms	Woese et al. 1977 6 kingdoms	Woese et al. 1990 3 domains
Monera	Eubacteria	Bacteria
	Archaebacteria	Archaea
Protista	Protista	Eukarya
Fungi	Fungi	
Plantae	Plantae	
Animalia	Animalia	



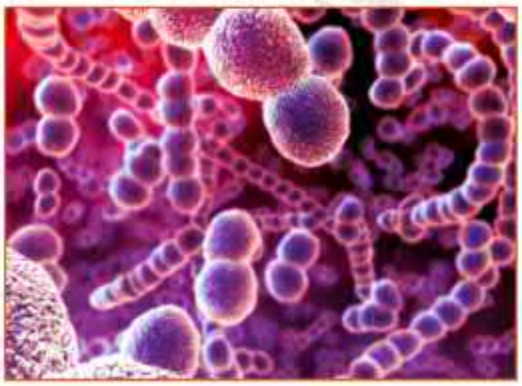
THE THREE-DOMAIN CLASSIFICATION SYSTEM

All organisms are classified into one of the three domains. "Notice that two domains, Bacteria and Archaea, both include prokaryotes"

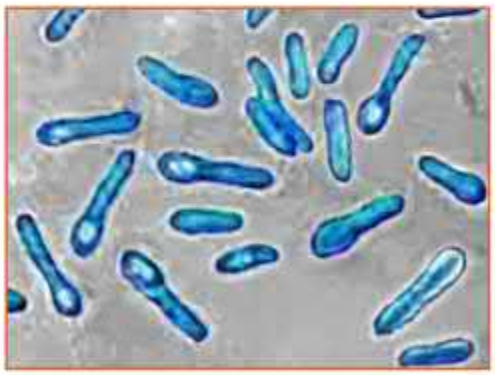
D. Bacteria

K. Eubacteria

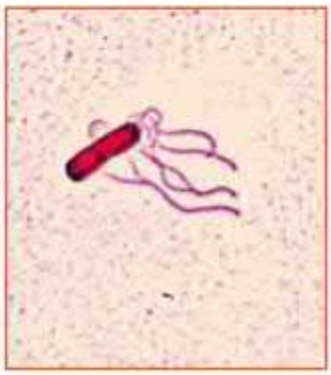
- Single celled
- Prokaryotes (no nucleus, no membranous organelles)
- Some are anaerobes; some are facultative anaerobes or aerobes.
- Mainly decomposers
- Many are pathogens, disease causing.
- Some bacteria carry out conjugation (sexual reproduction)
- cell wall containing peptidoglycan.
- Some carry out photosynthesis, but others don't.
- Has no introns (noncoding regions within the DNA)
- Small size 0.1– 15 micron
- Examples:
    1. Cyanobacteria (photosynthetic)
    2. E.coli that live in the human intestine,
    3. Clostridium botulinum and Streptococcus (pathogenic)
    4. Nitrogen-fixing bacteria



Streptococcus pneumnae bacteria. The bacteria causes many different diseases such as pneumonia



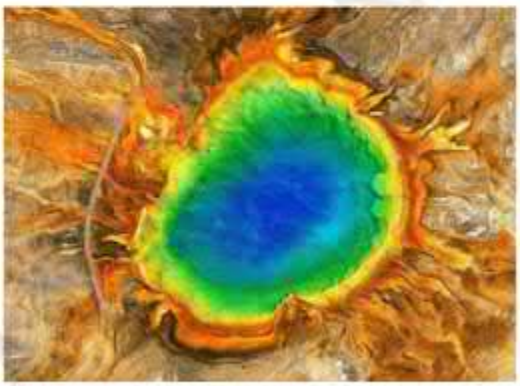
Clostridium botulinum



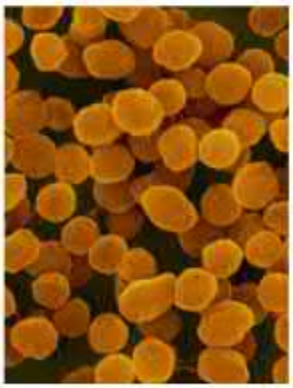
rod-shape E.coli bacteria, showing its long flagella

D. Archaea K. Archaebacteria

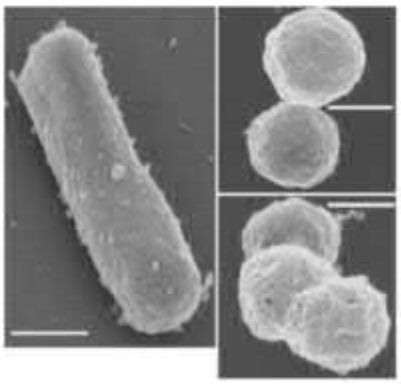
- Single celled
- Prokaryotes (no nucleus, no membranous organelles)
- Similar to D. Bacteria in shape and size
- Genes and several metabolic pathways more related to eukaryotes
- May contain introns
- Cell wall (not containing peptidoglycan)
- Archaea reproduce asexually by binary or multiple fission, fragmentation, or budding.
- Archaea are a major part of Earth's life, and may play roles in the **carbon cycle and the nitrogen cycle**.
- Includes **extremophiles** "live in extreme environments" like
  1. **Methanogens** Obtain energy by producing methane from hydrogen
  2. **Halophiles** Thrive in environments with high salt
  3. **Thermophiles** Thrive in very high temperatures
  4. **Psychrophiles** those that live at unusually cold temperatures



An aerial view show Grand Prismatic Spring in Yellowstone National Park. Where only archaebacteria could live



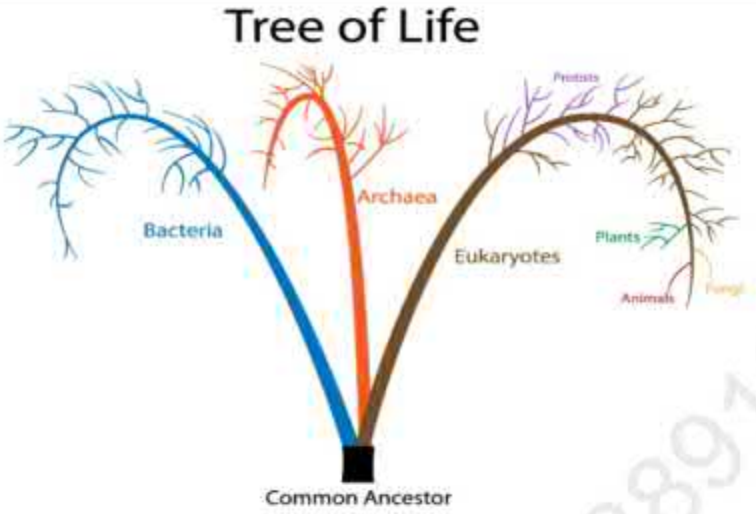
Methanococcales



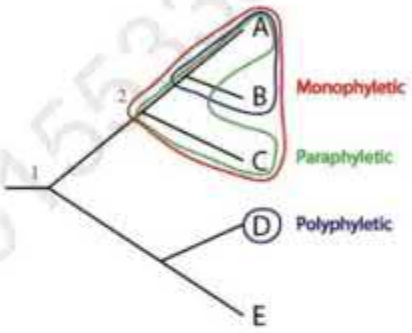
canning electron micro-graphs of Halobacterium salinarum

D. Eukarya

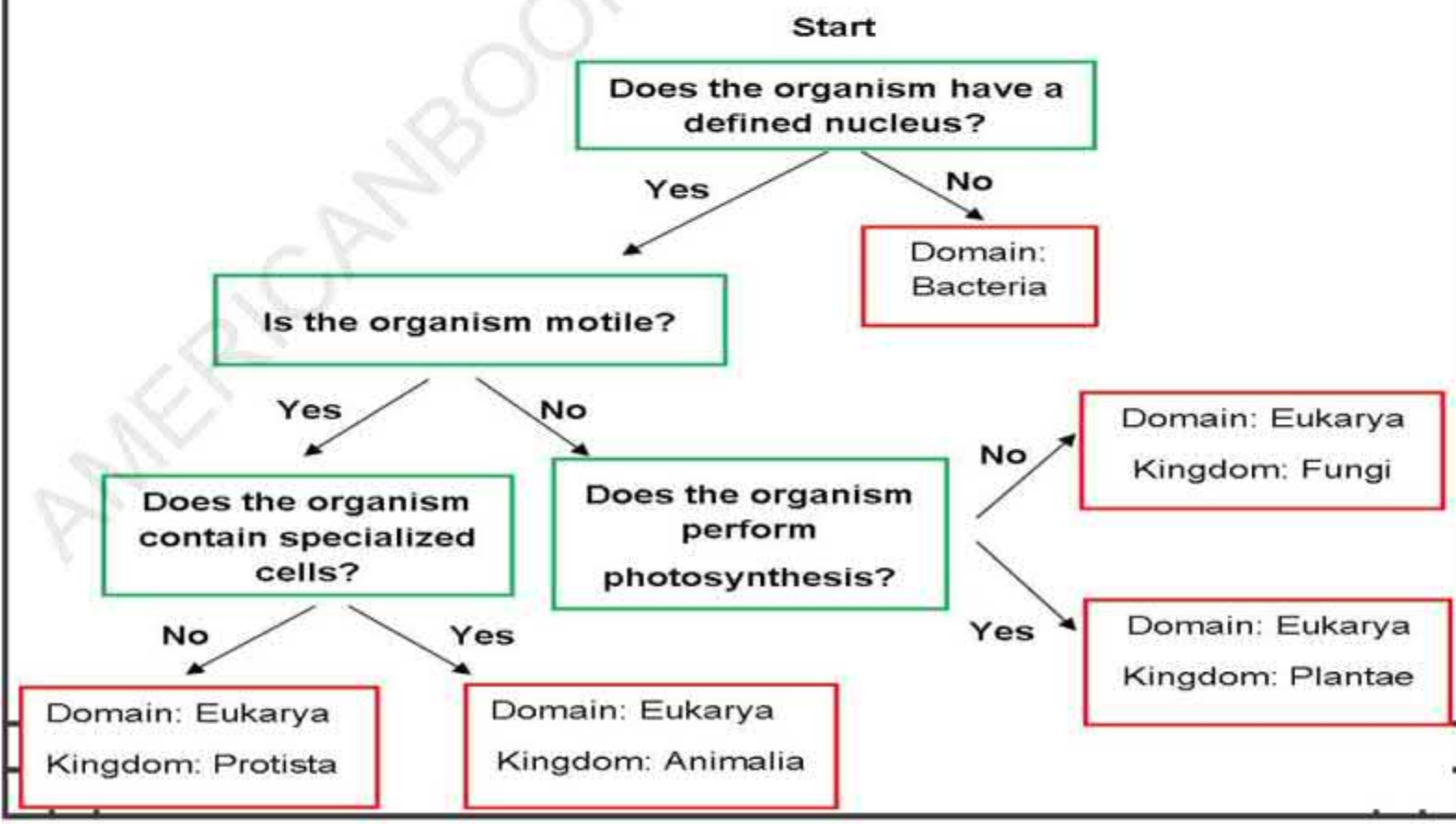
- K. Animalia
- K. Plantae
- K. Fungi
- K. Protista

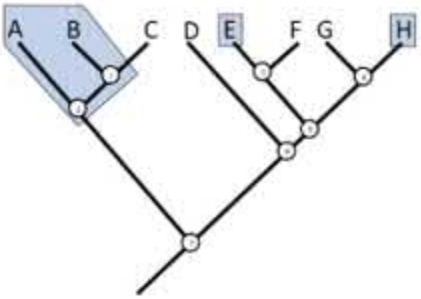


- Single or multicellular
- Eukaryotes (have nucleus and membranous organelles)
- Sexual or asexual reproduction
- The domain **Eukarya** appears to be monophyletic



- Eukaryotes represent a tiny minority of all living things. However, due to their generally much larger size, their collective worldwide biomass is estimated to be about equal to that of prokaryotes.
- **Eukarya** includes the four remaining kingdoms: **(Protista, Fungi, Plantae, and Animalia)**

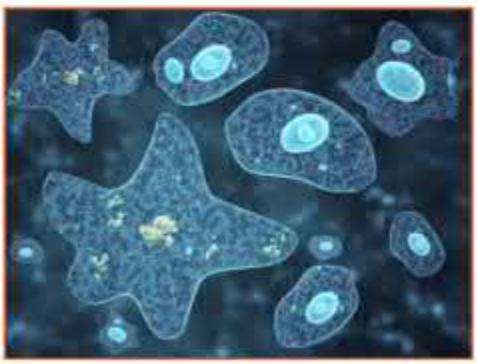




K. Protista

- Eukaryotes.
- The Protista are **polyphyletic**
- Most are single-celled, but many are primitive multi-celled
- Some have cell wall
- Most live in water (Aquatic)
- Includes heterotrophs and autotrophs.
- Examples of heterotrophs are **amoeba and paramecium**.
- Examples of autotrophs are **euglenas**
- Movement by various ways: amoeba uses pseudopods; paramecium uses cilia; euglena uses a flagellum.
- Protista includes organisms that do not fit into the fungi or plant kingdoms, such as seaweeds and slime molds.
- Some Protista (such as paramecium and algae) sometimes carry out conjugation.
- Some cause serious diseases, like amoebic dysentery and malaria.
- The three different types of protists:
  - animal like (**protozoa**) example paramecium
  - plant like (**algae**) example Diatoms
  - fungus-like (**mold**) example slim molds and water molds

Euglena



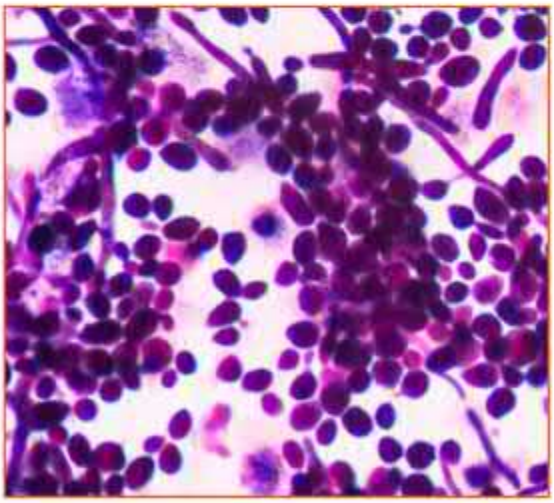
Amoeba

Paramecium

K. Fungi

- Eukaryotes.
- Multi cellular except yeast (unicellular)
- cell wall (chitin)
- Most live in water
- Heterotrophs (parasitic or decomposers)
- Fungi are **saprobes** (organisms that obtain food from decaying organic matter)
- Fungi carry out extracellular digestion by secreting hydrolytic enzymes outside the body, then absorb nutrients By Diffusion.
- Certain fungi combine with algae in a mutualistic, symbiotic relationship forming various **lichens**, which are photosynthetic. Lichens can survive harsh, cold environments and even live on bare rock.
- They reproduce asexually by **budding** (yeast), **spore formation** (bread mold), or **fragmentation** whereby a single parent breaks into parts that regenerate into whole new individuals.
- They also reproduce sexually.
- Examples include yeast, mold, mushrooms and Mucor (bread mold fungus)

British solider lichen

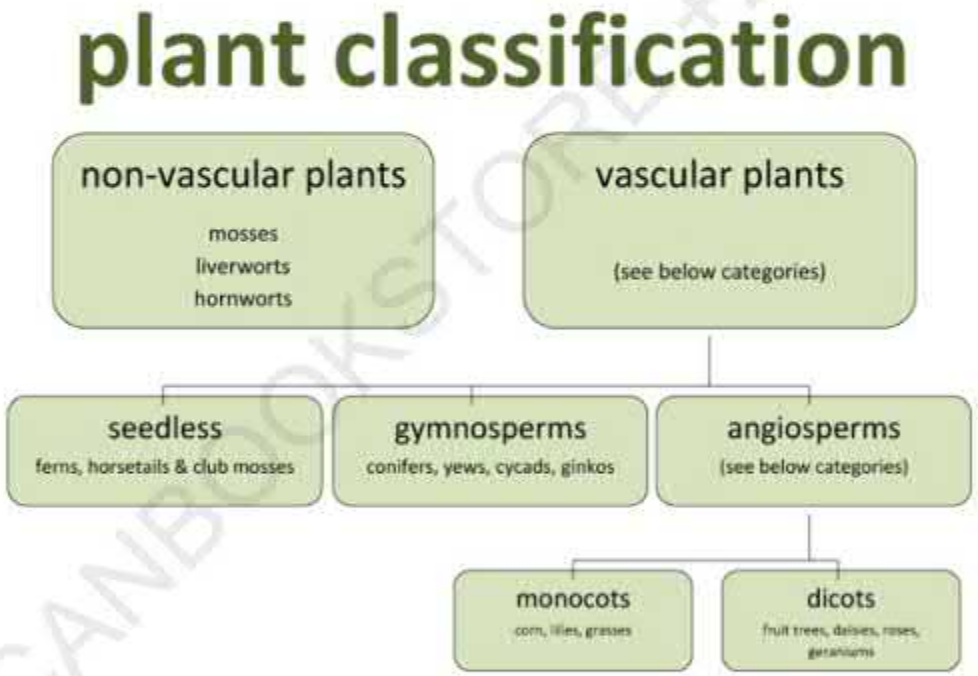


Yeast

Mucor

K. Plantae

- Multicellular
- Non-motile
- Autotrophic (carry out photosynthesis)
- Eukaryotes.
- Their cell walls are made of cellulose.
- They reproduce sexually and asexually by alternating between gametophyte (n) and sporophyte (2n) generations (known as alternation of generations).
- Examples include mosses, ferns, and cone-bearing and flowering plants.

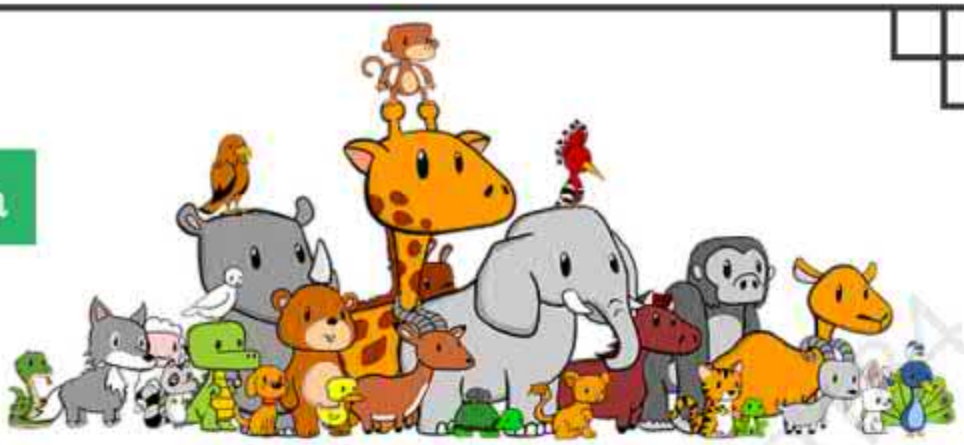


Mosses

Ferns

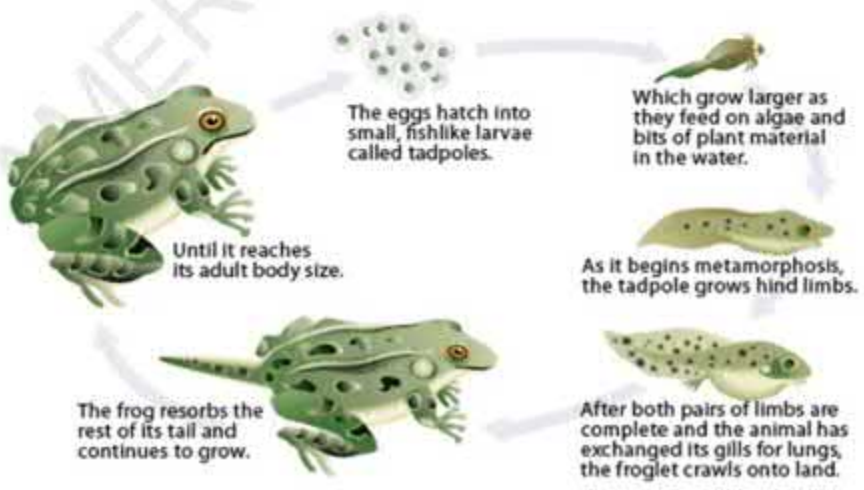
Mucor

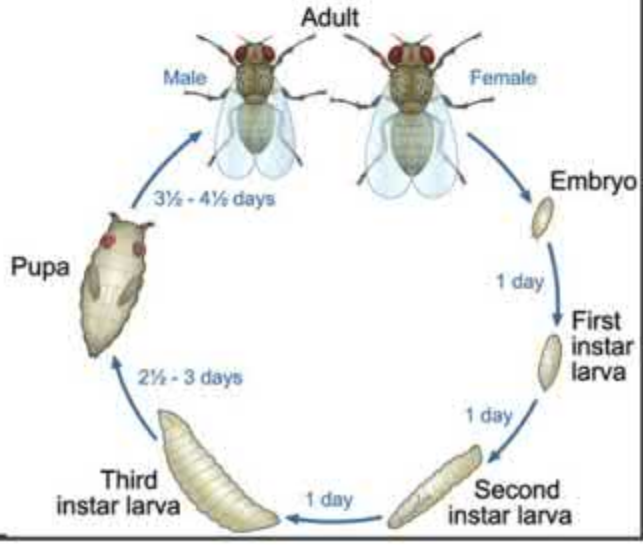
K. Animalia | 35 Phyla



- Multicellular
- Motile (most of them)
- Heterotrophic
- Eukaryotes.
- Reproduce sexually (most of them)
- Classified based on anatomical features & embryonic development.
- They are grouped in 35 phyla
- Examples: **porifera, cnidarians, Platyhelminthes, nematodes, annelids, mollusks, arthropods, echinoderms, and chordates.**
- Most animals show complex development, with extended embryonic phase, often with free living larval stages.
- all organisms pass through a characteristic life cycle involving changes in size and shape

  e.g. Frog: embryo - larva - adult
  Human: embryo - fetus - juvenile - adult
  Butterfly: embryo - caterpillar (larva) - pupa - adult
  Fly: embryo - maggot (larva) - pupa - adult
- Some involve alternation of two completely different body forms; one that reproduces asexually, one sexually
- The immature forms may be self-sufficient or completely dependent on mother for nourishment and protection

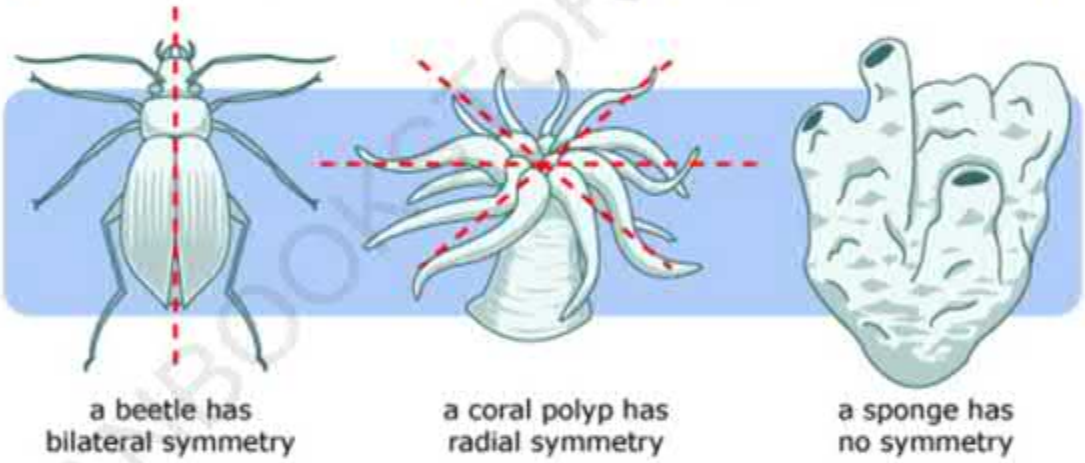




K. Animalia

- Animals can be classified into 34 phyla based mainly on:

1. Overall body form: sac like, tube like, segmented, solid body or with body cavity.
2. Level of complexity of structure cellular, tissue, organ, organ systems
   a. some have no true tissues or organs
   b. some have some tissues but few or no organs
   c. simple organs vs relatively complex organ systems
3. Complexity of the nervous system and sense organs e.g. nerve net, nerve cords and ganglia or brain and spinal cord.
4. Developmental and life cycle characteristics
5. Type of symmetry: asymmetrical, radial symmetry, bilateral symmetry.

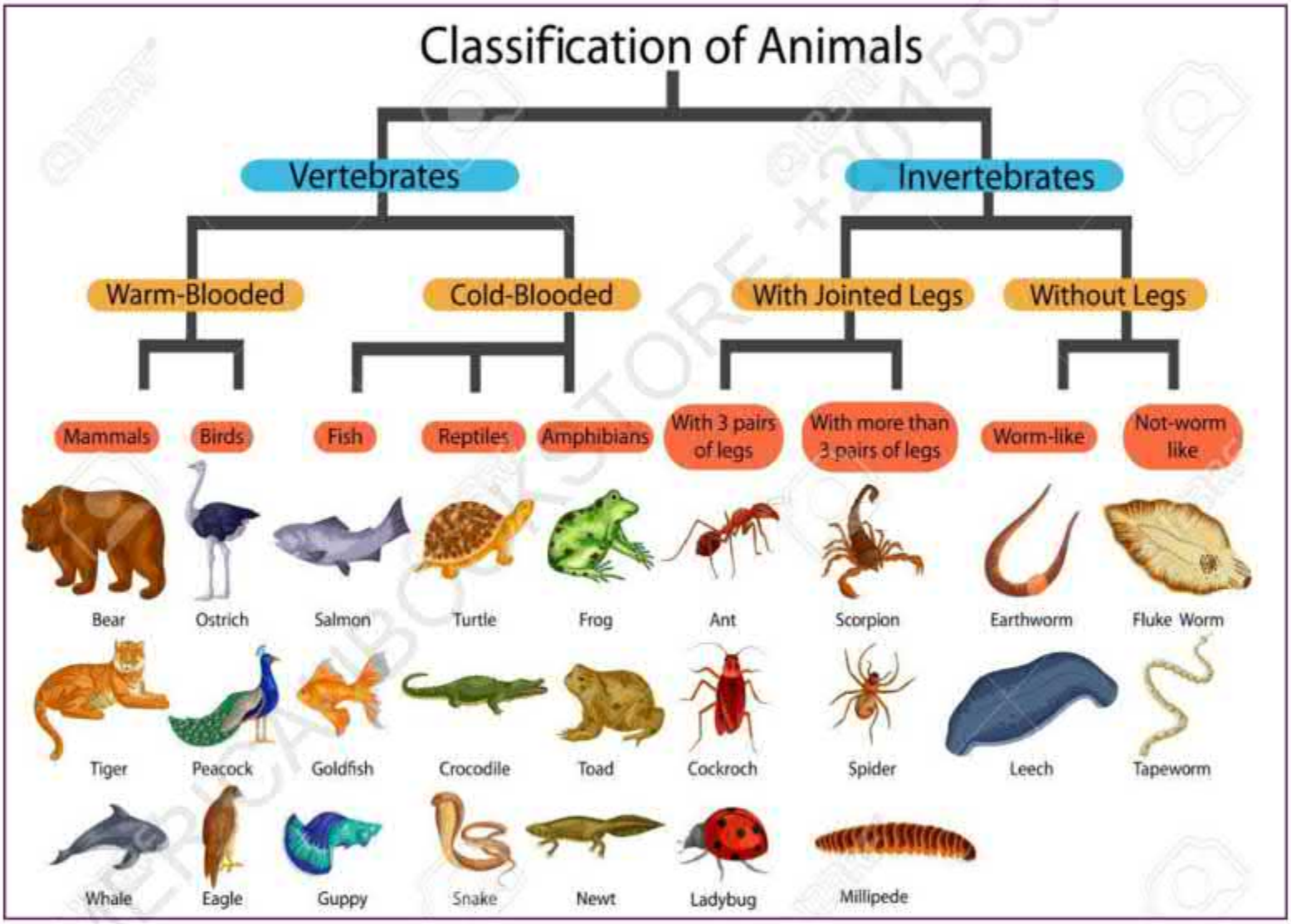


6. Degree of tissue and organ differentiation:
   Embryonic: ectoderm, mesoderm, endoderm
   Adult: epithelial, connective, muscle, nervous
7. Nature of body cavity or coelom "this is the actual space within the body in which most organs are found"
   acoelomate no body cavity - most primitive
   pseudocoelom - space, but missing tissue layers
   true coelom additional tissue layers enclosing the coelom allow for much more elaborate development of skin and internal organs, circulatory system, and nervous system

K. Animalia

8. Presence or absence of segmentation "serial repetition (segmentation) of body parts is an ancient feature of animal design"

9. Cephalization the formation of and the development of a nervous system leads to sense organs and mouth at anterior end of animal



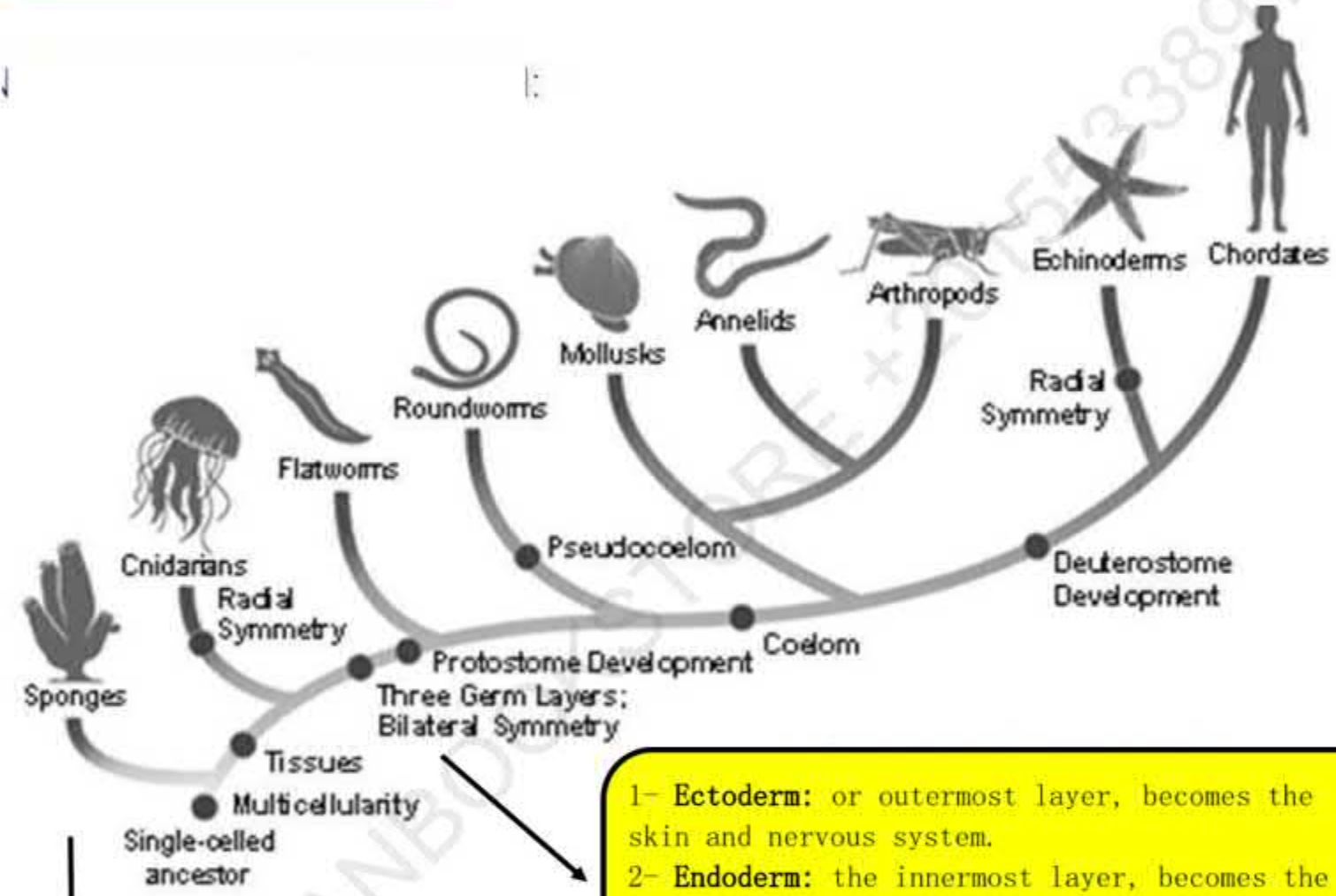
- Only 5% of animals are vertebrates
- Vertebrate is derived from the word vertebra, which refers to any of the bones or segments of the spinal column
- Found in only one phylum: Chordates

- Trends in animal evolution

Cnidarians like the hydra and jellyfish possess only the most primitive and simplest forms of tissue.

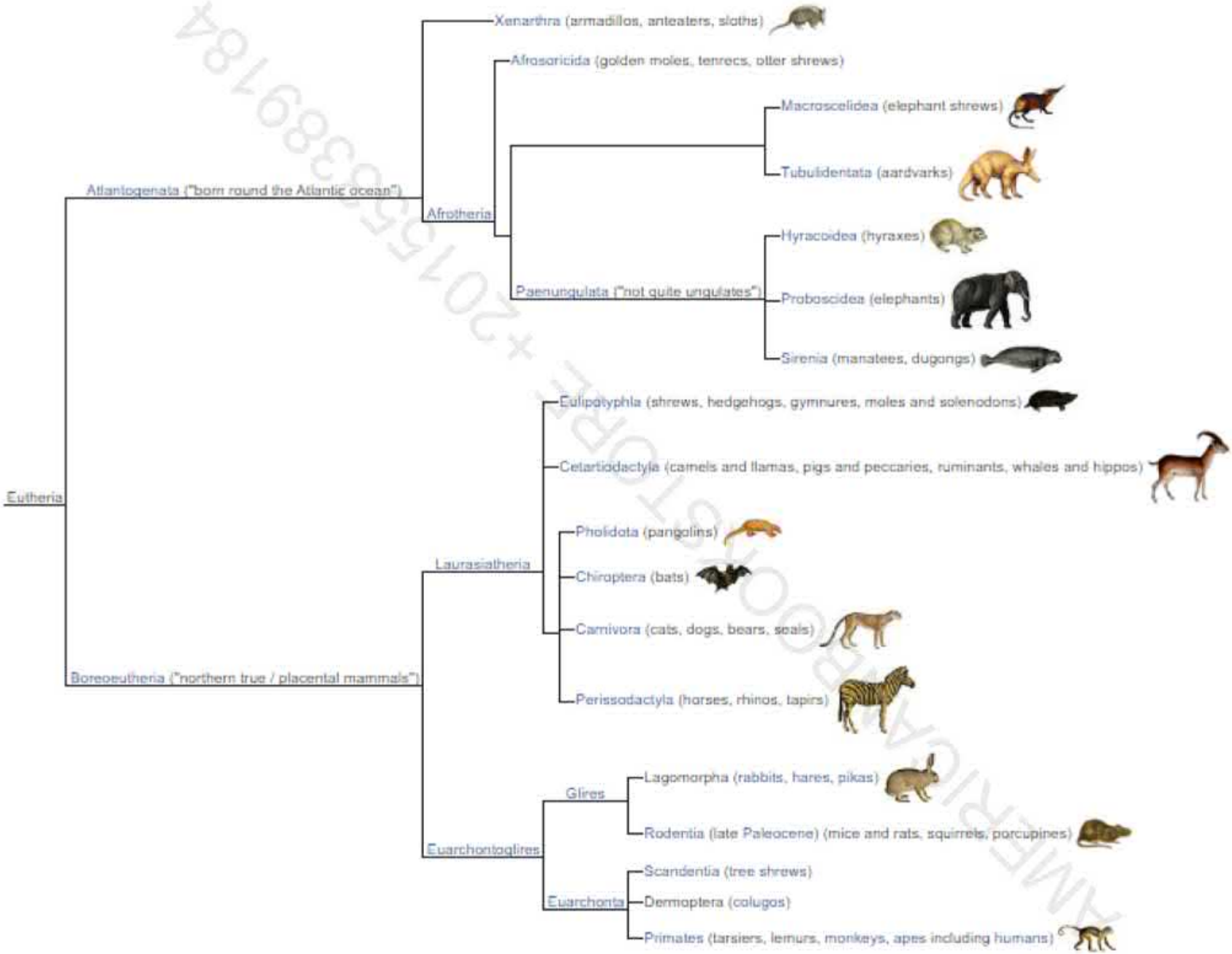
Flatworms have organs but no organ systems.

Annelids (earthworms) and **arthropods** (grasshoppers) have organ systems



1- **Ectoderm:** or outermost layer, becomes the skin and nervous system.
2- **Endoderm:** the innermost layer, becomes the viscera (guts) or the digestive system.
3- **The mesoderm:** middle layer, becomes the blood, muscles, and bones.

Sponges (porifera) consist of a loose federation of cells, which are not considered tissue because the cells are relatively unspecialized. They possess cells that can sense and react to the environment but have no real nerve or muscular tissue.


Xenarthra (armadillos, anteaters, sloths)
Afrosoricida (golden moles, tenrecs, otter shrews)
Macroscelidea (elephant shrews)
Tubulidentata (aardvarks)
Afrotheria
Atlantogenata ("born round the Atlantic ocean")
Hyracoidea (hyraxes)
Proboscidea (elephants)
Paenungulata ("not quite ungulates")
Sirenia (manatees, dugongs)
Eulipotyphla (shrews, hedgehogs, gymnures, moles and solenodons)
Cetartiodactyla (camels and llamas, pigs and peccaries, ruminants, whales and hippos)
Eutheria
Pholidota (pangolins)
Laurasiatheria
Chiroptera (bats)
Carnivora (cats, dogs, bears, seals)
Perissodactyla (horses, rhinos, tapirs)
Boreoeutheria ("northern true / placental mammals")
Lagomorpha (rabbits, hares, pikas)
Glires
Rodentia (late Paleocene) (mice and rats, squirrels, porcupines)
Euarchontoglires
Scandentia (tree shrews)
Euarchonta
Dermoptera (colugos)
Primates (tarsiers, lemurs, monkeys, apes including humans)

K. Animalia

1- Porifera (Sponges)

- Asymmetrical
- Immobile (sessile)
- No tissues, Intracellular digestion
- Consist of two cell layers only: ectoderm and endoderm.
- Reproduce asexually by fragmentation & sexually
- Hermaphrodites

2- Cnidarians (Coelenterate)

- Radial symmetry
- Body plan is the polyp (vase shaped), which is mostly sessile, or medusa (upside-down bowl shaped), which is mostly motile
- Two cell layers only: ectoderm and endoderm
- Have a gastrovascular cavity where extracellular digestion occurs
- Carry out intracellular digestion inside body cells in lysosomes
- Have no transport system
- All members have stinging cells containing stingers, which are called nematocysts

3-Flat worms (Platyhelminthes)

- Bilateral symmetry.
- Three distinct cell layers: ectoderm, endoderm, and mesoderm.
- The digestive cavity has only one opening for both ingestion and egestion
- The body is so flat and thin that many body cells can exchange nutrients and wastes by diffusion.
- Example: Planarian

4- Round worms (Nematodes)

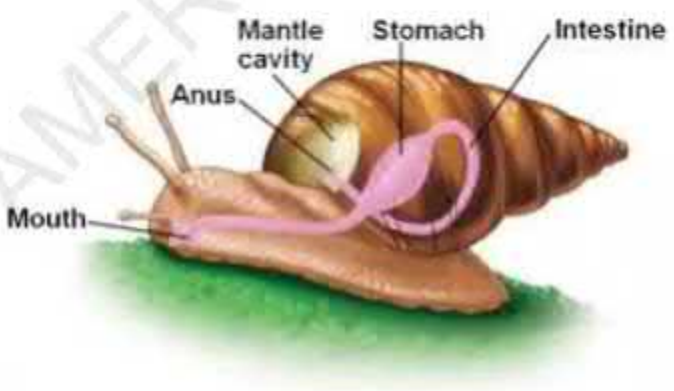
- Unsegmented worms
- Bilateral symmetry
- Little sensory apparatus.
- Parasitic or free living
- Example: Ascaris

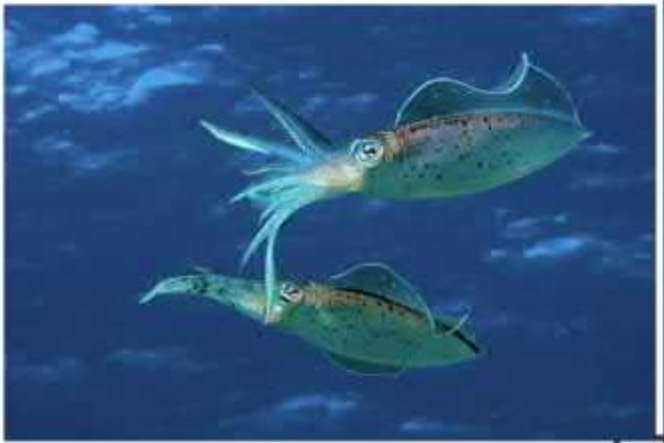
5- Segmented worms (Annelids)

- Bilateral symmetry
- Little sensory apparatus
- Digestive tract is a tube-within-a-tube
- Nephridia for excretion of the nitrogen waste, urea
- Closed circulatory system
- Heart consists of five pairs of aortic arches
- Blood contains hemoglobin and carries oxygen
- Diffusion of oxygen and carbon dioxide through moist skin
- Hermaphrodites

6- Mollusks

- Have soft body often protected by a hard calcium-containing shell
- Open circulatory system with blood-filled spaces called hemocoels or sinuses
- Have bilateral symmetry with three distinct body zones:
  1. **Head-foot**, which contains both sensory and motor organs
  2. **Visceral mass**, which contains the organs of digestion, excretion, and reproduction
  3. **Mantle**, a specialized tissue that surrounds the visceral mass and secretes the shell
- Have **Radula**, a movable, tooth-bearing structure, acts like a tongue
- Most have gills and nephridia
- Example: Snails, Oyster, Octopus and squids



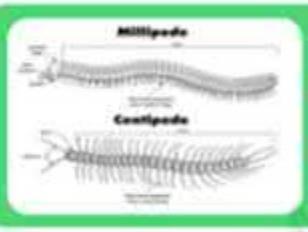


7- Arthropods

- Forms 2/3 of all species of animals
- Jointed appendages
- Segmented into head, thorax, abdomen
- More sensory apparatus than in annelids, giving them more speed and freedom of movement
- Chitinous exoskeleton protects the animal and aids in movement
- Open circulatory system with a tubular heart
- Malpighian tubules for removal of nitrogenous wastes, uric acid
- Air ducts called trachea bring air from the environment into hemocoels
- Have 4 classes:

Crustaceans

- Crusta means hard shell
- More than 4 pairs of jointed legs
- Example: Prawns, Crabs, Lobsters



Myriapoda

- Many similar segments, each with at least one pair of jointed legs
- Example: Centipedes and Millipedes

Insecta

- Body divided into head, thorax and abdomen,
- 6 jointed legs attached to the thorax
- 4 wings attached to the thorax
- Example: Cockroach, butterflies, grass hopper

Arachnids

- Body divided into head cephalothorax
- 4 pairs of jointed legs
- Example: Spider, Scorpion, Limulus, Ticks and mites

8- Echinoderms

- Marine animals
- Sessile or slow moving.
- Bilateral symmetryas an embryo
- primitive radial symmetry as an adult.
- Water vascular system
- Tube feet
- Reproduce by sexual reproduction with external fertilization.
- They can also reproduce by fragmentation and regeneration. Any piece of a sea star that contains part of the central canal will form a completely new organism.
- Sea stars have an endoskeleton consisting of calcium plates.
- Example: Sea star, sand dollars

9- Chordates

- Chordates have a notochord, a rod that extends the length of the body and serves as a flexible axis.
- They have a dorsal, hollow nerve cord.
- The tail aids in movement and balance. The coccyx bone in humans is a vestige of a tail.
- Birds and mammals are homeotherms– they maintain a consistent body temperature.
- All other chordates are cold- blooded although
- Some reptiles are endotherms (heat from within) and are able to raise their body temperature.

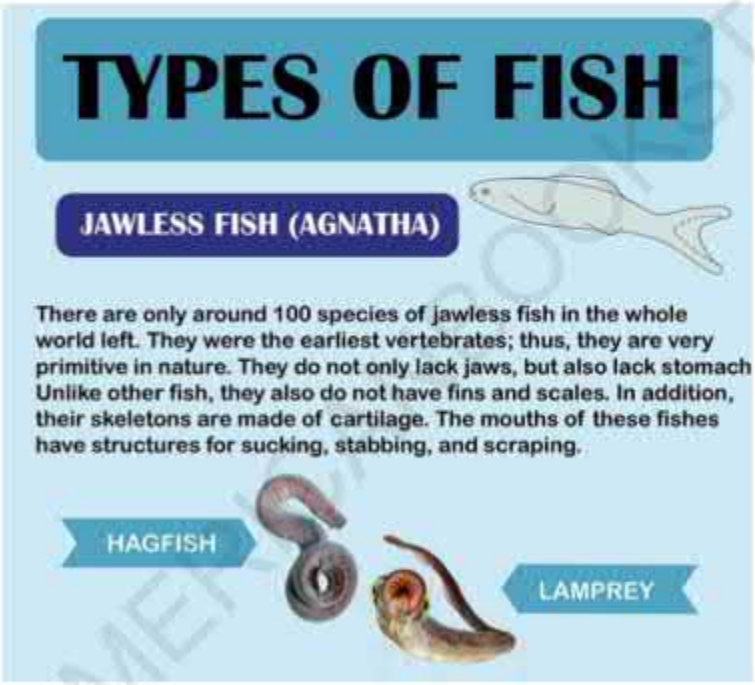
9- Chordates

- **Three subdivision:**

1- Cephalochordates
2- Tunicata (Urochordata)
3- Craniata (Vertebrata)

Subphylum Vertebrata

- Class Agnatha (jawless fishes)
- Class Chondrichthyes (cartilaginous fishes)
- Class Osteichthyes (bony fishes)
- Class Amphibia (amphibians)
- Class Reptilia (reptiles)
- Class Aves (birds)
- Class Mammalia (mammals)

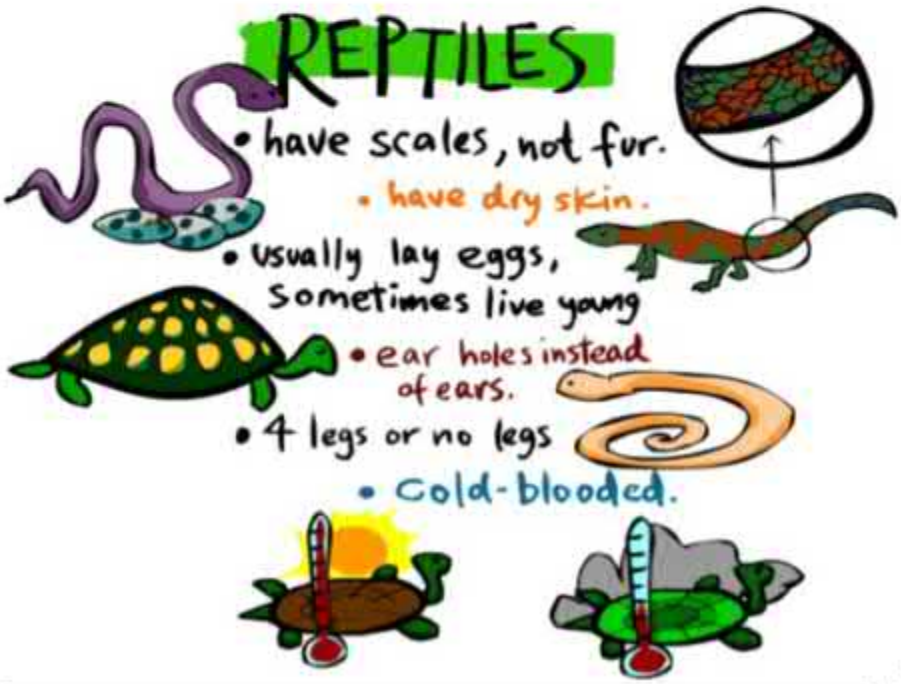


Class Amphibia

- Ectothermic (cold blooded)
- Tetrapod, amniotes
- Start out as larvae living in water then develop lungs
- They breathe through moist skin and lungs
- Amphibians have a juvenile stage and an adult stage. In the juvenile stage they have two-chambered heart pumps the blood through the gills where it is oxygenated. In the adult stage, amphibians (especially frogs) lose their gills and develop lungs. They have a heart that consists of a single ventricle and two atria (three chambered).
- Examples: frog, toad and salamander.

Class Reptilia

- Ectothermic, dry skin covered by scales
- Three or four chambered heart
- Most have two pairs of short legs and clawed feet
- Amniotes
- Have lungs
- Examples: Snakes, lizards, crocodile and turtle



Class Aves

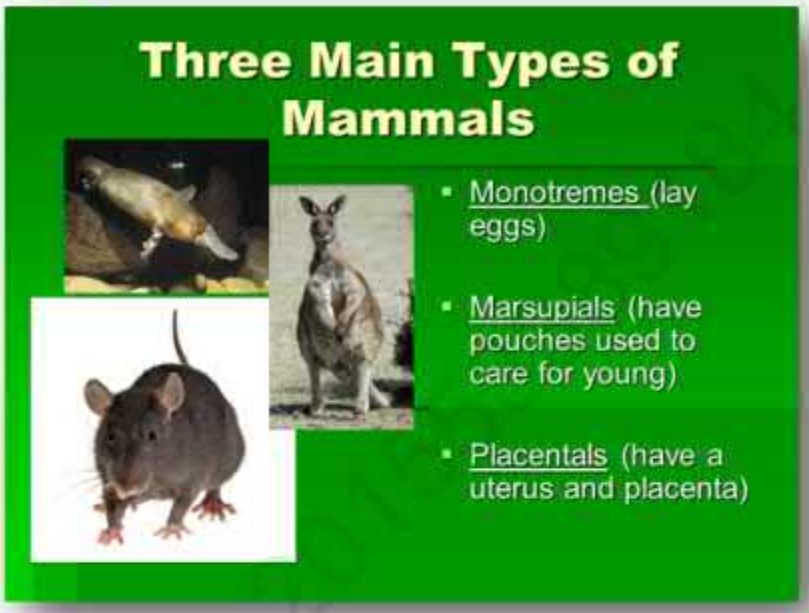
- Bipedal feathered and warm blooded (Endothermic) animals
- Their fore-limbs are modified into wings. Most of them can fly except flightless birds (e.g., Ostrich).
- The hind-limbs are adapted for perching, walking or swimming, etc., and usually bear four, sometimes three and rarely two toes.
- The alimentary canal has additional chambers, the crop and gizzard. The crop stores and softens the food; however, the gizzard helps in crushing and churning the food.
- four chambered heart
- Amniotic eggs
- Endoskeleton is fully ossified (bony) and the long bones are hollow with air cavities (pneumatic) to reduce weight.
- The birds show courtship, nest building, parental care, migration and territorial behavior

Class Aves

- Feathers
- No teeth
- Flexible long neck
- Scales on legs
- Bones with air spaces
- Endothermic
- Four chambered heart
- Amniotic egg
- Highly sexually dimorphic

Class Mammalia

- Warm blooded (Endothermic)
- Have hair and fur
- Have mammary glands
- Four chambered heart
- Heterodont dentition

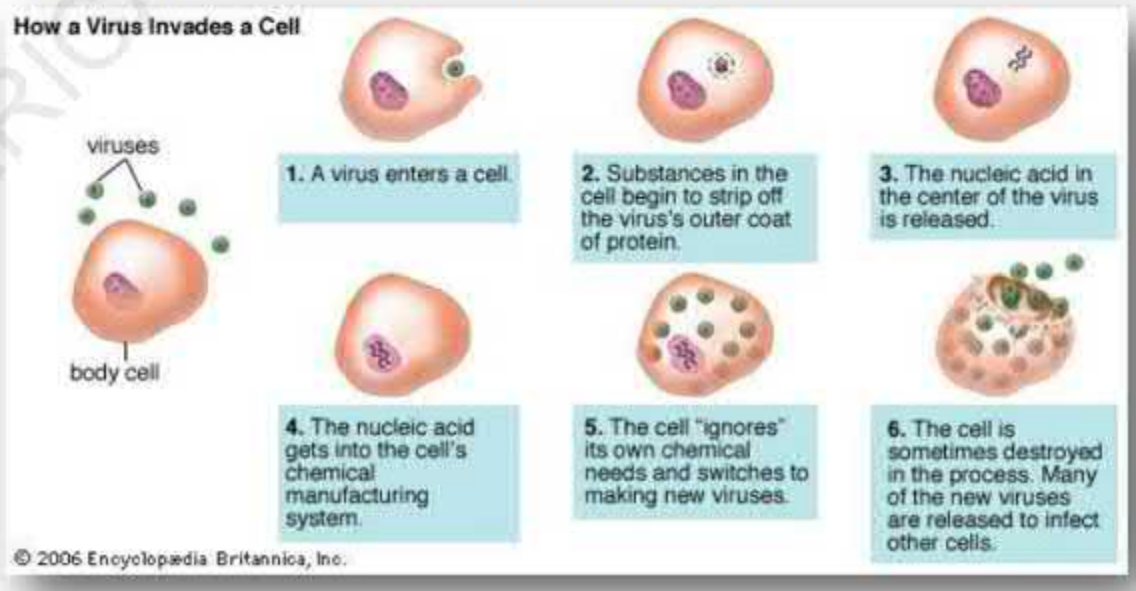


Types of mammals:

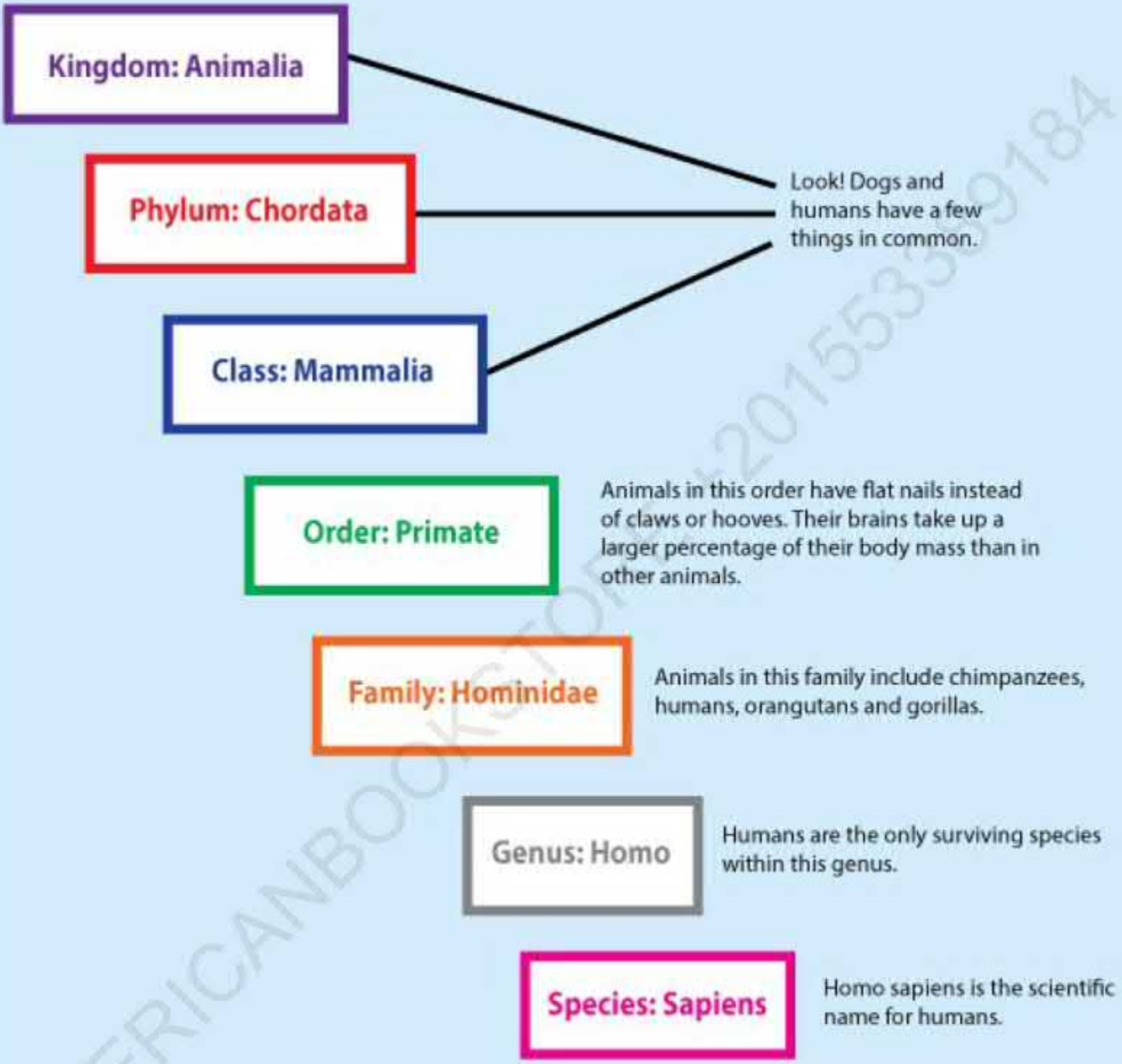
- Monotremes
- Marsupials
- Placentals

Viruses

- Viruses occupy a special taxonomic position: they are not plants, animals, or prokaryotic bacteria (single-cell organisms without defined nuclei), and they are generally placed in their own kingdom.
- Virus contains either DNA or RNA
- A distinctive large family of single-stranded RNA viruses is called Retroviridae; the viruses are equipped with an enzyme, called a reverse transcriptase, that copies the single-stranded RNA to form double-stranded DNA.

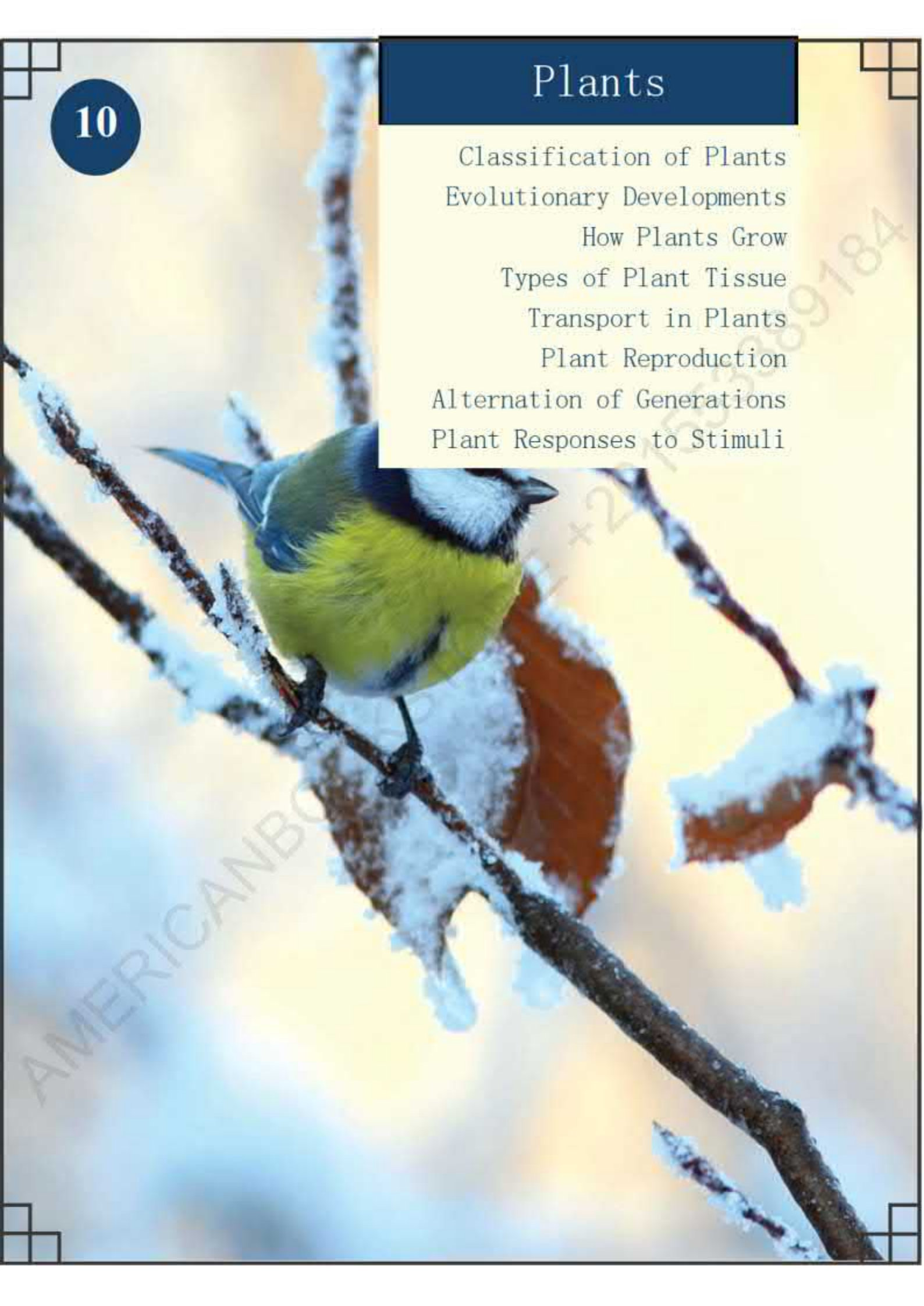


Human Classification



10

Plants



PLANTS

Plants classification

Based on system of carrying water	features	Based on method of reproduc-tion	Based on seed covering	Characteristics	Example
Non Vascular Bryophytes	No roots No vascular system Small and short Lives in water Produce spores				Moss Hornwort Liverwort
Vascular Tracheophytes	Water and nutrients carried through vascular system	**Seedless** reproduce by spores Lycophytes			Horsetail fern
		With seeds (reproduc-tion by seeds)	**Covered seeds** (In cones) Non flowering GYMNOSPERMS	Cone bearing Needle shaped leaves Thick cuticle	Palm tree Cedar Ginkgo
			Naked seeds Flowering Seeds inside ovaries of the flowers After pollina-tion ovary becomes fruits ANGIOSPERMS	Monocotyledon	Onion Corn Rice
				Dicotyledon	Cabbage Apple peaches

PLANTS

Plants classification

Moss	Hornwort	Liverwort	Horsetail	Fern
				
Palm tree	Cedar	Ginko tree	Onion	Corn
				
Rice	Cabbage	Apple	Peaches	Cone
				

Monocots Vs Dicots

Monocots

One cotyledon

Veins usually parallel
Long Narrow

Vascular bundles usually complexly arranged

Fibrous root system

Floral parts usually in multiples of three

Embryos	Leaf venation	Stems	Roots	Flowers

Dicots

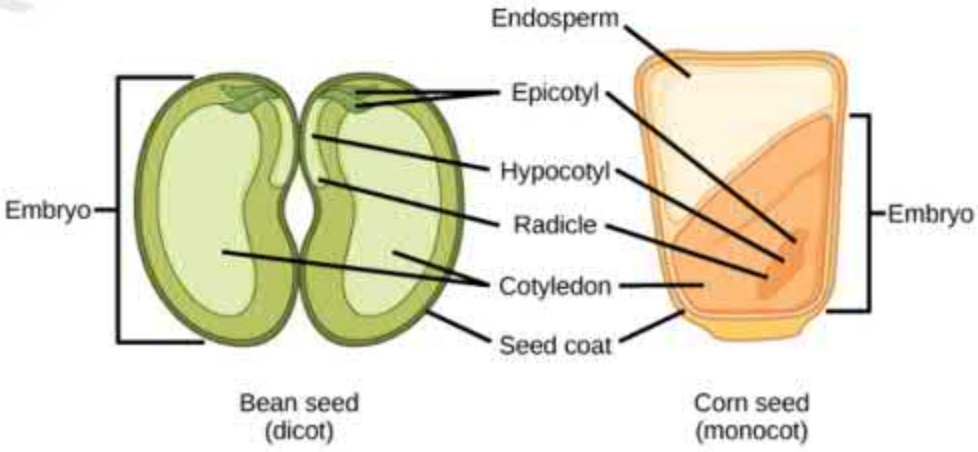
Two cotyledons

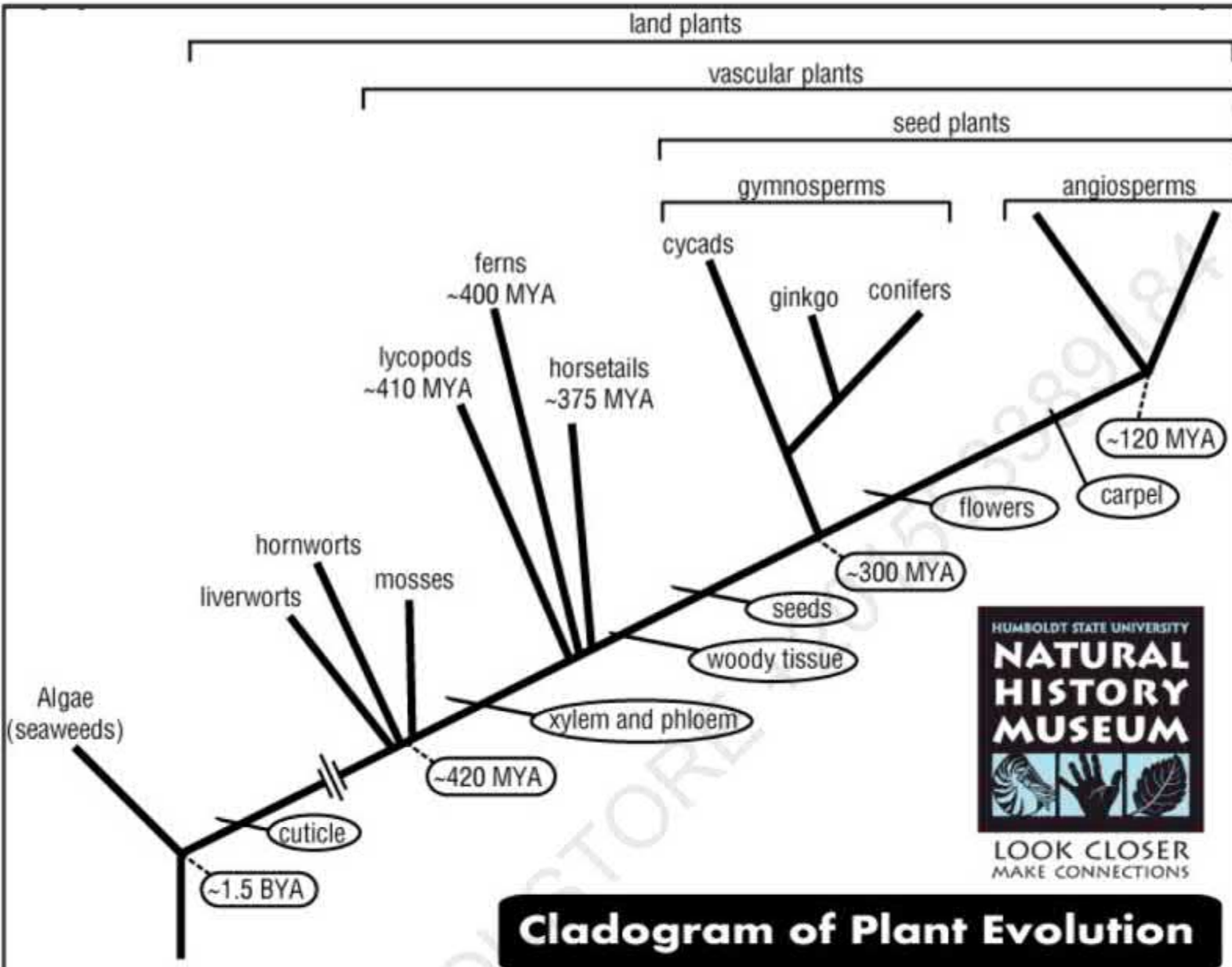
Veins usually netlike
Short broad

Vascular bundles usually arranged in ring

Taproot usually present

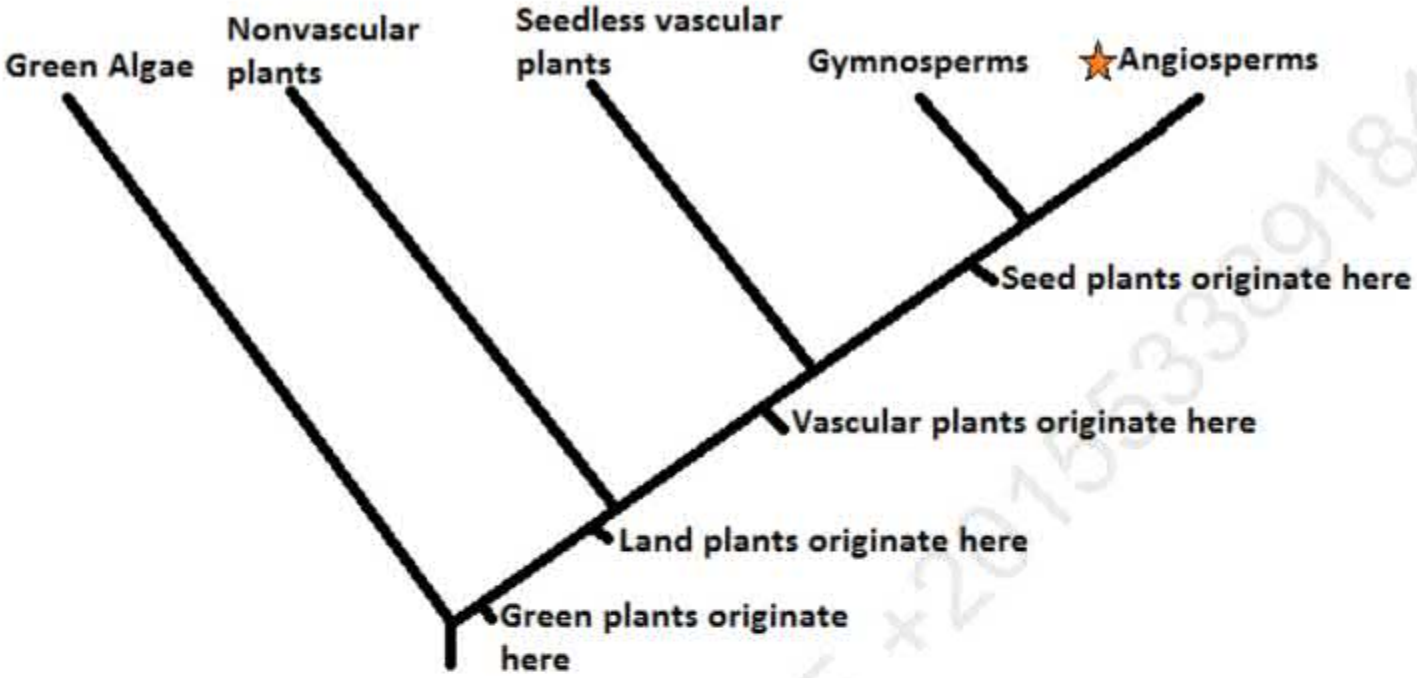
Floral parts usually in multiples of four or five





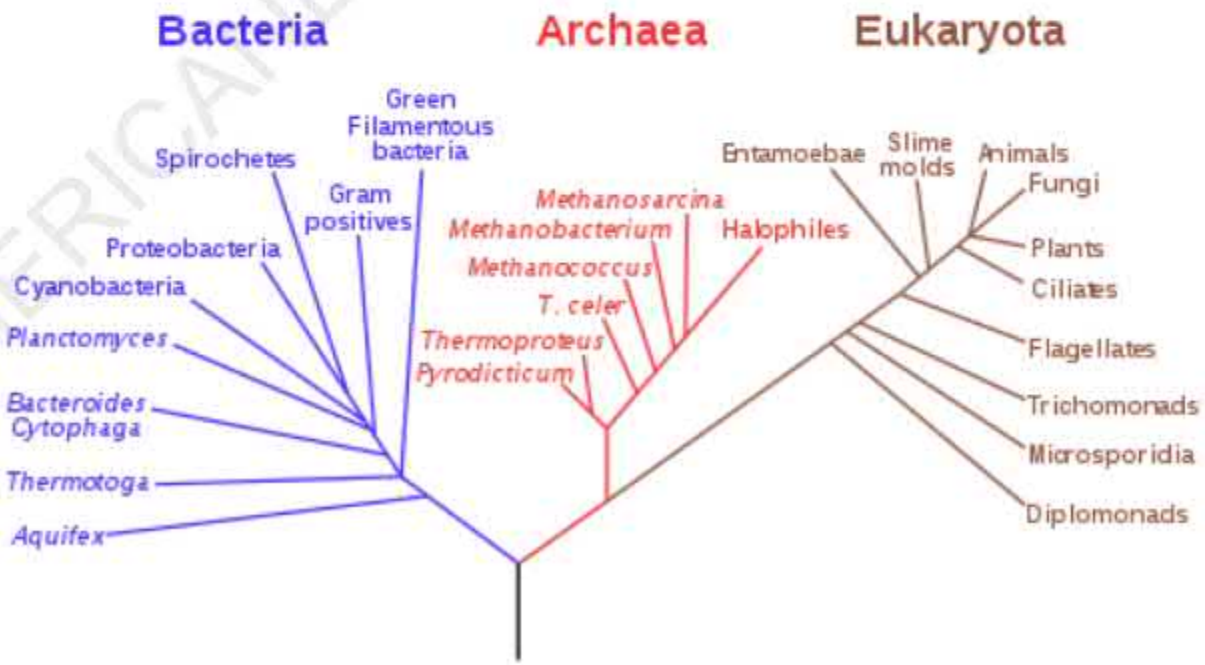
A cladogram: is a diagram used to show relations among organisms. A cladogram is not an evolutionary tree because it does not show how ancestors are related to descendants, nor does it show how much they have changed

Plants phylogenetic tree



A phylogenetic tree "or evolutionary tree"

It is a branching diagram or "tree" showing the evolutionary relationships among various biological species based upon similarities and differences in their physical or genetic characteristics. All life on Earth is part of a single phylogenetic tree, indicating common ancestry.



From Water to Land

Modifications enable plants to live on land

Modification	Function
Cellulose cell wall	To maintain shape
Roots & root hairs	Absorb soil water & nutrients
Stomates open & close	Allow gas exchange & minimize water loss
Leaves cutin coating	Prevent excess water loss
Develop of Gametangia	Prevent drying out of gametes
Appearance of sporopollenin	Protect plants in harsh environment
Seeds & pollen protective coat	Prevent desiccation

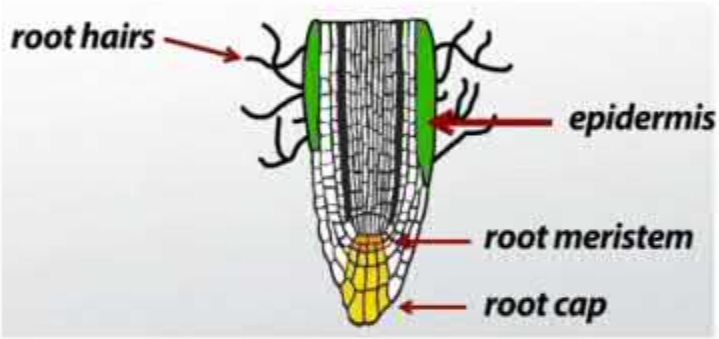
Growth in Plants

- Plants have **meristem** tissue that continually divides, so they continue to grow as long as they live.
- Plants grow in two ways: **primary growth** and **secondary growth**.

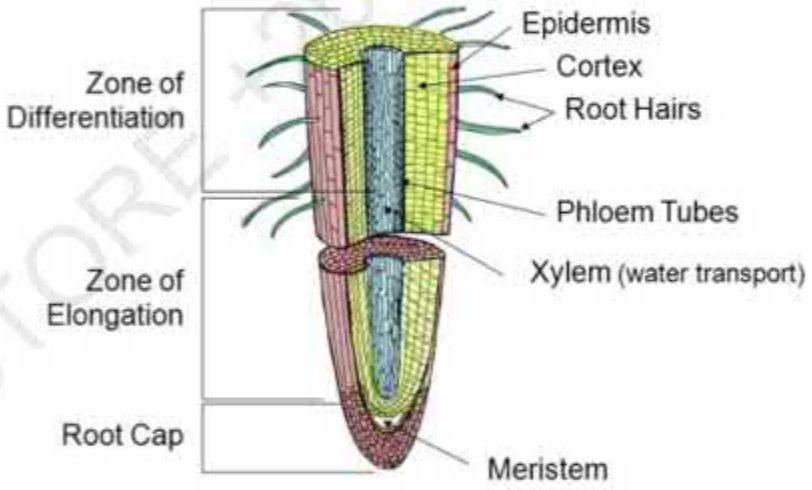
Primary growth:

- It is the elongation of the plant down into the soil and up into the air (Vertical growth).
- New cells arise from the constantly dividing growth layer called the **apical meristem** which is located at the **buds of shoots and the tips of the roots.**

- Root growth is concentrated near the root tip.
- Three zones of cells at different stages of primary growth are located there:
  1. **The zone of cell division** called apical meristem.
  2. **The zone of elongation**
  3. **The zone of differentiation.**
- The root tip is protected by a **root cap** that secretes a substance that helps digest the earth as the root tip grows through the soil.



Root Structure



Secondary growth:

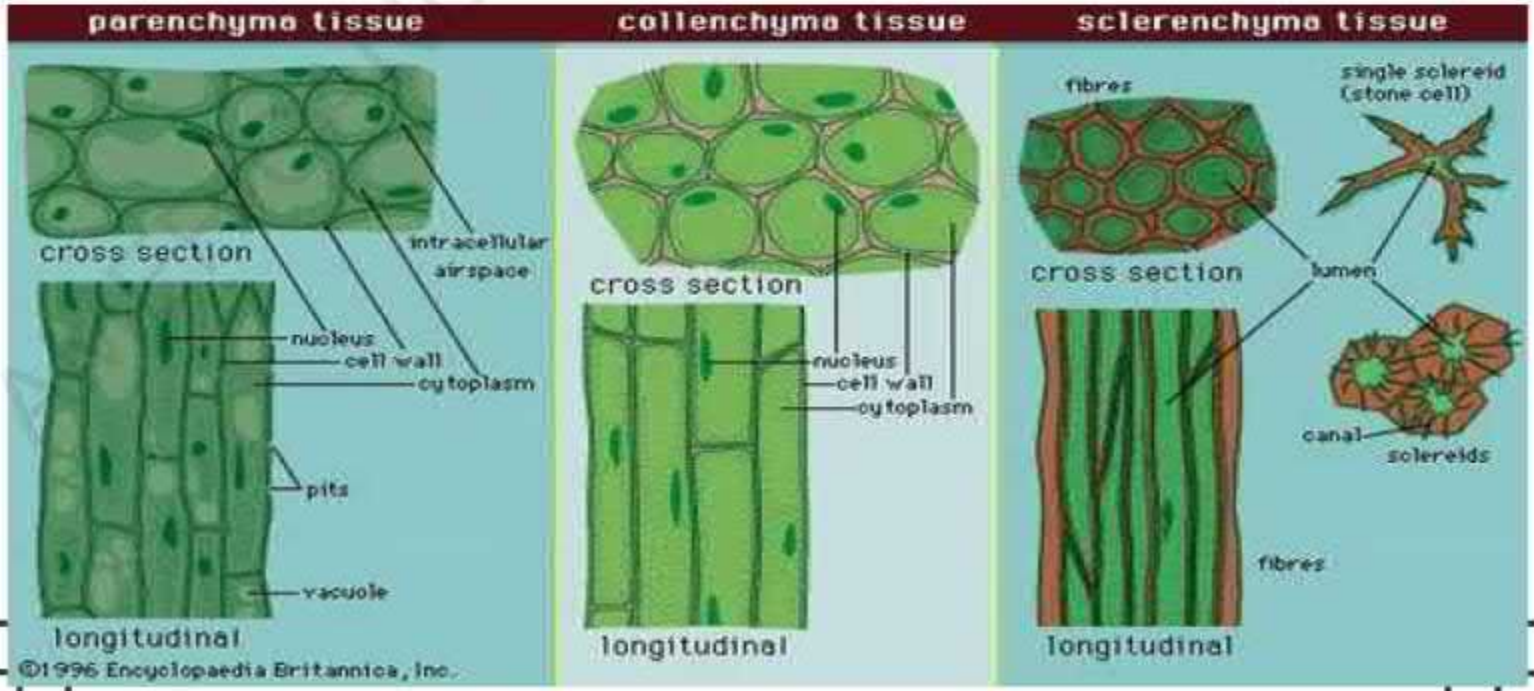
- Secondary growth means **lateral growth** or an increase in **girth.**
- New cells are provided by the lateral **meristem.**
- Not present in **herbaceous** (nonwoody) plants because these plants live for only one season.
- It is responsible for the enlargement of the trunk. For each year of growth, another ring is added. (*That's how to determine tree age*).

Plant tissues

Plants consist of three main tissue types: **dermal, vascular, and ground tissue**. A fourth tissue type, **meristem tissue** or growth tissue, is found only in the growing tips of shoots and roots.

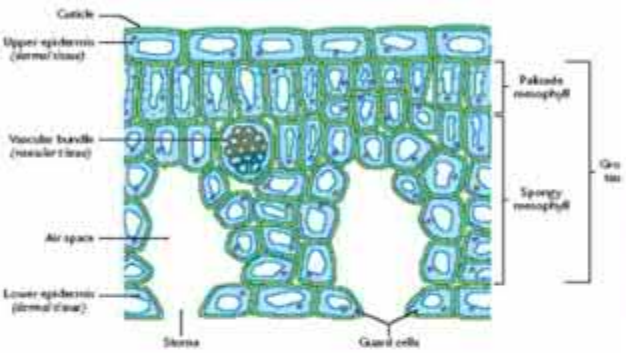
1. Ground Tissue:

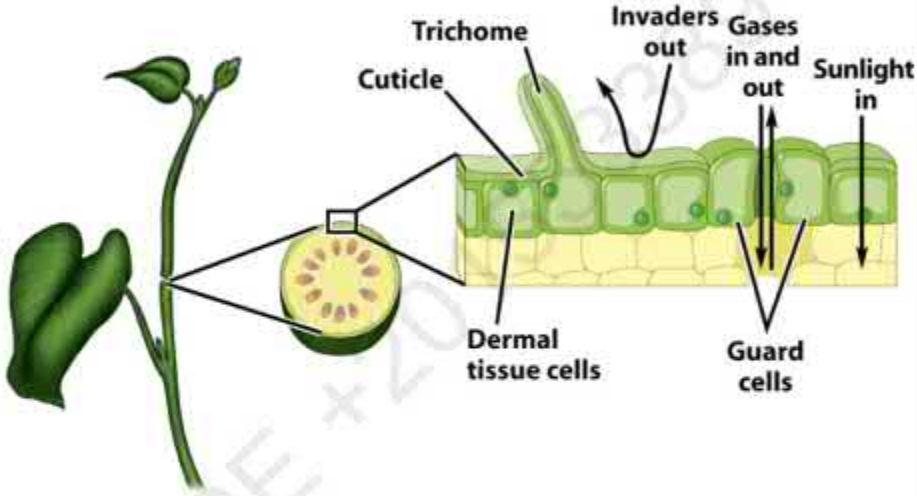
- It consists of three cell types: **parenchyma, collenchyma, and sclerenchyma.** It serves as support tissue.
- **Parenchyma cells:** are the traditional-looking plant cell. They have a primary cell wall that is thin and flexible, and they lack a secondary cell wall. The cytoplasm contains one or two large vacuoles. When the cell is turgid (swollen) with water, these cells lend support to the plant (Physiological support). They are found in all parts of the plant.
- **Collenchyma cells:** have unevenly thickened primary cell walls but lack secondary cell walls. Found in "strings" of celery.
- **Sclerenchyma cells** have very thick primary and secondary cell walls that are fortified with **lignin.** Their function is purely for support.



2. Dermal Tissue:

- **Dermal tissue is** the outer protective covering of plants and usually consists of a single layer of epidermal cells.
- On leaves, they are protected by the **cuticle**, Some leaves are also covered with tiny, spike like projections called **trichomes.**



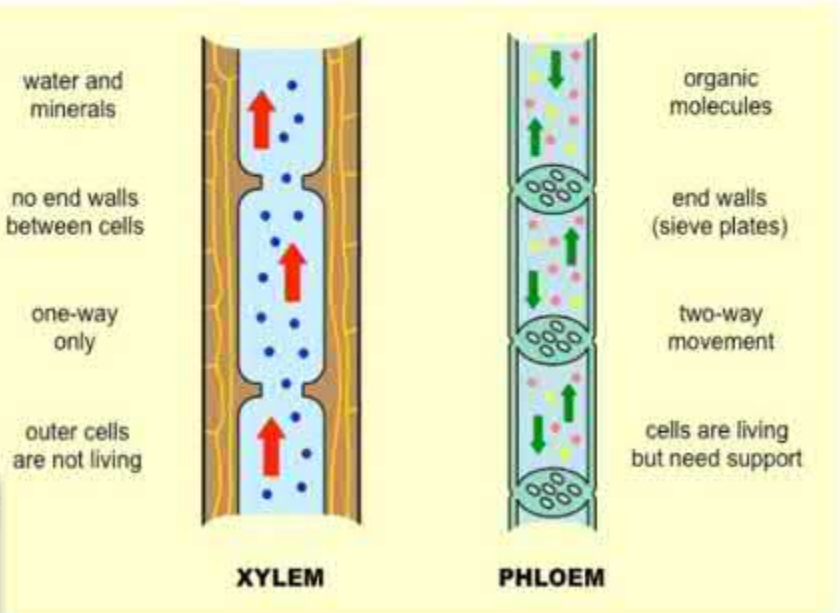


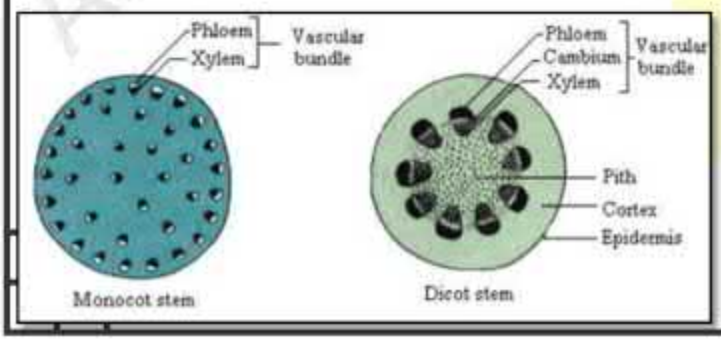
3. Vascular Tissue:

- Vascular tissue transports water and nutrients up and down the plant. There are two types: **xylem and phloem.**
- **Xylem** consists of tracheids and vessel elements. (perforated specialized cells form a long tube).
- **Phloem** consists of sieve tube elements and companion cells.
- **Cambium** undifferentiated vascular tissue

XP

Xylem always inside





Transport in Plants

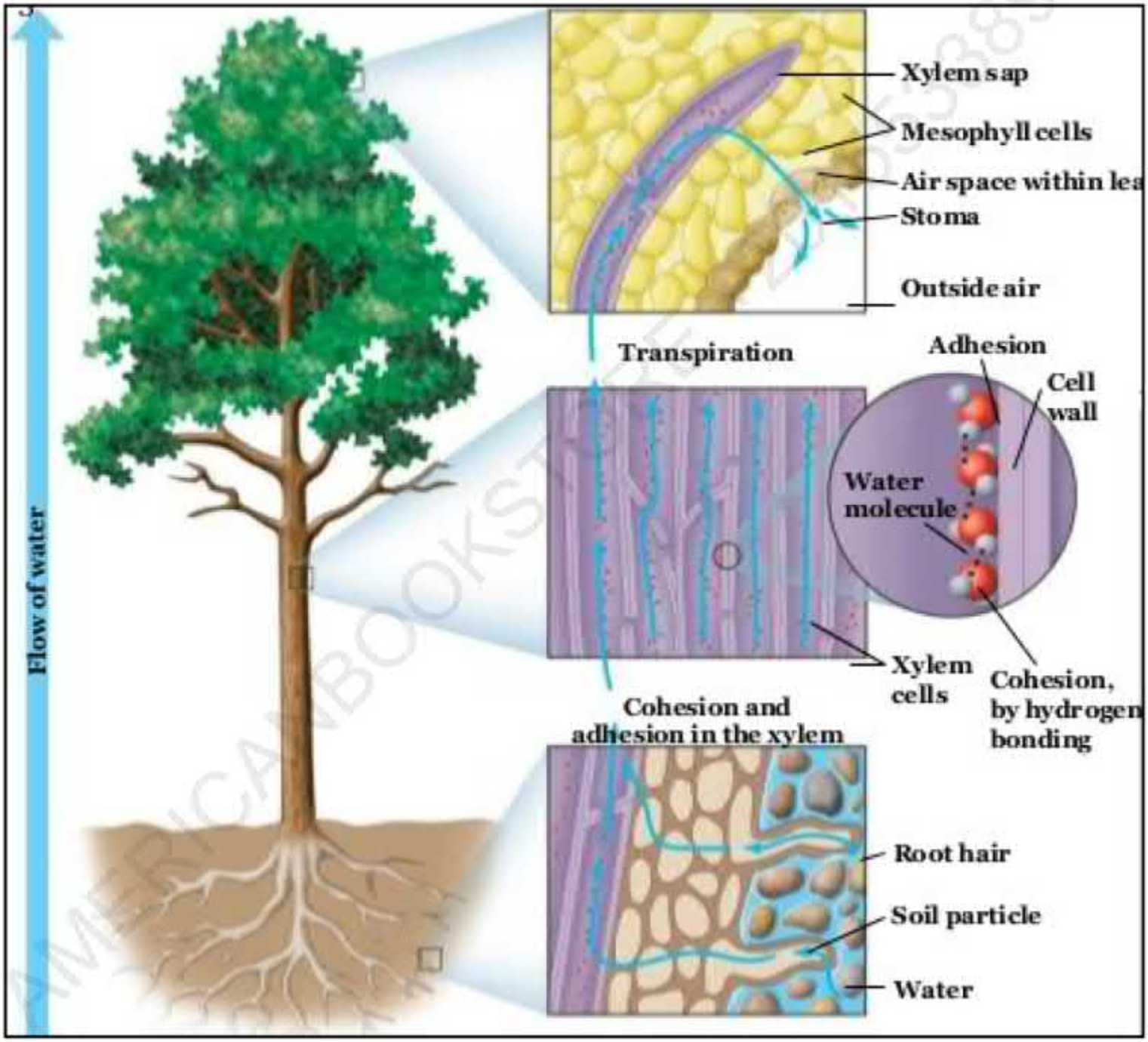
- Just like animals, plants need to transport water, nutrients, and gases. Unlike animals, plants do not have blood, arteries, or a heart to accomplish this. they have **xylem and phloem.**

1. Xylem:

- Xylem consists of two types of elongated cells: **tracheids and vessel elements.** The secondary cell walls of tracheids are hardened with **lignin** and function to support the plant as well as to transport nutrients and water. Xylem is what makes up the stuff we call **wood.**
- Xylem carries water and nutrients from the soil up to the tallest leaves against gravity with ***no expenditure of energy.*** Instead, they are pulled up by a combination of two phenomena: **"transpirational pull and cohesion tension."**
- **Transpiration** is the evaporation of water from leaves. **Cohesion** refers to the fact that water molecules are attracted to each other and stick together.
- **The transpirational pull-cohesion tension theory** states that for each molecule of water that evaporates from a leaf by transpiration, another molecule of water is drawn in at the root to replace it. The sunlight drives transpiration by causing water to evaporate from the leaf.
- Several factors affect the rate of transpiration and loss of water from a leaf:
  1. High humidity slows down transpiration.
  2. Wind can reduce humidity near the stomates.
  3. Increased light intensity.
  4. Closing stomates stop transpiration.

2. Phloem:

- Phloem vessels are made of chains of two types of cells: **sieve tube elements and companion cells**. They carry sugar from the photosynthetic leaves to the rest of the plant by a process called **translocation**. Sugar is stored in the roots.
- Unlike transport in the xylem, this process requires energy.



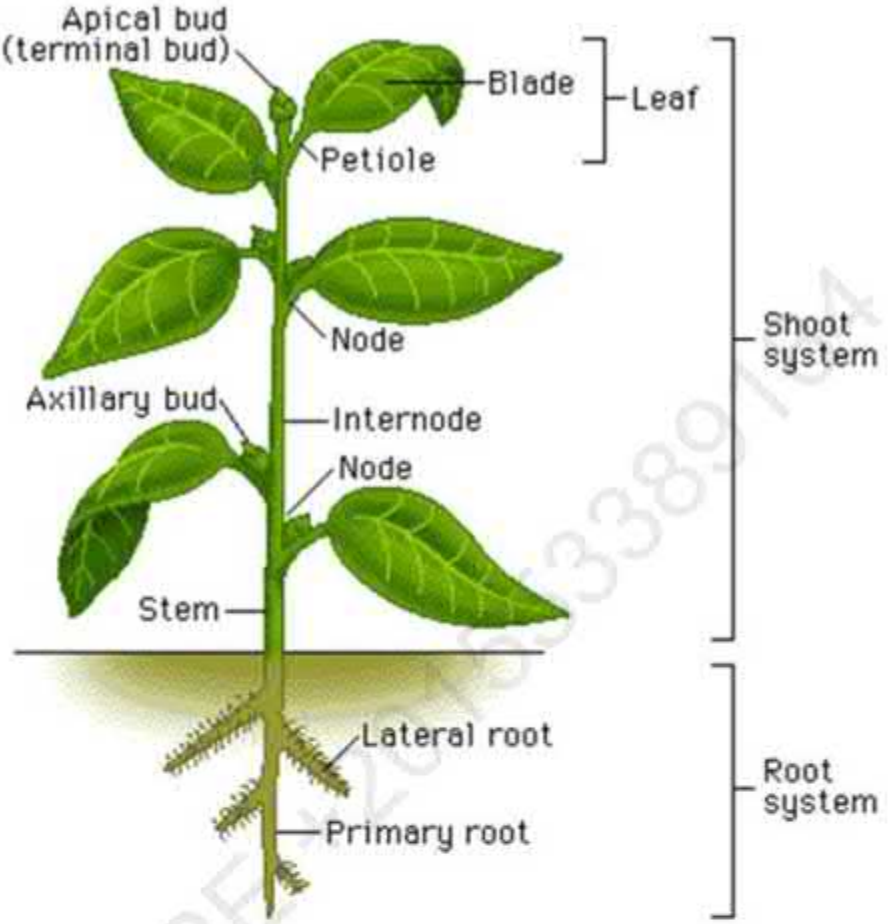
Plant Organs

- **Vegetative organs**

1. Roots
2. Stems
3. Leaves

- **Reproductive organs**

1. Fruits
2. Flowers
3. Seeds

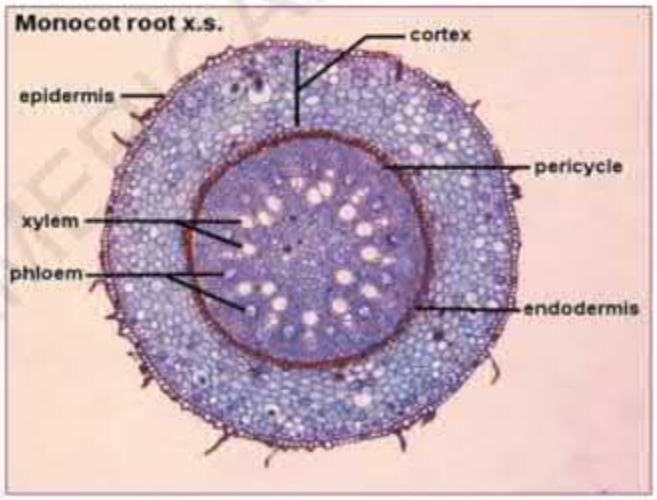


Roots

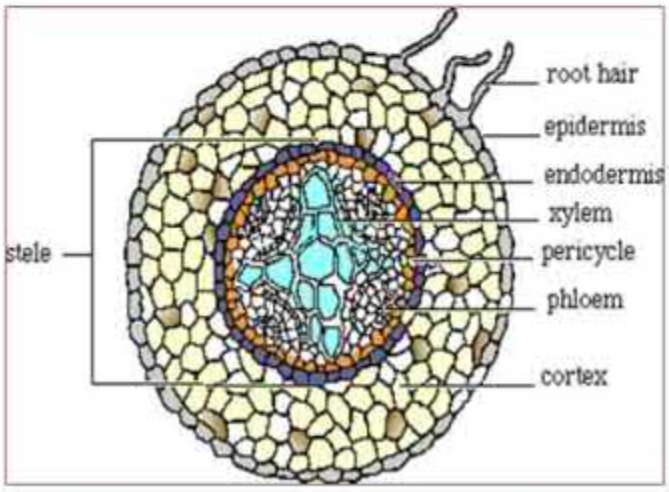
Functions

1- Absorb nutrients from the soil
2- Anchor the plant
3- Store food

Structure



Monocot Root



Dicot Root

1- Epidermis:
covers the entire surface of the root and is modified for absorption. Root hairs extends from epidermis to increase absorbing surface.

2- Cortex:
consists of parenchyma cells that contain many plastids (Leucoplasts) for the storage of starch and other organic substances.

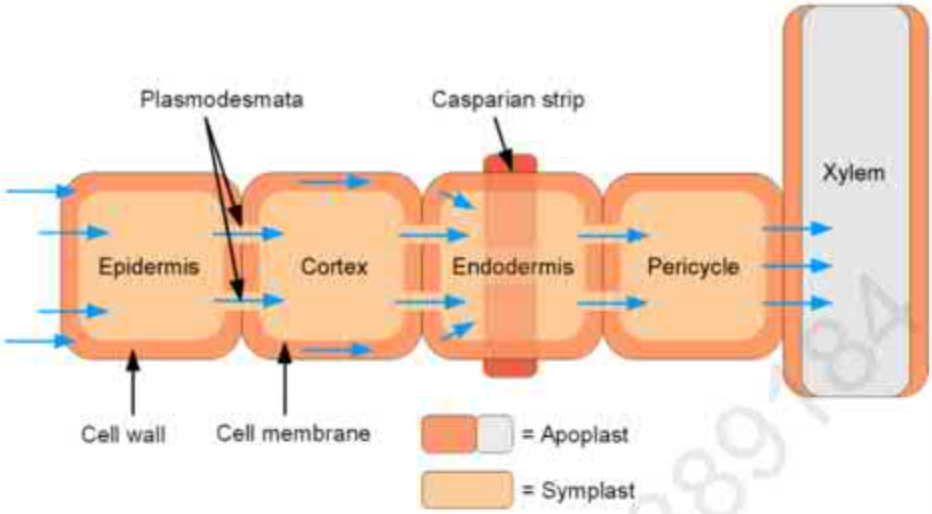
3- Vascular cylinder (STELE):
It consists of vascular tissues (xylem and phloem) surrounded by one or more layers of tissue called the pericycle, from which lateral roots arise.

4- Endoderm:
The function of the endoderm is to select what minerals enter the vascular cylinder and the body of the plant.
It has Casparian strip, Which is a continuous band of waxy material that is impervious to water and dissolved minerals.

Absorption of nutrients and water:
Plants use their roots to absorb nutrients and water from the soil then to the cells themselves.

The symplast: it is a continuous system of cytoplasm of cells interconnected by plasmodesmata.
The apoplast: it is the network of cell walls and intercellular spaces within a plant body that permits extensive extracellular movement of water within a plant.
Mycorrhizae: they are symbiotic structures consisting of the plant's roots intermingled with the hyphae (filaments) of a fungus that greatly increase the quantity of nutrients that a plant can absorb.
Rhizobium: it is a symbiotic bacterium that lives in the nodules

on roots of specific legumes. It fixes nitrogen gas from the air into a form of nitrogen the plant requires.

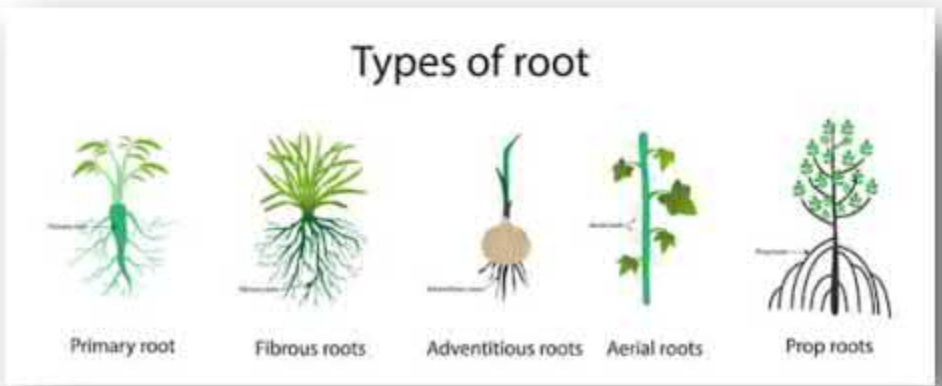


Fibrous root
Many Thin roots
Common in monocots like grasses

Tap root
Single, large root that gives rise to lateral branch roots.
In many dicots, the primary root is the taproot.
It helps in fixing the plant and also storage of starch

Prop roots
Grow aboveground out from the base of the stem
Help support the plant.

Adventitious roots
Stick up out of the water and serve to aerate the root cells



Stem

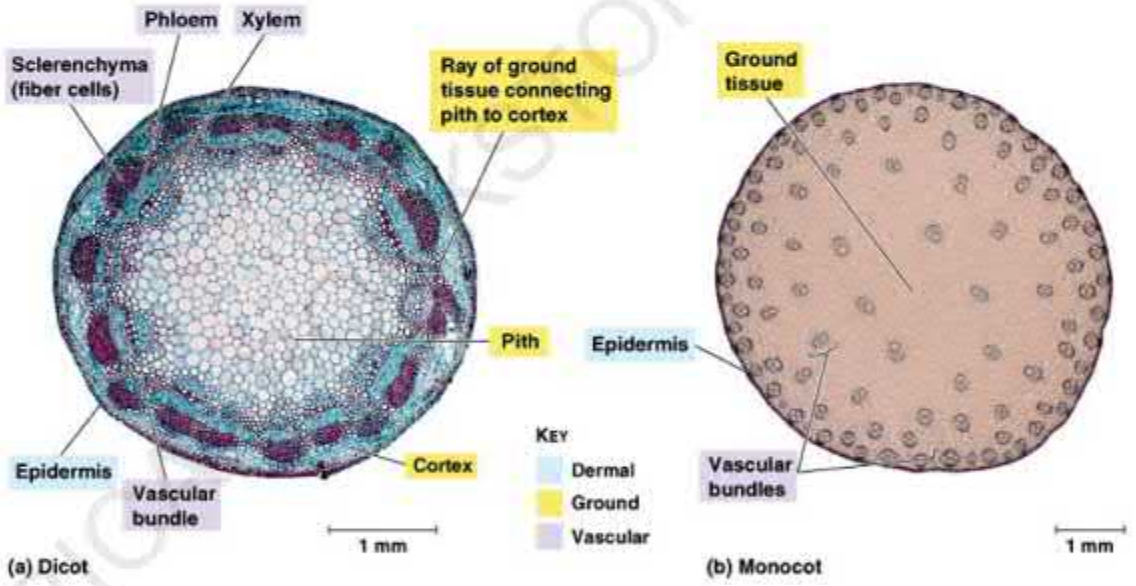
Functions

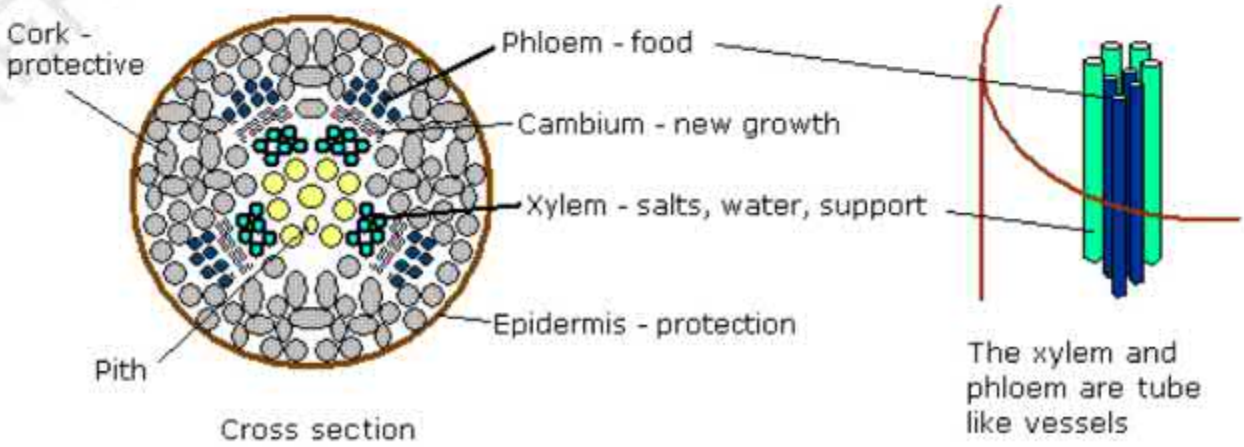
1-Support of the plant and carrying leaves & flowers
2- Transport of water , nutrients and food.
3- Storage in some cases like potato & Sugar cane.

Structure

- Vascular tissue runs the length of the stem in strands called vascular bundles.
- Each bundle contains xylem on the inside, phloem on the outside, and meristem tissue between the two.

- **In monocots,** the vascular bundles are scattered
- **In dicots,** they are arranged in a ring around the edge
- The ground tissue of the stem consists of cortex and pith, parenchymal tissues modified for storage.





Leaf

Functions

Epidermis: Protection

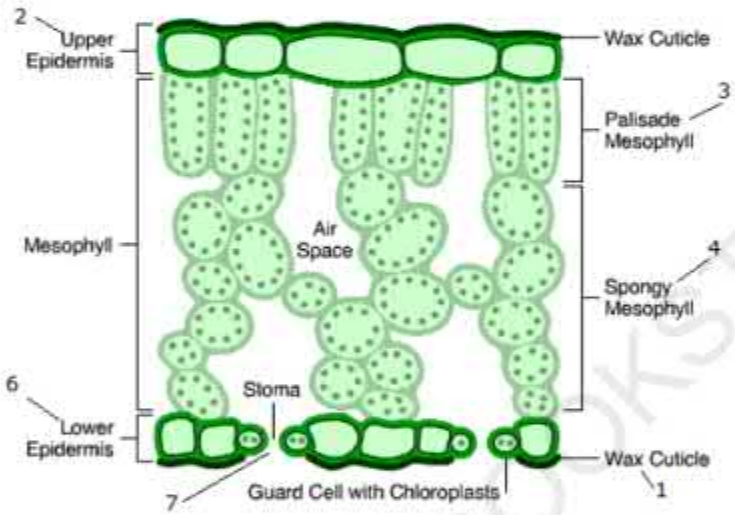
Waxy cuticle: Protection, Minimizes water loss

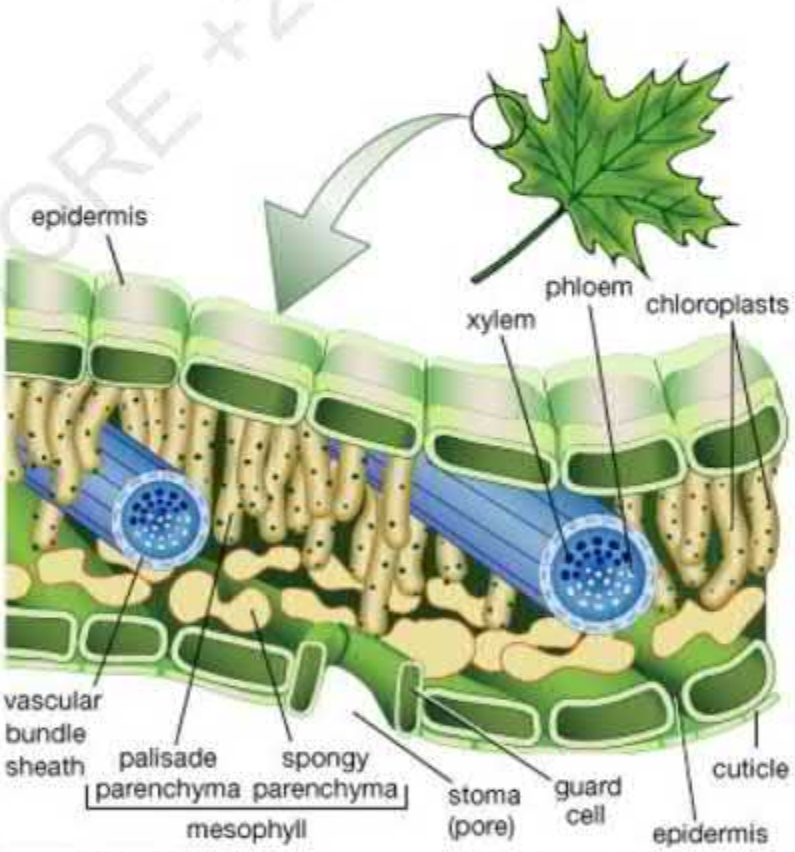
Guard cells: Control the opening of the stomata

Palisade mesophyll: Photosynthesis

Spongy mesophyll: Photosynthesis, exchange of gases

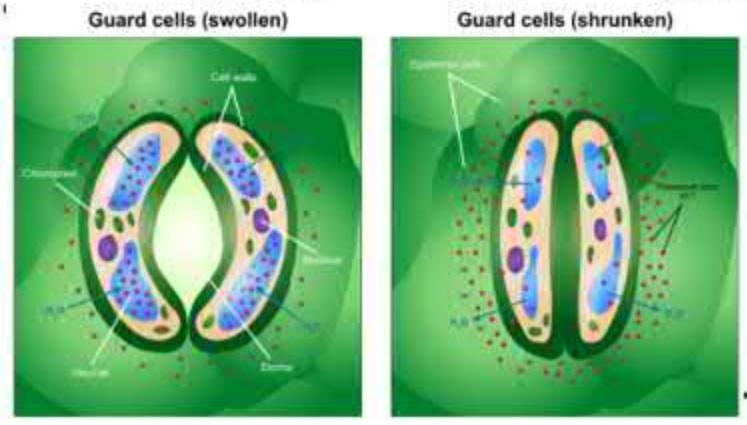
Veins: Carry water and nutrients from the soil to The leaves and carry sugar, the product of photosynthesis, from the leaves to the rest of the plant.



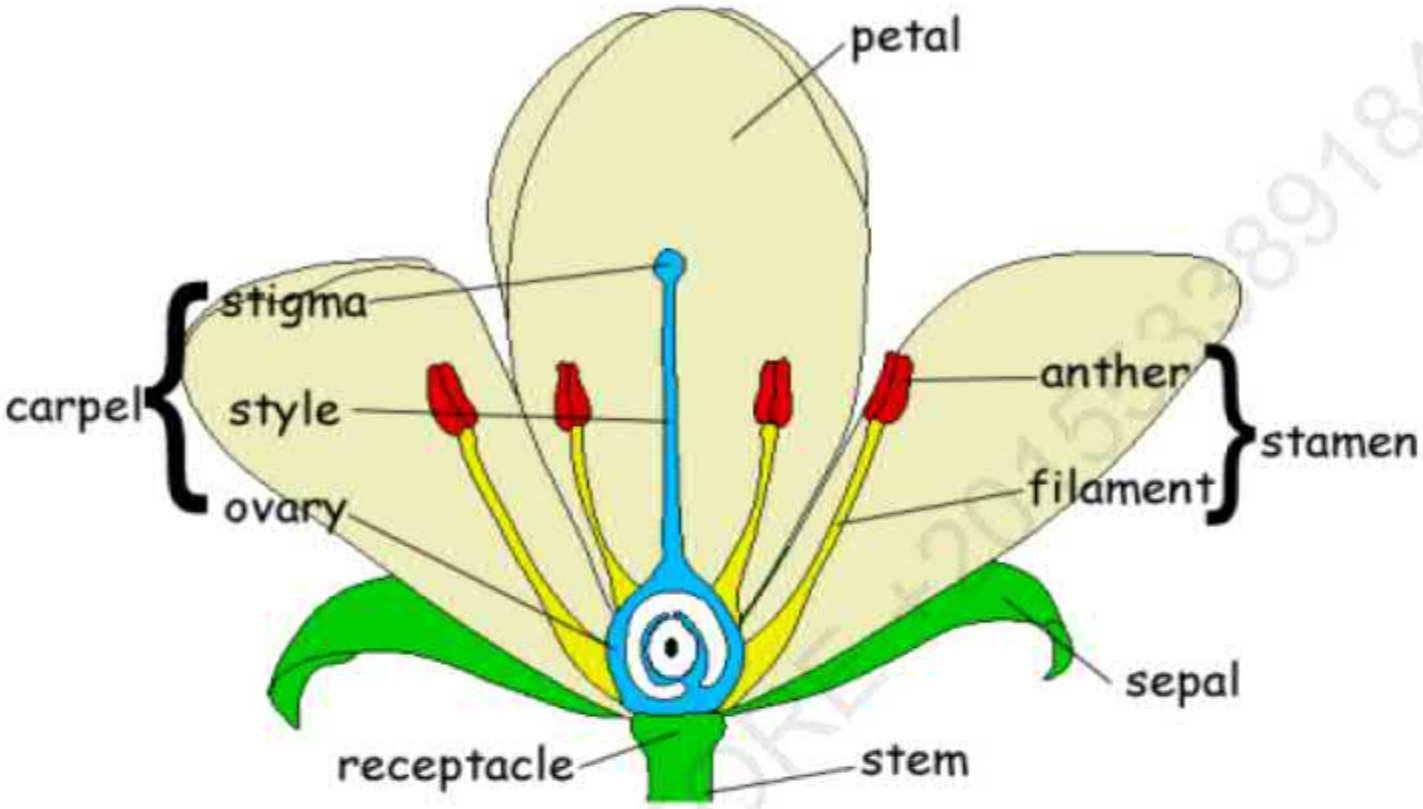


Guard cells:

When potassium ions enter the cell water diffuses into the cell by osmosis so the cells swollen and bend away leading to opening the stoma



Sexual Reproduction in Flowering Plants



The flower is the sexual organ of a plant, It consists of:

Petals. Brightly colored, modified leaves found just inside the circle of sepals; attract animals that will pollinate the plant.

Sepals. Outermost circle of leaves; are green and closely resemble ordinary leaves; enclose the bud before it opens and protects the flower while it develops.

Pistils or carpels. Female part of the flower; produce the female gametophytes; each consists of an ovary, stigma, and style

Ovary. Swollen part of pistil that contains the ovule, where one or more ova are produced by meiosis

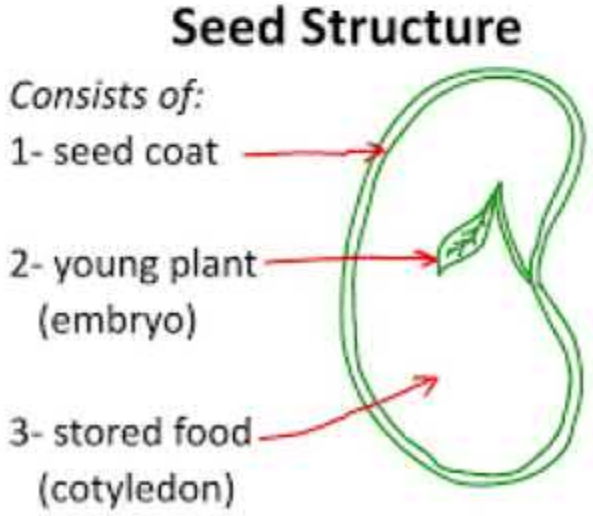
Ovule. The structure within the ovary where the ova (female gametophytes) are produced

Style. Long, usually thin stalk of the pistil
Stigma. Sticky top of the style where pollen lands and germinates

Stamen. Male part of the flower, made up of anther and filament
Anther. Male part of the flower where sperm (pollen) are produced by Meiosis
Filament. Threadlike structure that supports the anther.

POLLINATION AND FERTILIZATION IN FLOWERING PLANTS

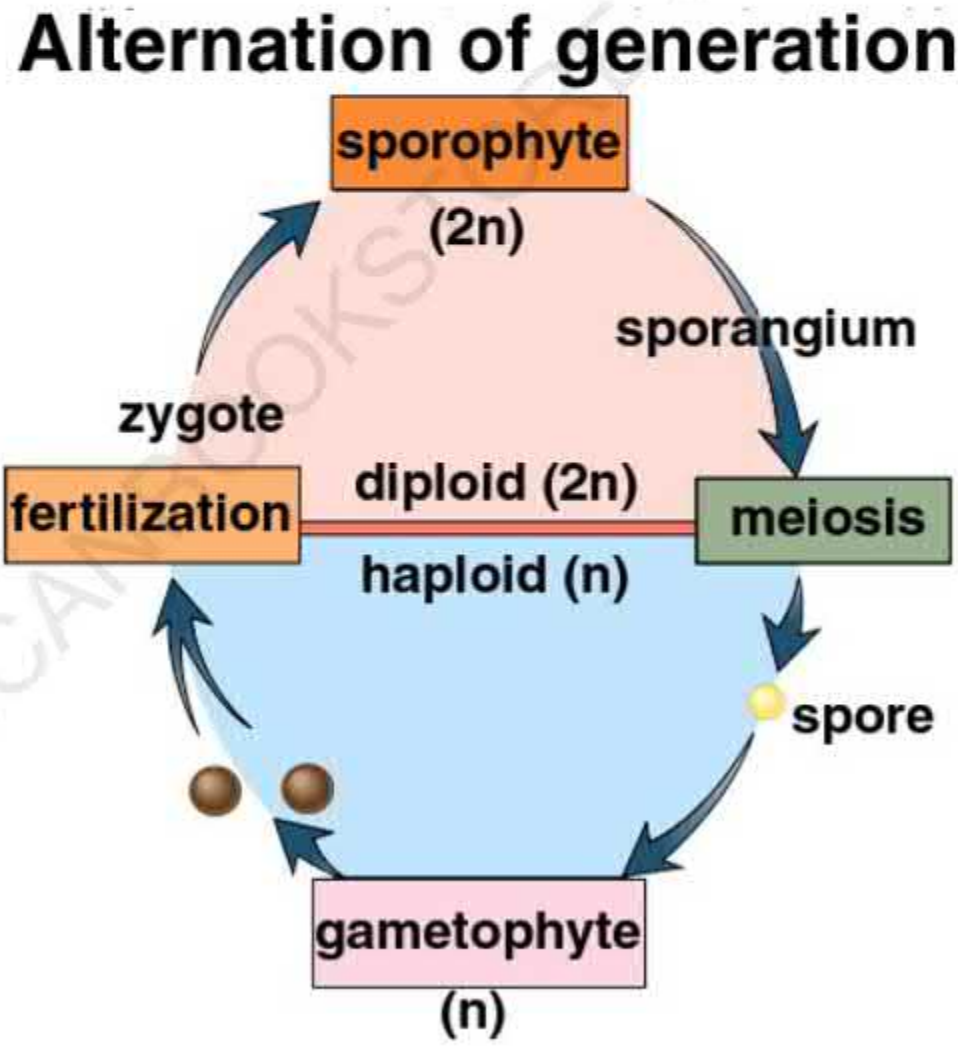
Sexual reproduction begins with pollination.
One pollen grain containing three haploid nuclei lands on the sticky stigma of the flower.
The pollen grain produce a pollen tube that burrows down the style into the ovary.
The two sperm nuclei travel down the pollen tube into the ovary. And enter the ovule through the micropyle.
One sperm nucleus fertilizes the egg and becomes the embryo (2n).
The other sperm nucleus fertilizes the two polar bodies and becomes the triploid (3n) endosperm or cotyledon, the food for the growing embryo "this process is known as double fertilization because two fertilizations occur".
After fertilization, the ovule becomes the seed and the ripened ovary becomes the fruit.



Alternation of generations

- The sexual life cycle of plants is characterized by the alternation of generations in which haploid (n) and diploid (2n) generations alternate with each other.

- The gametophyte (n) produces gametes by mitosis that fuse during fertilization to yield (2n) zygotes. Each zygote develops into a sporophyte (2n) that produces haploid spores (n) by meiosis. Each haploid spore forms a new gametophyte, and the cycle continue.



Plants response to stimuli

Hormones

- Plant hormones help coordinate growth, development, and response to environmental stimuli
- Although they are produced in very small quantities, they have a profound effect on the plant because the hormone signal is amplified.
- A plant's response to a hormone usually depends not so much on absolute quantities of hormones but on relative amounts.
- Hormones can have multiple effects on a plant, and they can work synergistically with other hormones or in opposition to them.

Hormone	Action
AUXINS	• Enhance epical growth • Phototropism occurs due to an unequal distribution of auxins
CYTOKININS	• Stimuli cell division • Delay aging
GIBBERELLINS	• Promote cell growth. • Promote fruit and seed development.
ABSCISIC ACID (ABA)	• Growth inhibitor. • It enables plants to withstand drought.
ETHYLENE	• Promote ripening

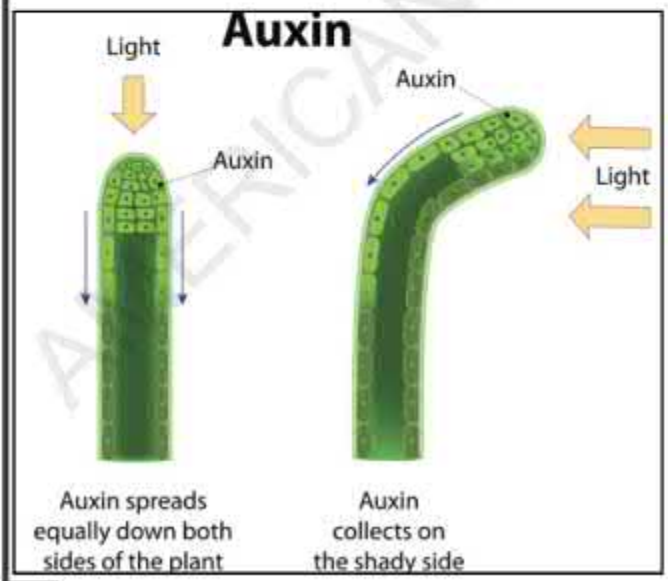
Tropism

- A tropism is the growth of a plant toward or away from a stimulus.
- Examples:
  - Thigmotropisms (touch),
  - Geotropisms or gravitropisms (gravity)
  - Phototropisms (light).
- A growth of a plant toward a stimulus is known as a **positive tropism**, while a growth away from a stimulus is a **negative tropism**.

- **Phototropism** result from an unequal distribution of auxins that accumulate on the side of the plant away from the light. Since auxins cause growth, the cells on the shady side of the plant enlarge and the stem bends toward the light.

- **Photoperiodism** is the response of plants to varying amounts of light over time, particularly the length of day and night.

- **Geotropism** result from an interaction of auxins and statoliths, specialized plastids containing dense starch grains.



11

ANIMAL PHYSIOLOGY

Movement and Locomotion

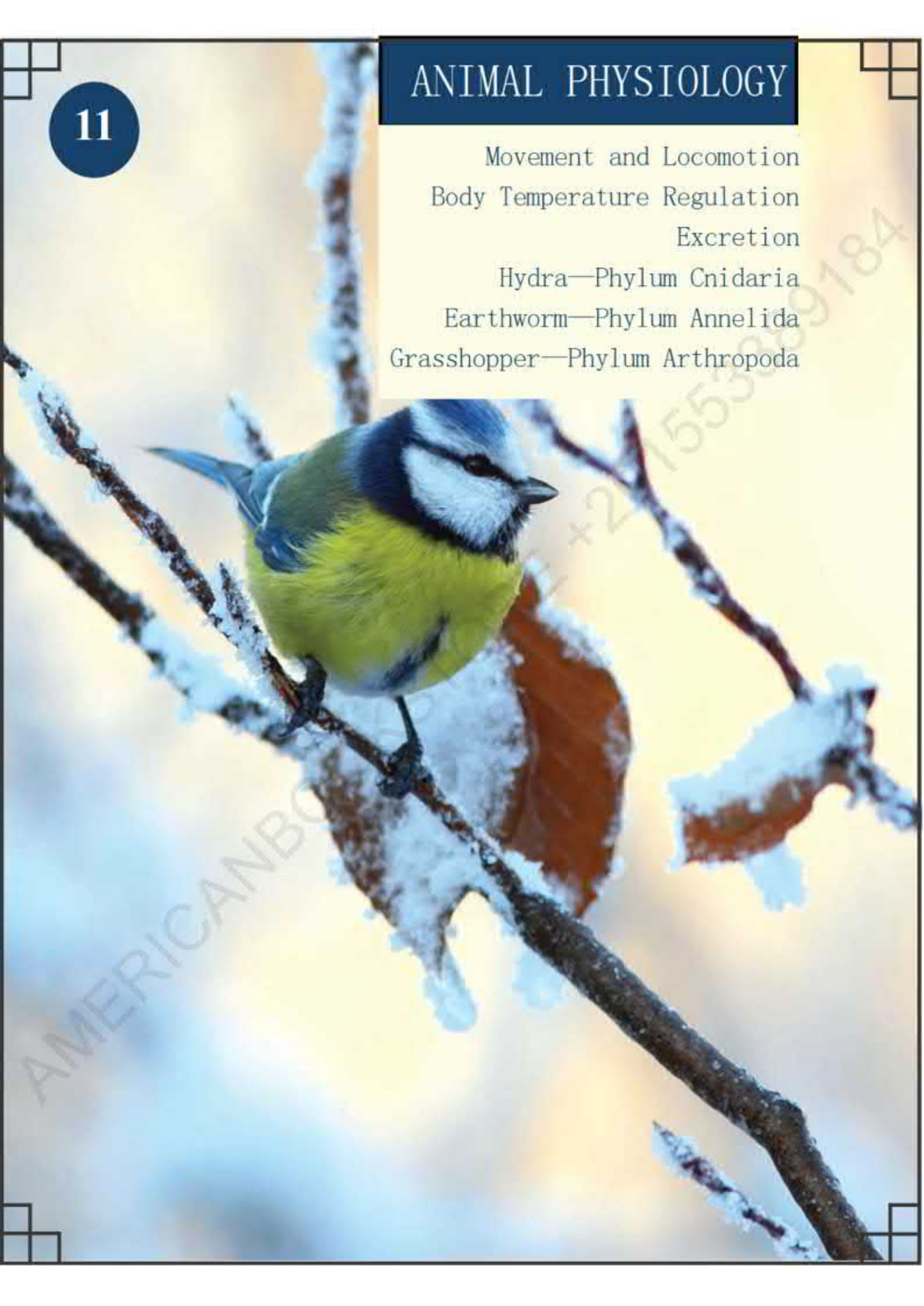
Body Temperature Regulation

Excretion

Hydra—Phylum Cnidaria

Earthworm—Phylum Annelida

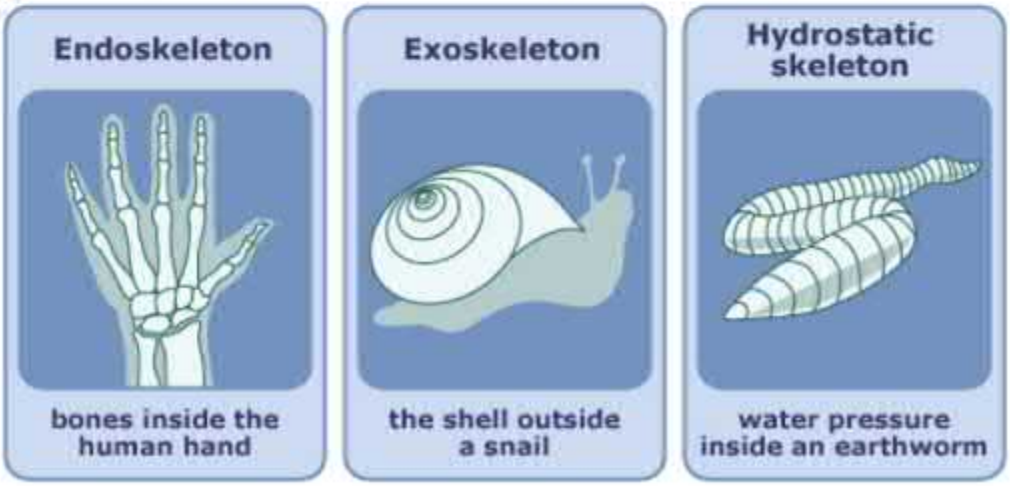
Grasshopper—Phylum Arthropoda



ANIMAL PHYSIOLOGY

Movement & Locomotion

- Animals are multicellular eukaryotes. All are heterotrophs and acquire nutrients by ingestion.
- Movement is a characteristic of almost all animals.
- Some animals like hydra or sponges are sessile.
- Most animals spend their time and energy capturing food, seeking a mate, or escaping danger.
- Some mollusks, like clams, have a mantle, which secretes a shell that offers protection.
- Some Arthropods, like crabs and grasshoppers, have an exoskeleton consisting mostly of the polysaccharide, chitin, which does not grow with the animal and must be shed periodically.
- It enables the animal to move rapidly.
- Animals, like the nematodes (roundworms), Flatworms (planaria), and annelids (earthworms) have a hydrostatic skeleton
- Chordates, like frogs, cats, and humans, have an endoskeleton made of bone and cartilage that grows as the animal grows. Bones are connected to each other at joints by ligaments, while tendons connect bones to muscles.



Thermoregulation

- Most life exists only within a fairly narrow range, from 0°C, to about 50°C.
- Animals must either seek out or create a suitable environment for themselves.
- The oceans are the most stable environment and experience the least fluctuation in environmental temperatures.
- Temperatures on land fluctuate enormously.
- Jackrabbits that evolved in cold, northern regions have small ears close to the head to minimize heat loss.
- Rabbits that evolved in warm have long ears to dissipate heat from the many capillaries that make their ears appear pink.
- Animals can also regulate body temperatures by changes in behavior. Here are some examples.
  - A snake can warm itself in the sun and cool off by hiding in the shade.
  - Animals on a cold prairie in winter huddle to decrease heat loss.
  - Bees swarming in a hive raise the temperature inside the hive.
  - Dogs pant and sweat through their tongues
  - Elephants lack sweat glands, but they wet down their thick skins with water and flap their ears, which are rich in capillaries.

  -Humans shiver and jump around to keep warm.

- Cold-blooded and warm-blooded are not scientific terms.
- **Ectotherm** means heated from outside and is probably closest in meaning to cold-blooded.
- **Endotherm (homeotherm)** is the scientific word for warm-blooded. It means maintaining a constant body temperature despite fluctuations in the environmental temperature.
- Among animals, only birds and mammals are endotherms .

Excretion

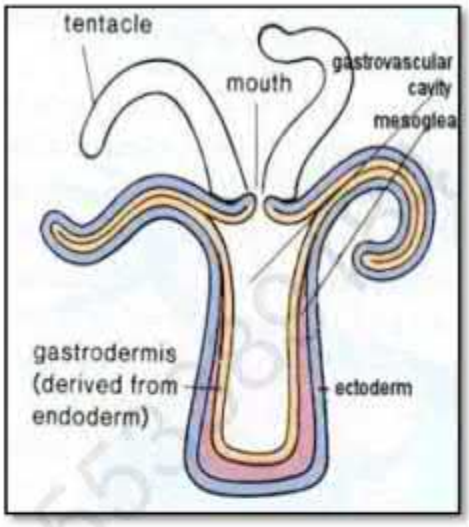
- Excretion is the removal of metabolic wastes. These include water, carbon dioxide, and nitrogenous wastes.
- There are three different types of nitrogenous wastes.

1. **Ammonia**
   - Very soluble in water and highly toxic
   - Excreted generally by organisms that live in water
2. **Urea**
   - Not as toxic as ammonia
   - Excreted by earthworms and humans
   - In mammals, is formed in the liver from ammonia
3. **Uric Acid**
   - Paste like substance that is not soluble in water and therefore not very toxic
   - Excreted by insects, many reptiles, and birds, **with a minimum of water loss**

Organism	Excretion Structure	Nitrogenous Waste
Hydra	None	Ammonia
Planaria	Flame cells	Ammonia
Earthworms	Nephridia	Urea
Insects	Malpighian tubules	Uric acid
Humans	Nephrons	Urea

Excretion in various animals

Nutrition



- Digestion occurs in the gastrovascular cavity, which has only one opening, the mouth.
- The animal has a two-way digestive tract, which means that food enters the same opening as waste exits.
- Cells of the gastrodermis secrete digestive enzymes into the cavity to aid in extracellular digestion where the main part of digestion occurs.
- Intracellular digestion by lysosomes.

Body Plan and Symmetry

- The basic body plan of the hydra is a polyp; while the body plan of the jellyfish is the medusa.
- The symmetry of all animals in this phylum is primitive and radial.
- The animal has only two cell layers, ectoderm and endoderm.
- Every cell is in direct contact with its environment, and therefore the hydra has no need of a circulatory system.

Nervous System

- All cnidarians have unique cells called **cnidocytes** that contain stingers, called nematocysts.
- Response to the environment is controlled by a primitive nervous system, a nerve net, where impulses travel in all directions from any site. As a result, the entire animal responds to a single stimulus.

Reproduction

- Cnidarians reproduce sexually, as well as asexually, by budding.

EARTHWORM– PHYLUM ANNELIDA

Nutrition

- The earthworm burrows in the ground and creates tunnels that aerate the soil.
- The digestive tract of the is a long, straight tube.
- The mouth ingests decaying organic matter along with soil.
- From the mouth, food moves to the esophagus and then to the crop, where it is stored.
- Posterior to the crop, the gizzard, which consists of thick muscular walls, grinds up the food with the help of sand and soil which were ingested.
- The rest of the digestive tract consists of the intestines where chemical digestion and absorption occur.
- Absorption is enhanced by the presence of a large fold in the upper surface of the intestine, called the typhlosole

Nervous and transport system

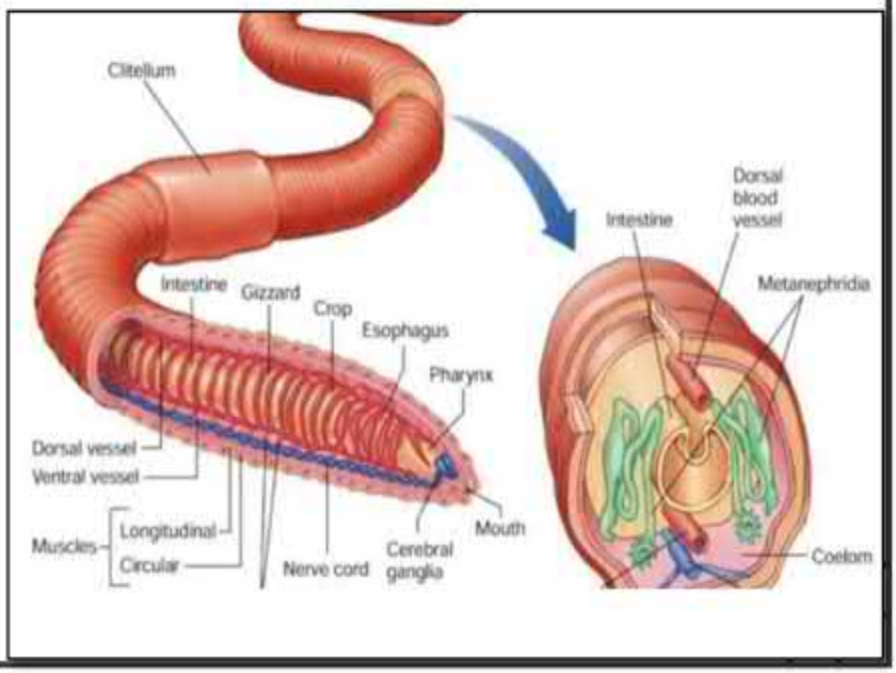
- Respiration by diffusion through moist skin.
- The heart consists of five pairs of aortic arches that pump blood through the body
- Earthworm has a closed circulatory system.
- The brain of the earthworm consists of two dorsal, solid, fused ganglia that connect to a solid, ventral nerve cord.

Excretion

- The earthworm has paired nephridia in every body segment to remove the nitrogenous waste urea.

Reproduction

- The earthworm is a hermaphrodite



Nutrition

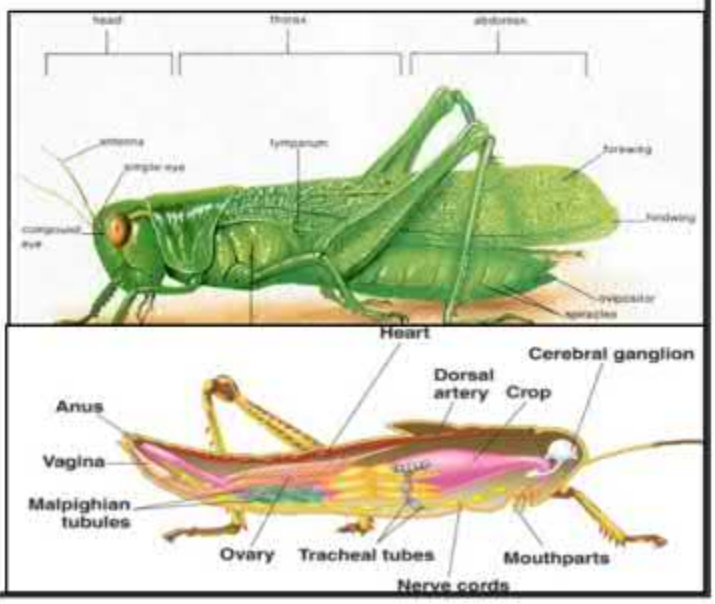
- Like the earthworm, the grasshopper has a digestive tract that consists of a long tube consisting of a crop and gizzard.
- The grasshopper has specialized mouthparts for tasting, biting, and crushing food and a gizzard that contains plates made of chitin that help grind food.
- The digestive tract is also responsible for removing the nitrogenous waste uric acid from the animal.

Nervous and Transport Systems

- The nervous system of the grasshopper is similar to that of the earthworm, but the transport system is different.
- The grasshopper heart is tubular, and the animal lacks capillaries.
- The grasshopper has an open circulatory system where blood normally leaves the artery and moves through interconnected sinuses or hemocoels, spaces surrounding the organs.
- Arthropod blood does not carry hemoglobin or oxygen.

Exchange of Respiratory Gases

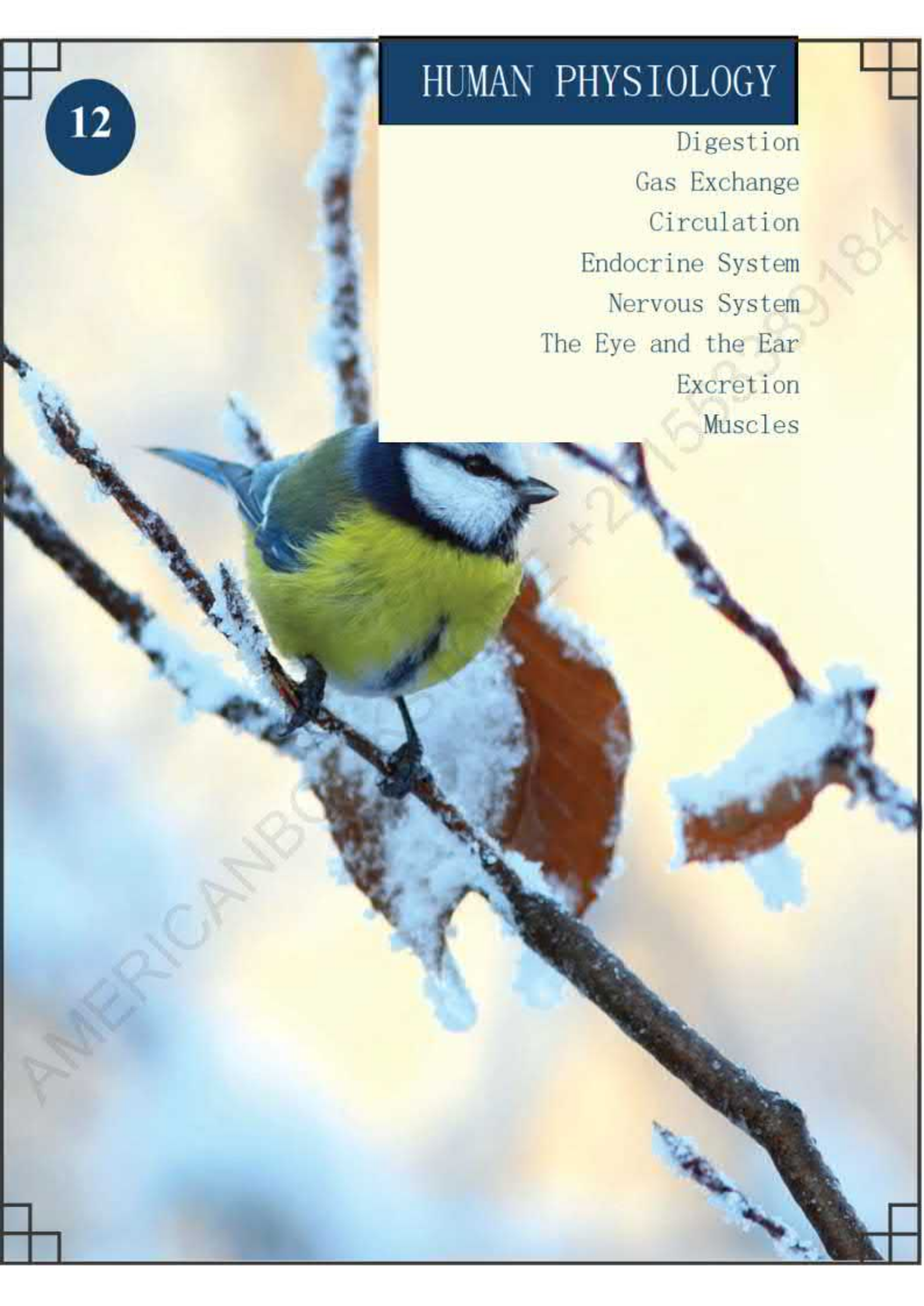
- have an internal respiratory surface inside the animal.
- Air enters the body through spiracles and travels through a system of tracheal tubes into the hemocoels or sinuses, where diffusion occurs.
- In arthropods and in some mollusks, oxygen is carried by **hemocyanin**, a molecule similar to hemoglobin but with copper, instead of iron, as its core atom.



12

HUMAN PHYSIOLOGY

Digestion
Gas Exchange
Circulation
Endocrine System
Nervous System
The Eye and the Ear
Excretion
Muscles



HUMAN PHYSIOLOGY

Digestion

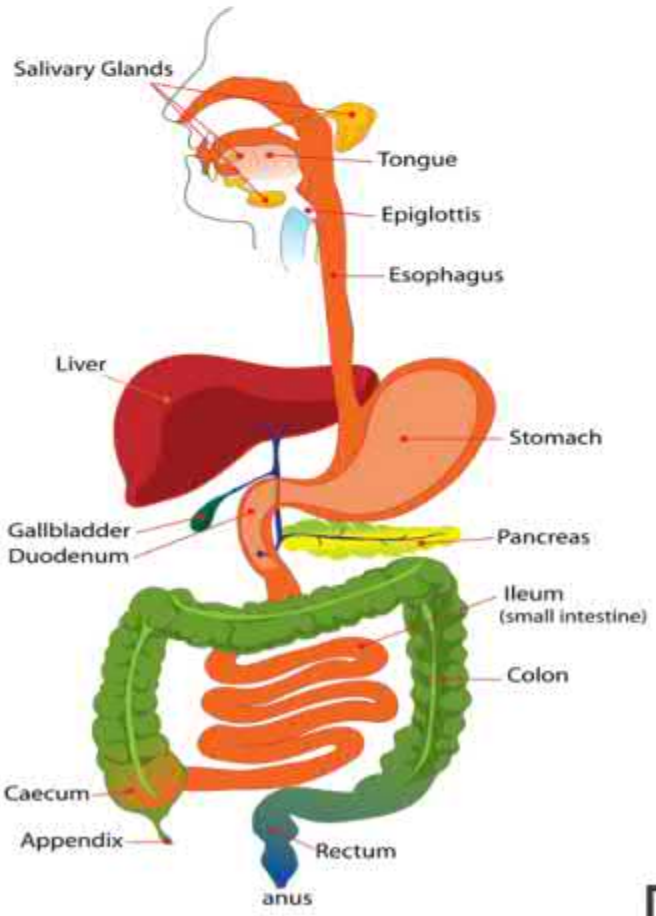
Human Digestive system (GIT)

Functions

1. Breaking down food molecules into smaller molecules
2. Absorbing these smaller molecules.
   - Fats get broken down into glycerol and fatty acids
   - Starch into monosaccharides
   - Nucleic acids into nucleotides
   - Proteins into amino acids.
   - Vitamins and minerals absorbed without digestion

Structure

- Elementary canal + accessory glands (liver, pancreas & salivary glands)
- The digestive tract is about 30 feet long and made of smooth (involuntary) muscle that pushes the food along the digestive tract by peristalsis and controlled by the autonomic nervous system
- It is lined by cells secrete mucous



Mouth

- Mechanical digestion (by teeth and tongue)
- Chemical digestion (salivary amylase in saliva begins starch digestion)
- Humans are **omnivores** and have three different types of teeth:
  - **Incisors for cutting**
  - **Canines for tearing**
  - **Molars for grinding**

Esophagus

- No digestion occurs here.
- The esophagus transports food from the throat to the stomach.
- Epiglottis prevent food from entering trachea.

Stomach

- **Mechanical digestion** (The stomach's thick, muscular wall churns food)
- **Chemical digestion**:
  - Protein digestion begins in the stomach.
  - The stomach's wall secretes gastric juice, which contains hydrochloric acid and protease enzymes that digest proteins.
  - Hydrochloric acid begins the breakdown of muscle (meat) and activates the inactive enzyme pepsinogen to become pepsin, which digests protein.
  - The enzyme rennin aids in the digestion of milk protein
- The pH in the stomach is acidic, ranging from 2 to 3.
- The cardiac sphincter at the top of the stomach and the pyloric sphincter at the bottom keeps acidified food in the stomach
- Excessive acid can cause an ulcer to form in the esophagus, the stomach, or the duodenum

Small Intestine

- All digestion is completed and nutrients are absorbed here.
- The pH in the small intestine is around 8.
- It is 6 meters long.
- All digestion is completed in the duodenum, the first 10 inches of small intestine.
- The intestinal enzymes are **amylases, proteases, lipases, and nucleases.**
- Millions of fingerlike projections called villi line the small intestine and absorb all nutrients that were previously released from digested food.
- Each villus contains capillaries, which absorb amino acids, vitamins, and monosaccharides directly into the bloodstream, and a lacteal, which absorbs fatty acids and glycerol into the lymphatic system.
- Villi have microscopic appendages called microvilli that further enhance the rate of absorption.

Liver

- Produces bile that emulsifies fats.
- Bile = pH 11; help in neutralizes chyme (acidified food from stomach) entering small intestine
- Store bile in gallbladder until its release into the SI
- Has other functions besides digestion
  1. Breaks down and recycles red blood cells
  2. Detoxifies blood– removes alcohol and drugs
  3. Produces cholesterol necessary for structure of cell membranes
  4. Produces the nitrogenous waste urea from protein metabolism
  5. Convert lactic acid into pyruvate
  6. Storage of fat soluble vitamins

Gallbladder

- Stores bile that is produced in liver
- Bile emulsifies fats in small intestine
- Body can function well without a gallbladder

Pancreas

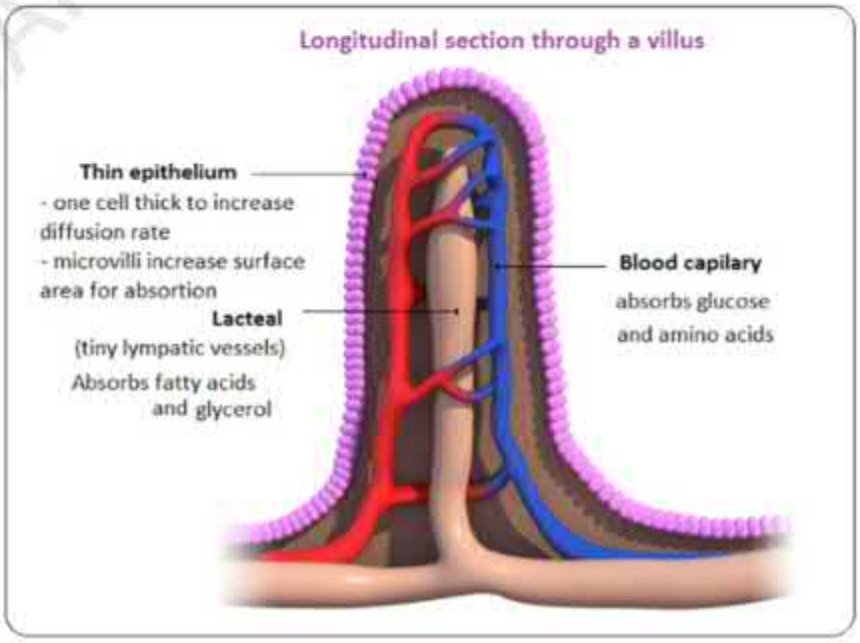
- Secretes peptidases, Lipase, Amylase and nuclease
- Secretes sodium bicarbonate to neutralize chyme

Large Intestine or Colon

- No digestion occurs here
- Functions: egestion, vitamin production & reabsorption of water
  - Egestion– removal of undigested waste
  - Vitamin production– bacteria symbionts living in the colon produce the B vitamins, vitamin K, and folic acid
  - Reabsorption of water

Rectum

- Egestion– removal of undigested waste
- Last 7 to 8 inches of the gastrointestinal tract stores feces until their release through the anus



Enzymes in the digestive tract

Enzyme	Site of origin	Site of action	Substrate	Product	PH
Amylase	Salivary glands	Mouth cavity	Starch	Maltose	6.5:7.5
Amylase	Pancreas	Small intestine	Starch	Maltose	7:8.5
Pepsin (protease)	Wall of Stomach	Stomach cavity	Proteins	Polypep-tides	2:3
Trypsin (protease)	Pancreas	Small intestine	Proteins	Polypep-tides	7:8.5
Trypsin (protease)	Small intestine wall	Small intestine	Polypep-tides (Proteins)	Amino acids	4:7
Lipase	Pancreas	Small intestine	Fats	Glycerol & fatty acids	7:8.5
Maltase	Small intestine wall	Small intestine	Maltose	Glucose	4:7
Lactase	Small intestine wall	Small intestine	Lactose	Glucose, Galactose	8
Nuclease	Pancreas	Small intestine	Nucleotide	Nucleotides	8
Bile*	Liver Gall Blad-der	Small intestine	Fats	Fat droplets	7:8.5

*Bile:

- It is not an enzyme.
- The action of bile is physical - not chemical - digestion.
- Bile is produced by liver and stored in gall bladder.

Inspiration

- The rib cage expands and forces the diaphragm to contract and move downward, thus expanding the chest cavity and decreasing the internal pressure. Air is drawn into the lungs by negative pressure
- Air enters the nasal cavity and is moistened, warmed, and filtered.
- Air passes through the larynx and down the trachea and bronchi into the tiniest bronchioles, which end in alveoli where diffusion of respiratory gases occurs.

- The **medulla** in the brain sets the breathing rhythm by **monitoring carbon dioxide levels** in the blood and by sensing changes in the pH of the blood.

- A blood pH lower than 7.4 triggers autonomic nerves from the medulla to increase the breathing rate to rid the body of more carbon dioxide.

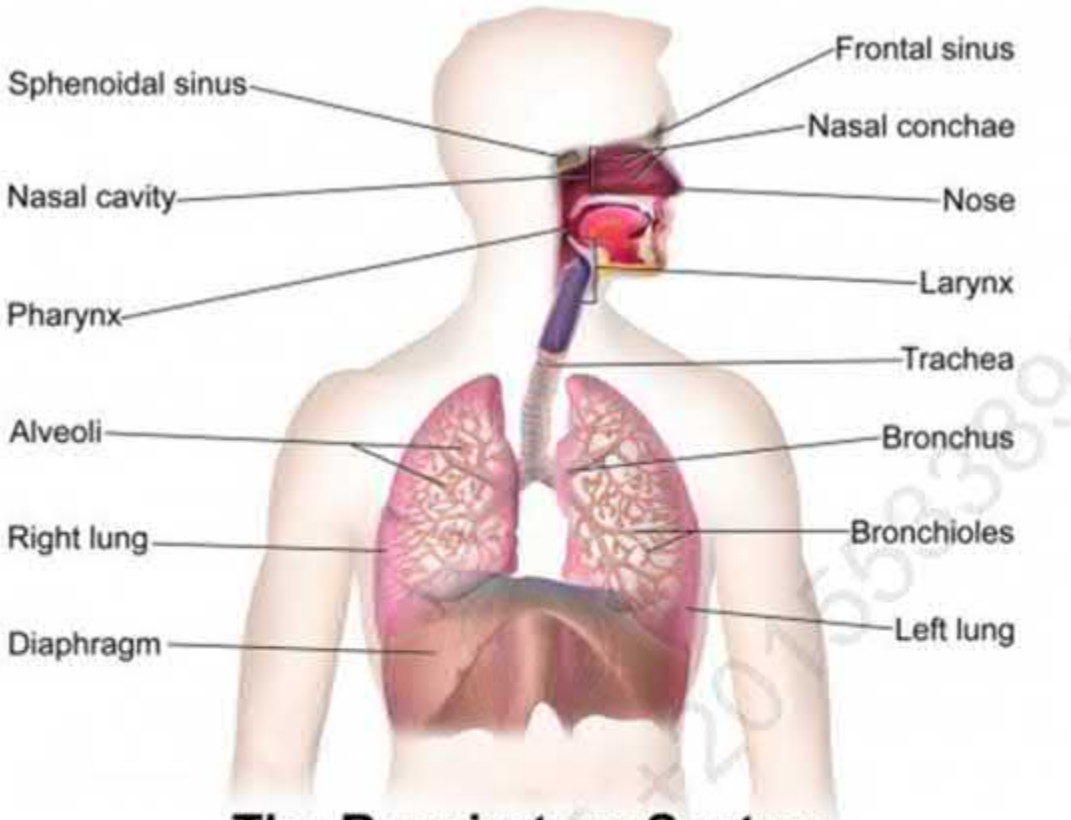
Transport of Oxygen and Carbon Dioxide

- Oxygen is carried in the human blood by hemoglobin which combines with oxygen molecules to form oxyhemoglobin.
- Carbon dioxide dissolves in the blood and carried in the plasma as part of the reversible blood-buffering carbonic acid-bicarbonate ion system, which maintains the blood at a constant pH of 7.4.
- Very little carbon dioxide is transported by hemoglobin.

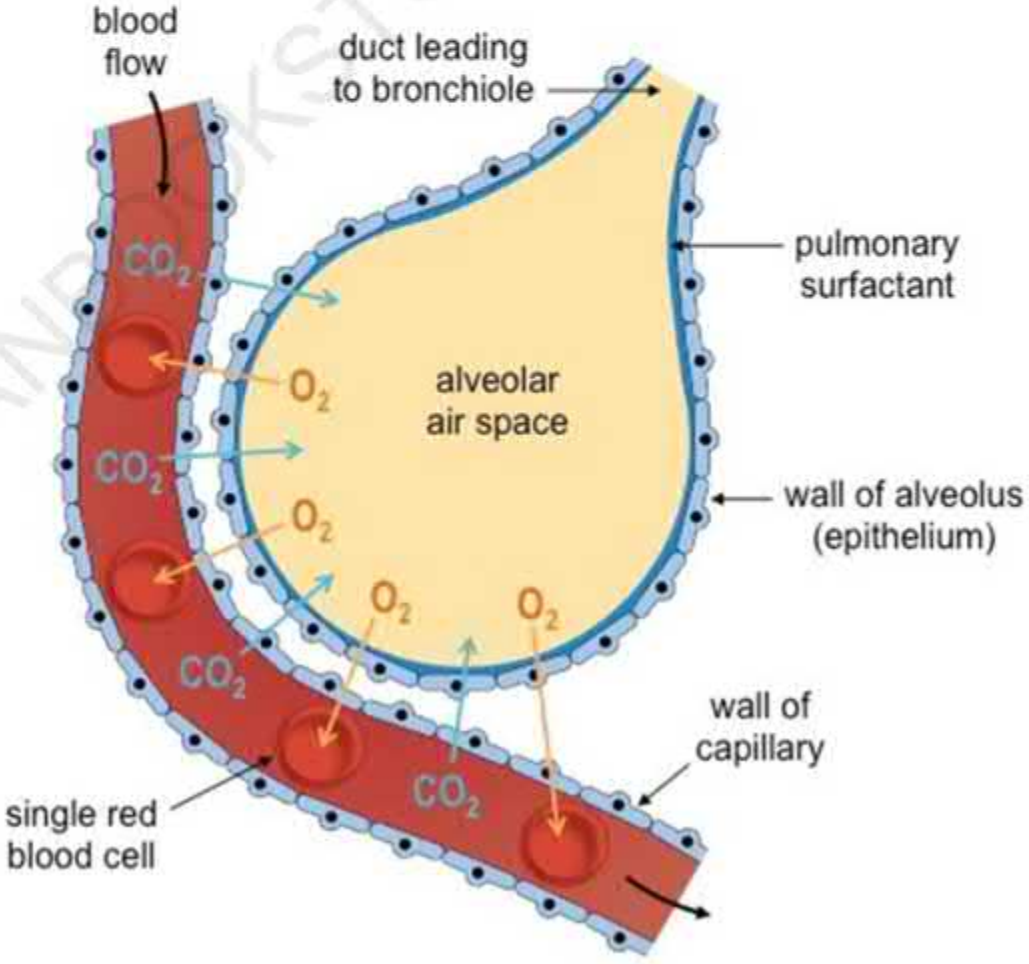
Features of gaseous exchange surface (alveoli)

1. Thin wall (one cell thickness)
2. Large surface area
3. Moist
4. Surrounded by blood capillaries network

Gas Exchange



The Respiratory System

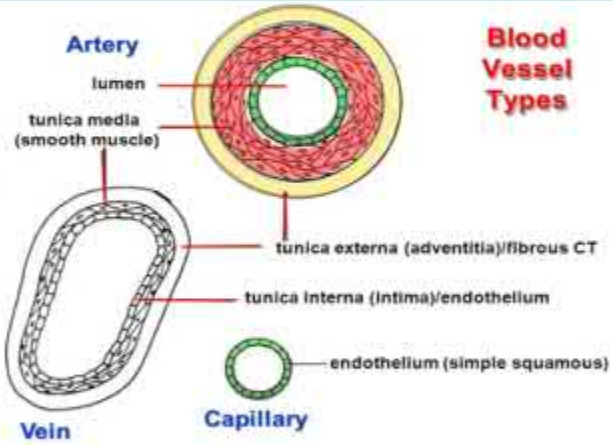


• Human circulation consists of a **closed circulatory system** with arteries, veins and capillaries

	Arteries	Veins	Capillaries
Function	Carries blood away from the heart under enormous pressure	Carries blood back to the heart under very little pressure	Allows for diffusion of nutrients and wastes between cells and blood
Structure	Walls made of thick layer of elastic, smooth muscle. Can withstand high pressure can contract and expand as needed.	Walls do not contain thick layer of muscle Has valves to help prevent backflow. Located within skeletal muscle, which propels blood upward and back to heart as the body moves and muscles contract.	Walls are one cell thick and so small that blood cells travel only single file. Blood travels slowly here to allow time for diffusion of nutrients and wastes
Valves	No valves	Contain valves	No valves
Gas carried	Mainly Oxygen Except pulmonary art.	Mainly Co2 Except pulmonary vein	Oxygen and Co2

Blood

• Blood consists of several different cell types suspended in a liquid matrix called plasma. The average human body contains 4 to 6 liters of blood.



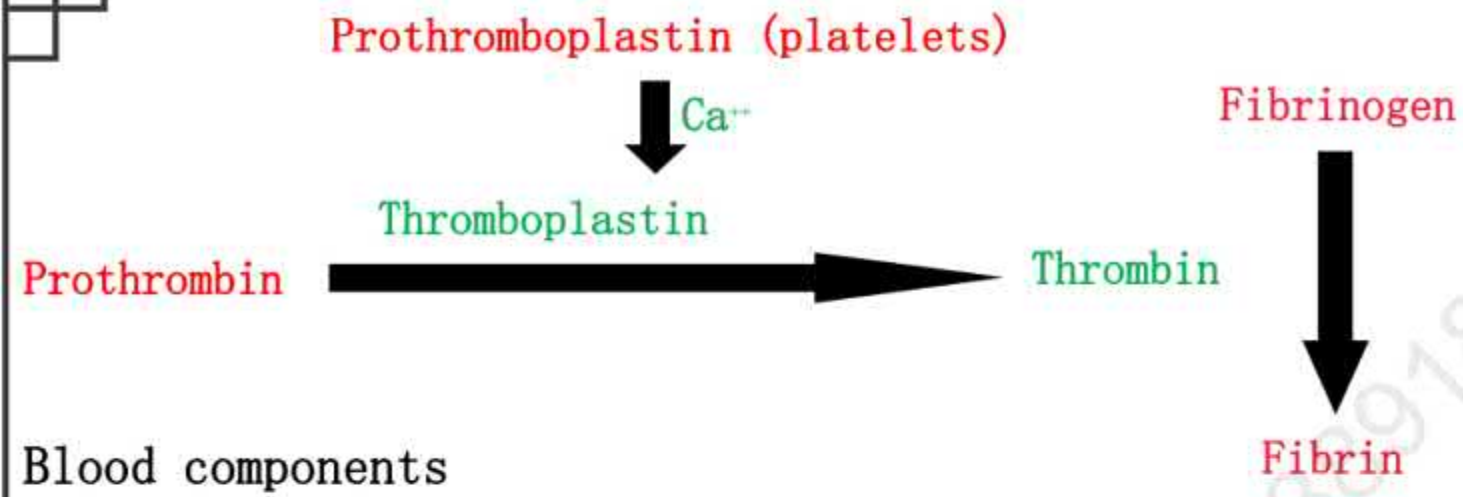
The Mechanism of Blood Clotting

• Complex mechanism that begins with the release of clotting factors from platelets and damaged tissue.

• Anticlotting factors constantly circulate in the plasma to prevent the formation of a clot or thrombus, which can cause serious damage in the absence of injury.

• Serum is plasma minus clotting factors.

• Calcium is necessary for normal blood clotting.

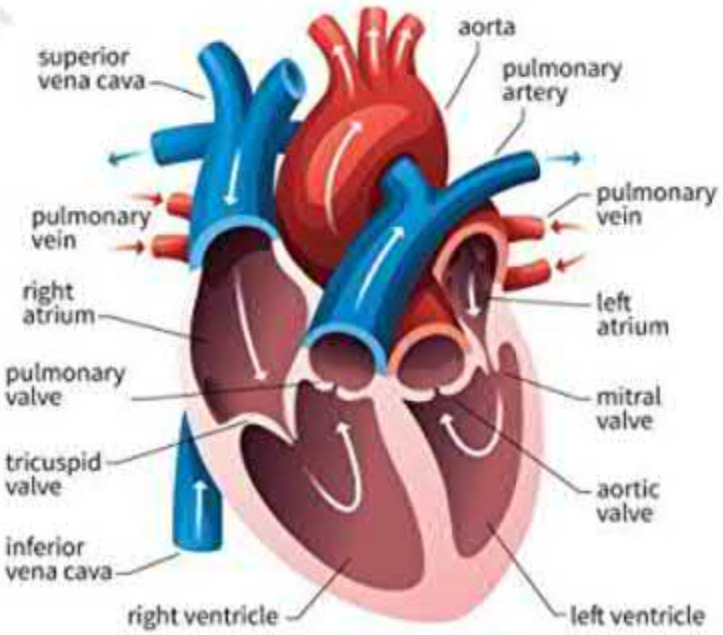


Blood components

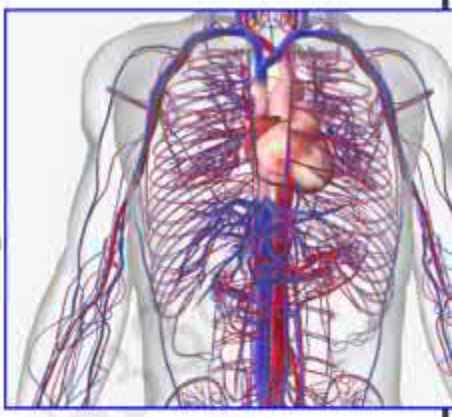
Component	Scientific name	Properties
Plasma 50%	(None)	Liquid portion of the blood. Contains: clotting factors Hormones Antibodies dissolved gases nutrients wastes. 90% water.
Red blood cells **RBCs**	**Erythrocytes**	Carry hemoglobin and oxygen. Do not have a nucleus. Live about 120 days. Formed in the bone marrow Recycled in the liver.
White blood cells **WBCs**	**Leukocytes**	Several types Fight infection. Formed in bone marrow & lymph nodes Die fighting infection One component of pus.
Platelets	**Thrombocytes**	Clot blood. Cell fragment formed in the bone Marrow. No nucleus

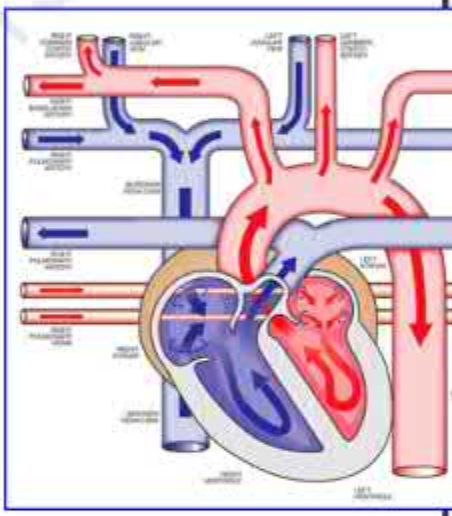
The Heart

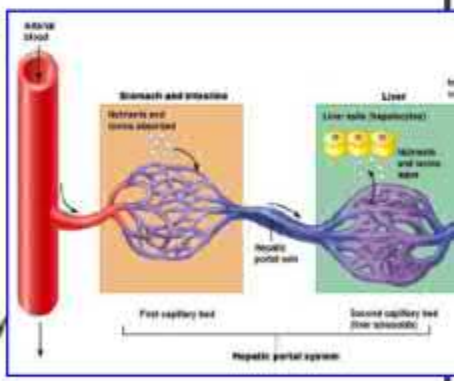
- The heart is located beneath the sternum and is about the size of your clenched fist.
- It beats about 70 beats per minute and pumps about 5 liters of blood— the total volume of blood in the body— each minute.
- Two atria (atria, plural; atrium, singular) receive blood from the body, and two ventricles pump blood out of the heart.
- The heart itself has its own pacemaker, the sinoatrial (SA) node, which sets the timing of the contractions of the heart.
- The heart's pacemaker is influenced by a variety of factors:
    1. The nervous system
    2. Hormones such as adrenaline
    3. Body temperature.
- Blood pressure is lowest in the veins and highest in the arteries when the ventricles contract.
- The average blood pressure for all normal resting adults is 120/80. The systolic number (120) is a measurement of the pressure when the ventricles contract, while the diastolic number (80) is a measure of the pressure when the heart relaxes.
- Remember that the right side of the heart in the figure is actually the left side of the heart in the body.



Blood circulation







jugular vein (also subclavian vein from arms)

head and arms

carotid artery (also subclavian artery to arms)

CO_2

O_2

pulmonary artery

lungs

pulmonary vein

superior vena cava

inferior vena cava

aorta

heart

hepatic vein

mesenteric arteries

hepatic portal vein

liver

digestive tract

renal artery

renal vein

kidneys

iliac vein

iliac artery

O_2

CO_2

trunk and legs

Blood circulates through:

1. coronary circulation
2. renal circulation
3. hepatic circulation
4. pulmonary circulation

ENDOCRINE SYSTEM

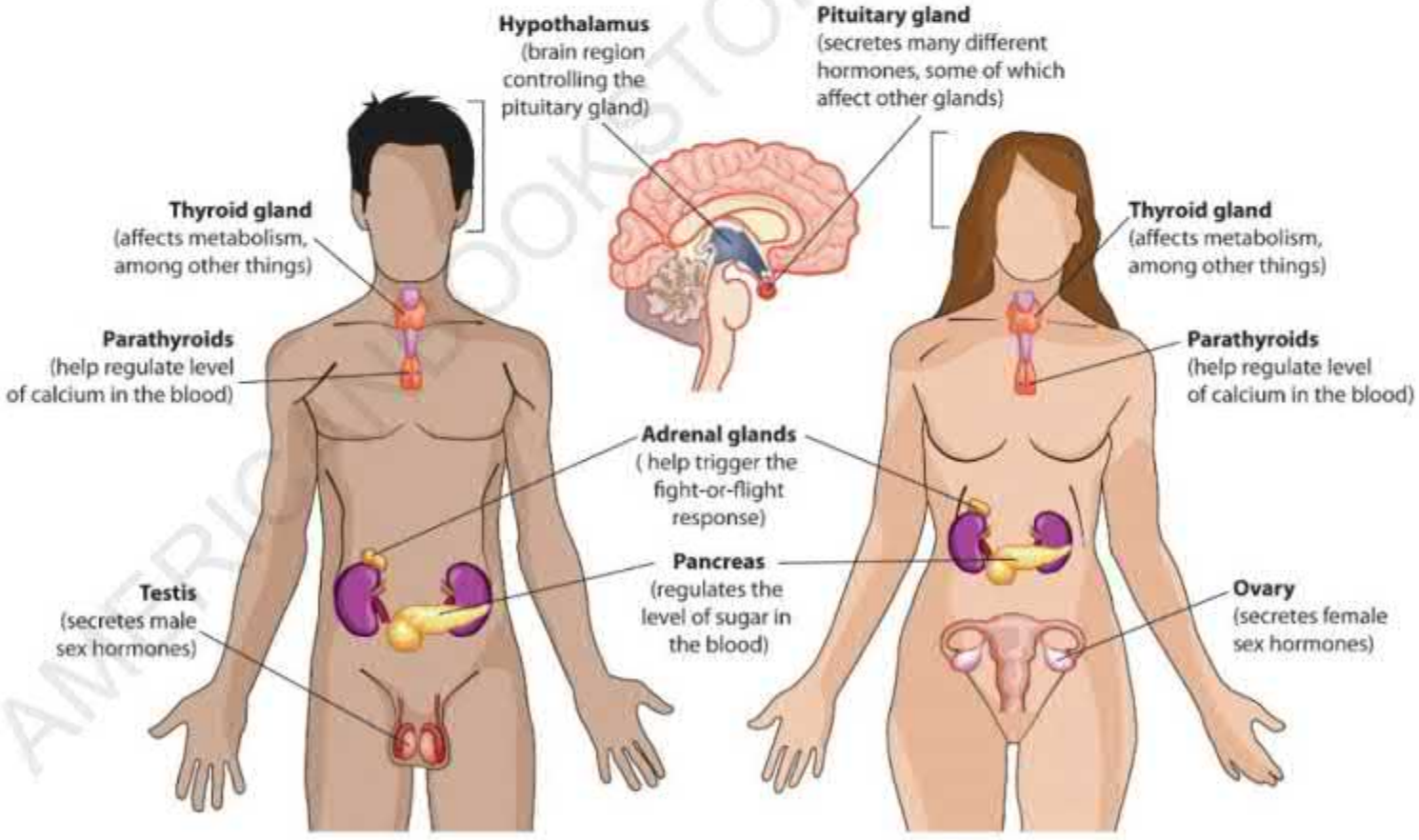
- The two major regulatory systems in the body are **endocrine system and the nervous system.**
- They regulate the body, to maintain **homeostasis.**
- The endocrine system secretes hormones, while the nervous system secretes neurotransmitters.
- They can produce either an immediate short-lived response or a long-term development of an entire organism.
- An example of a short lived response is the way adrenaline (epinephrine) causes the fear, flight, fight response.
- An example of a long-term response is the way ecdysone controls metamorphosis in insects.
- Tropic hormones are hormones that stimulate other glands to release hormones and can have a far-reaching effect.
- For example, the anterior pituitary in the brain releases thyroid-stimulating hormone (TSH), which stimulates the thyroid in the neck region to release thyroxin.
- Pheromones in the urine of a dog carry a message between different individuals of the same species.
- In vertebrates, nitric oxide (NO), a gas, is produced by one cell and diffuses to and affects only neighboring cells before it is broken down.

Hypothalamus

- The hypothalamus is the bridge between the endocrine and nervous systems.
- The hypothalamus acts as part of the nervous system when, in times of stress, it sends electrical signals to the adrenal gland to release adrenaline.
- It acts as an endocrine gland when it produces oxytocin and antidiuretic hormone (ADH)
- The hypothalamus also contains the body's thermostat and centers for regulating hunger and thirst.

Gland	Hormone		Effect
Anterior pituitary	Growth hormone	GH	Stimulates growth of bones
	Luteinizing hormone	LH	Stimulates ovaries and testes
FLAT G	Follicle-stimulating hormone	FSH	Stimulates gonads to produce sperm and ova
	Thyroid-stimulating hormone	TSH	Stimulates thyroid gland
	Adrenocorticotropic hormone	ACTH	Stimulates adrenal cortex to secrete glucocorticoids
Posterior pituitary	Oxytocin		Stimulates contractions of uterus and mammary glands
	Antidiuretic hormone	ADH	Promotes retention of water by kidneys
Thyroid	Thyroxin		Controls metabolic rate
	Calcitonin		Lowers blood calcium levels
Parathyroid	Parathormone		Raises blood calcium levels
Adrenal Cortex	Glucocorticoids		Raises blood sugar levels
Adrenal medulla	Epinephrine (adrenaline)		Raises blood sugar level by Increasing rate of glycogen breakdown by liver
	Non-epinephrine (noradrenaline)		
Pancreas	Insulin		Lowers blood glucose levels
	Glucagon		Raise blood glucose levels

Gland	Hormone	Effect
Thymus (in neck)	Thymosin	Stimulates T lymphocytes as part of the immune response
Pineal (in brain)	Melatonin	Involved in biorhythms
Ovaries	Estrogen	Stimulates uterine lining, promotes development and maintenance of primary and secondary characteristics of female
	Progesterone	Promotes uterine lining growth
Testes	Androgens	Support sperm production and promote secondary sex characteristics



How Hormones Trigger a Response in Target Cells

There are two types of hormones:

- steroid
- nonsteroidal or polypeptide hormones.

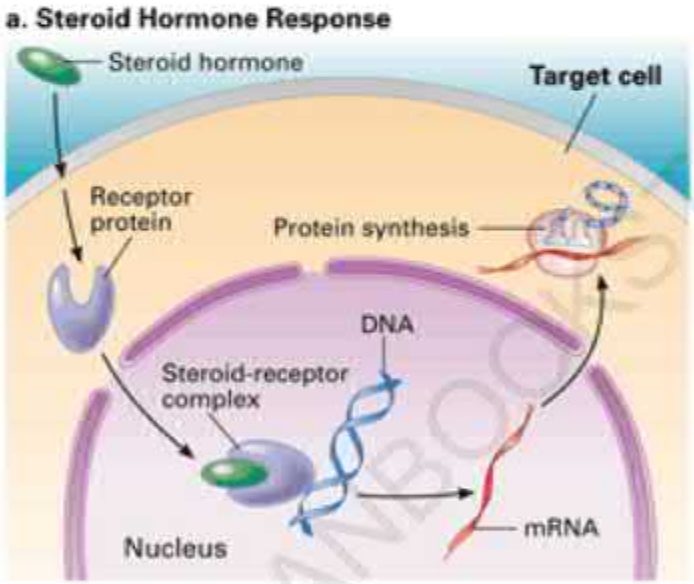
They stimulate target cells in different ways.

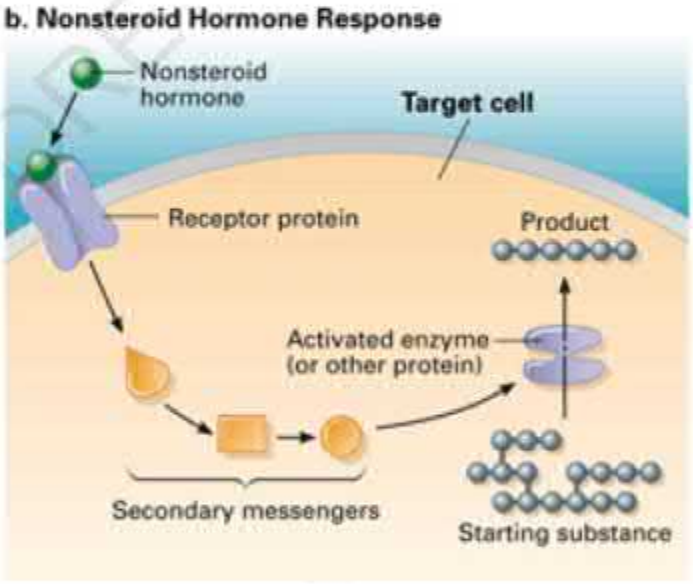
Lipids or steroid hormones:

- diffuse directly through the plasma membrane and bind to a receptor inside the cell that triggers the cell's response.

Protein or polypeptide hormones (nonsteroidal)

- cannot dissolve in the plasma membrane so they bind to a receptor on the surface of the cell. It triggers a secondary messenger such as c-AMP, which converts the extracellular chemical signal to a specific response inside the cell.

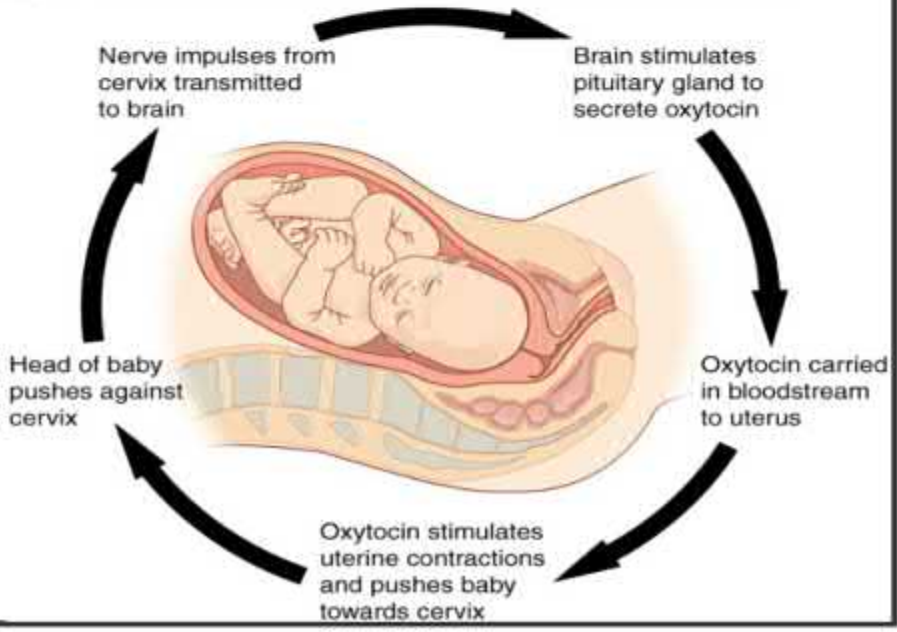




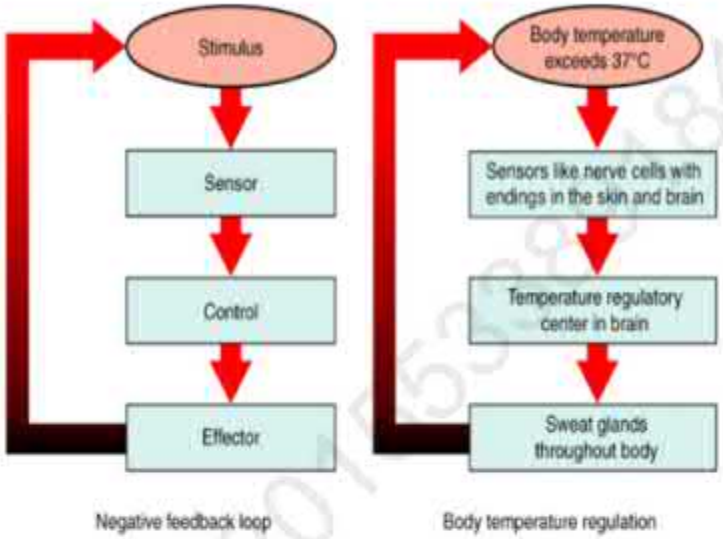
Feedback Mechanisms

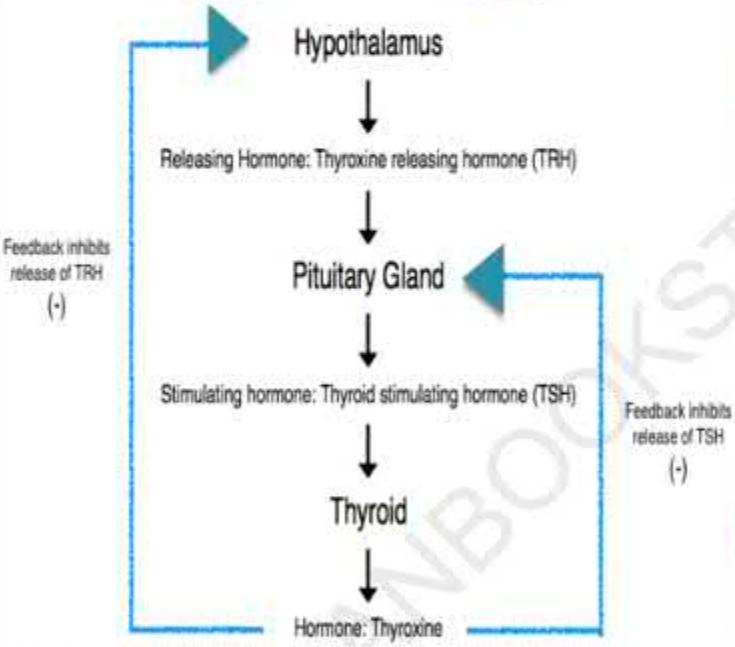
Self-regulating mechanism

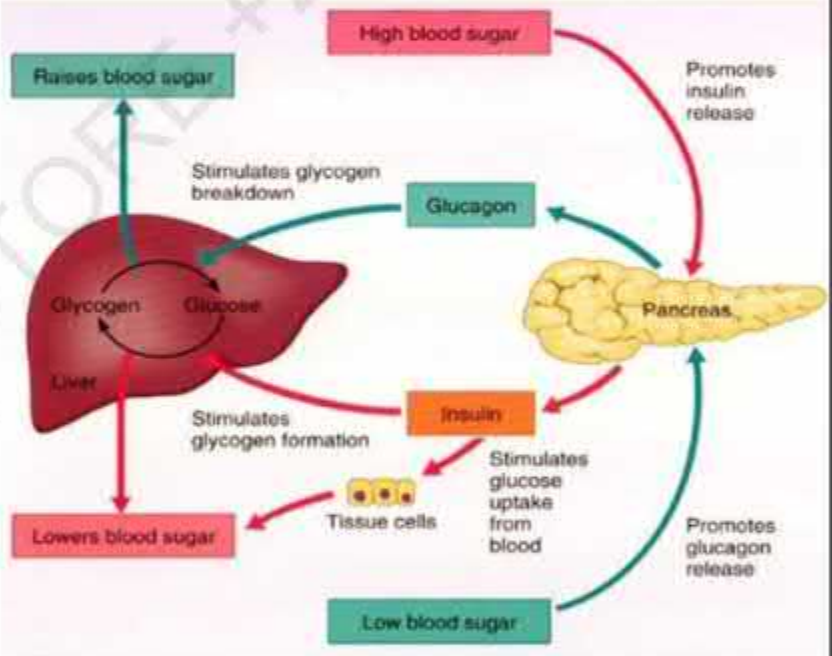
Positive feedback enhances an already existing response.

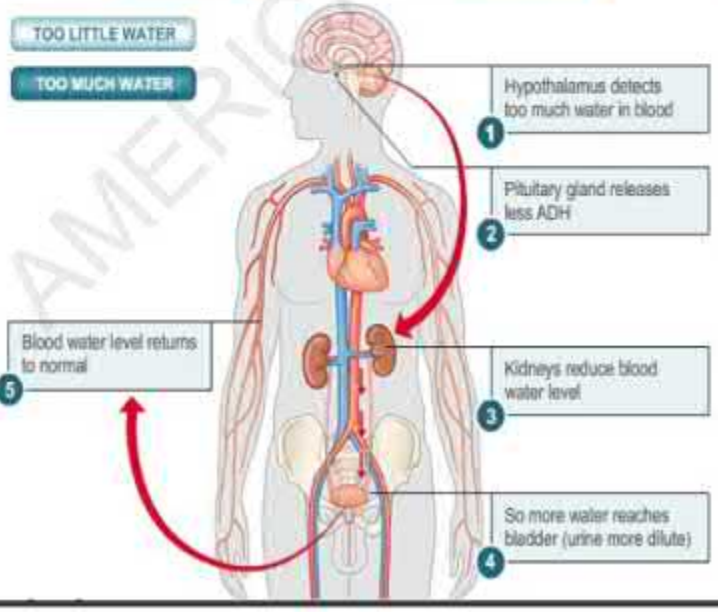


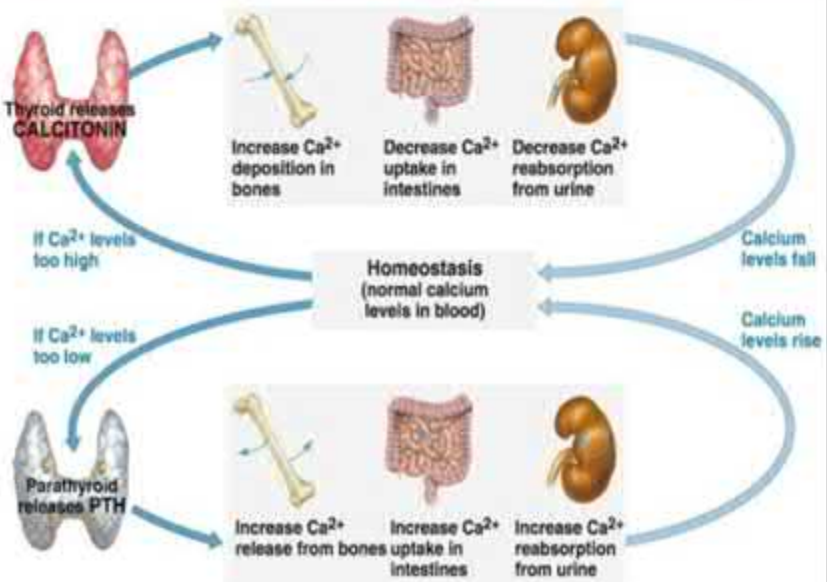
Negative feedback is a common mechanism in the endocrine system (and elsewhere) that maintains homeostasis.

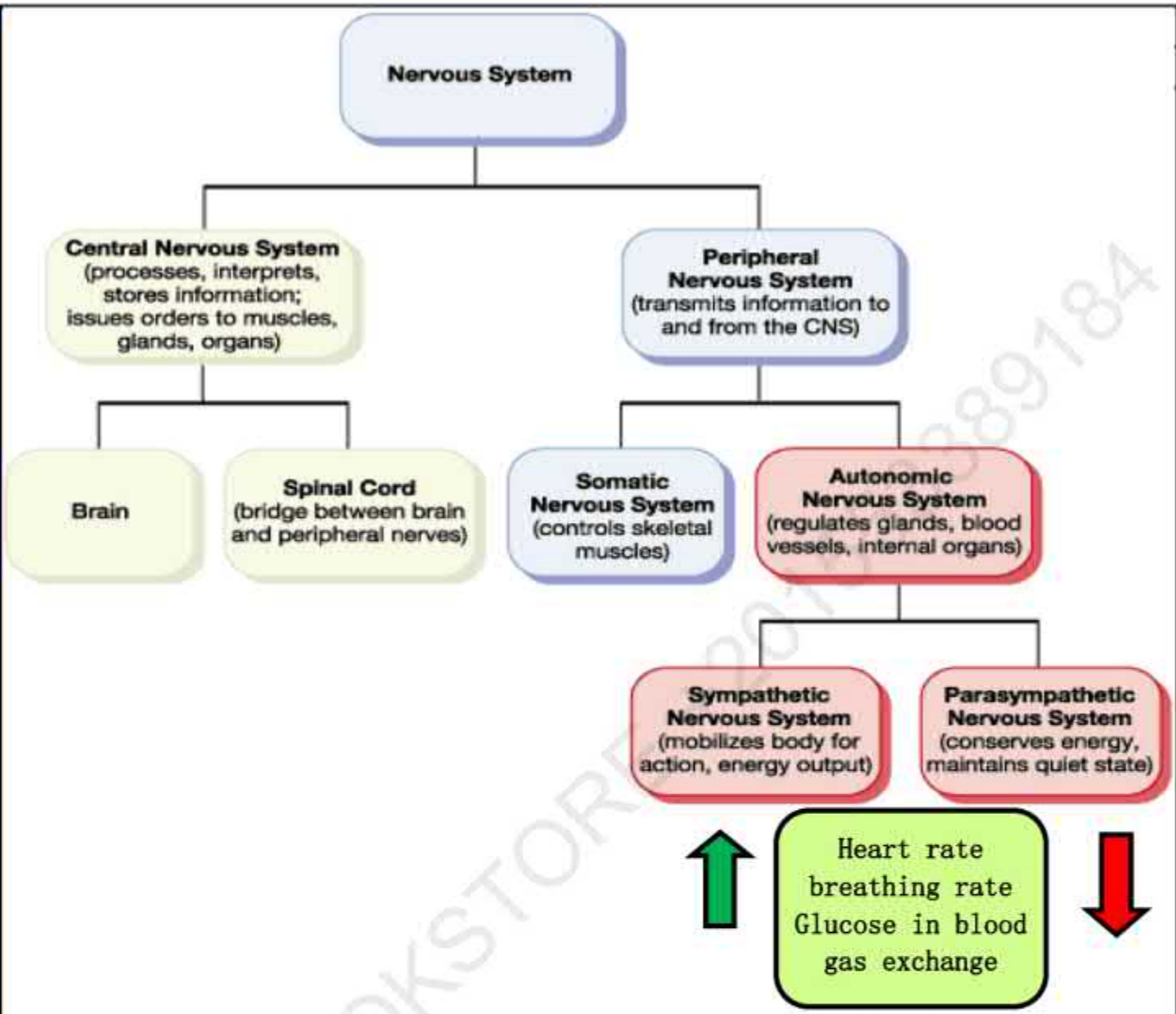






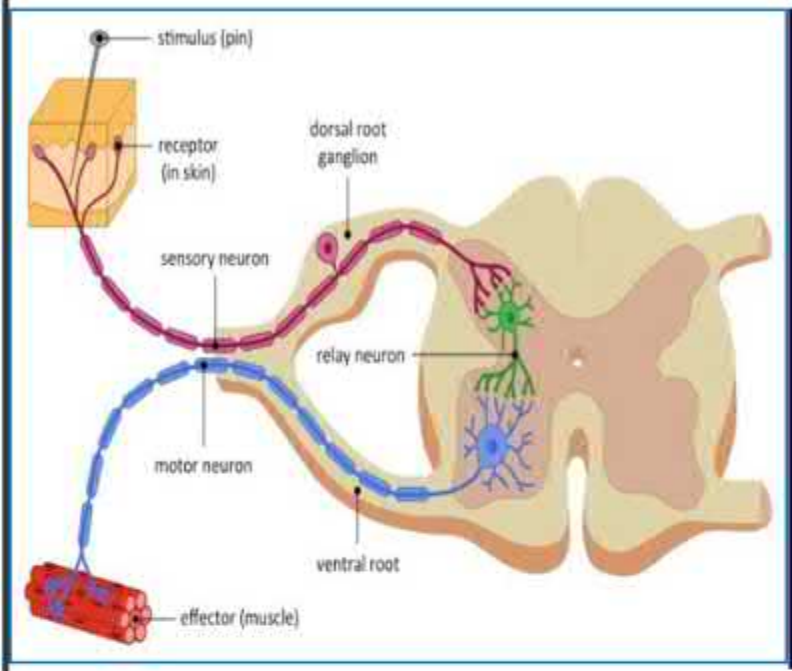


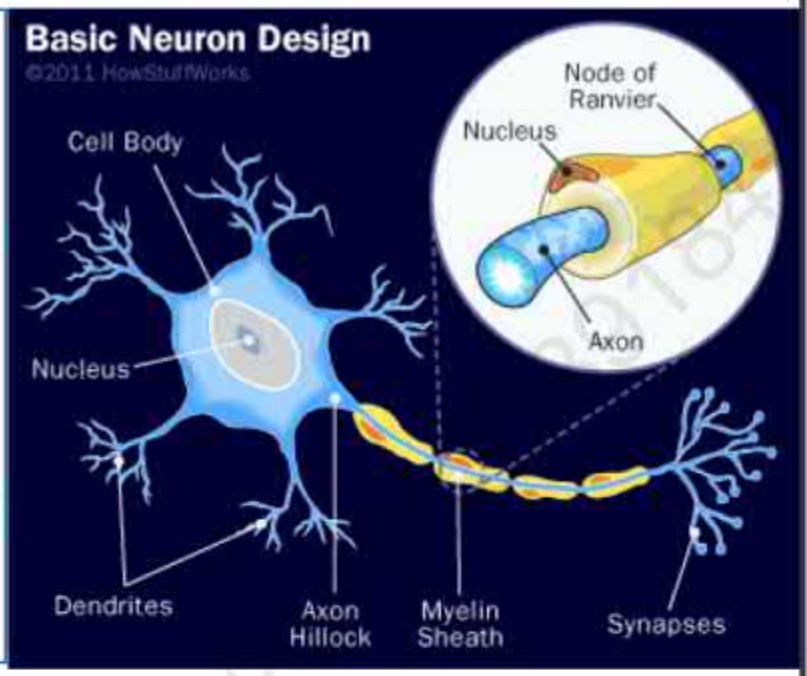




The Neuron

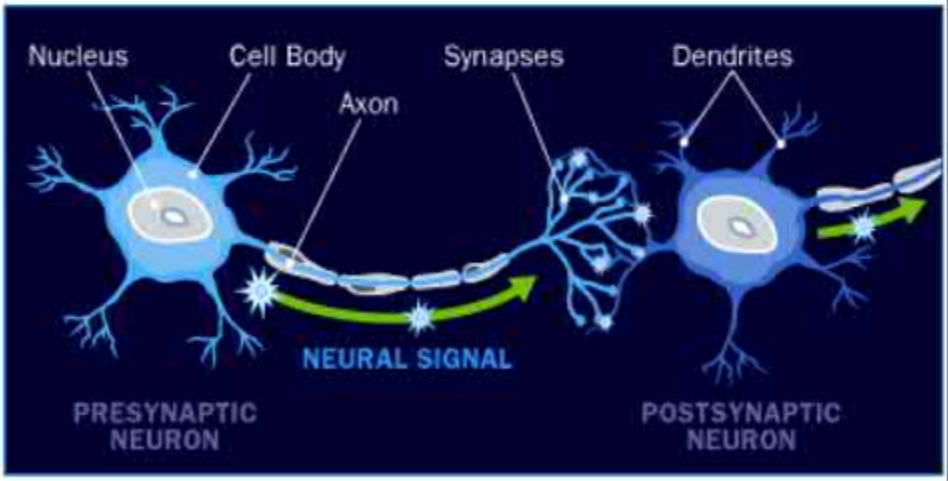
- The neuron is the basic functional unit of the NS
- It consists of:
  - **Cell body** which contains the nucleus and organelles
  - Two types of cytoplasmic extensions **dendrites and axons.**
- Dendrites are sensory. They receive incoming messages from other cells and carry the electrical signal to the cell body. A neuron can have hundreds of dendrites.
- Axons transmit an impulse from the cell body outward to another cell. A neuron has only one axon, which can be several feet long in large mammals.
- Most axons are wrapped in a myelin sheet that protects the axon and speeds the impulse.





The Reflex Arc

- The simplest nerve response
- It is inborn, automatic, and protective.
- An example is the knee-jerk reflex
- It consists of only a sensory and a motor neuron.
- The impulse moves from the sensory neuron in your knee to the motor neuron that directs the thigh muscle to contract.
- A more complex reflex arc consists of three neurons:
  - Sensory
  - Motor
  - Interneuron



How a Neuron Functions

- There is a difference in electrical charge between the cytoplasm (negative charge) and extracellular fluid (positive charge).
- This difference in membrane potential to be between -50mV to -100mV. "inside of the cell is negative to the outside"

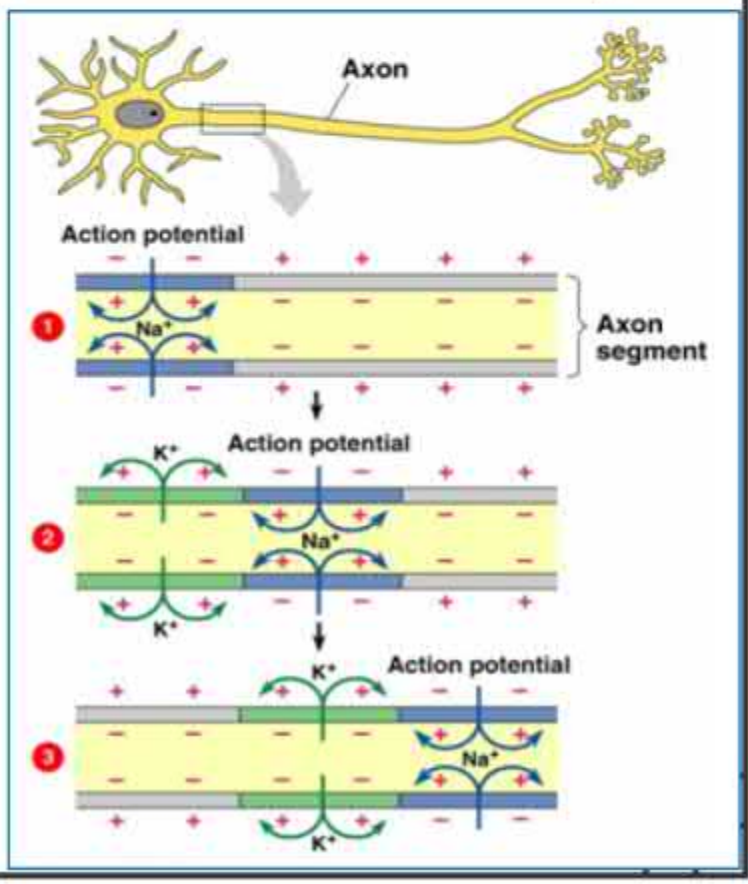
- RESTING POTENTIAL

A neuron at rest or unstimulated (resting potential) is polarized and has a membrane potential of about −70 mV. The sodium-potassium pump maintains this polarization by actively pumping ions out of the cell that leak inward. the stimulus cause the nerve to fire.

- ACTION POTENTIAL
  - Axon is stimulated
  - The permeability of a region of the membrane changes.
  - Sodium floods into the cell, down the concentration gradient
  - Potassium floods out of the cell.
  - This movement of ions or is called an action potential.
  - It is localized and lasts a very short time.
  - The impulse moves along the axon, propagating itself without losing any strength.
  - If the axon is myelinated, the impulse travels faster.
  - It is an all-or-nothing event

- The sodium-potassium pump restores the membrane to its original polarized condition by pumping sodium and potassium ions back to their original positions.

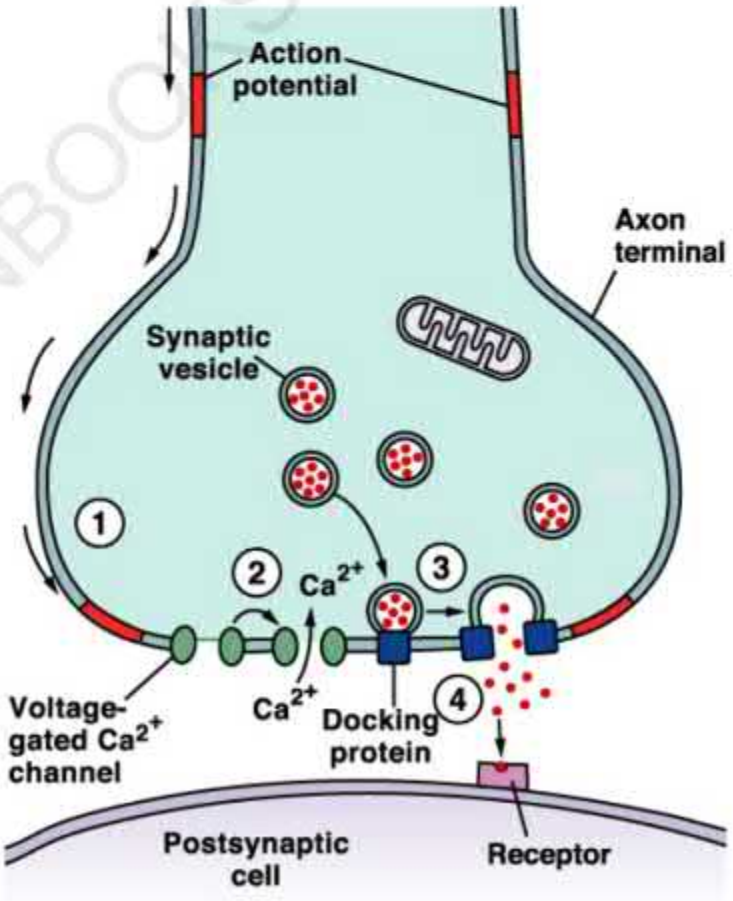
- This period of repolarization, which lasts a few milliseconds, is called the refractory period, during which the neuron cannot respond to another stimulus.



THE SYNAPSE

- Impulse crosses a synapse chemically.
- The cytoplasm at the terminal branch of the neuron contains many vesicles, each containing thousands of molecules of neurotransmitter.
- Depolarization of the presynaptic membrane causes Ca++ ions to rush into the terminal branch through calcium-gated channels. This cause the release the neurotransmitter by exocytosis into the synapse and sets up another action potential on the adjacent cell.
- The most common neurotransmitters are **acetylcholine, serotonin, epinephrine, norepinephrine, dopamine, and GABA.** In addition, many cells release the gas **nitric oxide (NO)** to stimulate other cells.

"Impulse go through neuron electrically and from one neuron to another chemically through synapse"



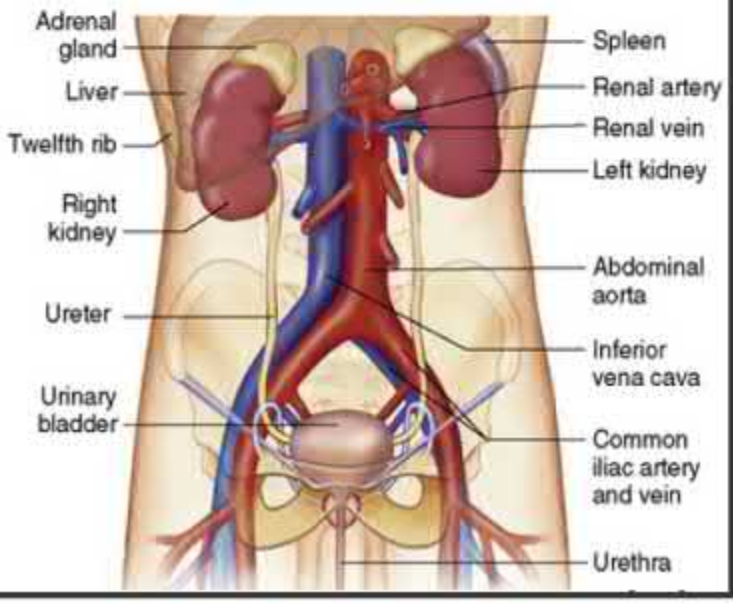
Excretion

- It is the removal of metabolic wastes.
- This includes removing Co_2 and water from cell respiration, and nitrogenous wastes from protein metabolism.
- The organs of excretion in humans are the **skin, lungs, liver, and the kidneys.**
    - **Skin** excretes sweat consisting of water and salts, including urea.
    - **Lungs** excrete water vapor and carbon dioxide from the Krebs cycle.
    - **The liver** does not excrete any substances from the body, but it is the site of deamination of amino acids and the production of urea.
    - **The kidneys** excrete excess water and urea.

The Human Kidney

- The kidneys adjusts volume and the concentration of urine depending on the animal's intake of water and salt and the production of urea.
- The kidneys filter about 1,500 liters of blood per day and produce, on average, 1.5 liters of urine.
- The kidney is under hormonal control.

Antidiuretic hormone (ADH), is released by the posterior pituitary and targets the collecting tube of the nephron. It regulates blood pressure by controlling how much water is reabsorbed by the kidneys.



THE NEPHRON

- It is the basic functional unit of the kidney.
- Each human kidney contains about 1 million nephrons.

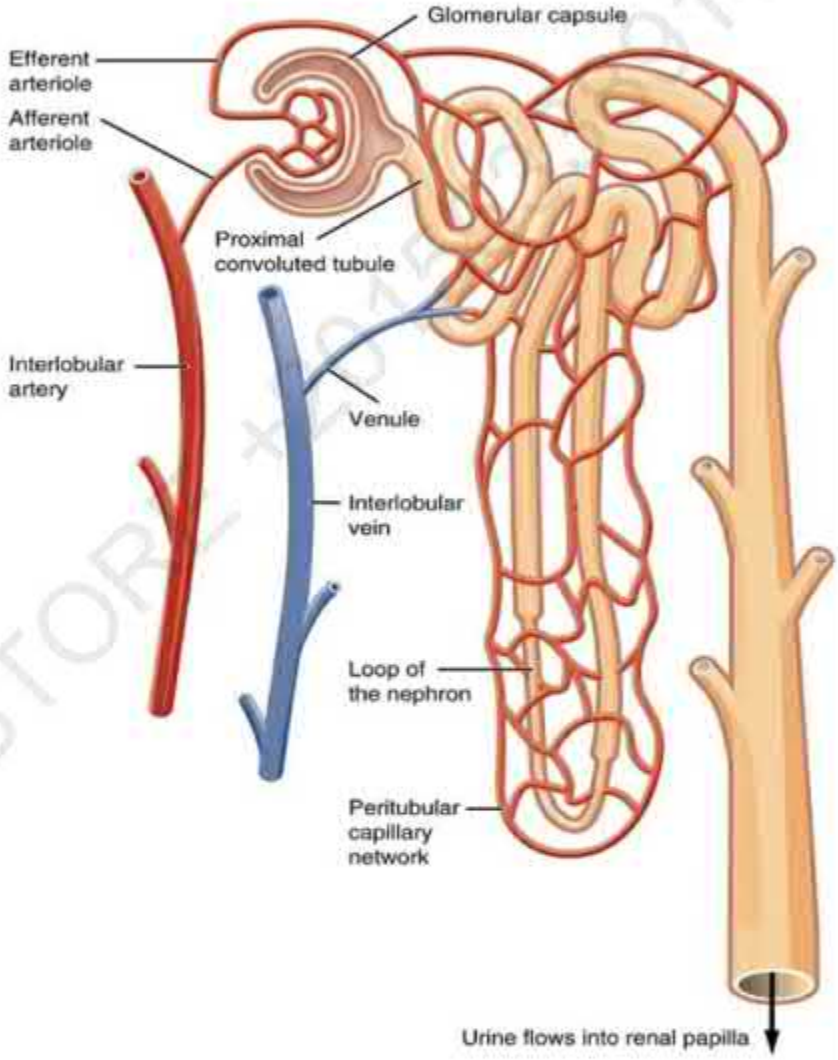
Structure:

-A cluster of capillaries, known as the glomerulus

-A cuplike structure called Bowman's capsule

-A long narrow tube called the tubule

-The loop of Henle.

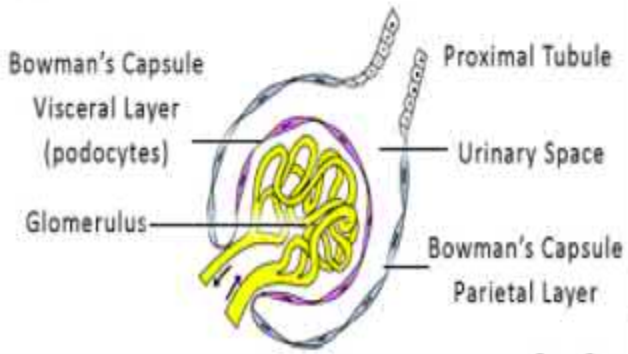


Function:

1. Filtration
2. Secretion
3. Reabsorption
4. Excretion.

1. Filtration:

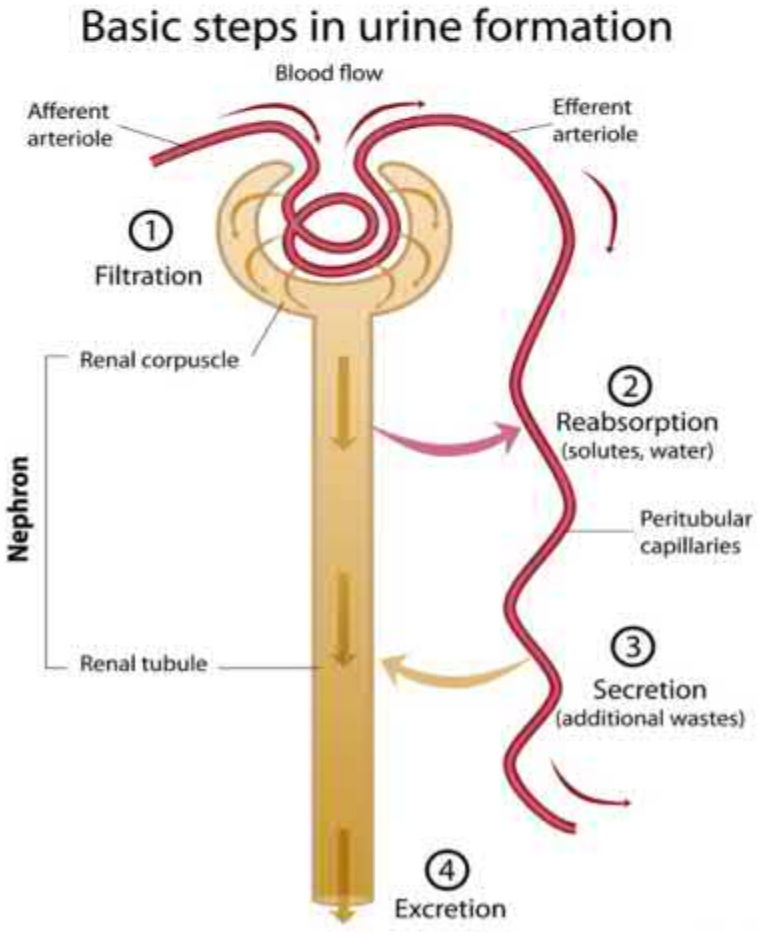
- Filtration out of the glomerulus and into Bowman's capsule by diffusion.
- It is passive and nonselective including glucose, salts, vitamins, wastes such as urea, and other small molecules.
- From Bowman's capsule, the filtrate travels into the loop of Henle and then the collecting duct or tubule.
- From the collecting tubule, the filtrate trickles into the ureter and the urinary bladder for temporary storage and then to the urethra and out of the body.



2. **Secretion:**
   - Secretion is the active, selective uptake of molecules that did not get filtered into Bowman's capsule.
   - This occurs in the tubules of the nephron.

3. **Reabsorption:**
   - Reabsorption is the process by which most of the water and solutes are transported back into the body.
   - This process occurs in the tubule, the loop of Henle, and the collecting tubule.
   - The longer the loop of Henle, the greater is the reabsorption of water.

4. **Excretion:**
   - Excretion is the removal of metabolic wastes
   - Example nitrogenous wastes.
   - Everything that passes into the collecting tubule is excreted from the body.



Muscles

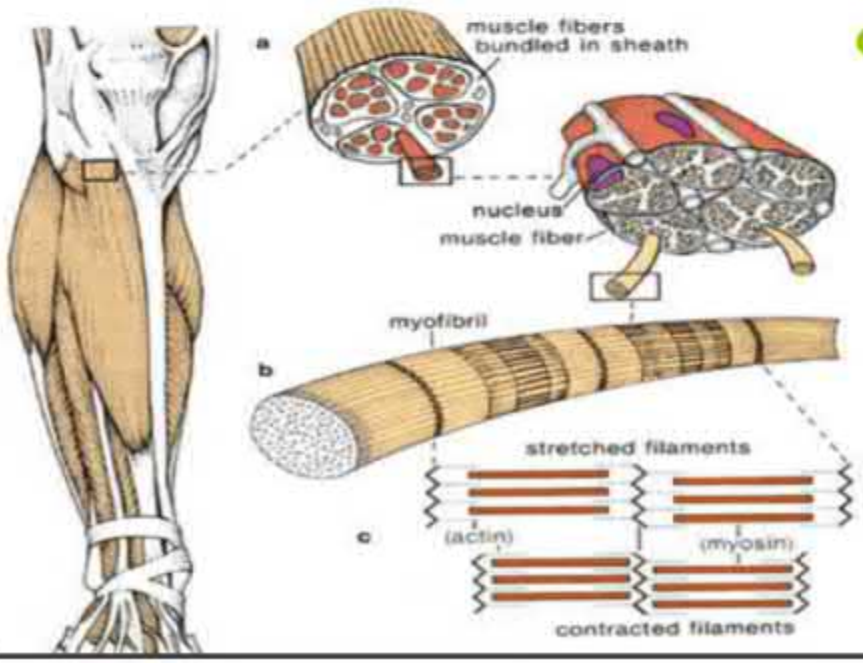
MUSCLES

- There are three types of muscle: smooth, cardiac, and skeletal.

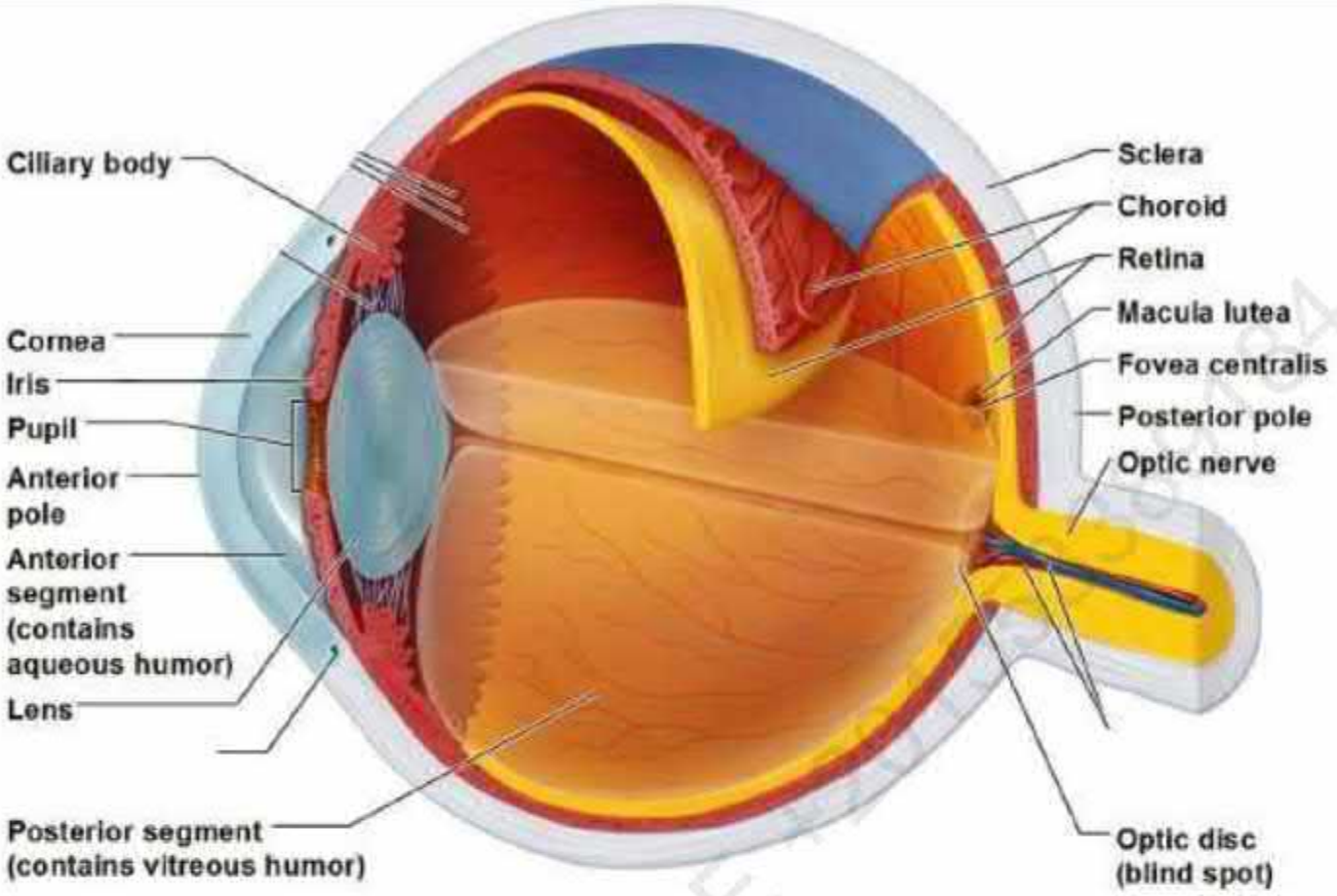
1. **Smooth (involuntary muscle)**
   - Makes up the walls of blood vessels and the digestive tract.
   - It does not have a striated appearance
   - It is under the control of the autonomic NS
2. **Skeletal (voluntary (striated) muscles)**
   - They are very large and multinucleate.
   - They work in pairs, one muscle contracts while the other relaxes. Example biceps & triceps in the arm
3. **Cardiac muscle**
   - It is found in the heart and is striated like a skeletal muscle.

The Sliding Filament Theory

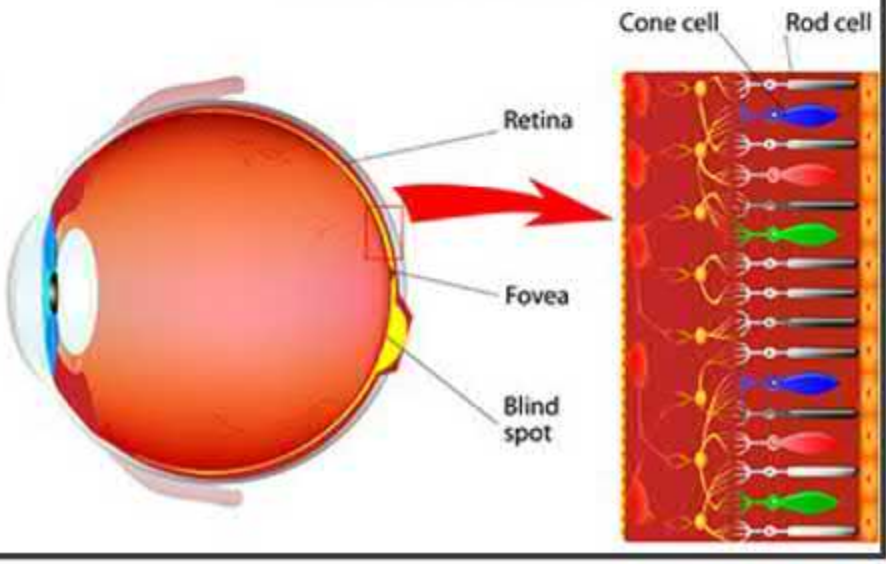
- Within the cytoplasm of each skeletal muscle cell are thousands of fibers called myofibrils that run parallel to the length of the cell.
- Myofibrils consist of thick and thin filaments.
- Each thin filament consists of **actin proteins**; each thick filament is composed of **myosin proteins**.
- Muscles contract as thick and thin filaments slide over each other.



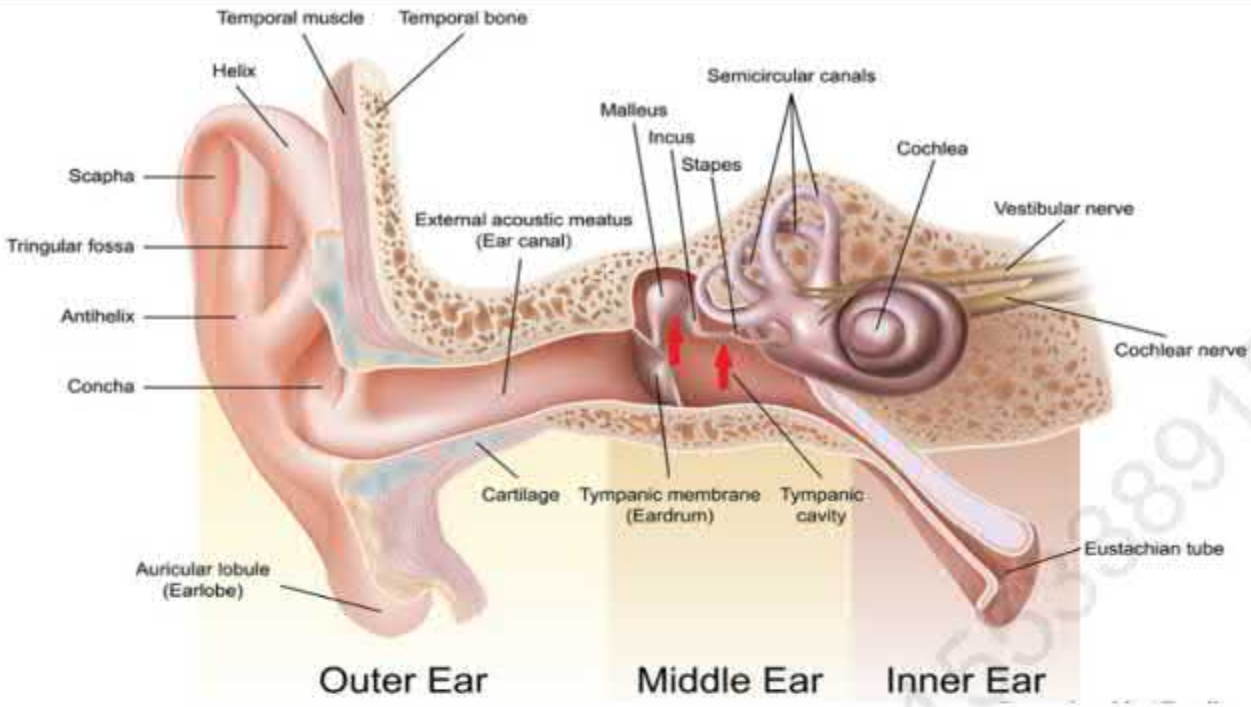
The Eye



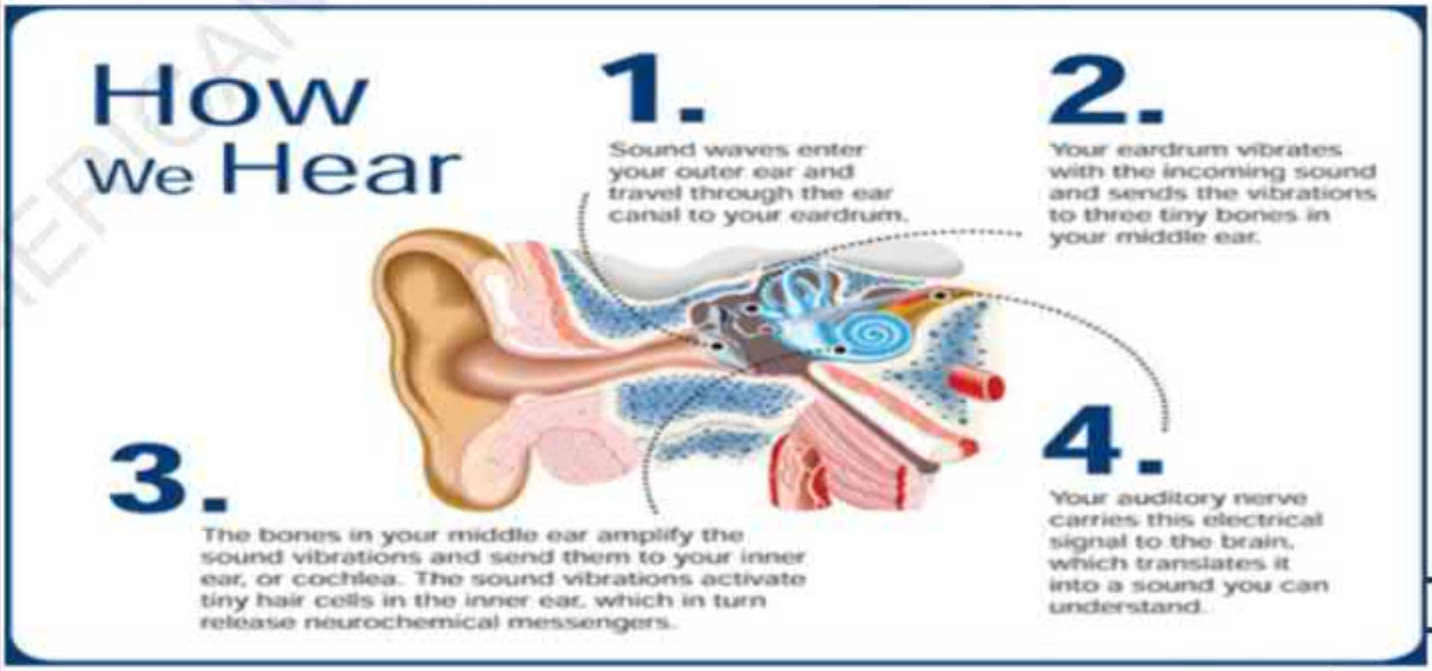
- **Cornea:** tough, clear covering that protects the eye and allows light to pass through
- **Humor:** fluids that maintain the shape of the eyeball
- **Iris:** colored part of the eye that controls how much light enters the eye
- **Lens:** focuses light onto the retina
- **Pupil:** small opening in the middle of the iris
- **Retina:** converts light into nerve impulses that are carried to the brain
- **Cones:** photoreceptors in the retina that distinguish different colors
- **Rods:** photoreceptors in the retina that are extremely sensitive, but do not distinguish different colors



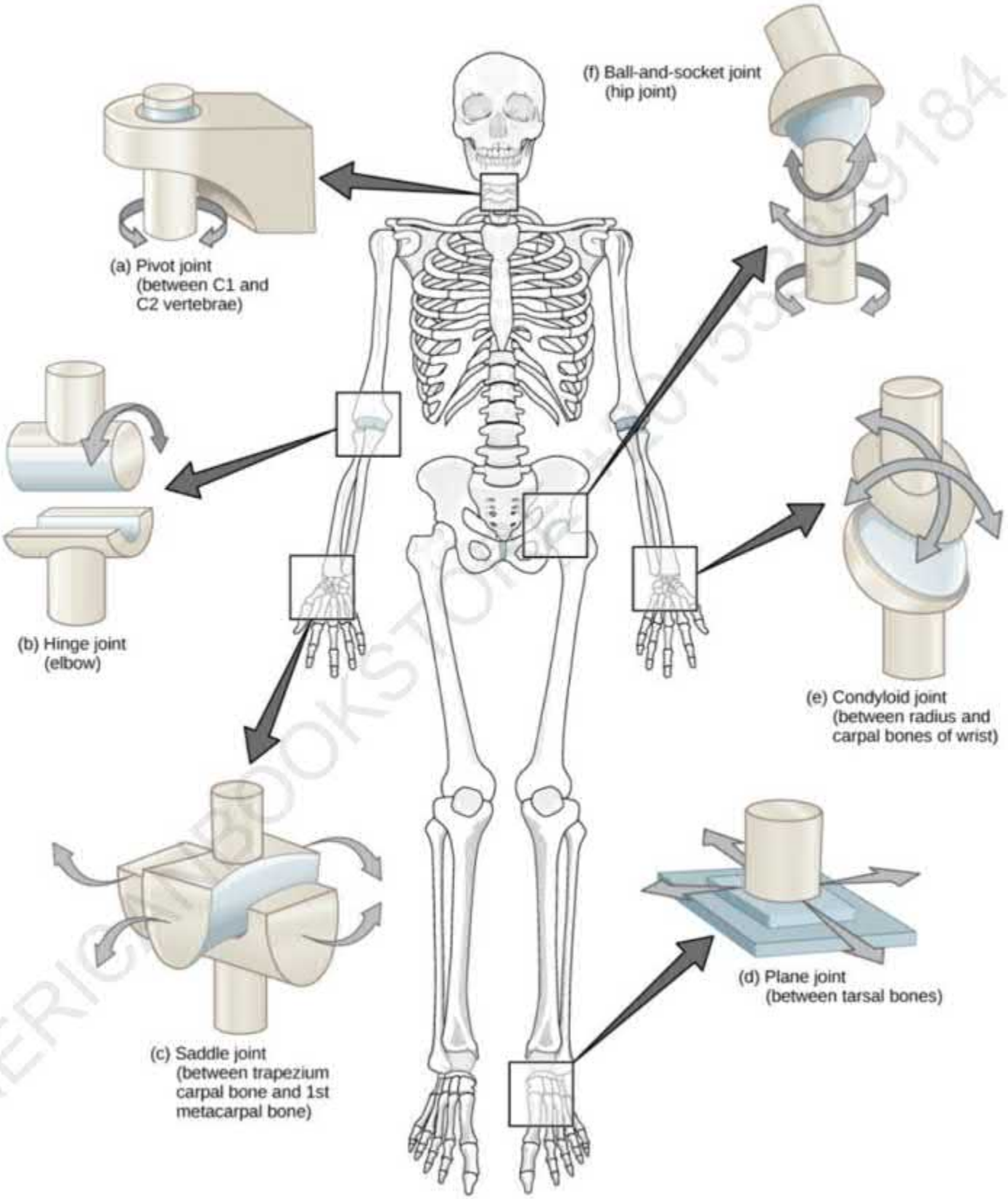
The Ear



- **Auditory canal:** ear canal, where sound enters
- Cochlea: fluid-filled part of inner ear, sends nerve impulses to brain
- **Ear bones:** hammer, anvil, and stirrup; transmit vibrations from eardrum to oval window
- **Eustachian tube:** equalizes pressure between environment and inner ear
- **Oval window:** sends waves of pressure to the cochlea
- **Semicircular canals:** fluid filled, helps you maintain your balance
- **Tympanum:** ear drum, vibrates as sound waves hit it



Types of Synovial Joints



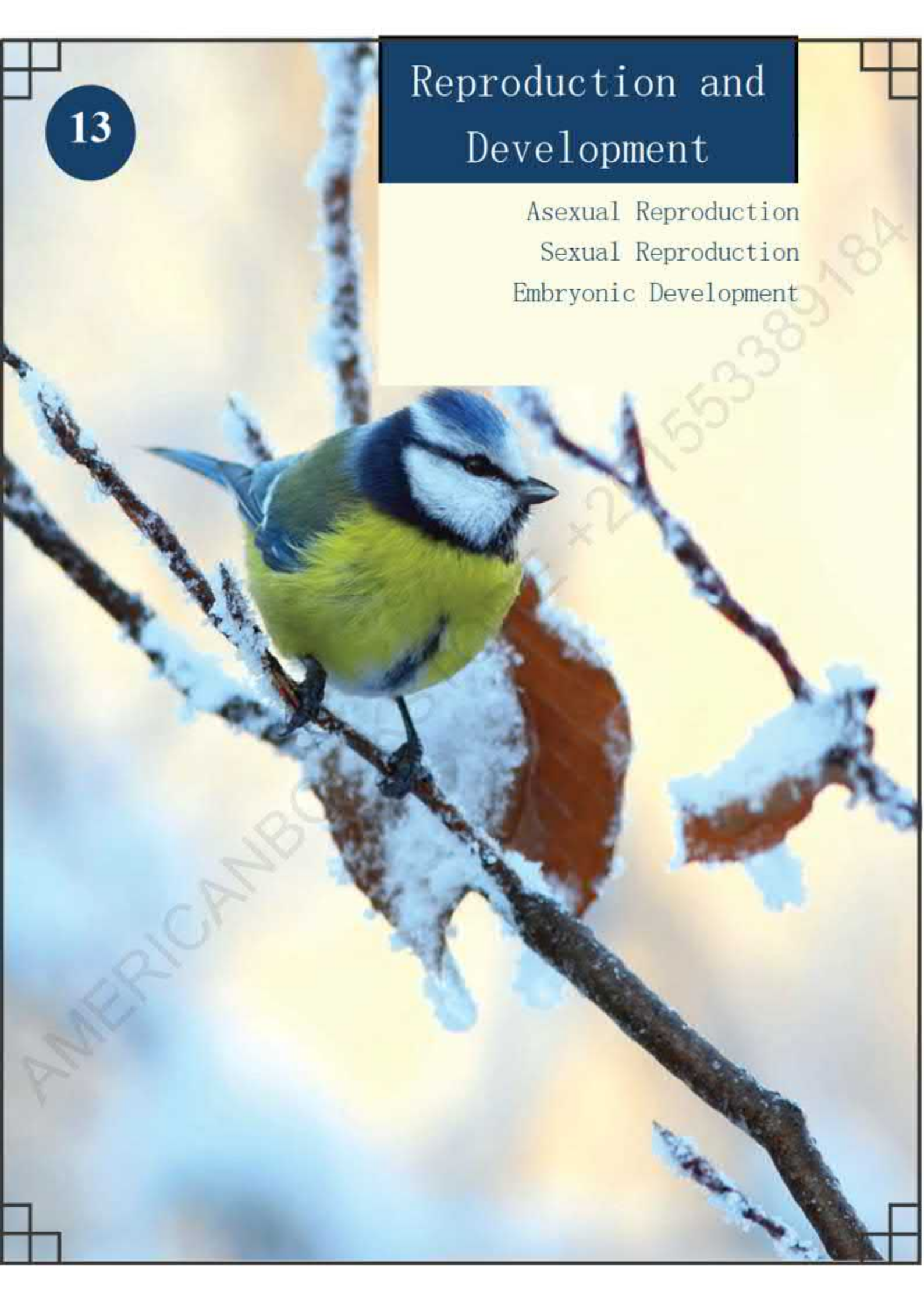
13

Reproduction and Development

Asexual Reproduction

Sexual Reproduction

Embryonic Development

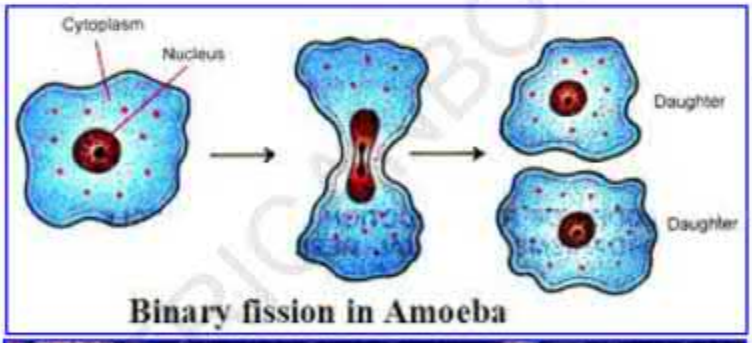


ASEXUAL REPRODUCTION

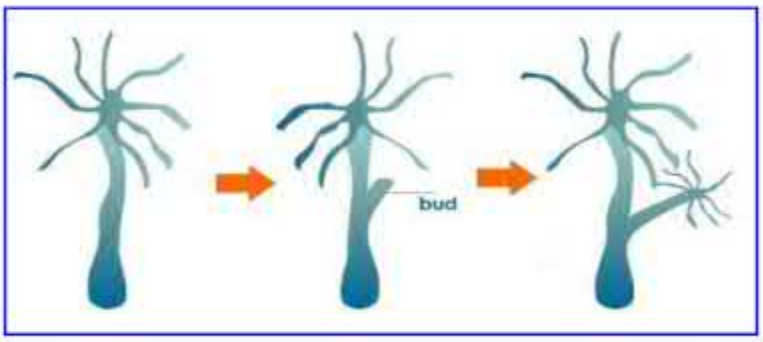
- It produces offspring genetically identical to the parent.
- It has several advantages over sexual reproduction.
  1. It enables isolated animals to reproduce without a mate.
  2. It creates numerous offspring quickly.
  3. There is no expenditure of energy needed
  4. It is advantageous when the environment is stable

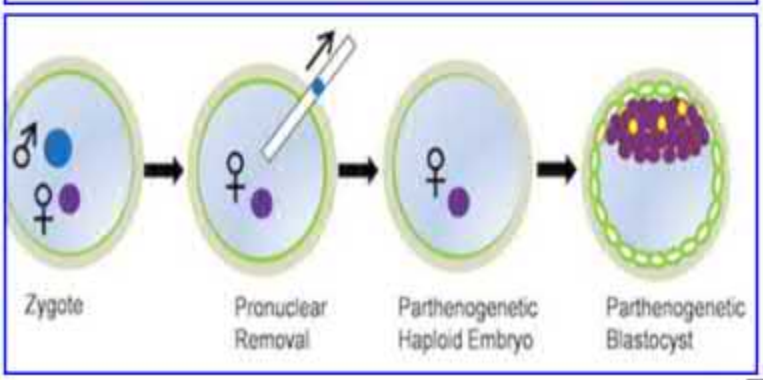
TYPES OF ASEXUAL REPRODUCTION IN SAMPLE ORGANISMS

- **Fission**:- is the separation of an organism into two new cells.
  Example: **(Amoeba, bacteria)**
- **Budding**:- involves the splitting off of new individuals from existing ones. **(Hydra)**
- **Fragmentation and regeneration** occur when a single parent breaks into parts that regenerate into new individuals.
  (Sponges, planaria, sea star)
- **Parthenogenesis** involves the development of an egg without fertilization. The resulting adult is haploid. **(Honeybees)**



Binary fission in Amoeba



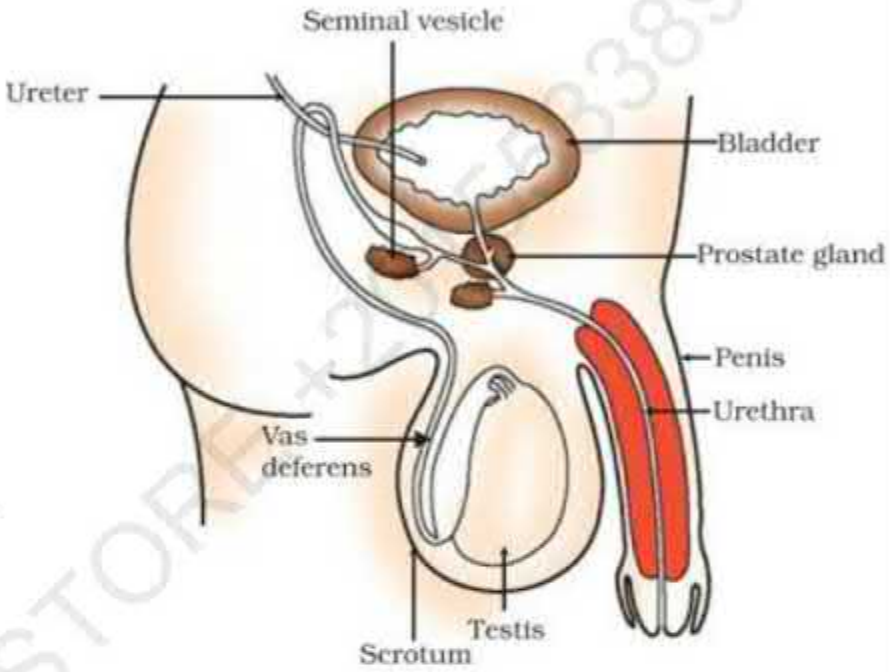


SEXUAL REPRODUCTION

- It is the main source of variation.
- It is advantageous when the environment is changing

The Human Male Reproductive System

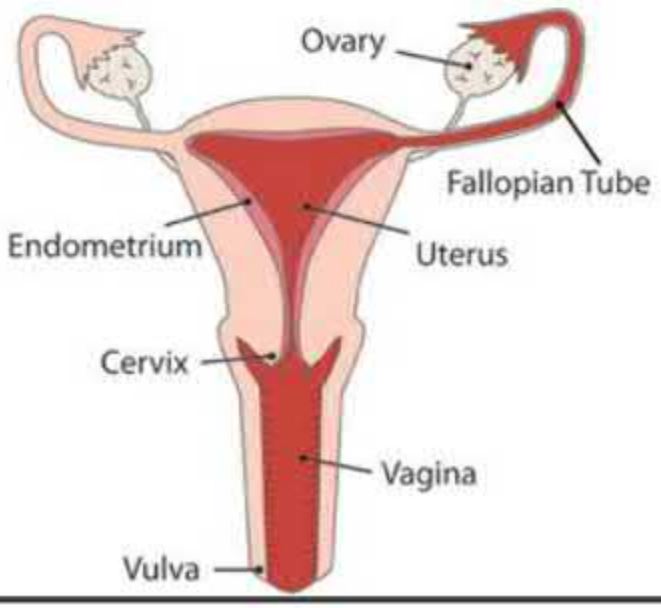
- **Testes**: male gonads, the site of sperm formation
- **Vas deferens**: the duct that carries sperm during ejaculation from the epididymis to the penis
- **Prostate gland**: the large gland that secretes semen directly into the urethra
- **Scrotum**: the sac outside the abdominal cavity that holds the testes
- **Urethra**: the tube that carries semen and urine



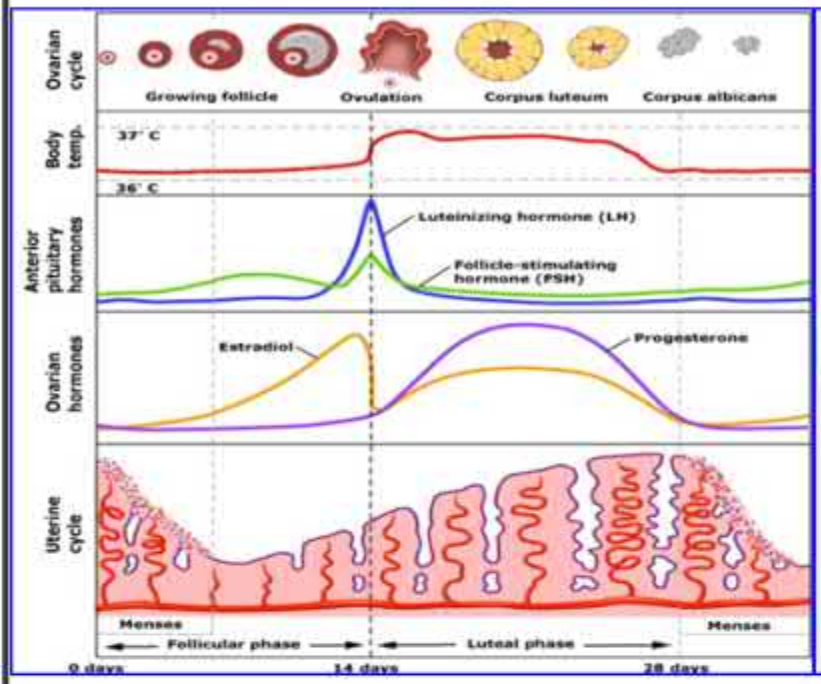
Human–male reproductive system

The Human Female Reproductive System

- **Ovary**: where meiosis occurs and where the secondary oocyte forms prior to birth
- **Oviduct or Fallopian tube**: where fertilization occurs
- **Uterus**: where the blastula stage of the embryo will implant and develop during the nine-month gestation
- **Vagina**: the birth canal
- **Cervix**: the mouth of the uterus
- **Endometrium**: lining of the uterus



The Menstrual Cycle of the Human Female



FOLLICULAR PHASE

- Anterior pituitary secrete **FSH**
- Follicles in the ovaries grow and secrete **estrogen**

OVULATION

- Anterior pituitary secrete **LH**
- The secondary oocyte ruptures out of the ovaries
- Ovulation occurs on or about the 14th day after menstruation.

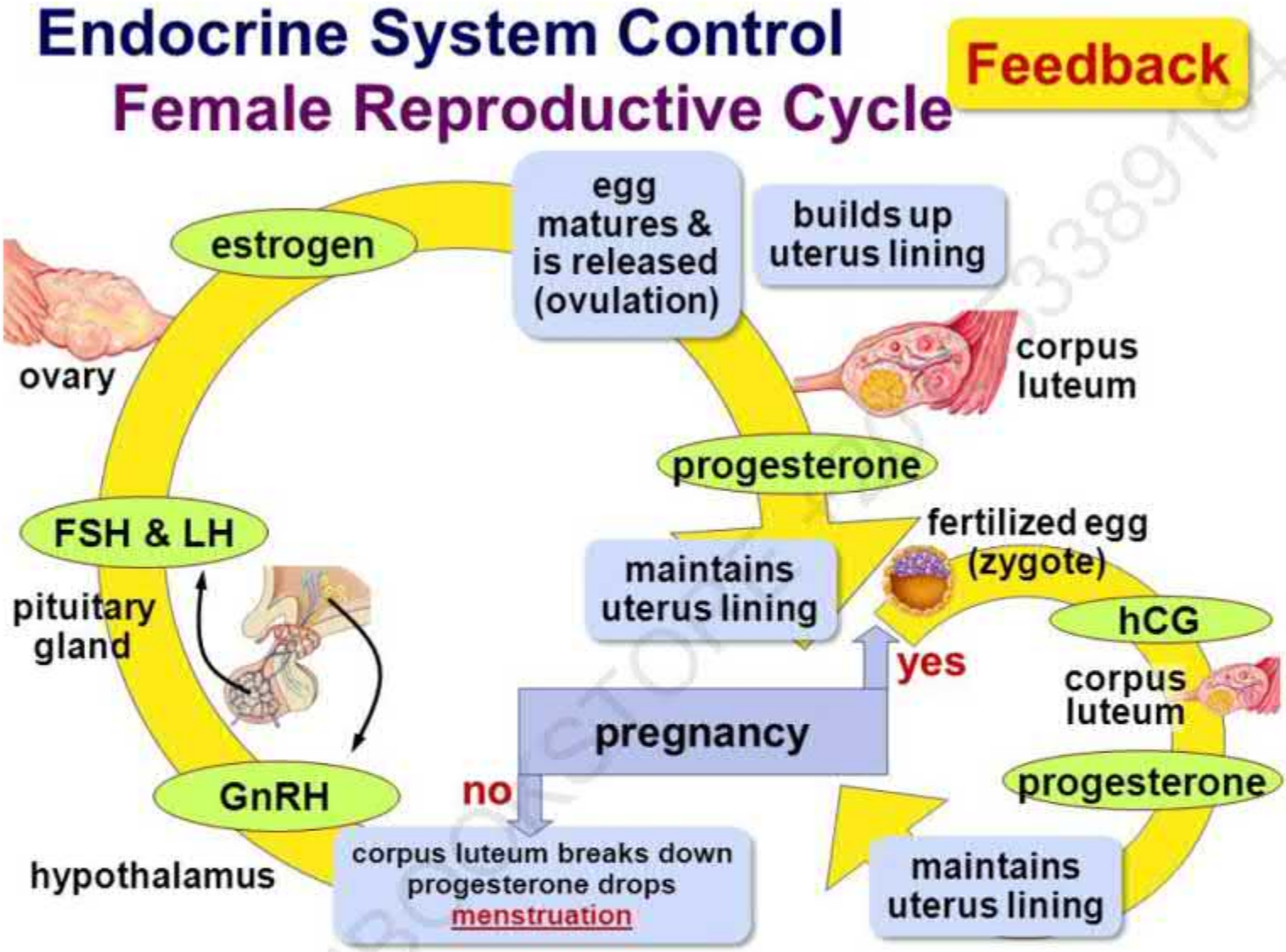
LUTEAL PHASE

- After ovulation, the corpus luteum (the cavity of the follicle left behind) forms and secretes estrogen and progesterone that thicken the endometrium (lining) of the uterus.

MENSTRUATION

- If implantation of an embryo does not occur, the buildup of the lining of the uterus breaks down and is shed. Tissue and some blood are discharged from the vagina.
- This bleeding is commonly called the period.

Hormonal Control of the Menstrual Cycle

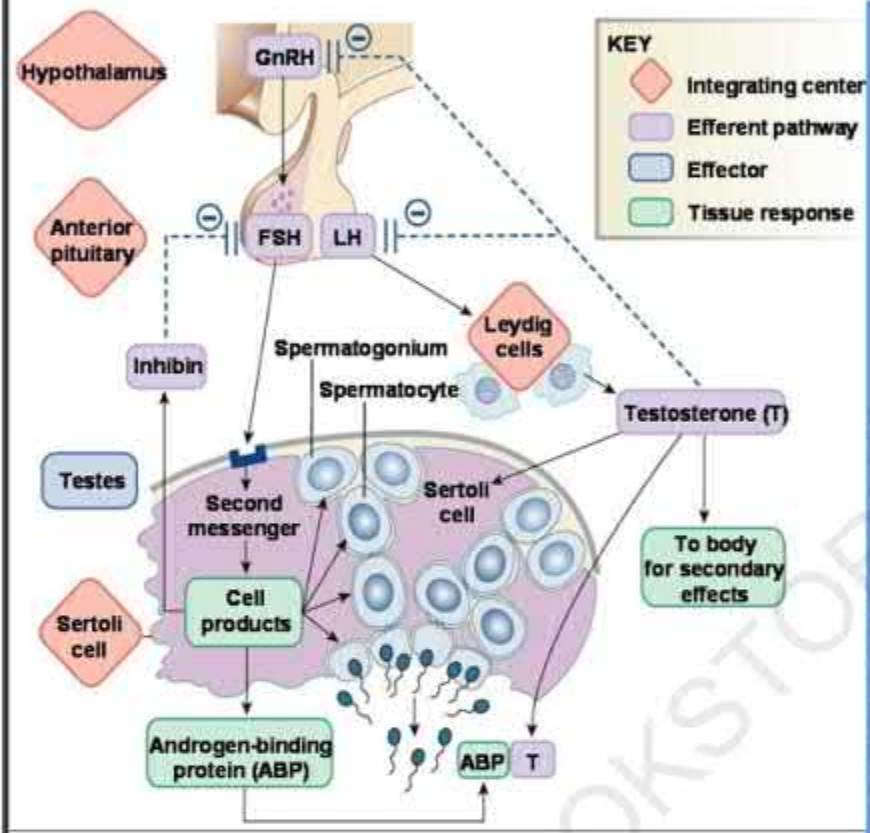


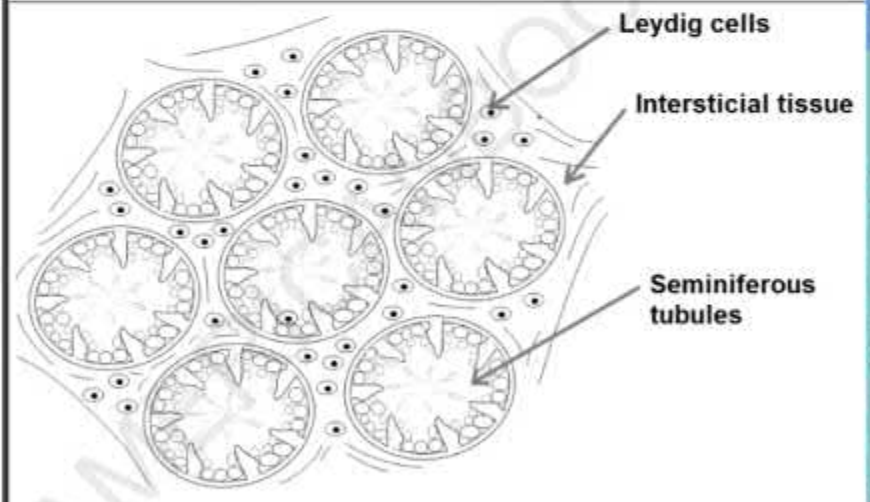
- The hypothalamus in the brain releases gonadotrophic-releasing hormone GnRH, which stimulates the anterior pituitary to release FSH and LH, which, in turn, stimulate the ovary to release estrogen and progesterone.

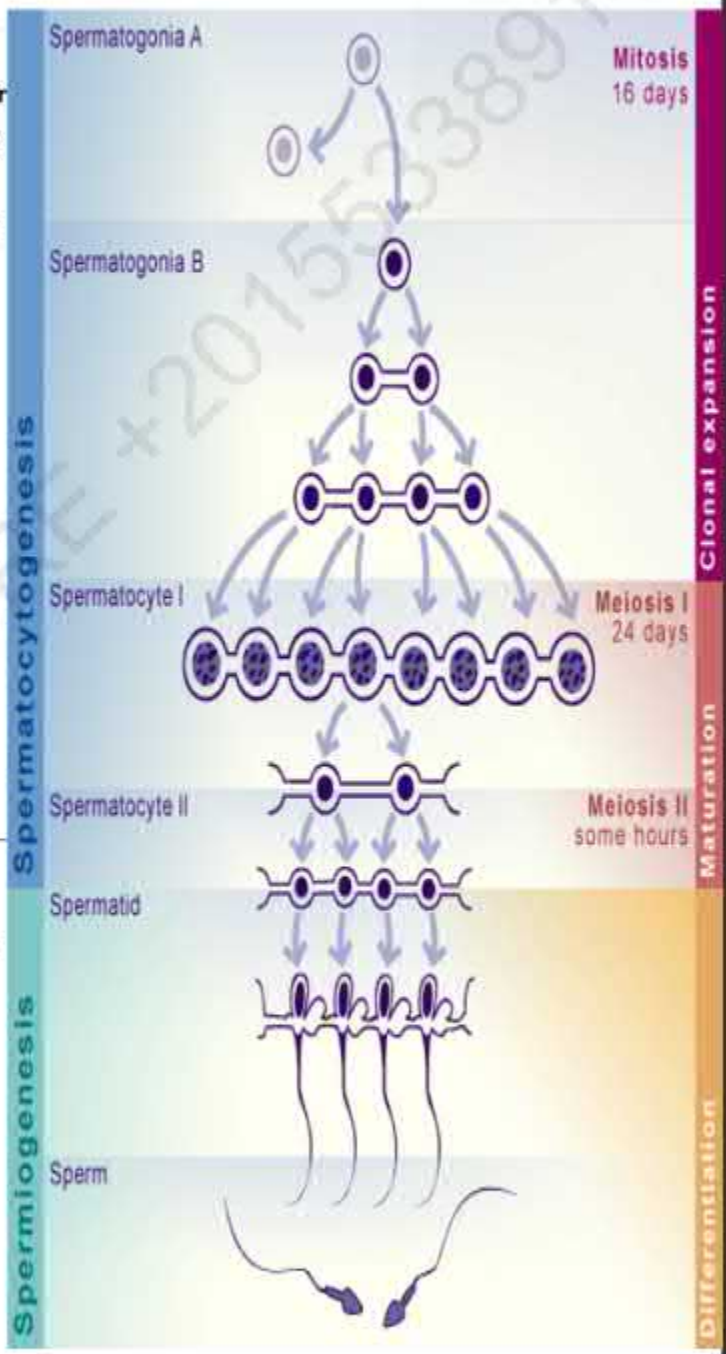
- These two hormones prepare the uterus for implantation of an embryo.

Spermatogenesis

- It is the process of sperm production
- It is a continuous process that begins at puberty and can continue into old age.

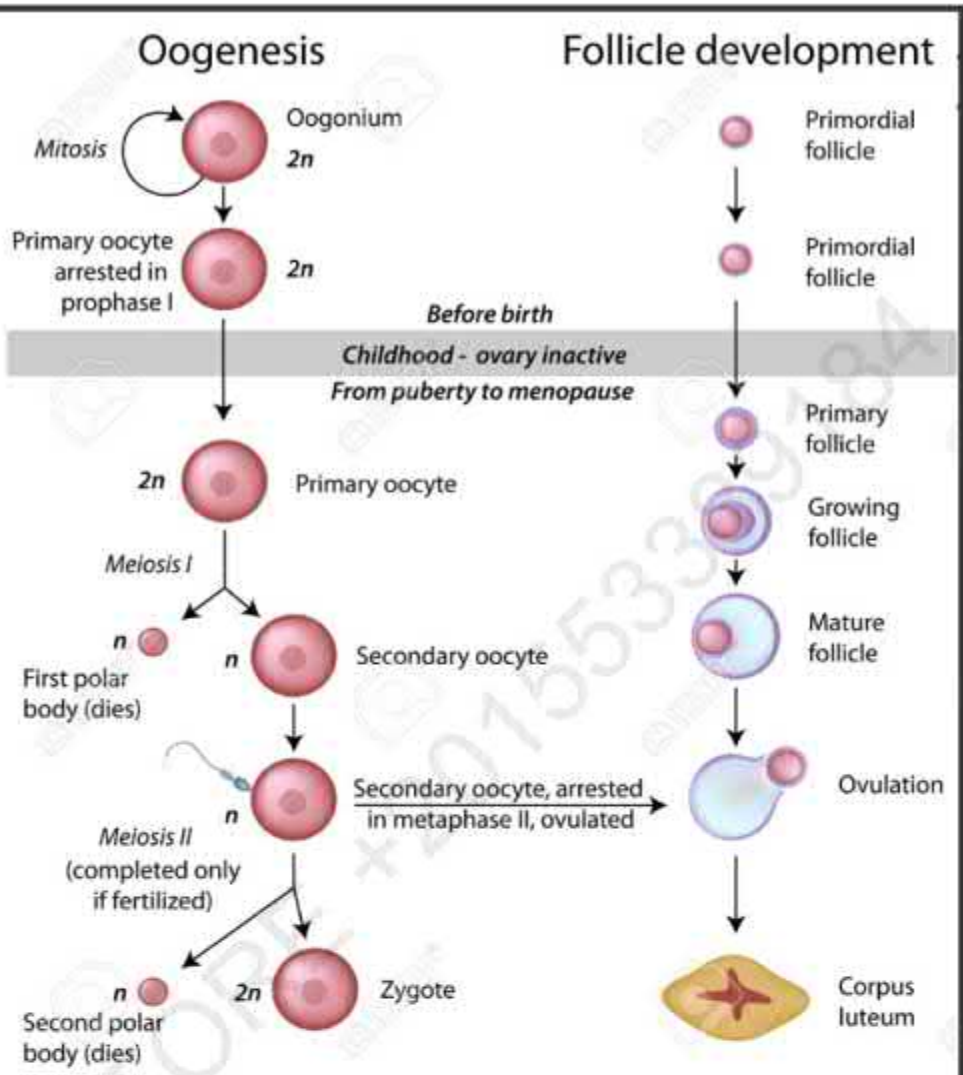


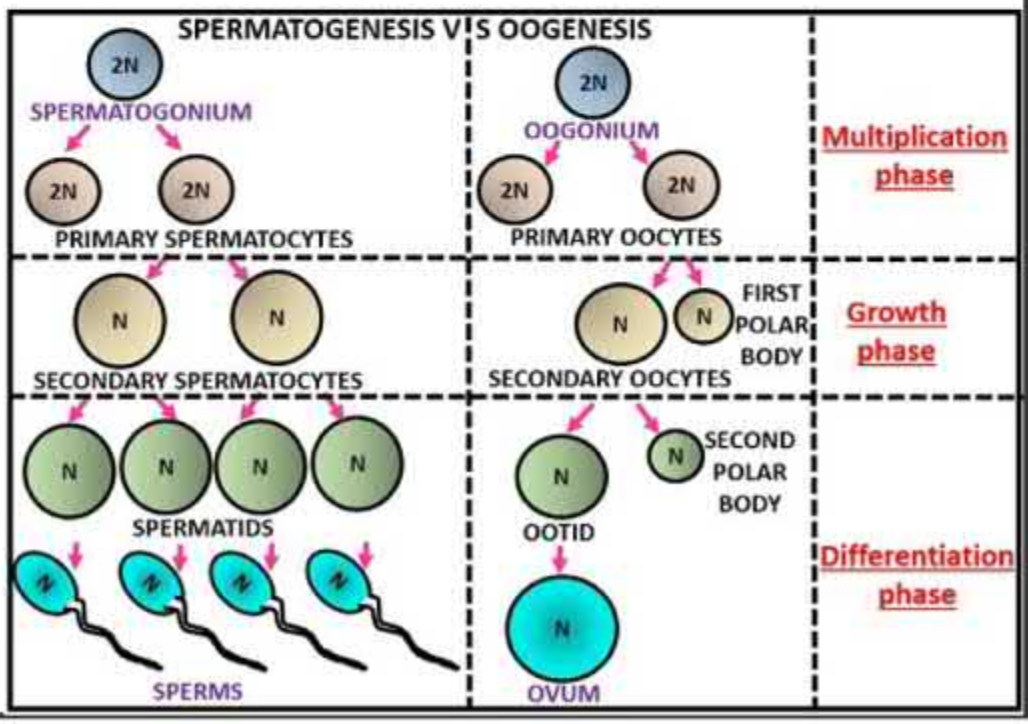




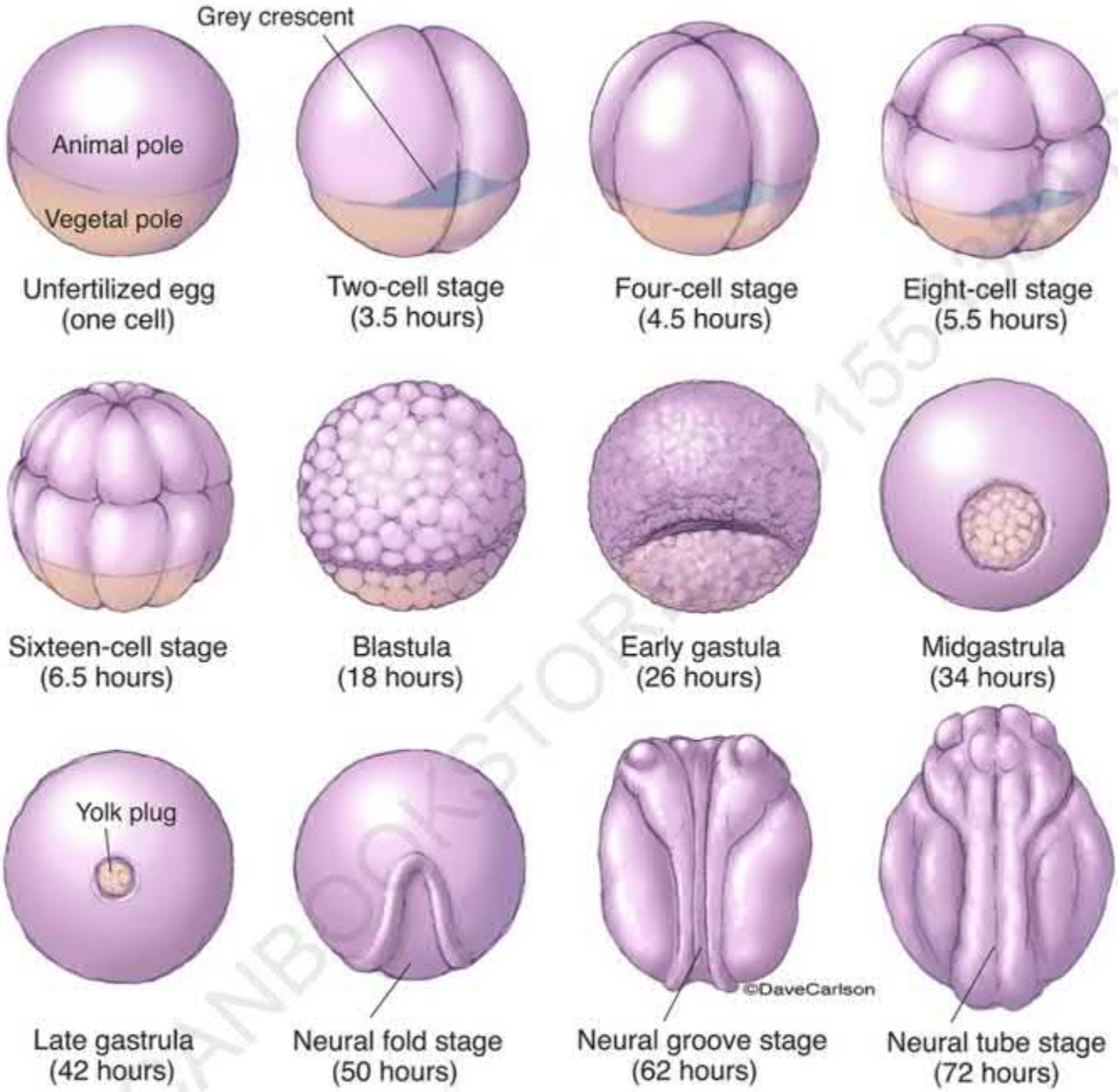
Oogenesis

- The production of ova, begins prior to birth.
- A female baby is born with all the primary oocytes she will ever have.
- Within the embryo, an **oogonium** cell (2n) undergoes mitosis to produce two **primary oocytes** (2n).
- These remain inactive within follicles in the ovaries until puberty, when they become reactivated by hormones.
- At that time, meiosis I occurs, producing **secondary oocytes** (n) that are released monthly at ovulation.
- Meiosis II does not occur until a sperm penetrates the secondary oocyte during fertilization. "This could be 40 years after meiosis I."
- One primary oogonium cell produces only one active egg cell





EMBRYONIC DEVELOPMENT

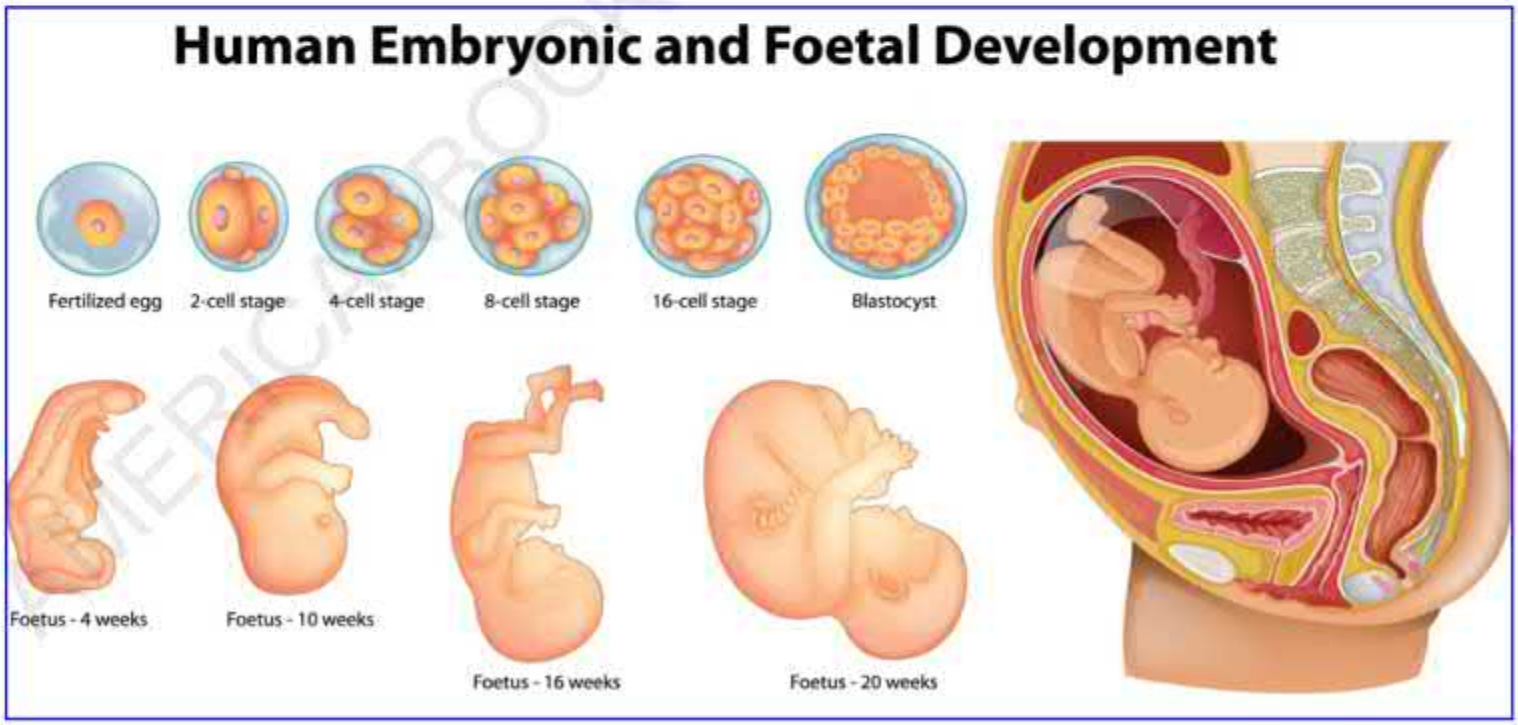


Embryonic development consists of three stages:
cleavage, gastrulation, and organogenesis.
Cleavage: rapid mitotic cell division of the zygote that begins immediately after fertilization. The cells are dividing so quickly till the production of blastula.
The individual cells of the blastula are called blastomeres and the fluid-filled center is a blastocoel.

Gastrulation is the continuation of the process that began during cleavage.
It involves differentiation; the rearrangement of the blastula two produces a three-layered embryo called a gastrula.
The gastrula consists of three differentiated layers called embryonic germ layers.
These three germ layers are the ectoderm, endoderm, and mesoderm. They will develop into all the parts of the adult animal.

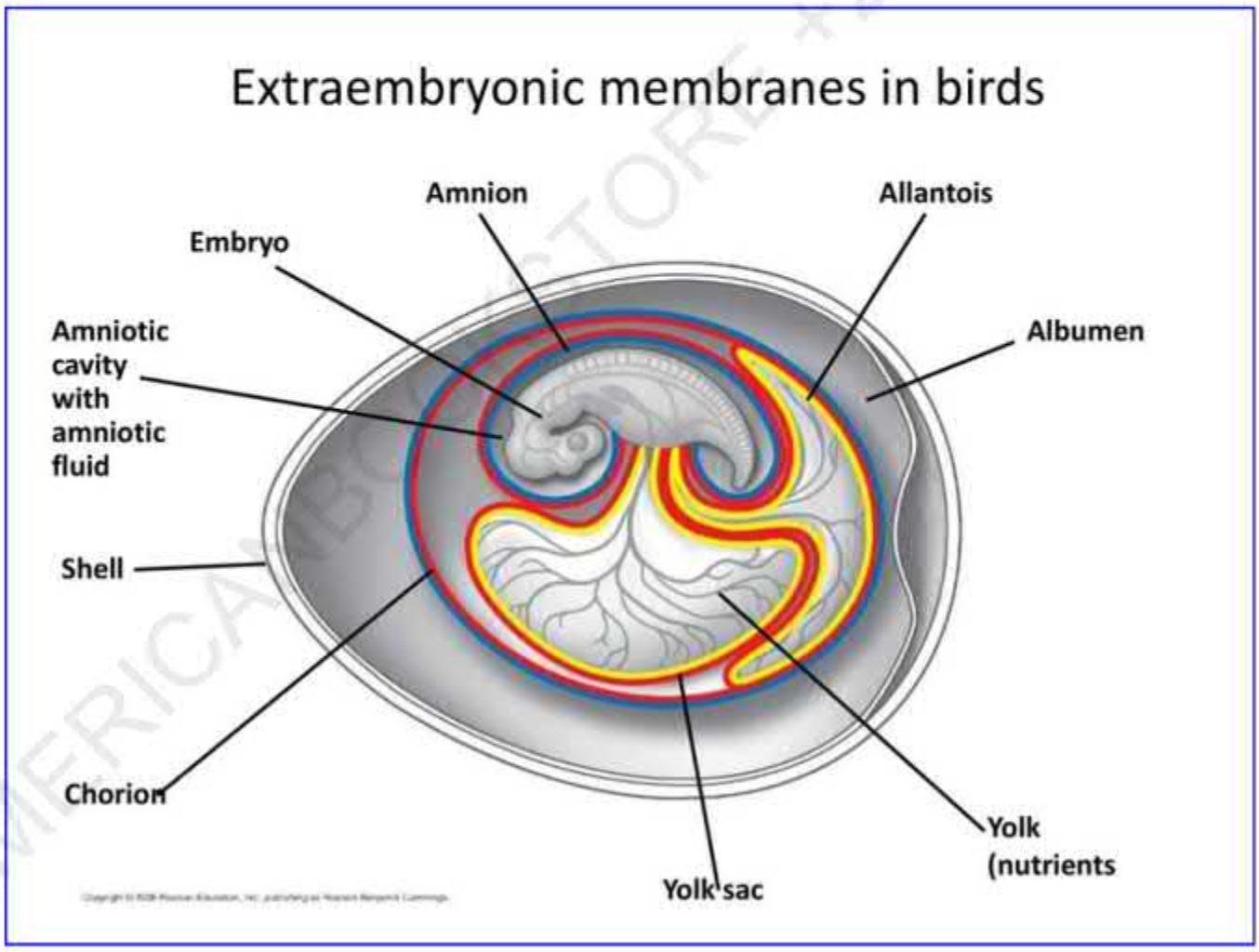
1. The ectoderm will become the skin and the nervous system.
2. The endoderm will form the viscera, including the lungs, liver, and digestive organs.
3. The mesoderm will give rise to the muscle, blood, and bones

Organogenesis is the process by which cells continue to differentiate, producing organs from the three embryonic germ layers
Once all the organ systems have been developed, the embryo increases in size and becomes a fetus.



Extraembryonic Membranes of the Bird Embryo

- They consist of the chorion, yolk sac, amnion, and allantois.
  1. **Chorion**: it lies under the shell and allows for diffusion of respiratory gases between the outside environment and the inside of the shell.
  2. **Yolk sac**: it encloses the yolk, the food for the embryo.
  3. **Amnion**: it encloses the embryo in protective amniotic fluid.
  4. **Allantois**: it is analogous to the placenta in mammals. It is the conduit for respiratory gases to and from the embryo. It is also the place where the nitrogenous waste uric acid accumulates until the chick hatches.



14

The Human Immune System

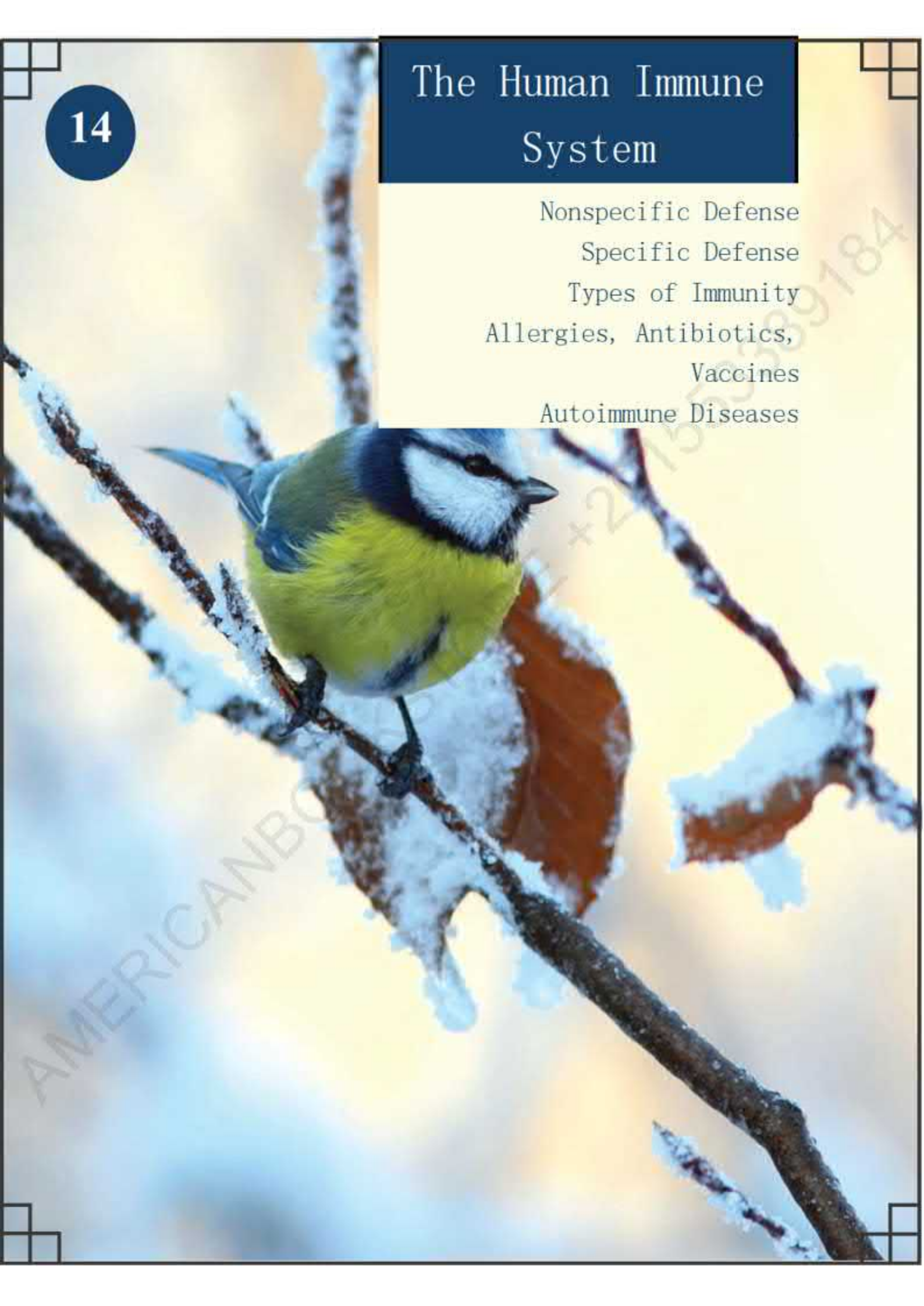
Nonspecific Defense

Specific Defense

Types of Immunity

Allergies, Antibiotics, Vaccines

Autoimmune Diseases



HUMAN IMMUNE SYSTEM

- The human body has evolved a complex system of defenses to fight pathogens (organisms that cause disease)
- Types of body defense:

- NONSPECIFIC DEFENSE

1. First Line of Defense

- To prevent entrance of MO.
- Example: (skin, Mucous, Cilia, Stomach acid)

2. Second Line of Defense

- To limit spread of invaders until specific immune responses.
- There are 3 types:

1. Inflammatory response:

- 5 symptoms (swelling, redness, heat, pain, lose of function).
- Cause increase the blood supply to the area containing **WBCs** to fight disease.
- The inflammatory response works in several ways:-

-**Histamine** triggers vasodilation, increases blood supply to the area, bringing more phagocytes. Histamine is also responsible for sneezing, coughing, redness, and itching and runny nose and eyes all an attempt to rid the body of invaders.

-**Increased temperature** speeds up the immune system and makes it more difficult for microbes to function.

2. Phagocytes:

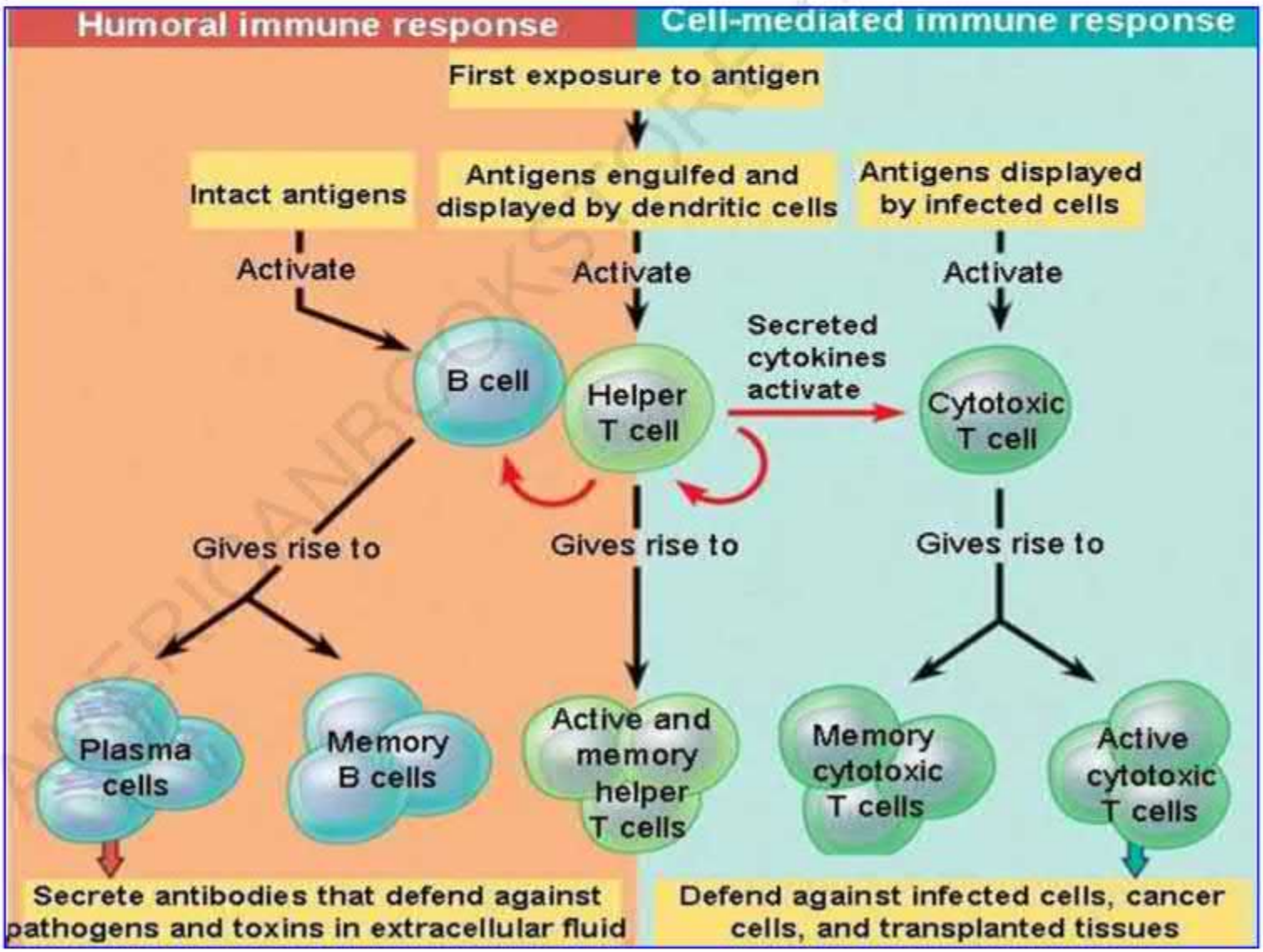
- **Macrophages** are a type of WBCs that extend pseudopods and engulf huge numbers of microbes over a long period of time.

3. Interferons:

- Chemicals released by the immune system to block against viral infections.

- SPECIFIC DEFENSE (THIRD LINE OF DEFENSE)

- Specific and consists of lymphocytes.
- There are two types of lymphocytes, **B and T**
- Lymphocytes originate in the bone marrow.
- They circulate in the blood, lymph, and lymphatic tissue: spleen, lymph nodes, tonsils, and adenoids.
- They recognize different specific antigens (an **antigen** is anything that triggers an immune response).
- **B lymphocytes** produce antibodies against a specific antigen in what is called a **humoral response.**
- **T lymphocytes** fight pathogen in what is called a **cell-mediated response.**



Antibodies

- Part of the specific immune response.
- Each antibody has the ability to bind to only one particular antigen.
- Example, antibodies against influenza bind to and neutralize only influenza virus.
- Antibodies bind to antigen forming an antigen-antibody complex that can this attract phagocytes to attack them.

Clonal Selection

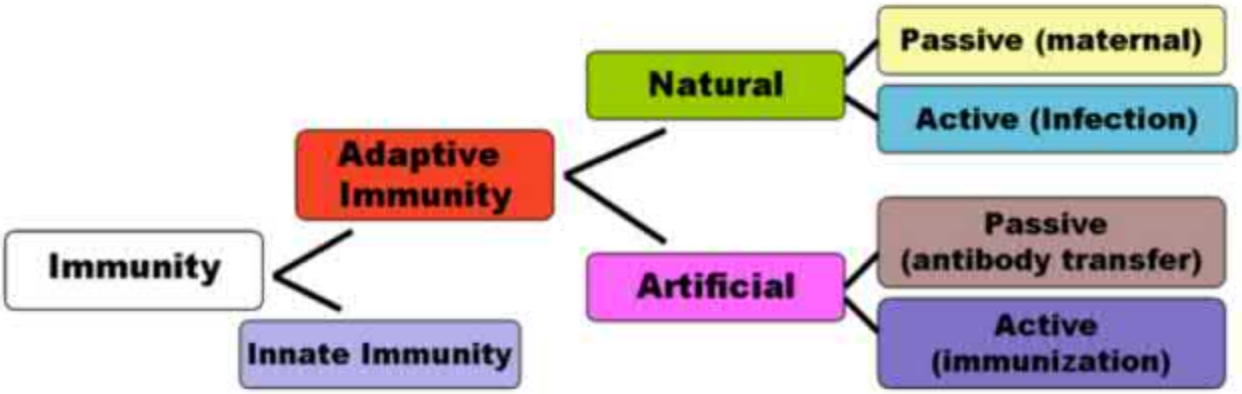
- Antigens bind to specific B lymphocytes
- Lymphocyte **activation**, **proliferation** (clones thousands of copies of itself) and **differentiation** (into plasma cells and memory cells.)

PLASMA CELLS

These fight antigens immediately in what is called the primary immune response. They do not live long.

MEMORY CELLS

- They remain circulating in the blood in small numbers for a lifetime forming what is called "The immunological memory".
- The immunological memory is the mechanism that prevents you from getting any specific viral infection, such as chicken pox, more than once.



Active and passive immunity

Natural	Active immunity refers to immunity, which results from the production of antibodies by the person's own immune system in response to a direct contact of an antigen	Passive immunity refers to a short-term immunity which results from the introduction of antibodies from the outside	Natural
 Infection			 Maternal antibodies
Artificial	Mediated by the antibodies produced by the person's own cells	Mediated by the antibodies produced outside the body	**Artificial**
 Vaccination	The pathogen has direct contact with the body	The pathogen doesn't have direct contact with the body	 Monoclonal antibodies
	Does not generate a rapid response	Generates a rapid response	
	May last for a long time	May not last for a long time	
	Generates an immunological memory	Does not generate an immunological memory	

ABO Blood Types

- ABO antibodies circulate in the plasma of the blood and bind with ABO antigens in the event of an improper transfusion.
- Certain danger from a transfusion comes when the recipient has antibodies to the donor's antigens.
- Blood type **O** is known as **the universal donor** because it has no antigens to be clumped by the recipient's blood.
- Blood type **AB** is known as the **universal recipient** because there are no antibodies to clump the donor's blood.

AIDS Virus

- AIDS stands for acquired immune deficiency syndrome.
- People with AIDS are highly susceptible to infections that take advantage of a collapsed immune system.
- The virus that causes AIDS, HIV (human immunodeficiency virus) mainly attacks helper T cells.
- HIV is a retrovirus. (the viral RNA uses the enzyme reverse transcriptase to make DNA).
- The host cell then integrates this newly formed DNA into its own genome.

Allergy

- Hypersensitive immune responses to certain substances called **Allergens** causing release of excessive amounts of histamine.
- Symptoms: redness, runny nose, and itchy eyes.
- Taking antihistamines can normally counteract these symptoms.
- Acute allergic response can result in a life-threatening response called **anaphylactic shock** that can result in death within minutes.

Autoimmune diseases

- When immune system attack the body itself.
- Example: multiple sclerosis, lupus, arthritis & type-I diabetes
- In the case of multiple sclerosis, the immune system attacks the myelin sheath surrounding certain neurons.
- Treatment goal for these cases is to reduce symptoms by suppressing the immune system while maintaining the body's ability to fight disease.

- NB Antibiotics kill bacteria or fungi. While vaccine prevent illness caused by viruses.

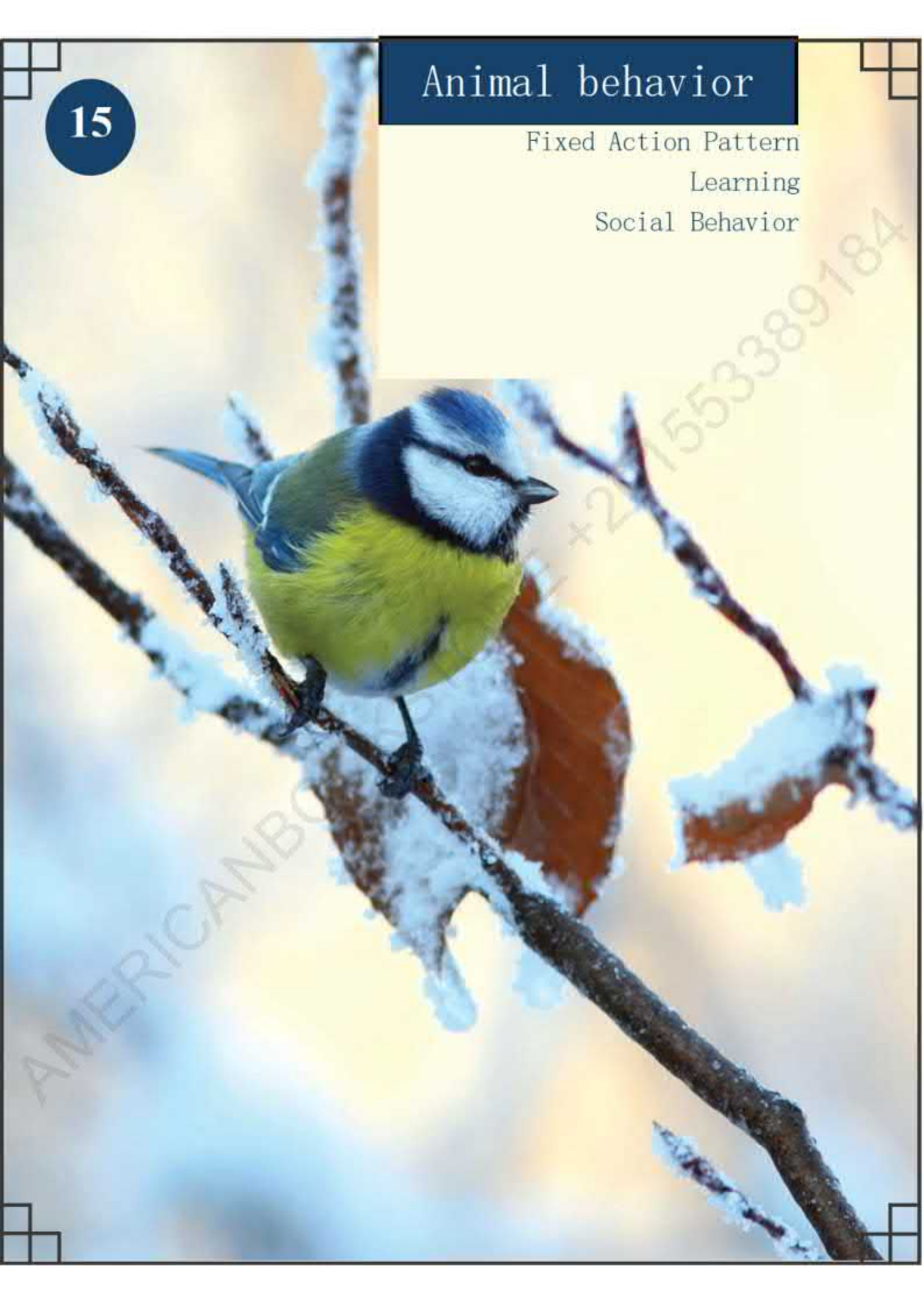
15

Animal behavior

Fixed Action Pattern

Learning

Social Behavior



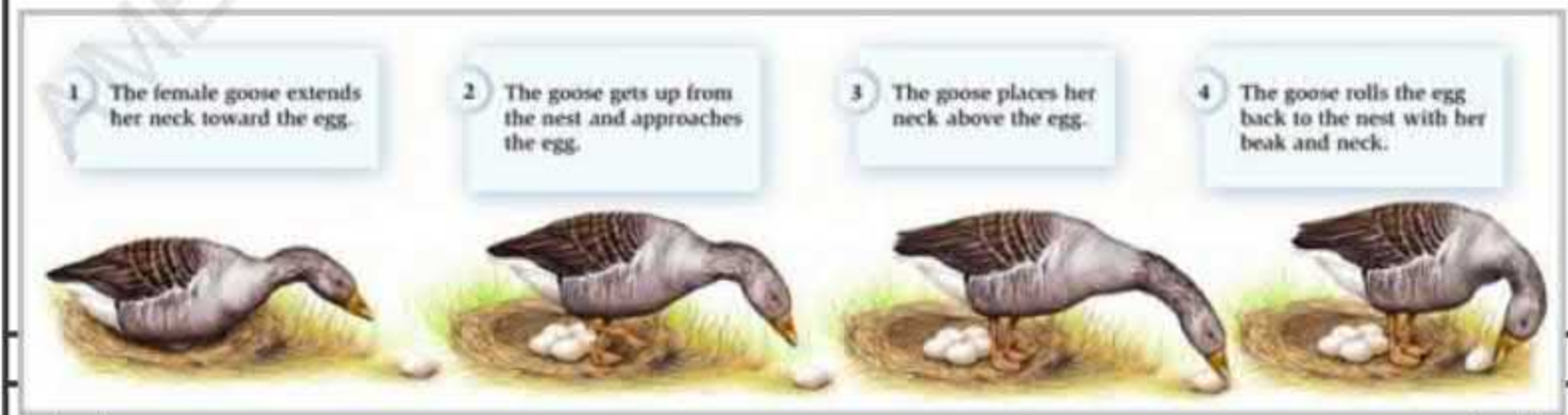
- **Behavior** is the way an organism responds to changes in its internal or external environment (stimuli).
- Example: A monkey eats a banana (behavior) in response to hunger (stimulus).
- A behavior can be **innate (inborn)**, such as running for shelter upon hearing a loud noise or **learned**, such as one child sharing her toys with another child.
- The study of behavior and its relationship to its evolutionary origins is called ethology.

Concepts of animal behavior

- FIXED ACTION PATTERN (FAP)

- It is an innate, highly stereotypical behavior that, once begun, is continued to completion
- FAPs are initiated by external stimuli called **sign stimuli**. When these stimuli are exchanged between members of the same species, they are known as releasers.
- An example of a FAP involves the stickleback fish, which attacks other males that invade its territory. The releaser for the attack is the red belly of the intruder. The stickleback will not attack an invading male stickleback lacking a red underbelly, but it will readily attack a non-fishlike wooden model as long as a splash of red is visible.

- humans also demonstrate fixed action patterns. **Yawning** is a great example.



Kinesis and Taxis

- Some organisms have innate behaviors in which they change their movement in response to a stimulus, such as high temperature or a tasty food source.

- In kinesis, an organism changes its movement in a non-directional way— e.g., speeding up or slowing down— in response to a cue. For example, woodlice move faster in response to temperatures that are higher or lower than their preferred range. The movement is random, but the higher speed increases the chances that the woodlouse will make its way out of the bad environment.

- Taxis is a form of movement behavior that involves movement towards or away from a stimulus. This movement can be
  -in response to light, known as phototaxis
  - chemical signals, known as chemotaxis
  - gravity, known as geotaxis

- among other stimuli. It can also be directed towards, positive, or away from, negative, the source of the stimulus.

Reflexes

- The simplest example of an innate behavior
- An involuntary and rapid response to a stimulus
- Example "the knee-jerk reflex." To test this reflex, a doctor taps the tendon below your kneecap with a rubber hammer. The tap activates nearby neurons, causing your lower leg to kick involuntarily. This automatic response depends on circuits of neurons that run between the knee and the spinal cord— it doesn't even involve your brain!

- LEARNING

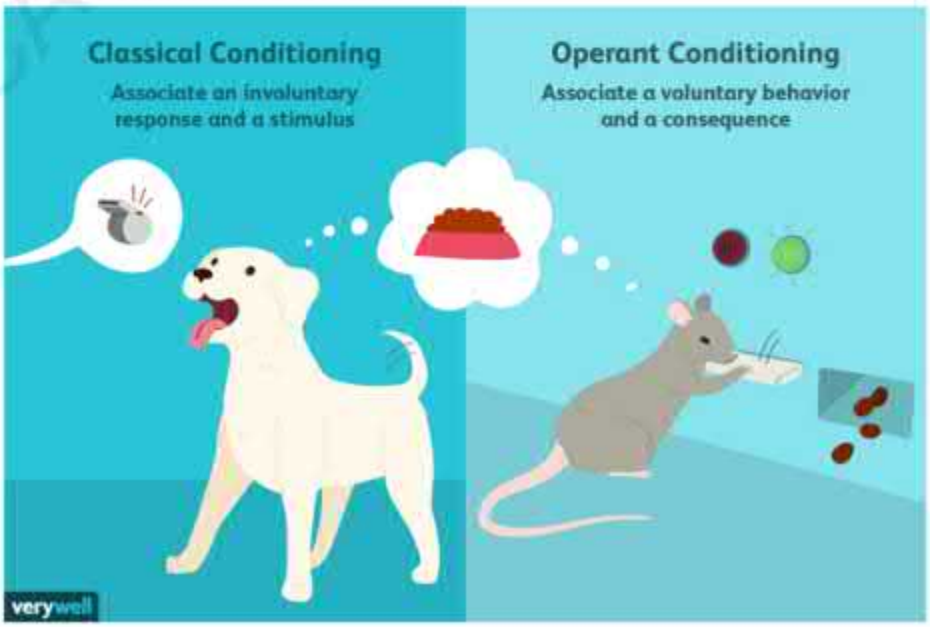
- Learning is a sophisticated process in which the responses of the organism are modified as a result of experience.
- The capacity to learn correlated to:
  - length of life
  - complexity of the brain.
- If the animal has a very short life span it must rely on FAB.
- If the animal lives a long time and has a complex brain, then its behavior mainly depends on prior experience and learning.
- Forms of learning:

Habituation

- It is one of the simplest forms of learning
- It means that the animal got used to something
- example: If you tap the dish containing a hydra, it will quickly shrink and become immobile. If you keep tapping, after a while the hydra will begin to ignore the tapping, elongate, and continue moving about. It has become used to the stimulus.

Associative learning

- It is one type of learning in which one stimulus becomes linked to another through experience.
- Examples of associative learning are **classical conditioning and operant conditioning.**



Imprinting

- It is learning that occurs during a sensitive or critical period in the early life of an individual and is irreversible for the length of that period.
- Mother-offspring bonding in animals that depend on parental care is critical to the safety and development of the offspring.
- When the offspring can survive without the parent, the response disappears.

- SOCIAL BEHAVIOR

- It is any kind of interaction between two or more animals, usually of the same species.
- Types of social behaviors are: **cooperation, agonistic, dominance hierarchies, territoriality, and altruism.**

1. **Cooperation** enables the individuals to carry out a behavior, such as hunting, which they can do as a group more successfully than they can do separately.

2. **Agonistic behavior** is aggressive behavior between individuals commonly over access to food, mates, or shelter. A dog shows aggression by baring its teeth and erecting its ears and hair. It stands upright to appear taller and looks directly at its opponent (symbolic behavior). If the aggressor succeeds in scaring the opponent, the loser engages in **submissive behavior** that says, "You win, I give up." Examples of submissive behaviors are looking down or away from the winner. Submissive dogs or wolves put their tail between their legs and run off.

3. **Dominance Hierarchies** are pecking order behaviors that dictate the social position of an animal in a culture. This is commonly seen in hens where the alpha animal (top-ranked) controls the behaviors of all the others. The next in line, the beta animal, controls all others except the alpha animal. Each animal threatens all animals beneath it in the pecking order.

4. **Territoriality:** a territory is an area an organism defends and from which other members of the community are excluded.

5. **Altruism** is a behavior that reduces an individual's reproductive fitness (individual sacrifices and the animal may die) while increasing the fitness of the group or family. When a worker honeybee stings an intruder in defense of the hive, the worker bee usually dies. However, it increases the fitness of the queen bee that lays all the eggs. How can altruism evolve if the altruistic individual dies?

Scientist	Field of study
Von Frisch	studies of honeybee communication description of the bee waggle dance
Niko Tinbergen	Explanation of the fixed action pattern
Konrad Lorenz	Imprinting in geese
Ivan Pavlov	Classical conditioning in dogs
B. F. Skinner	Operant conditioning in rats

16

Ecology

Properties of Populations

Population Growth

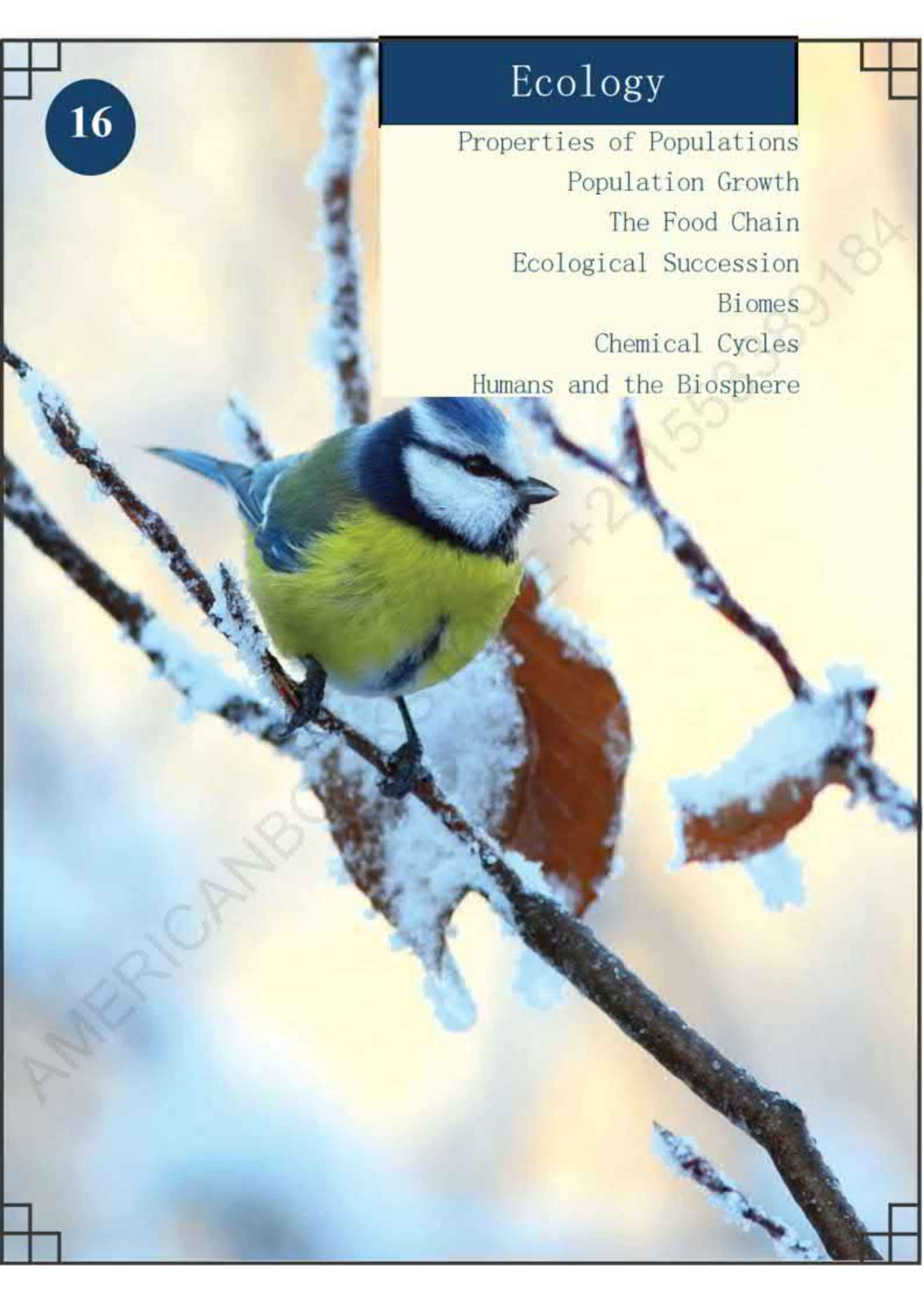
The Food Chain

Ecological Succession

Biomes

Chemical Cycles

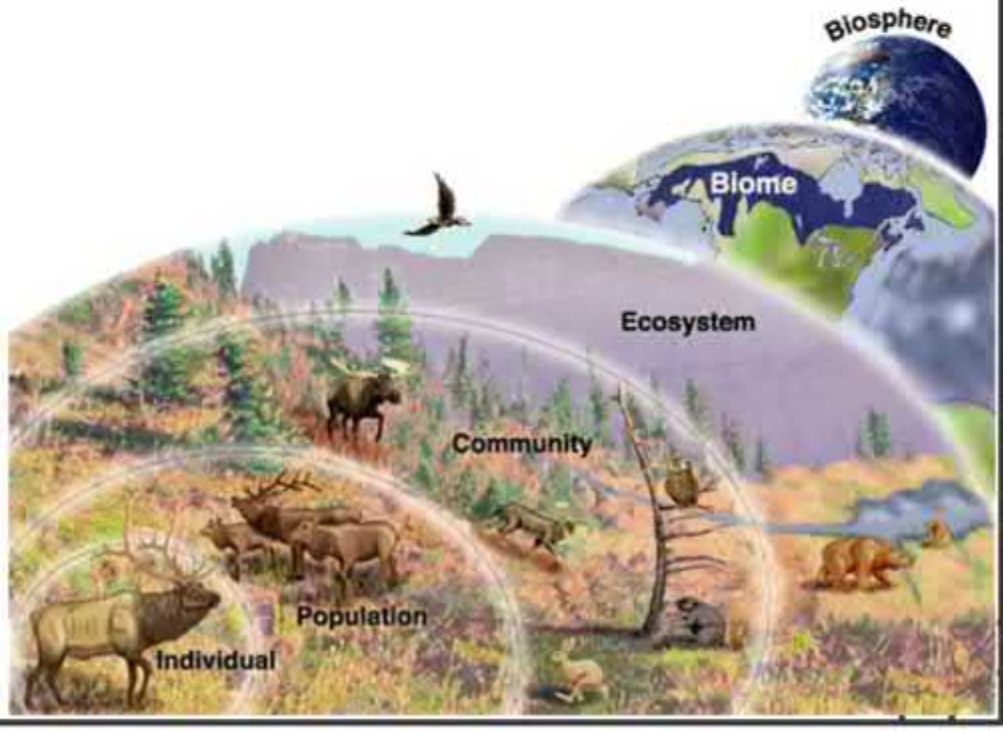
Humans and the Biosphere



ECOLOGY

Definitions

- **Ecology** is the study of the interactions of organisms with their physical environment and with each other.
- **A population** is a group of individuals of one species living in one area who can interbreed and interact with each other.
- **A community** consists of all the organisms living in one area.
- **An ecosystem** includes all the organisms in a given area and the abiotic (nonliving) factors with which they interact.
- **Abiotic factors** are nonliving and include temperature, water, sunlight, wind, rocks, and soil.
- **Biotic factors** include all the organisms with which an organism might react, such as birds, insects, predators, prey, and parasites.
- **The biosphere** is the global ecosystem.
- **A niche** includes what an organism eats and what it needs to survive.



PROPERTIES OF POPULATIONS

1. Size

Size is the total number of individuals in a population. Four variables limit the size of a population: the number of births, the number of deaths, immigration, and emigration.

2. Density

- Density is the number of individuals per unit area
- Scientists use sampling techniques to estimate the number of organisms living in one area.
- One sampling technique commonly used to estimate the size of a population is called mark and recapture.

In this technique, organisms are captured, tagged, and then released. Some time later, the same process is repeated and a special mathematical formula is used to determine the density of the population.

3. Dispersion

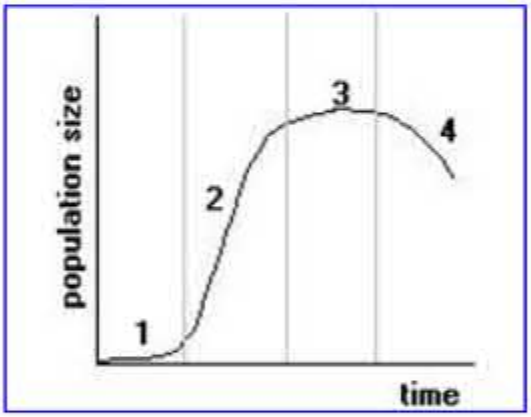
- Dispersion is the pattern of spacing of individuals within the area the population inhabits.
- The most common pattern of dispersion is clumped. Fish travel this way
- Some populations are spread in a uniform pattern. For example, certain plants may secrete toxins that keep away other plants that would compete for limited resources.
- Random spacing occurs in the absence of any special attractions or repulsions. Trees can be spaced randomly in a forest.

Uniform dispersion Random dispersion Clumped dispersion

POPULATION GROWTH

- Every population has a characteristic **biotic potential**, "the maximum rate at which a population could increase under ideal conditions".
- Biotic potentials that are influenced by several factors:
  - **Age at which reproduction begins**
  - **Life span during which of reproducing**
  - **Number of reproductive periods in the lifetime**
  - **Number of offspring per one time**
- characteristics about growth are common to all organisms.

1. Initial period of slow growth
2. The population grows exponentially.
3. The population grows until it reaches (**carrying capacity**)
4. The population may crash. (due to predation, parasitism, severe competition, an end to resources, and/or too much waste that poisons the environment.)



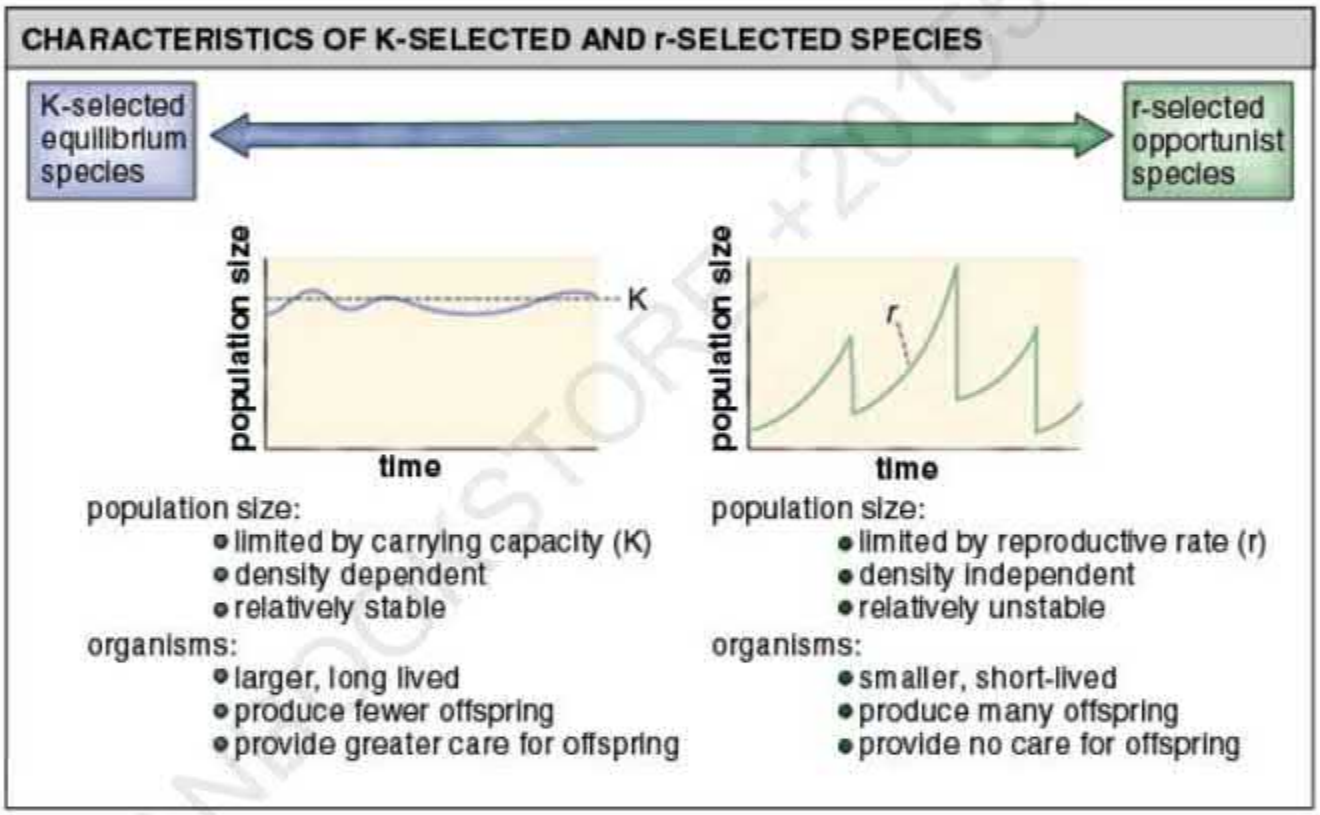
Exponential Growth

- The simplest model for population growth is one with unrestrained or exponential growth
- A population with **no predation, parasitism, or competition, no immigration or emigration, and in an environment with unlimited resources.**
- This is characteristic of a population that has been recently introduced into an area, such as a sample of bacteria newly inoculated onto a petri dish.
- Although exponential growth is usually short-lived in nature, the human population has been in the exponential growth phase for over 300 years.

Reproductive Strategies

- Some organisms are opportunistic. They reproduce rapidly when the environment is uncrowded and resources are vast. They are referred to as **r-strategists**.

- Other organisms, the **K-strategists** (K for carrying capacity), tend to maximize population size near the carrying capacity for an environment.



Feature	Norway rat (r-selected)	African elephant (K-selected)
Reaches sexual or reproductive maturity	3-4 months	10-12 years
Average gestation period	22-24 days	22 months
Time to weaning	3-4 weeks	48-108 months
Breeding interval (female)	Up to 7 times per year	Every 4 to 9 years
Offspring per litter	2-14 (average 8)	1 average, 2 high

Limiting Factors

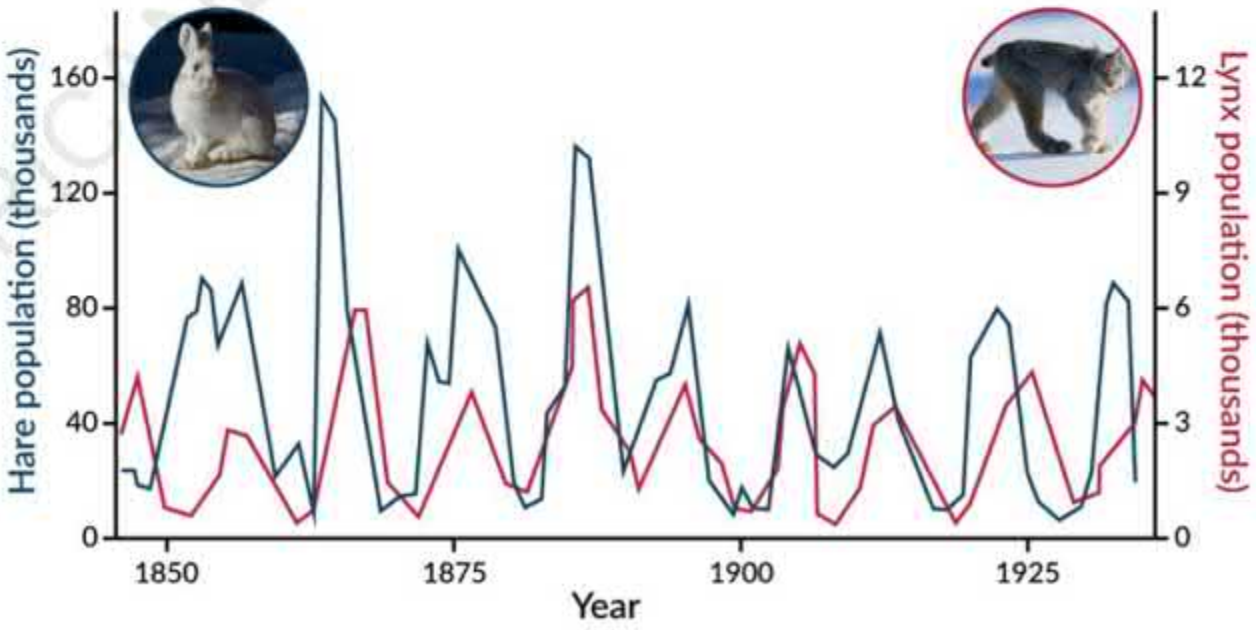
- Limiting factors are those factors that limit population growth. They are divided into two categories:

1. Density-dependent factors are those factors that increase directly as the population density increases. They include **competition for food, buildup of wastes, predation, and disease.**

2. Density-independent factors are those factors whose occurrence is unrelated to the population density. They include **earthquakes**, **storms**, and naturally occurring **fires** and **floods.**

A Case Study of Two Populations— Hare and Lynx

- A study involves the populations of snowshoe hare & lynx
- The data reveal fluctuations in the populations of both animals.
- The hare feeds on grass, and the lynx feeds on the hare. So, the cycles in the lynx population are probably caused by cyclic fluctuations in the hare population.
- Additionally, cycles in the hare population are probably due to a limited food supply, cyclical overcrowding, overgrazing and predation by the lynx.



COMMUNITY STRUCTURE AND POPULATION INTERACTIONS

Communities are made of populations that interact with the environment and with each other.

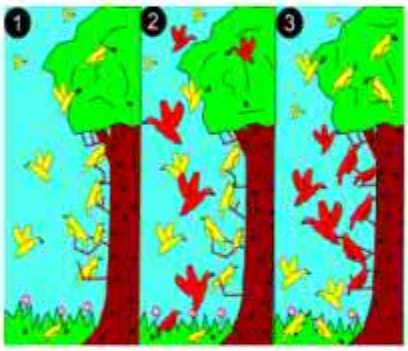
These interactions can be divided into: competition, predation, parasitism, mutualism, and commensalism.

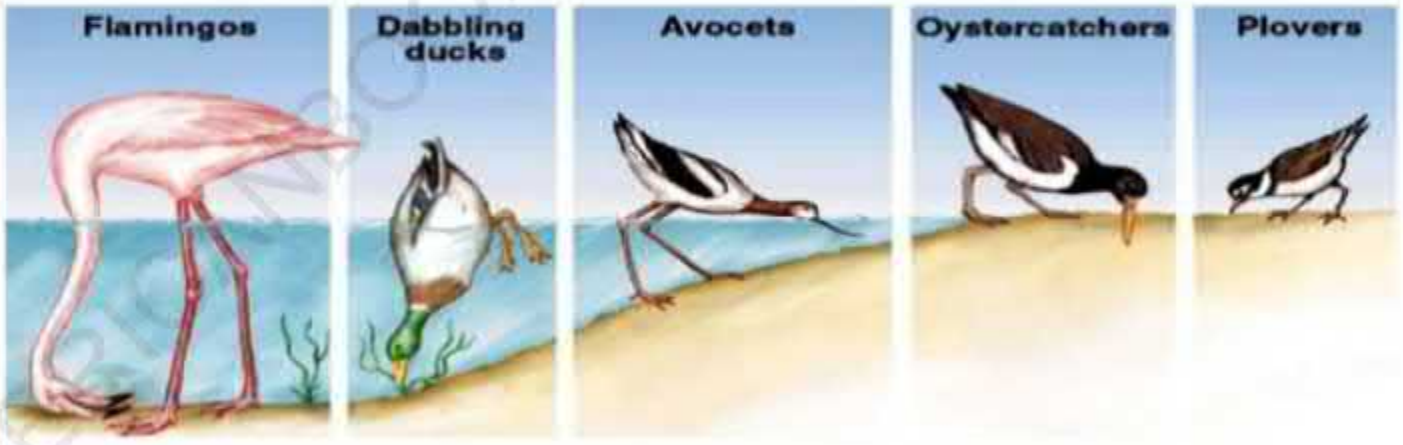
Competition

(G. F. Gause) made experiment on two species of Paramecium and he stated that "two species cannot coexist in a community if they share a niche, that is, if they compete for the same Resources".

In nature if two species inhabit the same area and occupy the same niche, the following could happen:

- One of the species will become extinct
- One will evolve through natural selection to exploit different resources (resource partitioning).
- One will evolve to eat different kinds of food and avoid competition (character displacement) as seen in (Galapagos Islands)





Predation

Predation can refer to one animal eating another animal, or it can also refer to animals eating plants.

For their protection, animals and plants have evolved defenses against predation.

Plants have evolved spines and thorns and chemical poisons such as strychnine, mescaline, morphine, and nicotine to fend off attack by animals.

Animals have evolved active defenses, such as hiding, fleeing, or defending themselves. These, however, can be very costly in terms of energy.

Animals have also evolved passive defenses that rely on cryptic coloration or camouflage.

1. Aposematic coloration. The very bright, often red or orange coloration of poisonous animals is a warning that possible predators should avoid them.

2. Batesian mimicry. This is copycat coloration, where one harmless animal mimics the coloration of another that is poisonous. One example is the viceroy butterfly that is harmless but looks very similar to the monarch butterfly that stores poisons in its body that it absorbs from the milkweed plant.

3. Müllerian mimicry. Two or more poisonous species resemble each other and gain an advantage from their combined numbers. Predators learn more quickly to avoid any prey with that appearance.

- Animals have evolved a variety of ways to feed.
  - **Herbivores** feed on plants.
  - **Carnivores** eat other animals.
  - **Detritivores** are animals that feed decomposed organic matter called detritus.

- Relationships based on feeding behaviors:

Mutualism

- Mutualism is a symbiotic relationship where both organisms benefit (+/+).
- An example is the bacteria that live in the human intestine and produce vitamins for the host.

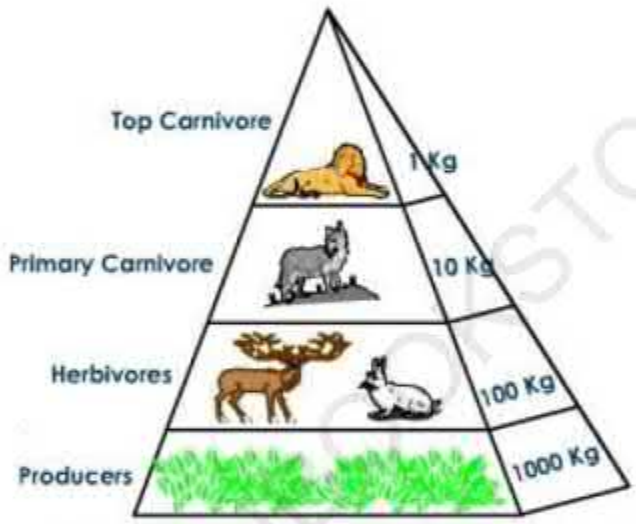
Commensalism

- Commensalism is a symbiotic relationship in which one organism benefits and one is neither helped nor harmed by the other organism (+/o).
- Barnacles, which are small, sessile crustaceans that attach themselves to the underside of a whale, benefit by gaining access to a variety of food sources as the whale swims into different areas.

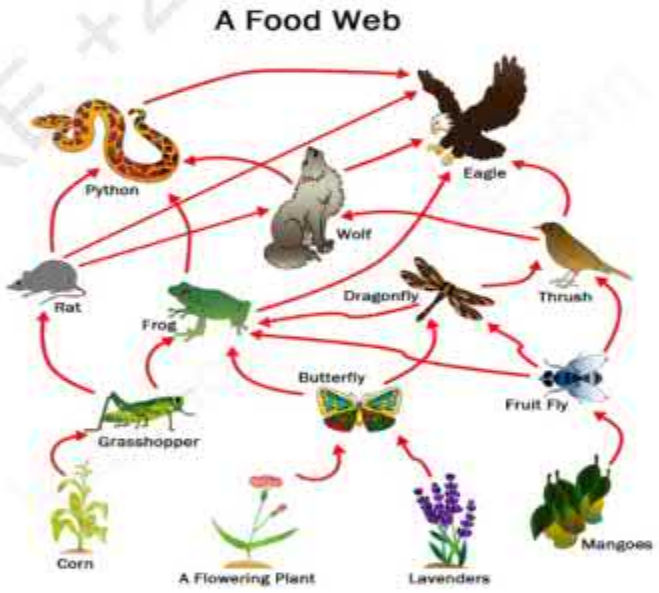
Parasitism

- Parasitism is a symbiotic relationship (+/−) where one organism, the parasite, benefits while the host is harmed.
- A tapeworm in the human intestine is an example.

- The **food chain** is the pathway along which energy is transferred from one trophic or feeding level to another.
- Energy, in the form of food, moves from the producers to the herbivores to the carnivores.
- Only about 10 percent of the energy stored passed to the next trophic level.
- This means that if you begin with 1,000 g of plant matter, the food chain can support 100 g of herbivores (primary consumer), 10 g of secondary consumer (carnivore), and only 1 g of tertiary consumer (carnivore).
- As a result of the loss of energy from one trophic level to the next, food chains never have more than four or five trophic levels.



Upright Pyramid of biomass in a Terrestrial Ecosystem



Food Web

Producers Photosynthetic (plants, diatoms, cyanobacteria)

Primary consumers Herbivores (grasshoppers and zooplankton)

Secondary consumers Carnivores (frogs and small fish)

Tertiary consumers

- Carnivores, top of the food chain
- Fewer of than any organism in the food chain
- Least stable trophic level and most sensitive to fluctuations in populations of the other trophic levels
- Examples: hawk or larger fish

Energy and Productivity in Food Chains

- **Productivity** is the rate at which organic matter is created by producers.
- **Gross primary productivity** is the amount of energy converted to chemical energy by photosynthesis per unit time in an ecosystem.
- **Net primary productivity** is the gross primary productivity minus the energy used by the primary producers for respiration.

Biological Magnification

- It means that organisms occupying higher trophic levels have greater concentration of accumulated toxins stored in their bodies than those at lower trophic levels.

- The bald eagle almost became extinct because Americans sprayed crops heavily with the pesticide DDT in the 1950s. DDT entered the bottom of the food chain and accumulated in the bald eagle, DDT interferes with the deposition of calcium in eggshells, the thin-shelled eggs were broken easily and few eaglets hatched.
DDT is now outlawed, and the bald eagle was saved from extinction.

Why it is better for human to feed on producers ?

1- Avoid losing energy in different trophic levels
2- Avoid accumulation of toxins

Biological succession

- Most communities are dynamic, always changing.
- The size of a population increases and decreases around the carrying capacity.
- Migration of a new species into a habitat can alter the entire food chain.
- Major disturbances, both natural and human-made, like volcanic eruptions, strip mining, clear cutting a forest, and forest fires, can suddenly and drastically destroy a community or an entire ecosystem.
- **Ecological succession** is the process of sequential rebuilding of the ecosystem.

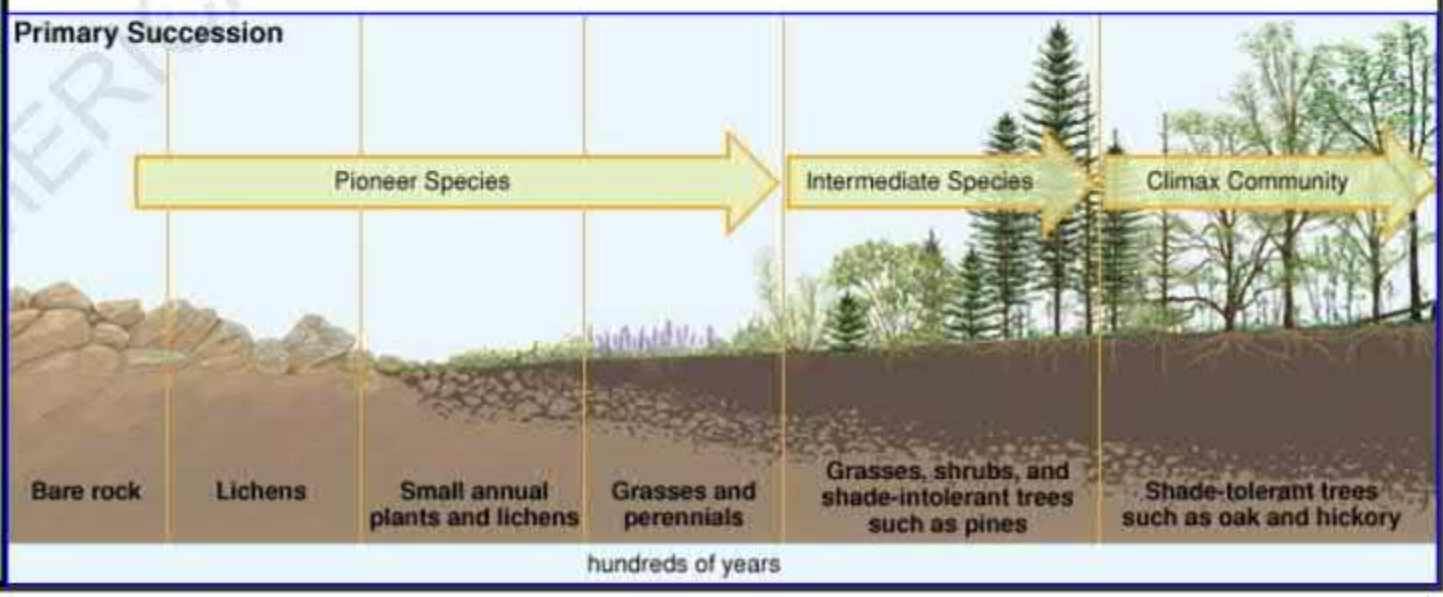
- primary ecological succession

- It begins in a lifeless area where even soil has been removed it includes:

1. Soil building.
2. **Pioneer organisms** development (like lichens and mosses) which are introduced into the area as spores by the wind.
3. Larger organisms: grasses, bushes, and then trees.
4. Forming of **Climax community**

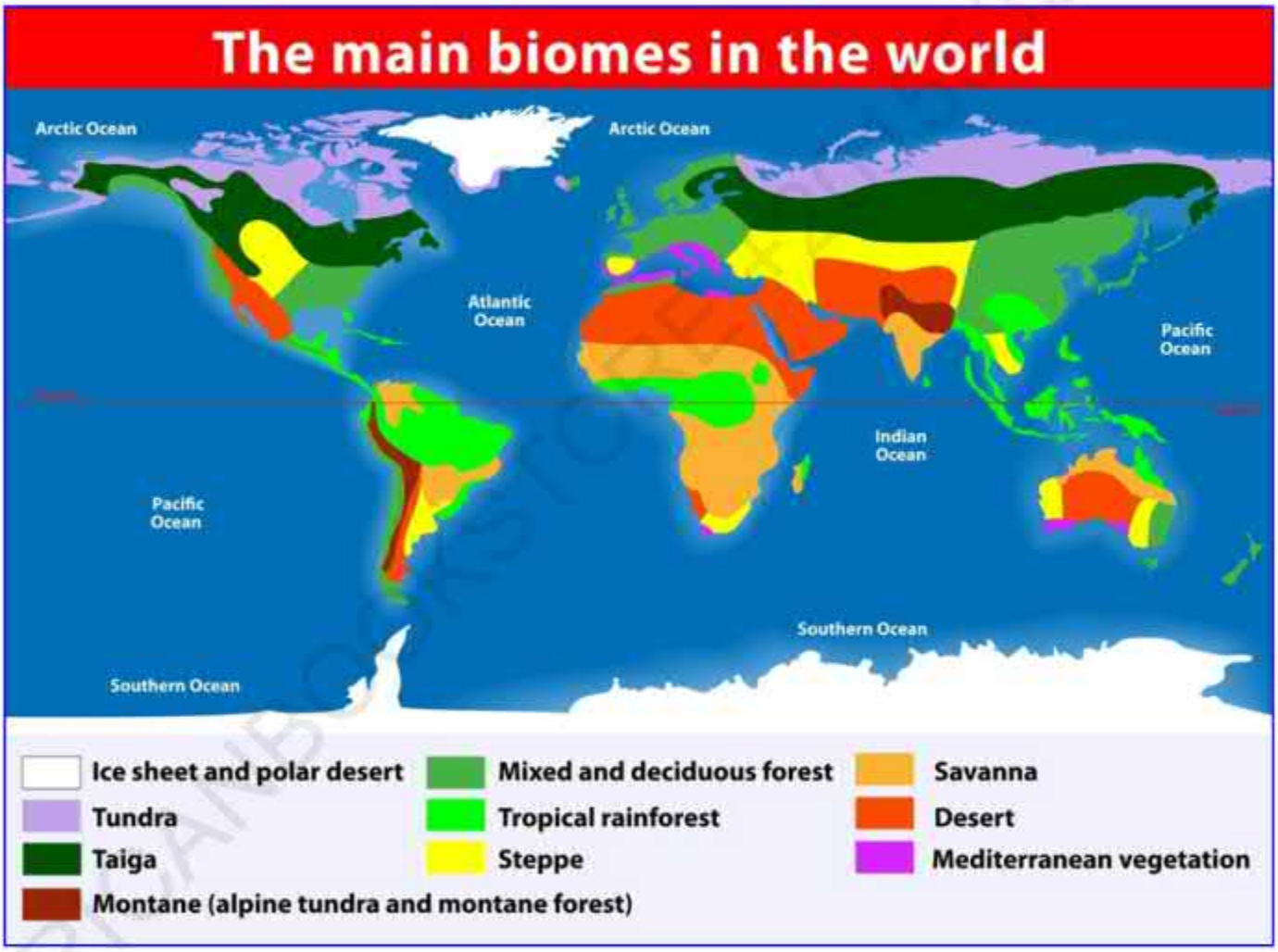
- Secondary succession

- It occurs when an existing community has been cleared by some disturbance that leaves the soil intact. (Like after a fire in the forest that destroys everything but leaves the soil)



Biomes

- **Biomes** are distinct biological communities that have formed in response to a shared physical climate.
- Biome is a broader term than habitat; any biome can comprise a variety of habitats.
- Each biome is characterized by different vegetation and animal life.
- There are many biomes, including freshwater, marine, and terrestrial biomes.

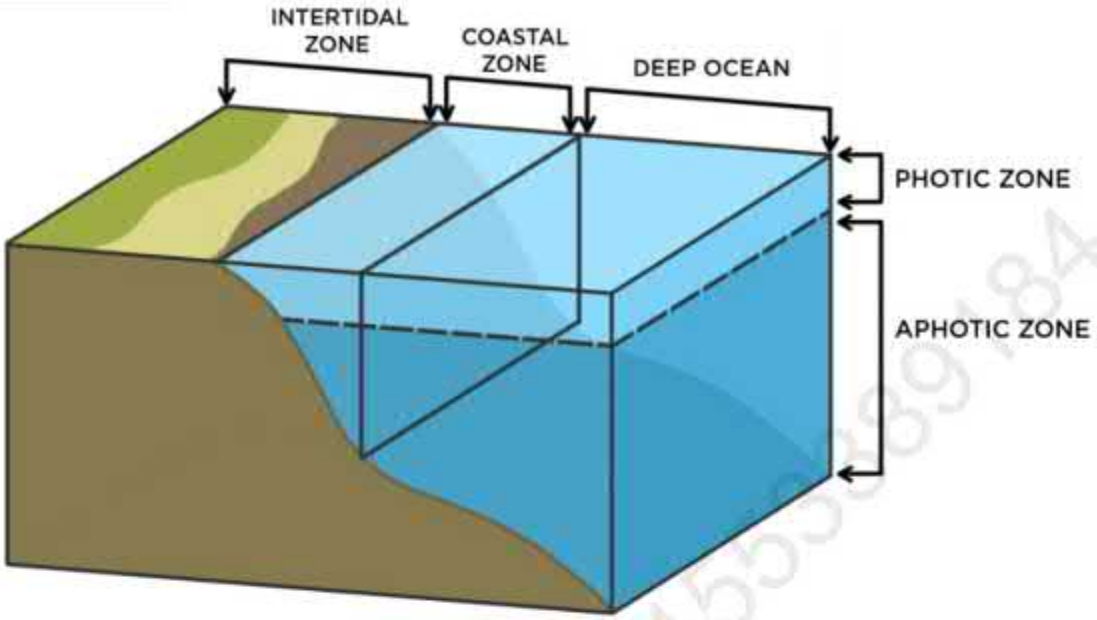


Marine

- The largest biome, covering 75% of Earth surface
- The most stable biome
- Provides most of Earth's food and oxygen
- Subdivided into different regions classified by amount of sunlight they receive, distance from shore and water depth, and whether open water or ocean bottom

Biomes

The Marine Biome

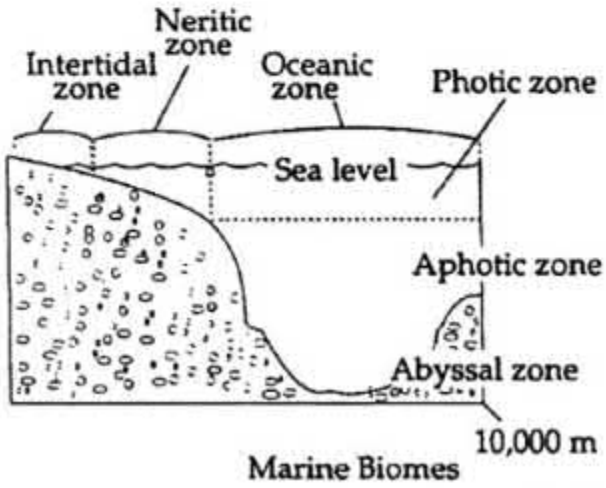


The Marine Biome

- **Intertidal zone**: This is land that is covered by water when the tide is high, but is above water when the tide is low.
- **Coastal zone (Neritic zone)**: Water which borders the land. This area is home to very diverse animal and plant life.
- **Open ocean**: The part of the ocean past the continental shelf. This is the largest part of the marine biome and is also known as the **pelagic zone.**

The marine biome can also be divided into the **photic and aphotic zone.**

The photic zone is the upper layer of water which absorbs sunlight. The aphotic zone is the deeper layer of water which does not receive sunlight.



Abyssal zone is the ocean floor

Biomes

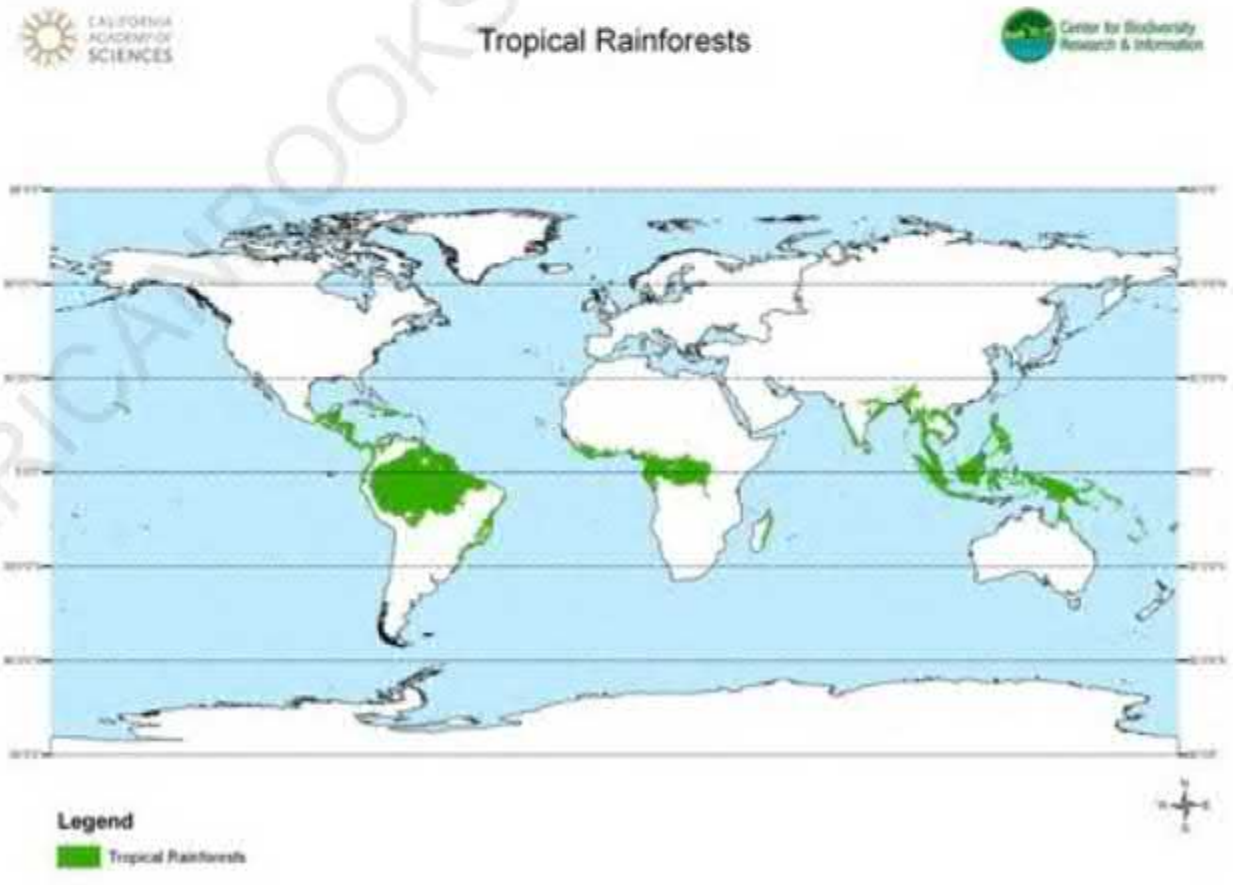
Tropical Rain Forest

- This biome is found near the equator with very high annual rainfall, high average temperatures , and high humidity.
- Cover only 4-6% of Earth's land and produce 20% of Earth' food (photosynthesis process)
- Dominant trees are very tall with interlacing tops that form a dense canopy, keeping the floor of the forest dimly lit even at midday and prevents rain from falling directly onto the forest floor, but leaves drip rain constantly.
- Many trees are covered with **epiphytes**, photosynthetic plants that grow on other trees rather than supporting themselves.

Tropical Rain Forest

- **Soil Composition**: Since there is a tremendous amount and diversity of foliage in tropical rainforests, you might assume that rainforest soils are rich in nutrients. In fact, rainforest soils are nutrient-poor because nutrients are not stored in them for very long. The heavy rains that occur in rainforests wash organic material from the soil.

- **Biodiversity**: Tropical rainforests are areas of extremely high biodiversity compared to other ecosystems. In the topical rainforests of Borneo, scientists have documented more than 15,000 plant species, including 2,500 species of orchids! Biologists estimate that tropical rainforests contain about 50% of the world's terrestrial plant and animal species, yet they encompass only about 6% of the world's land area.



Biomes

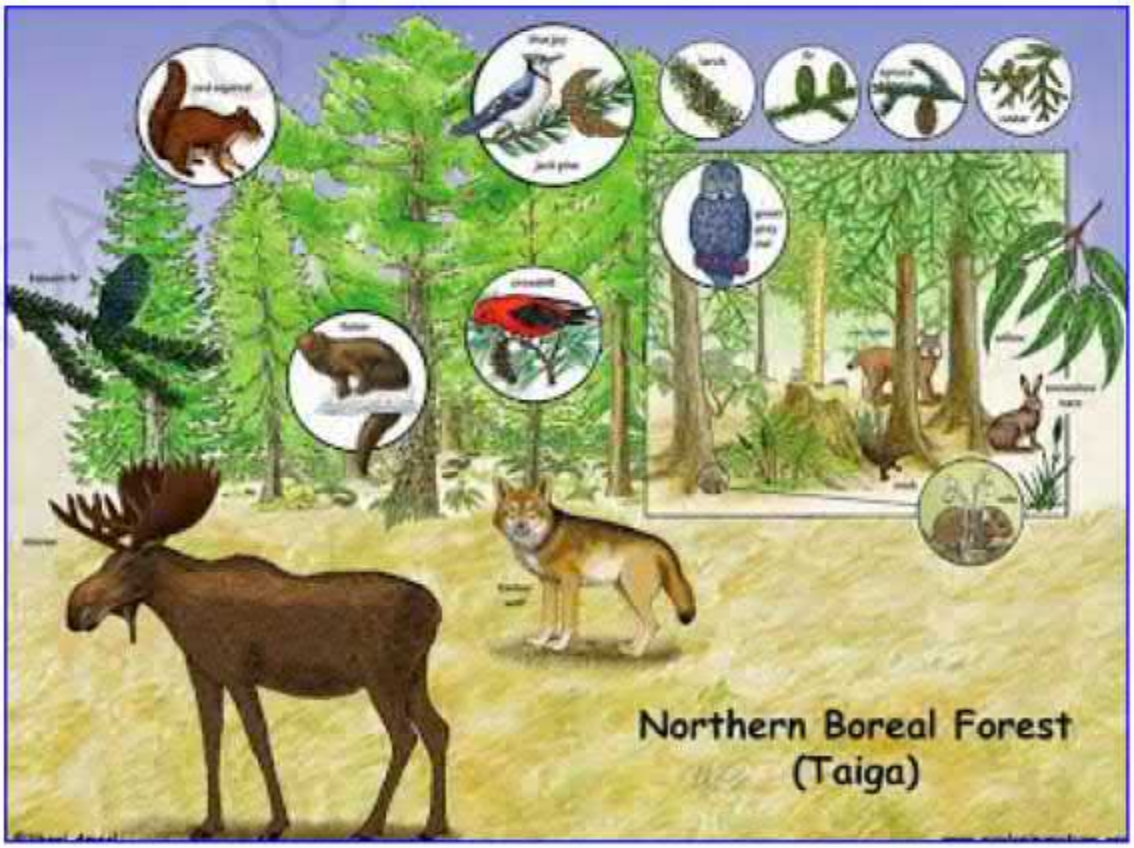
Desert

- It receives less than 10 inches of rainfall per year
- Most of plants even grasses can not survive.
- Most extreme temperature fluctuations of any biome could reach 70℃. At night temperatures drop drastically.
- Plants: **Cacti**, sagebrush, creosote bush, and mesquite.
- Most animals remain cool during daytime by burrowing underground or hiding in the shade.
- Cacti can expand to hold extra water and have modified leaves called spines, which protect against animals attacking a cactus for its water.
- Characteristic animals include rodents, kangaroo rats, snakes, lizards, arachnids, insects, and a few birds.

Biomes

Conifer Forest-Taiga

- Found in the world's northern regions
- Dominated by conifer forests, like spruce and fir
- Presence of lakes, ponds, and bogs
- Has very cold winters
- Is the largest terrestrial biome
- Characterized by heavy snowfall; trees are shaped with branches directed downward to prevent accumulations of snow from breaking their branches
- Principal large mammals include moose, black bear, lynx, elk, wolverines, martens, and porcupines
- Flying insects and birds are prevalent in summer
- Has greater variety in animal species than does the tundra



Biomes

Temperate Grasslands

- Found in temperate and tropical regions
- low total annual rainfall or uneven seasonal occurrence of rainfall, making conditions inhospitable for forests
- Principal grazing mammals include bison and pronghorn antelope in the United States, and wildebeest and gazelle in Africa
- Burrowing mammals, such as prairie dogs and other rodents, are common

Temperate Deciduous Forest or Boreal Forest

- Found in the northeast of North America, south of taiga
- Characterized by trees that drop their leaves in winter
- Includes many more plant species than does the taiga
- Shows vertical stratification of plants and animals
- Some species live on the ground, some in the low branches, and some in the treetops
- Rich soil due to decomposition of leaf litter
- Principal mammals include squirrels, deer, foxes & bears

Biomes

Tundra

- Located in the far northern parts of North America, Europe, and Asia including Alaska
- Commonly referred to as the frozen desert because it gets very little rainfall
- Has the appearance of gently rolling plains with many lakes, ponds, and bogs in depressions
- Insects, particularly flies, are abundant
- Vast numbers of birds nest in the tundra in the summer to eat the insects and migrate south in the winter
- Principal mammals include reindeer, caribou, Arctic foxes, Arctic wolves, Arctic hares, lemmings, and polar bears
- Though the number of individual organisms in the tundra is high, the number of species is small

Chemical cycles

The water cycle

- Water evaporates
- Forms clouds
- Rains
  - groundwater.
  - river & seas.
  - Evaporates directly
- plants transpiration

Nitrogen Cycle

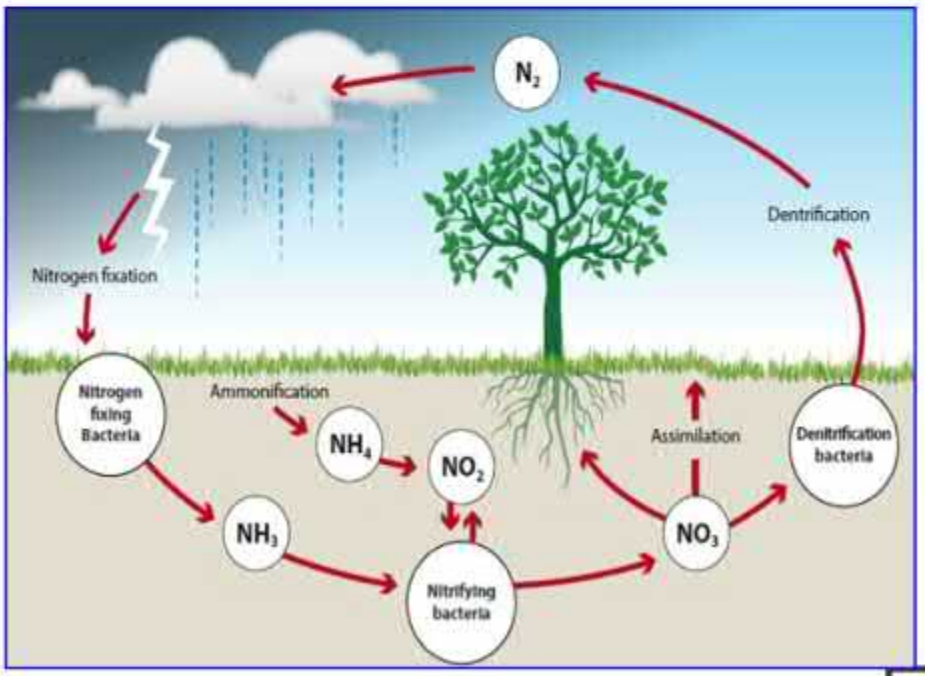
Nitrogen enters ecosystems by way of bacterial processes.

- Nitrogen-fixing bacteria live in the nodules in the roots of legumes and convert free nitrogen (N2) into the ammonium ion (NH4+).

- Nitrifying bacteria convert the ammonium ion (NH4+) into nitrites (NO2−) and then into nitrates (NO3−).

- Denitrifying bacteria convert nitrates into free atmospheric nitrogen.

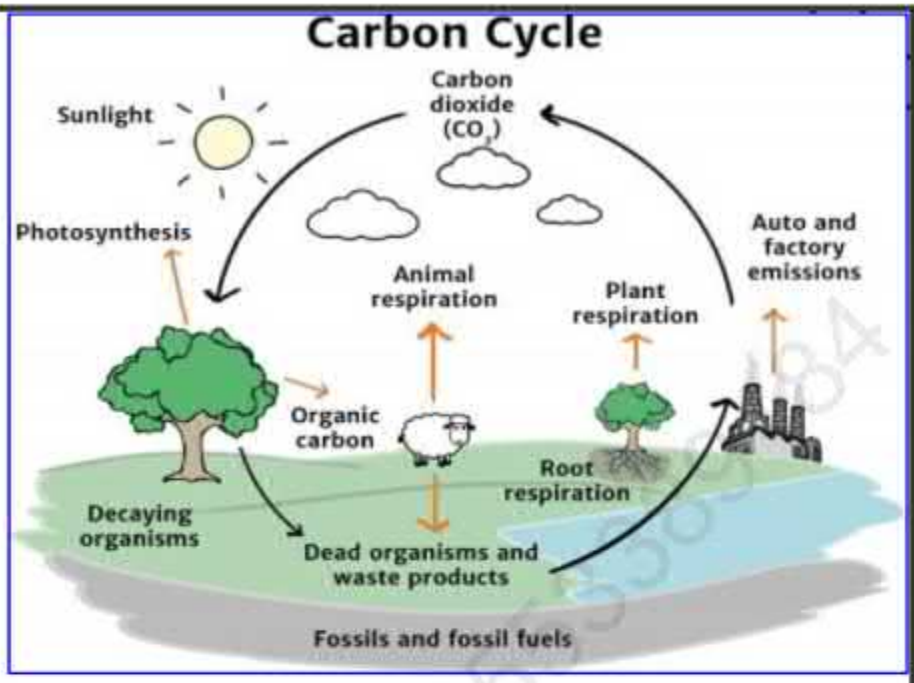
- Decomposers are bacteria that break down dead organic matter, like dead plants and animals, into ammonia (NH4+).



The Carbon Cycle

• Cell respiration adds carbon dioxide to the air and removes oxygen.

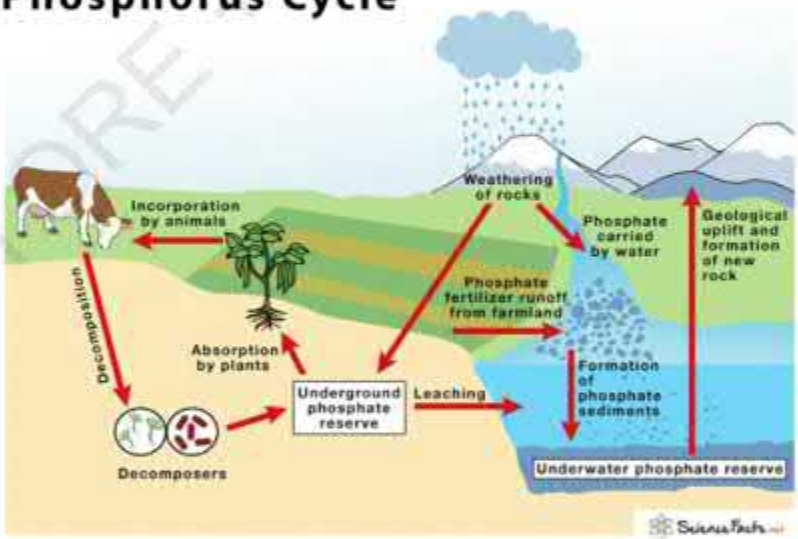
• The burning of fossil fuels adds carbon dioxide to the air. Photosynthesis removes carbon dioxide from the air and adds oxygen



The Phosphorus Cycle

1) Weathering

Over a long period, phosphates found in the sedimentary rocks as PO4, are leached out of the disintegrated rocks from its various environmental sources in the form of inorganic phosphate ions. volcanic ash, aerosols, and mineral dust also serve as other significant phosphate sources.



2) Mineralization by plants

Plants absorb organic phosphorus present in soil and underground water and convert them to inorganic forms for utilization is called mineralization.

3) Assimilation by animals

Herbivorous and carnivorous animals, including humans,

absorb phosphorus when they consume these plants for their food.
Besides, animals obtain phosphorus directly from drinking water.

4) Decomposition by microorganisms
Microorganisms such as bacteria and fungi decompose organic phosphates back into the inorganic form, which is then returned to the soil and water bodies. Phosphorus-containing compounds may also be carried in the surface runoff to rivers, lakes, and oceans to form sediments.

5) Geological uplift by tectonic movements
Over long periods, sedimentary rocks containing phosphorus may be moved from the ocean to the land by a process called geological uplift.

The phosphorus thus deposited as sediments are ultimately released back into the environment through the process of weathering, thus completing the cycle.

Eutrophication of the Lakes

- Runoff from sewage and manure from pastures increase nutrients in lakes
- This cause excessive growth of algae and other plants.
- large populations of photosynthetic organisms die
- Organic material accumulates on the lake bottom
- Use up oxygen lead to fish mortality
- The process continues, more organisms die, the oxygen levels decrease, more decomposing matter accumulates on the lake bottom until the lake disappears.

Acid Rain

- Acid rain is caused by pollutants in the air from the combustion of fossil fuels.
- Nitrogen and sulfur pollutants in the air turn into nitric, nitrous, sulfurous, and sulfuric acids
- This cause the pH of the rain to be less than 5.6
- This causes the death of the organisms in lakes.

Toxins

- Toxins from industry have gotten into the food chain.
- Most cattle and chicken feeds contain antibiotics and hormones to accelerate animal growth
- This have serious ill effects on humans who eat the chicken and beef.
- Any carcinogens or teratogens that get into the food chain accumulate and remain in our body's fatty tissues.

Depleting the Ozone Layer

- The accumulations in the air of chlorofluorocarbons, have caused the formation of a hole in the protective ozone layer
- This allows more ultraviolet (UV) light to reach Earth
- This increase in the incidence of skin cancer

Global Warming

- Excessive burning of fossil fuels has caused the concentrations of carbon dioxide in the air to increase
- This causes the **greenhouse effect.**
- This means that carbon dioxide and water vapor in the air absorb much of the infrared radiation reflecting off of Earth, causing the average temperature on Earth to rise.
- This increase in temperature is called global warming and could have disastrous effects for Earth.
- An increase of 1.0℃ on average temperature worldwide would cause the polar ice caps to melt, raising the level of the seas and tremendous changes in weather patterns.
- Major coastal cities in the United States, including New York and Los Angeles would be under water.

Pesticides vs. Biological Control

- Pesticides, chemicals that kill undesirable organisms
- These include insecticides, herbicides, fungicides, and mice and rat killers.
- This increase food production and by killing animals that carry and cause diseases
- Exposure to pesticides can cause cancer in humans.
- Development of resistant strains of pests through natural selection.
- An alternative to widescale spraying with pesticides is called biological control.
  1. Use crop rotation— change the crop planted in a field.
  2. Introduce natural enemies of the pests
  3. Use natural plant toxins instead of synthetic ones.
  4. Use insect birth control— male insect pests can be sterilized by exposing them to radiation and then releasing them into the environment to mate unsuccessfully with females.

Biology Process

I - Scientific inquiries

II - Measurement in science

Other Types of Scientific Investigations

Experiments are sometimes hard or even impossible to do. For example, a scientist who is studying an extinct animal cannot experiment with the animal because it no longer exists. The scientist must rely instead on evidence in the natural world, such as fossils that the extinct animal left behind.

1. Natural Studies

When scientists do studies in nature, they usually cannot control factors that might affect the variables they are investigating. This is a drawback, because it may make the observations difficult to interpret. Without controls, it may not be possible to determine which of many factors explain the observations. For example, assume you are studying how plants grow in a forest or field. You cannot control the amount of sunlight or rain water the plants receive, so it will be difficult to determine which factors most influence plant growth. On the other hand, a natural study shows what actually occurs in nature. Therefore, it may provide a truer picture of what happens in the real world than an experiment does. methods and point out any possible problems with the investigation. Other researchers might be able to think of ways to avoid this error in future studies.

2. Modeling

Another way to gain scientific knowledge without experiments is by making and manipulating models. A model is a representation of part of the real world. Did you ever build a model car?

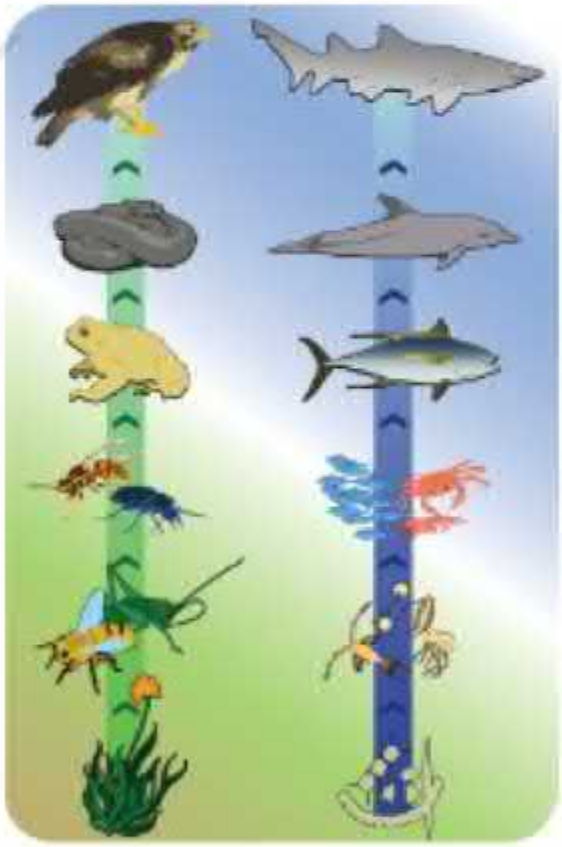
Scientific models are something like model cars; they represent the real world but are simpler than the real world. This is one reason that models are especially useful for investigating complex systems.

By using a model, scientists can better understand how the real system works.

Like a hypothesis, a model must be evaluated. It is assessed by criteria such as

- how well it represents the real world,
- what limitations it has
- how useful it is.

The usefulness of a model depends on how well its predictions match observations of the real world.



Food chain Model

Math and measurement in science

Measurements are a basic necessity in science. Scientists have designed thousands of different tools to help in the vital process of measuring.

Measurement

- We already know that observations are an important part of the scientific method. Hypotheses are accepted or rejected based on how well they explain observations.

- Some observations, such as "the plant turned brown" are qualitative;

- A quantitative observation includes numbers, and is also called a measurement. A measurement is obtained by comparing an object to some standard.

- Any observation is useful to a scientist, but quantitative observations are commonly considered more useful. Even if the measurement is an estimate, scientists usually make quantitative measurements in every experiment.

- Since accurate measurement is a vital tool for doing science, a consistent set of units for measurement is necessary.
- Physicists throughout the world use the International System of Units (also called the SI system).

- The SI system is basically the metric system, which is convenient because units of different size are related by powers of 10. The system has physical standards for length, mass, and

time.

- These are called fundamental units because they have an actual physical standard.

- The standard SI unit for length is the meter, and is denoted by "m". Originally, the meter was defined as the length between two scratches on a piece of metal which was stored in a secure vault under controlled conditions. The meter's definition has changed over time, but it is now accepted to be the distance light travels in a vacuum over 1/299792458 of a second.

- The standard unit of time, the second, was once defined as a fraction of the time it takes the earth to complete an orbit around the sun, but has now been redefined in terms of the frequency of one type of radiation emitted by a cesium-133 atom. Seconds are denoted by "s" or, less commonly, "sec."

- The standard unit for mass is the kilogram. The kilogram's standard is a block of platinum-iridium metal kept near Paris, France. Other countries, of course, keep copies. A kilogram is denoted "kg" and is a multiple of the smaller unit of mass, the gram ("g").

- Meters, seconds, and kilograms are not the only unit entities. Take, for example, speed. Speed is a derived unit, measured in meters per second (m/s).

- Derived units are units that are expressed using combinations of the fundamental units.

- As mentioned earlier, the SI system is a decimal system. Prefixes are used to change SI units by powers of ten. Thus, one hundredth of a meter is a centimeter and one thousandth of a gram is a milligram.

Common Prefixes Used with SI Units

Prefix	Symbol	Fractions	Example
pico	p	1×10^{-12}	picometer (pm)
nano	n	1×10^{-9}	nanometer (nm)
micro	μ	1×10^{-6}	microgram (μg)
milli	m	1×10^{-3}	milligram (mg)
centi	c	1×10^{-2}	centimeter (cm)
deci	d	1×10^{-1}	decimeter (dm)
		Multiples	
tera	T	1×10^{12}	terameter (Tm)
giga	G	1×10^{9}	gigameter (Gm)
mega	M	1×10^{6}	megagram (Mg)
kilo	k	1×10^{3}	kilogram (kg)
hecto	h	1×10^{2}	hectogram (hg)
deca	da	1×10^{1}	decagram (dag)

Converting metric units

King Hector died Monday drinking chocolate milk.
Kilo hecto deca meter deci centi milli

- Kilometer (km) 1000m
- Hectometer (hm) 100m
- Decameter (dam) 10m
- Meter (m) 1m
- Decimeter (dm) .1m
- Centimeter (cm) .01m
- Millimeter (mm) .001m
- Micrometer (um) .000001m
- Nanometer (nm) .000000001m

Example Convert 500 millimeters to meters.

The equivalency statement for millimeters and meters is

1000 mm = 1 m.

To convert 500 mm to m, we multiply 500 mm by a conversion factor that will cancel the millimeter units and generate the meter units. This requires that the conversion factor has meters in the numerator and millimeters in the denominator.

This conversion factor is constructed from the equivalency statement 1000 mm = 1 m.

$$(500.\ \text{mm})\left(\frac{1\ \text{m}}{1000\ \text{mm}}\right) = 0.500\ \text{m}$$

So 500 mm is equivalent to 0.5 m.