Water

What are the criteria that can be used to distinguish Scientific claims from pseudoscientific claims?

- Memory of water
- Ancient astronauts built the pyramids
- Flat earth theory

Water

- Life first evolved in water. Water is a polar molecule and contains elements and compounds necessary for life.

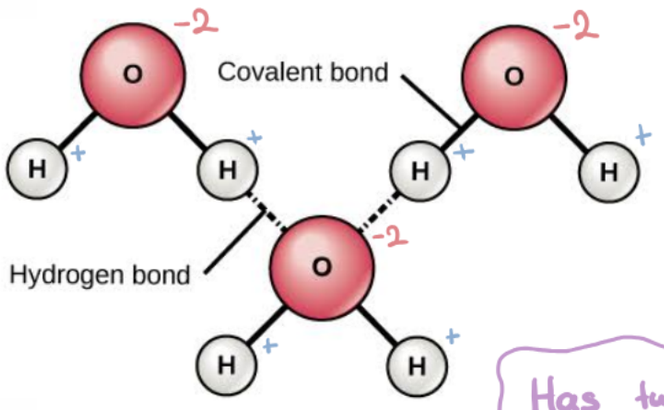
Advantages

- Provides bouyancy.
- Provides thermal properties for organisms.

Disadvantages

- High viscosity compared to air.
- Organisims adapted their body shape to move easily.

- The first cells originated in water. All living organisms including humans need water to exist. Enzymes and biological molecules needs water to work.



Has two poles

~Adhesion~

- Water molecules tend to stick another substances. The water molecules stick to xylem walls.

Polar - hydrophilic - dissolve water (salt, sugar)

Non-polar — hydrophobic - not dissolve water (oil)

~ Cohesion of water due to hydrogen bonding~

- Water can form hydrogen bond with other water molecules. Cohesion water molecules tend to stick together.

- The water in the soil drawn up by the xylem vessels by the plant and they carried to the leaves. It's Cohesive.

Water is a powerful solvent for polar substances such as salt, sugar, ions, a.a. glucose, protein.

Non-polar substances can not dissolve in water such as oil. They're repelled by water. Testosterone and some proteins.

property	Water	Air
Buoyancy force	Force is upwards and equal to the weight of the object.	Object has an special buoyancy force. Force is equal to the displaced water.
Viscosity	Water's resistance to an object. >	Air's resistance to an object.
Thermal Conductivity	The substances ability to transfer heat. >	—
Specific Heat Capacity	Even tho the cold temperature the water can keep its temp. the same. >	—

Which are the factors to promote the retention of water in a liquid?

- Strong gravitational pull due to Earth's size.
- Itensity of sunlight due to the distance from the sun keeps the Earth 100°C and mostly above 0°C.

Why is the water important for all living organisims?

- Water is used during all metabolic activity.

Goldilac zone: Suitable zone for a living. Presence of liquid water, Optimal distance from its star, Atmosphere, Stable temperatures Essential chemical elements, Geological activity.

The Goldilocks zone is the range of distance from a star where the right temperatures would exist for liquid water to exist on a planet

The relevant distances will depend on the size and temperature of the star - the habitable zone will be further away from hotter stars

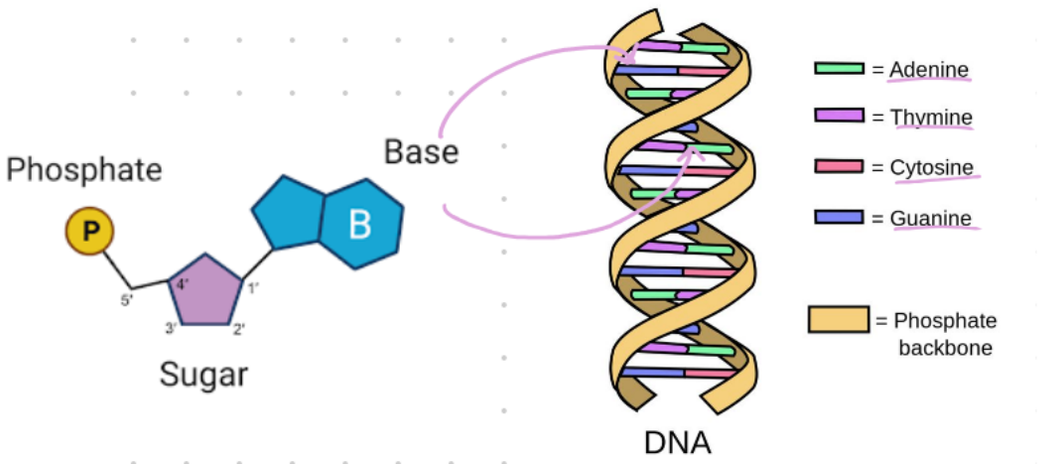
Nucleic Acids

DNA:

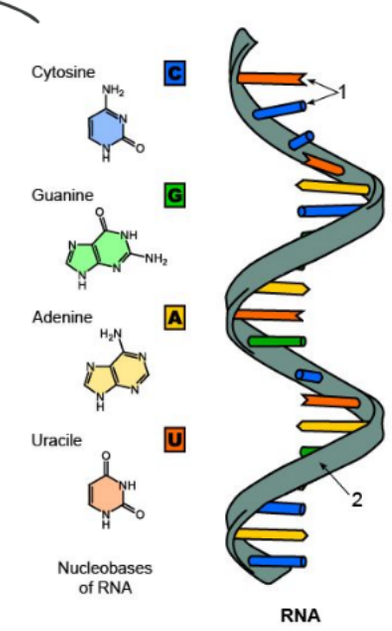
- Double stranded
- All nucleotides contains deoxyribose sugar.
- Thymine
- Shaped into a double helix.
- Permanent genetic code of a cell.

RNA:

- Single stranded
- All nucleotides contains ribose sugar.
- Uracil
- Variety of shapes
- Does not contain genetic code except in RNA viruses.



- Produce mRNA from DNA and produce polypeptide. (protein)



Phosphate + sugar + base → Nucleotide + H_2O

Condensation

Two Types Of Base Group

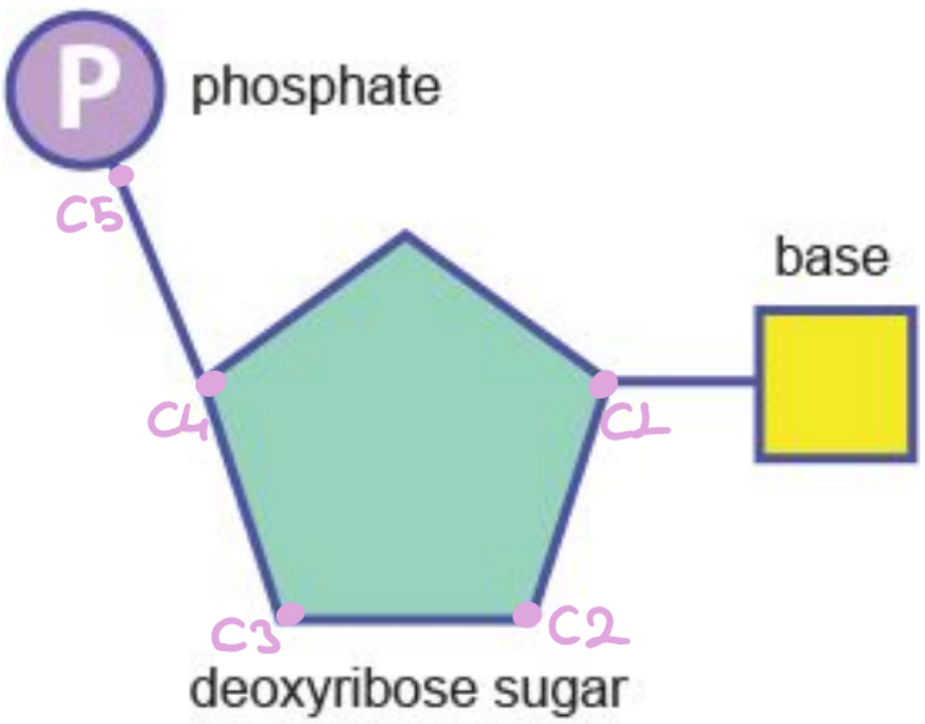
Purine: (Two Rings)
- Guanine
- Adenine

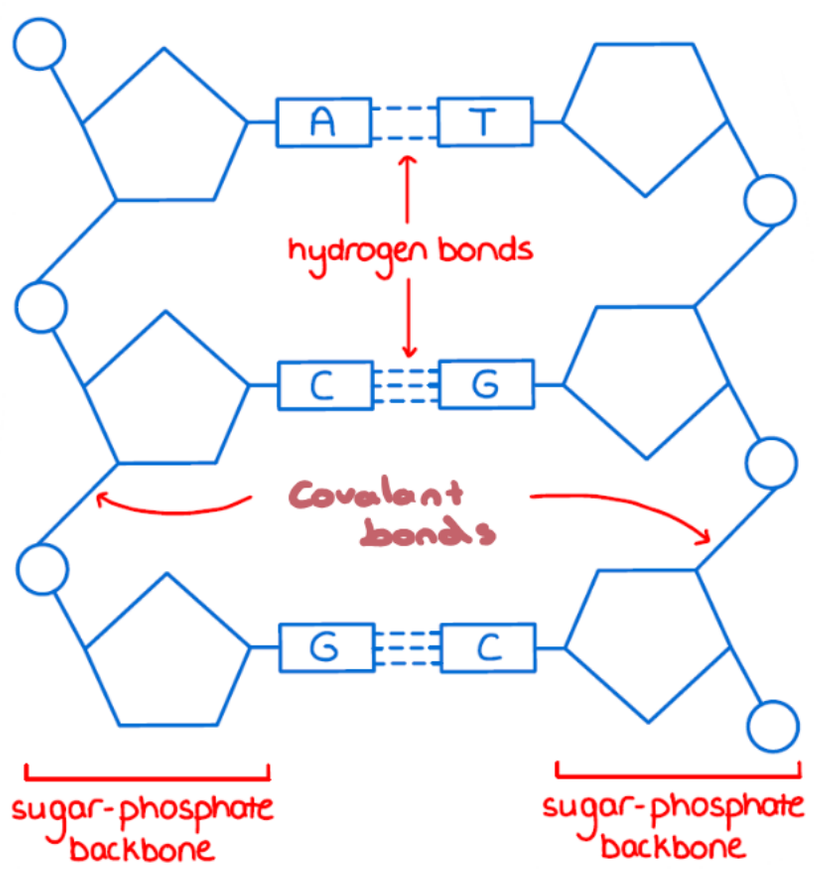
Pyrimidine: (One Ring)
- Cytosine
- Thymine (DNA)
- Uracil (RNA)

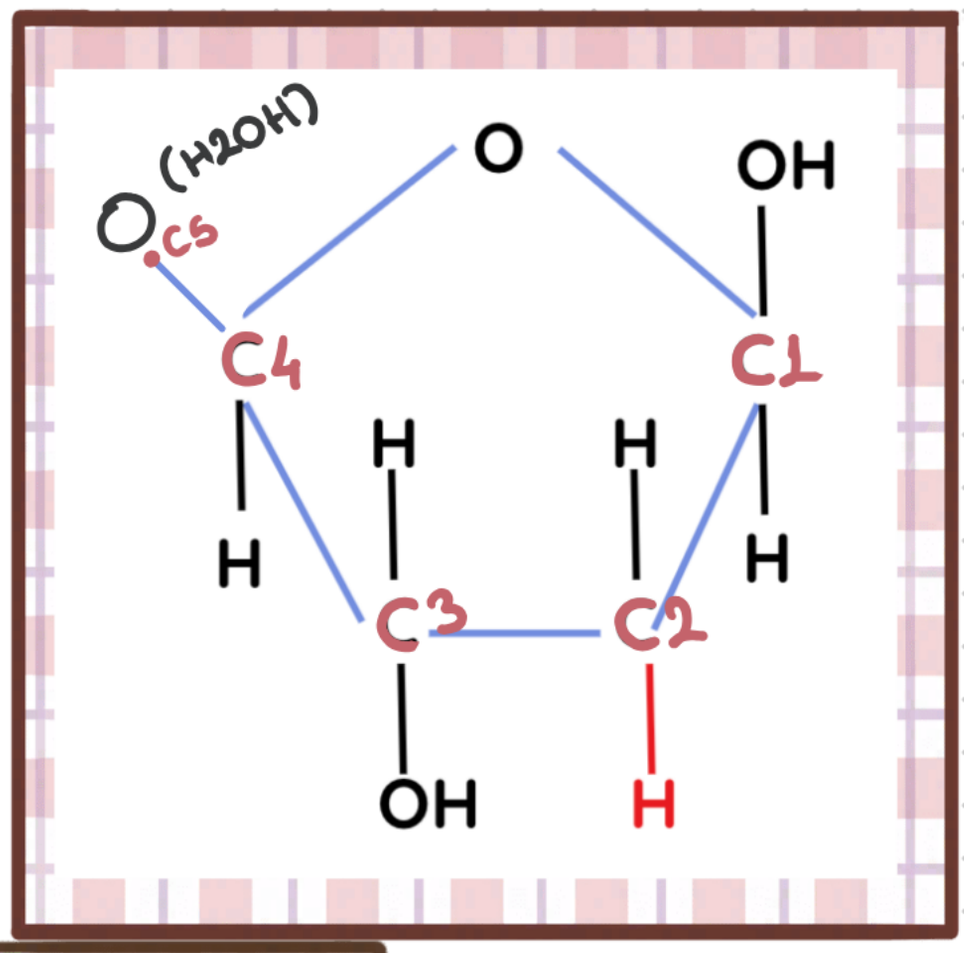
Purine and Pyrimidine → Complementary Base

G≡C → 3 hydrogen bond

A=T → 2

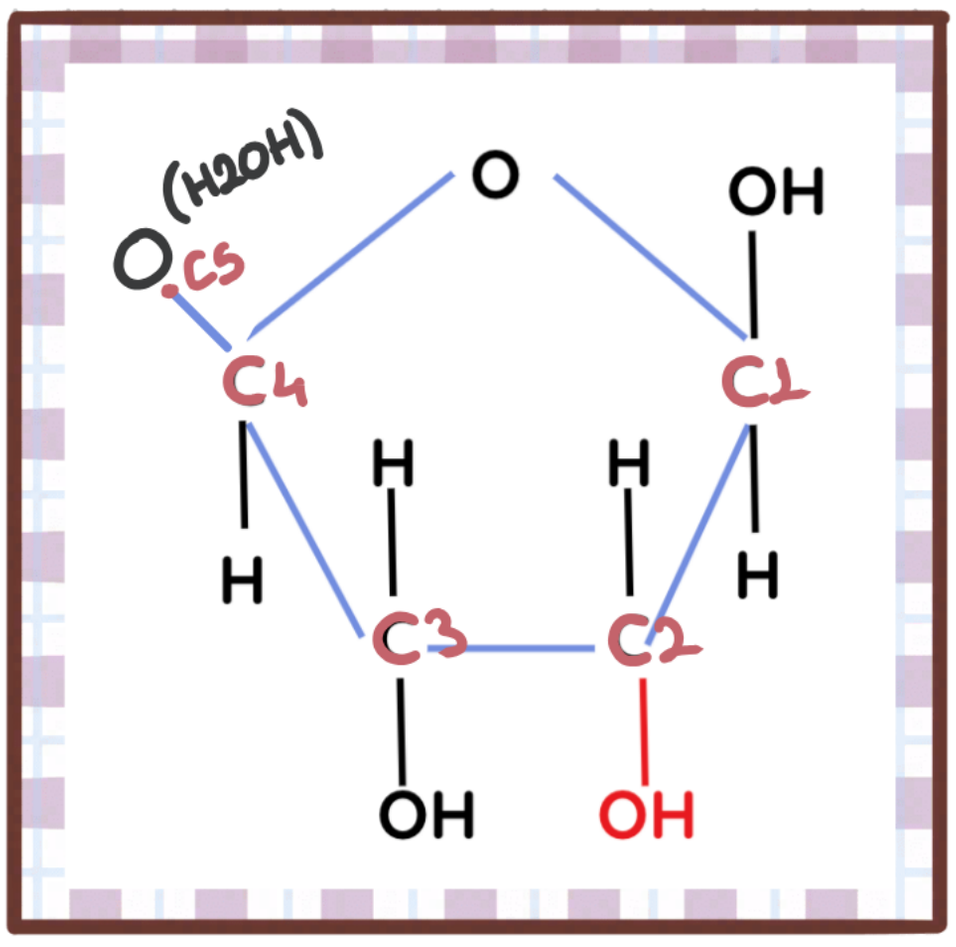






The bondings should bond with the oxygen part.

Deoxyribose
1 oxygen removed



Ribose 5C

Origin Of Cell

Origin of Cell

- Conditions on early Earth: 4 Billion years ago Earth started developing atmosphere, thick water vapour and other compounds released by volcanic eruptions.



- Free oxygen is not present!!!! If it was, it would form a layer of ozone and block the ultraviolet light penetration and which prevents developing higher temperatures

Cells as the smallest units of self-sustaining life → unicellular / multicellular

- Metabolism: Living things minimizing essential chemical reactions
- Reproduction: Producing babies either sexually or asexually
- Sensitivity: Responding to internal/external stimuli
- Homeostasis: Maintaining a stable body temperature.
- Excretion: Removing of waste products
- Nutrition: Exchanging materials and gases with the environment
- Growth: Can move, change shape or size

Cell Theory.

- All living things are composed of cells.
- The cell is the smallest unit of life.
- Cells only arise from pre-existing cells.

Exceptions:

- Striated muscle fibres
- Aseptate fungal hyphae
- Giant algea

All cells have three common features:

- A stable membrane surrounding cell components
- Genetic material → Controls the function of the cell
- Metabolic processes → energy generation, growth, self-maintenance, reproduction

Formation of cells from unalive materials

- Synthesis of simple organic molecules → amino acids, sugar etc.
- Transformation of these molecules into polymers
- Development of self-replicating molecules → nucleic acids
- Keeping these molecules in membranous sacs so that an internal chemistry developed

THEORIES FOR THE ORIGIN OF LIFE

- Protocell-first: A cell-like living (that had a basic metabolism but lacked a fully developed genetic system) grew and divided into daughters that resembled the mother cell. These protocells produced until they create a genetic system.

- Gene-first: A genetic molecule grew capable of replication. The replicators created forming gene variants that could make membranes and start metabolism.

- Metabolism-first: A self-sustaining system capable of feeding grew, absorbed on and in mineral surface. This chemical mixture evolved and became evolving cells and genetic systems.

- Many scientists favour the Metabolism-first theory because growth, replication and division are the essential processes for protocells evolution and it all requires energy.

carbon } DNA
sugar }

EVIDANCE FOR THE ORIGIN OF CARBON COMPUNDS

Simple compound. → (Became.) Complex Polymerase. → (Formed a capacity of) Self replicate. → (Packed into) Surrounding Membrane

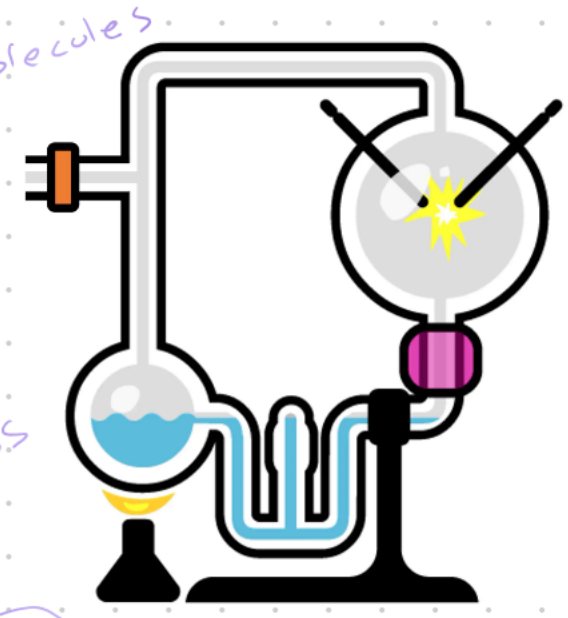
Miller-Urey Experiment

- To recreate the postulated conditions of prebiotic Earth:

- Water was boiled to reflect the high temperature → hydrogen
- The vapour was mixed with gases (H_2, CH_4, NH_3) creating a reduced atmosphere → no oxygen → Methane, Ammonia
- The mixture exposed to an electrical discharge (i.e. light energy)
- The mixture was allowed to cool (for 1 week)
- Result: the mixture contained traces of simple organic molecules (amino acids)

Result: Simple organic molecules formed. ✓

not life! Just some simple molecules



$CH_3-(CH_2)_n-COOH$

Formation of fatty acids into spherical bilayers → phospholipids

fatty acids ≠ triglyceride

1 glycerol + 3 fatty = trigly

- A membrane → essential to the origin of the first cells
- provides a barrier ✓
- maintenance of activities in the cell ✓

- compartmentalization (Organelles with different functions): Development of a boundary around a vesicle Becomes evident in the outer boundary, allowing specialization of functions in different regions inside the fatty acid bilayer.

bölümlere ayrılma

Evolutions of cell membranes from primitive to modern

ilkel hücre

Protocells formed. from fatty acids → Condensation of. Fatty acids. (With glycerol to form triglycerides) → Phosphorylation → simplest phospholipid

1 glycerol
3 Fatty acids

1 glycerol
3 Fatty acids
1 phosphate group

RNA as a presumed first genetic material

- For the evolution of life, two special situations need to emerge:
  → a self-replication system (nucleic acids)
  → an ability to catalyse chemical change

nucleotides
1 deoxyribose
1 phosphate
1 nitrogenous base

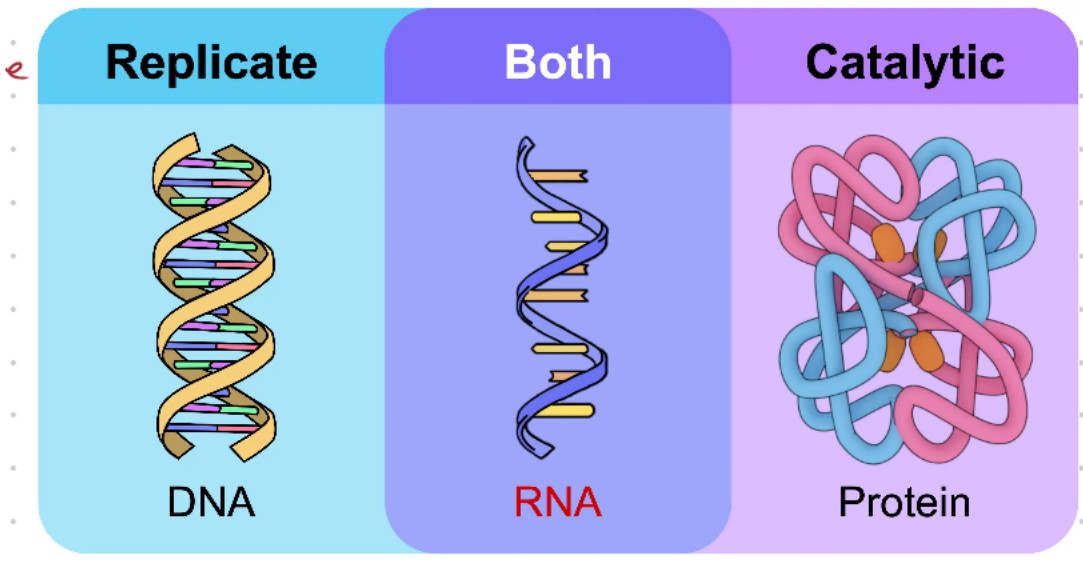
- Today, these situations are achieved by DNA and enzymes.

a.a.
bic aa → amino group
carboxyl group
R group

But neither of them have been used in any experiment that repeats Miller and Ureys. → By-product of a genetic engineering experiment investigating the enzymes needed to join short lengths of RNA.

- RNA can be information molecules and may also function as enzymes.

RNA + catalytic activity = ribozyme
rRNA (ribosomal RNA)



Evidence for a last universal common ancestor:

- Universal genetic code carried by DNA and shared by all cells
- Over 300 genes of DNA common to all cells
- Same building blocks for both DNA and RNA in all cells
- Common molecular processes in all cells (DNA replication and protein production)
- Similar transport mechanisms for cellular materials in and out of cells

Evidance for the last universal common ancestor (LUCA)

Hydrothermal Vents: A theory suggests that the location for the origin of life on Earth is around these vents. Where hot water emanates from beneath the ocean floor.

Evidance for supporting the appearance of the LUCA at hydrothermal vents

- Worlds oldest fossilized traces originated at these vents.
- Commonality of genetic sequences in the organisms near vents.
- The mineral-rich enviroment with acidic and basic fluids.
- The hydrogen and carbondioxide at these locations.



Okyanusun **çok derinlerinde**, deniz tabanında çatlaklar var. Su bu çatlaklardan yerin altına giriyor → magma tarafından **çok ısınıyor** → mineralleri çözüyor → sonra tekrar denize **sıcak, mineral-rich su** olarak çıkıyor.

İşte suyun çıktığı bu baca/çatlak sistemlerine **hydrothermal vents** deniyor.

Senin notundaki:

> **"hot water emanates from beneath the ocean floor"**

= "sıcak su okyanus tabanının altından dışarı çıkar."

Peki LUCA'yla ne alakası var?

Buradaki fikir şu:

Hydrothermal vent → sıcak su + mineraller + H_2 + CO_2 + chemical energy

Bunlar erken yaşamın ihtiyaç duyabileceği **kimyasal reaksiyonların gerçekleşmesi için uygun koşullar** sağlayabilir.

Diversity Of Organisms

Gelişmişlik Sırası:

1- Amoeba
2- Euglena
3- Paramecium
4- Plant
5- Fungi
6- Animal

Diversity Of Organisms

- Organism: an individual plant, animal bacterium.
- No two individuals are identical in all their traits.
- More variantation between two different organisms.

Defining a species

- In the 18th century Carl Linne named living things based on their morphological structures.

Topic	Description
Body structure	Skeletal and muscular structure in animals; root, stem, and leaf shapes in plants.
Organ arrangement	The relative positions of organs.
Symetry	Whether the organism is symetrical.
External appereance	Features like color, shape and size.

Dear Kevin Please Come Over For Gay Sex

Binomial Naming System

- Organisms with shared characteristics are grouped by a series of hierarchical units called Taxa.

- The more similar two organisms are the more taxonomic ranks they will share.

Taxonomy

HIERARCHY OF BIOLOGICAL CLASSIFICATION



SPECIES	(Sapiens)
GENUS	(Homo)
FAMILY	(Hominidae)
ORDER	(Primates)
CLASS	(Mammalia)
PHYLUM	(chordata)
KINGDOM	(Animalia)
DOMAIN	(Eukarya)

Cats Taxonomy

Species - Felis catus

Genus - Felis

Family - Felidae

Order - Carnivora

Class - Mammalia

Phylum - Chordata

Kingdom - Animalia

Domain - Eukaryota

Taxonomy: The binomial system of all living species classified.

The binomial system of nomenclature provides value because:

- It allows identification and comparison.
- It allows all organisms to be named globally.
- It shows how closely related organisms are.
- It makes it easier to collect and sort information.

The binomial system has these features

- The first name is the genus name.
- The genus name is given an upper case first letter.
- The second name is the species name.
- The species name is given a lower case first letter.
- Italics are used when a binomial appears in a printed or typed document.

Examples of binomials:

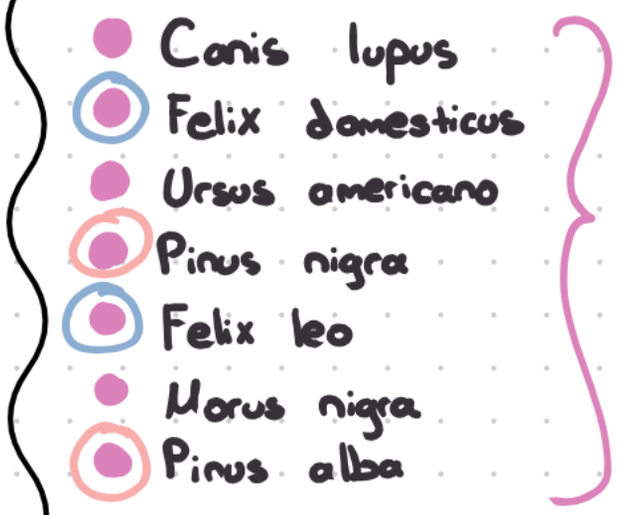
- Animals: Homo sapiens
- Scrophularia landroveri
- Fungi - Candida auris
- Bacteria - Yersinia pestis

Homo sapiens

Defining the biological species concept

- The mostly used definition of species in modern science was developed by Ernst Mayr.
- According to his biological species concept "a species is a group of organisms that can breed and produce fertile offspring."
- Through mating (hybridization members of a species share genes
- Interspecific hybridization is rare and the offspring hybrids are sterile (kısır)

- Which are they more similar?



- Alternative species concept
  Ecological species concepts

- This concept uses ecological factors to define species. Every species has a specific role, "niche" in their environment.

- non-living : abiotic
  living : biotic

- Two species may be living in the same environment, what defines them is what they feed on.

- Today's genetic techniques allows scientists to form evolutionary species concept.

Species concept	Approach and methodology
Morphological species concept	morphological data, emphasizes groups of physical traits
Biological species concept	behavioural information, emphasizes reproductive isolation between groups.
Ecological species concept	how organisms interact with their biotic/abiotic environment.
Evolutionary species concept	genetic data, emphasizes distinct evolutionary links between groups.

Speciation

★ Formation of new species result of individuals from the same ancestor becoming so genetically different that they can not reproduce from each other.
(it takes time ▽°)

★ Example

- **Darwin's finches:** These birds, which live in the galapagos islands, adopted to different conditions resulting with different species.

- **Apple Maggots:** Due to different nutrition feeding these flies become different species between each other.

★ **NOTE:** **Genetic Drift** is the change in allele frequencies within a population due to purely random causes.

- **Natural Selection:** occurs regardless it is advantageous or disadvantegous

- **Allele frequency:** How common an allele is in the gene pool of a population.

Stages of SPECIFICATION

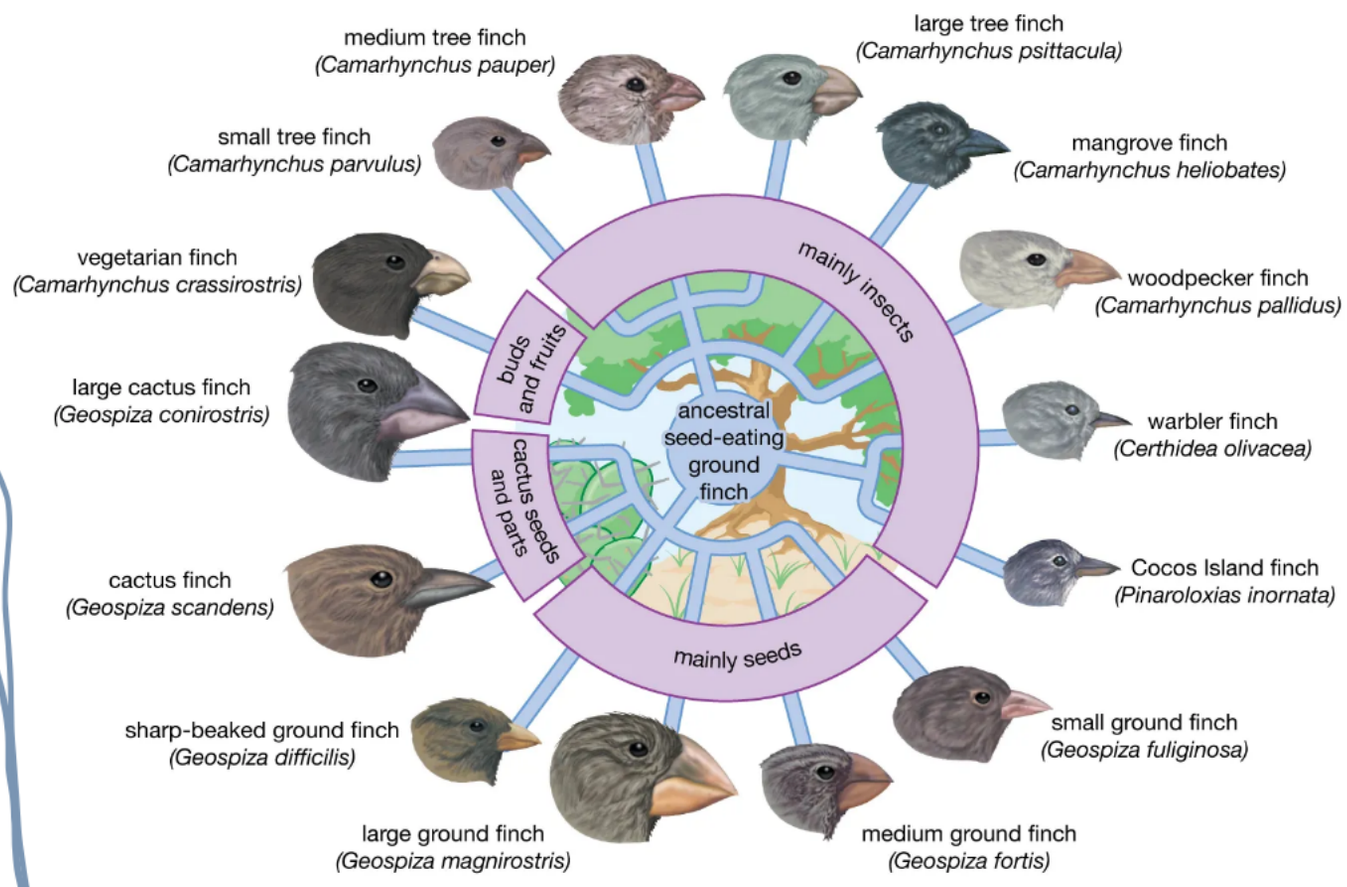
1.) A bird population divided by the formation of a river.

2.) Seperated groups become genetically different due to enviromental conditions.

3.) Reproductive Isolation occurs, different groups cannot mate.

4.) New species forms, these groups are now different species.

Adaptive radiation in Galapagos finches



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Consequences of genetic drift:

- Genetic diversity may decrease.
- Some alleles may lost entirely.
- The direction of population may change.

Examples of genetic drift

1.) Bottleneck Effect: A large portion of a population is lost due to natural disasters. Smal surviving group determines the genetic makeup of later generations.

2.) Founder Effect: A group of individuals seperates from the existing group to form a new population.

*NOTE! "Difference between natural selection and genetic drift

- **Genetic Drift:** Changes in allele frequencies due to random (chance) events.

- **Natural Selection:** The spread of advantageous genes, with individuals better adapted enviromental conditions having an increased chance of survival and reproduction.

★Chromosome number differs among plant and animal species.

- The number of chromosomes is a characteristic feature of members of a species. It varies considerably.

n chromosome
- bacteria
- archebacteria
- amoeba
- euglena

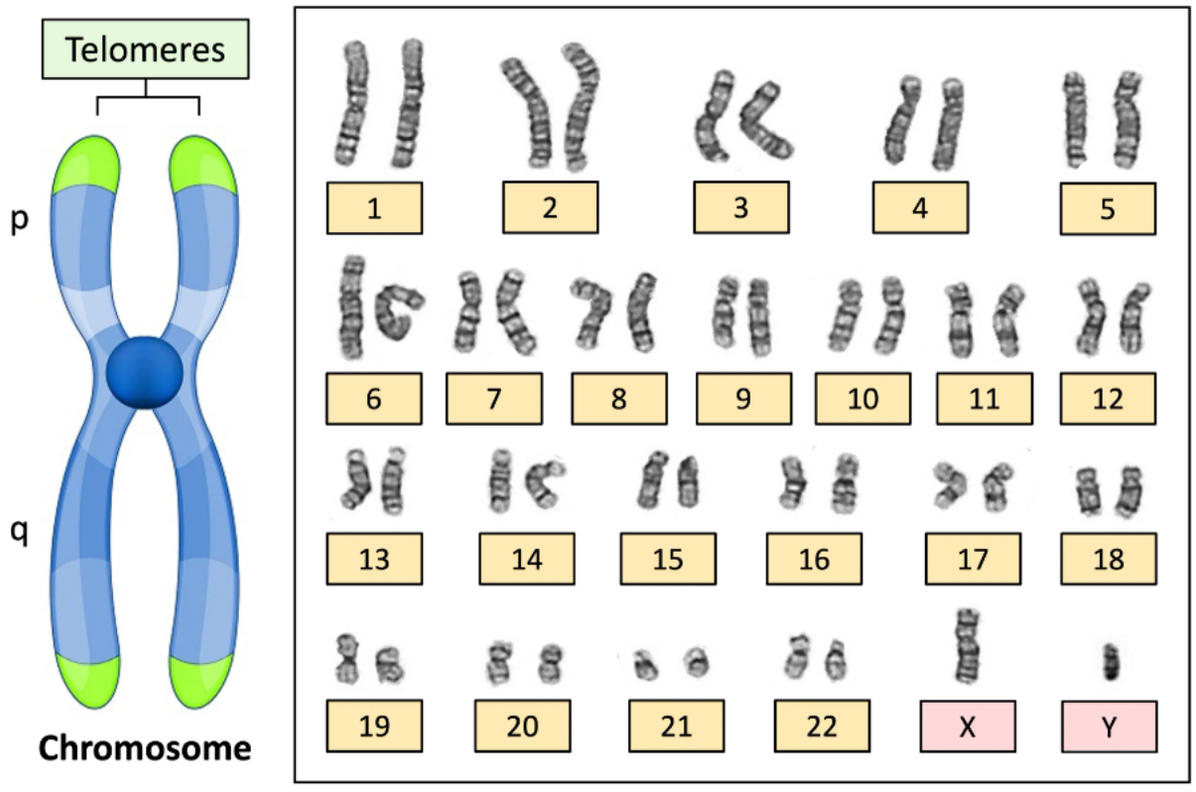
2n chromosomes
- Plant
- Fungi
- Animal

Karyotyping and Karyograms

- **Karyotype:** It describes the number, shape and structure of an organism's entire set of chromosomes.

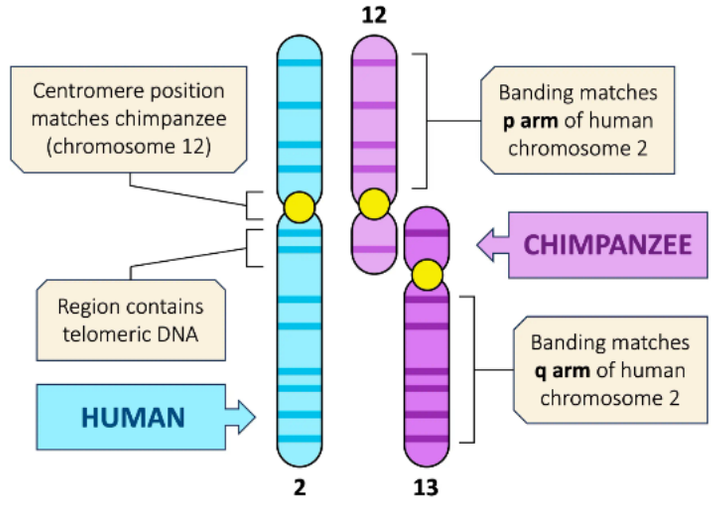
Human karyotype: $2n = 46 \rightarrow 44 + XX$
$44 + XY$
44 → Autosomal, XX / XY → Sex

- **Karyogram:** A visual representation of a karyotype.
- A karyogram is used to identify species, sex and any abnormalities.
- It's kind of a chromosome map/diagram.
- Photographs of the chromosomes are sorted based on their sizes, centromere location and banding pattern (larger to smaller).
- Some stains give chromosomes distinctive banding pattern



Karyogram from a male human

- Humans have 46 chromosomes. Our closest relatives (chimpanzees, gorillas and orangutans) all have 48 chromosomes.
  - Evidence: Comes from chromosome banding patterns.



Genoms in a Species Show unity and diversity

- **Genome**: Whole DNA sequencing or the total DNA amount.
- **Genes**: Small part of DNA which is coding protein for RNA.
- Organisms in the same species will share most of their genome but variations such as Single Nucleotide Polymorphosis (SNP) will give diversity.
- **SNP**: A change in a single nucleotide in DNA. (smallest and most common variation)
- The human genome contains a 4k-5k SNPs. But these SNPs are generally harmless, however some can cause diseases or affect drug response.

Variation in genomes between species

- Genome size diversity
- Base sequence diversity

Using databases to compare genome size

- Genome sizes varies based on organisms complexity.

In Eukaryotes: Genome size is given as nuclear DNA content of a haploid cell such as a gamete.

In prokaryotes: they are given as the DNA concent of a typical cell

- **Uses of whole genome sequencing**: It's identifying all the essential DNA sequences within an organism. Genetic diseases and harmful genes are identified.
- Identifying SNPs in a person's genome is the treatment of health problems.

Asexual reproduction and horizontal gene transfer defy the biological species

- What is the biological Species Concept? (By Ernst Mayr)

- Populations in which individuals of the same species can mate and produce offspring under natural conditions.

1-) Asexual Reproduction: A single individual produces similar individual without sharing genetic material with another individual.

"Why is it anomalous?"

- No mating
- Reproductive isolation is not observed because there's no mating!
- Genetic change is mostly limited.

Example: Bacteria and some protists.

2-) Horizontal Gene transfer: The transfer of genetic material outside the parent-child relationships.

"Why is it anomalous?"

- Genes can cross between different species.

Example: In bacteria genes can cross species through conjugation, transduction and transformation.

★ Conclusion: Asexual reproduction and horizontal gene transfer are not fully compitable with the biological species concept because they violate reproductive isolation criteria.

Importance of chromosome number for producing fertile offspring

- If two organisms with different chromosome numbers mated and produced offspring, the offspring certainly would have problems in carrying out meiosis.

- Some chromosomes would not be homologous to any other chromosome so they wold not be able to pair during metaphase I.

- So offsprings of parents with different chromosome numbers are usually infertile.

~ Using and constructing dichotomous keys ~

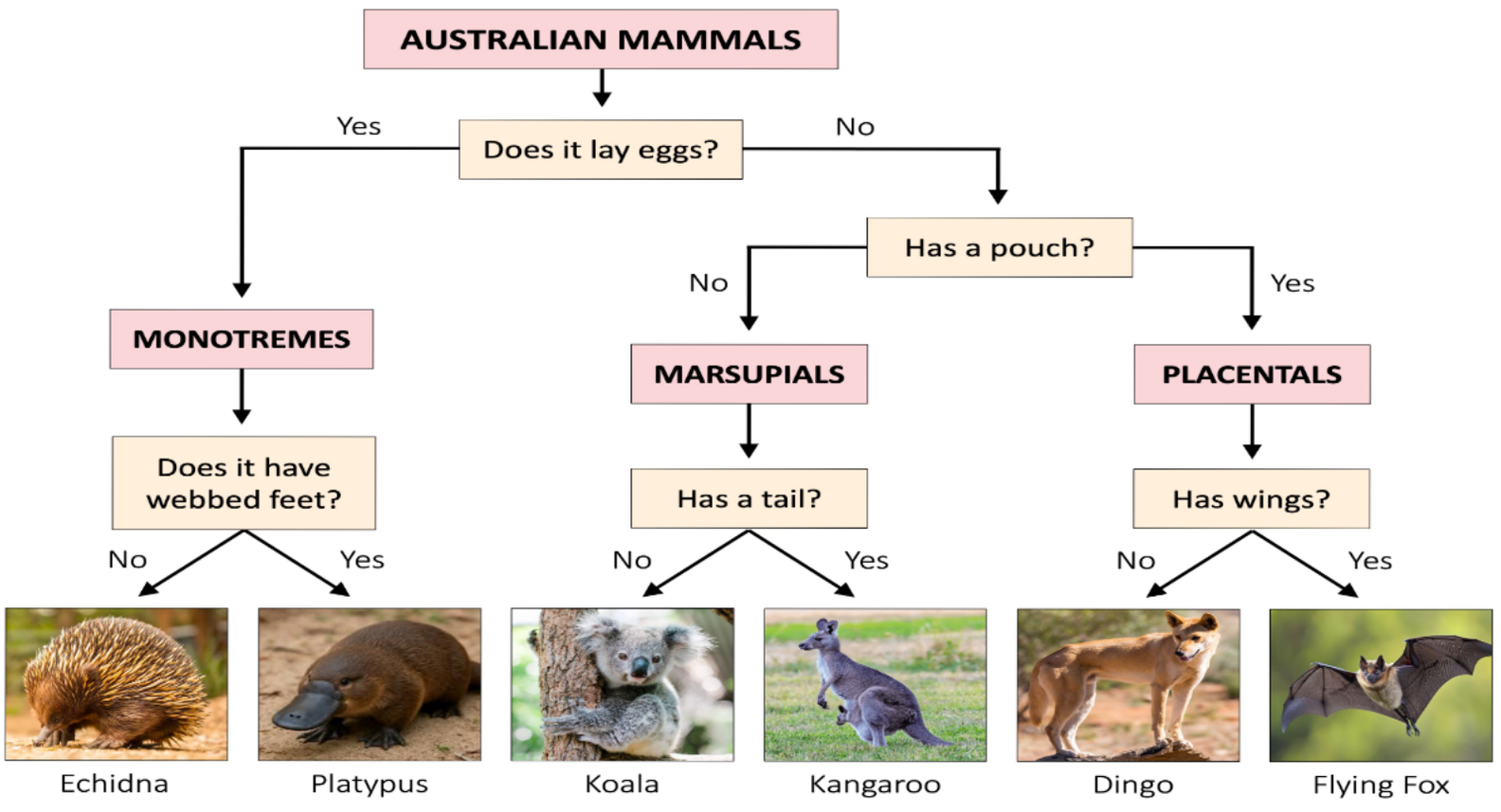
Dichotomous key: Is a tool that can be used to identify organisms or objects in the natural world, such as plants, animals or rocks.

- Provides a stepwise guide toward identifying each entity.

- Dichotomous keys are useful for biological classification as well as identification.

- Features:

- The key consits of a series of numbered stages.
- Each stage consits of a pair of alternative characteristics.
- Some alternatives state which numbered stage of the key to go to next.
- Some alternatives state the name of the species.



Identifying species using barcodes and enviromental DNA

- DNA barcodes are short sections of DNA from one gene, or at most several genes, that are distinctive enough to identify a species.
- Enviromental DNA is obtained from samples of abiotic environments.
- DNA barcoding allows scientists to identify the organisms that are interacted in these environments.

Classification and Cladistics

Need for classification of organisms

- **Classification is needed because:**
- **Information storage:** Millions of species have been named, classification makes it easier to store information.
- **Identification:** This makes it easier to identify specific species.
- **Predictive value:** Species have traits based on their group. The characteristics can be predicted from it's group.
- **Researching evolutionary origins:** Species share traits (therefor groups) if they evolved from a common ancestor.

• Why are living things classified

- It covers millions of living things individually.
- It provides convenient grouping.
- Classifying living things makes it easier to study them.
- It allows for more detailed information about living things.
- It reveals the relationship between living things.
- Belonging to a group allows us to learn about other living things within that group.
- Systematic nomenclature (Latin names) used to classify living things is used worldwide. They share this data with each other.

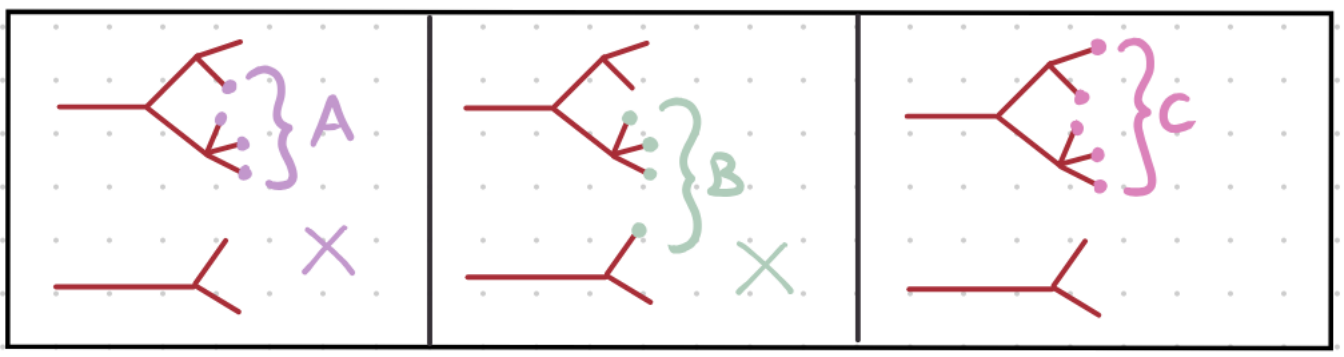
Difficulaties classifying organisms into the Traditional hierarchy of taxa

- Taxa (Tekil ismi) are groups used to classify organisms. Taxonomic group is taxon. (çoğul taxas isimleri)
- Taxonomy: assigning organisms to taxonomic groups.

★ It's difficult to use traditional hierarcy of taxa because it can be unclear how populitions should be grouped.

Advantages of classification corresponding to evolutionary relationships

- Two criteria can be used to judge whether a classification achieve this:



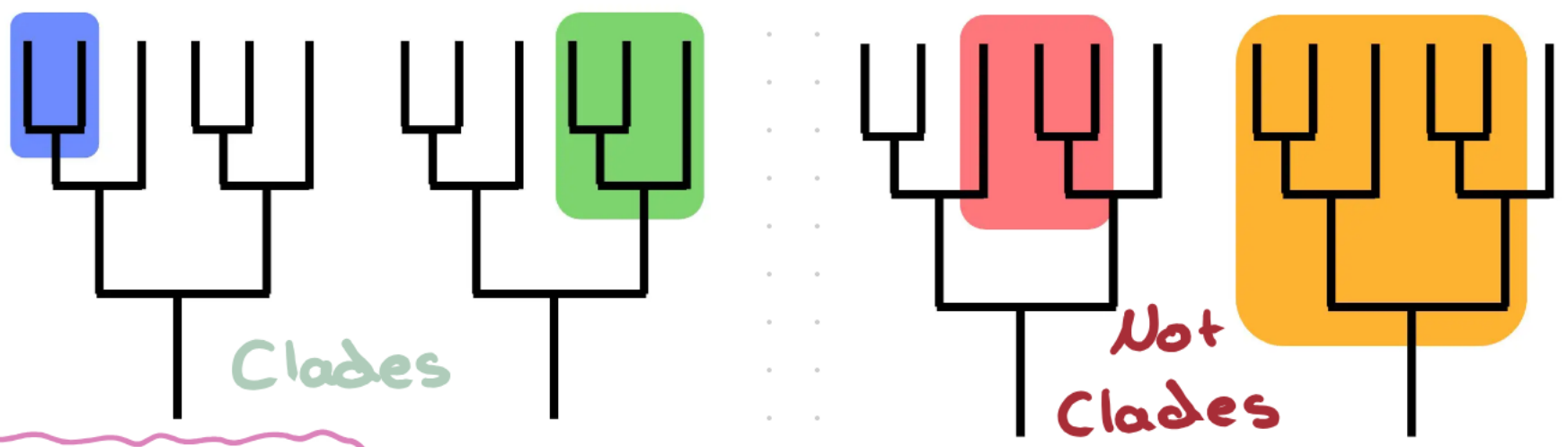
→ Every organism that has evolved from a common ancestor is included in the same taxonomic group. A fails

→ In each taxonomic group, all the species are evolved from the same ancestor. B fails.

- If these criteria are satisfied (c) all members of a taxonomic group will share traits.

(genel isim)

- Cladistics: A method of classifying organisms into groups of species called clades (grupların)
- Members of a clade will have common characteristics.
- Cladogram: A diagram that shows relationships between species.

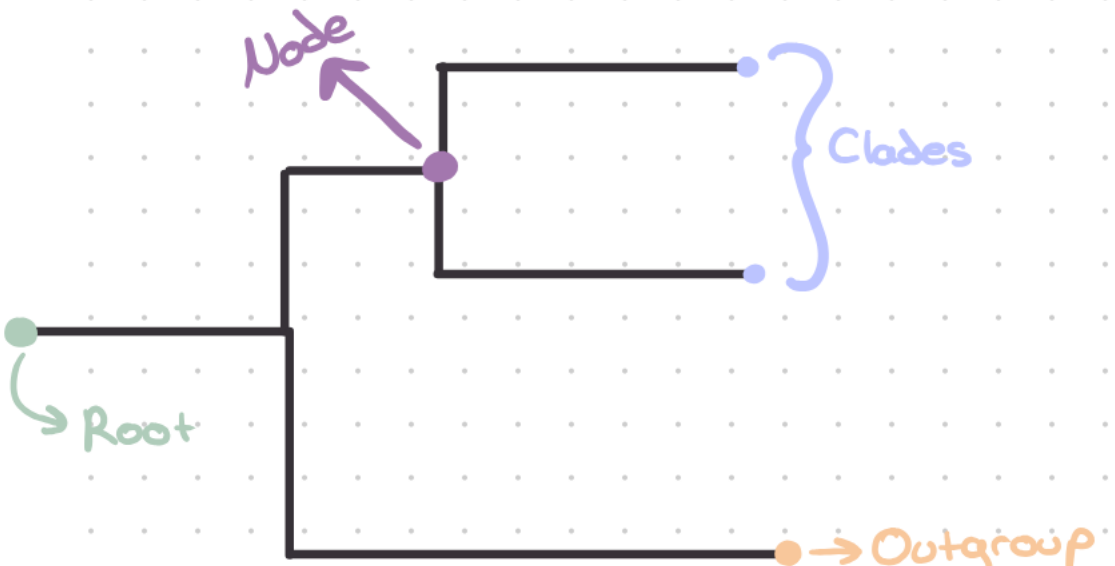


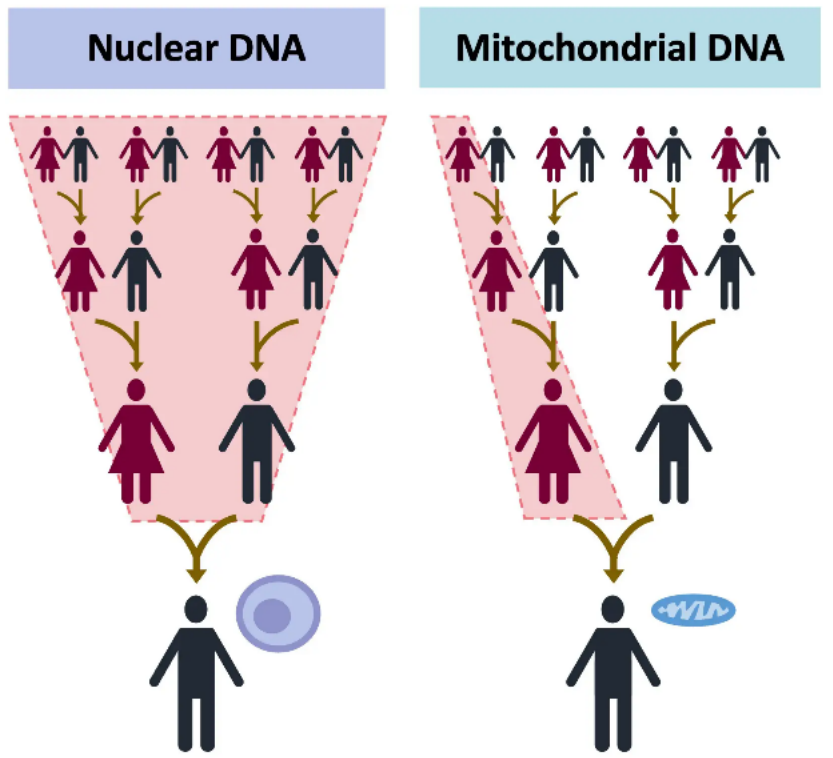
🔍 **Temel farklar (tabloyla)**

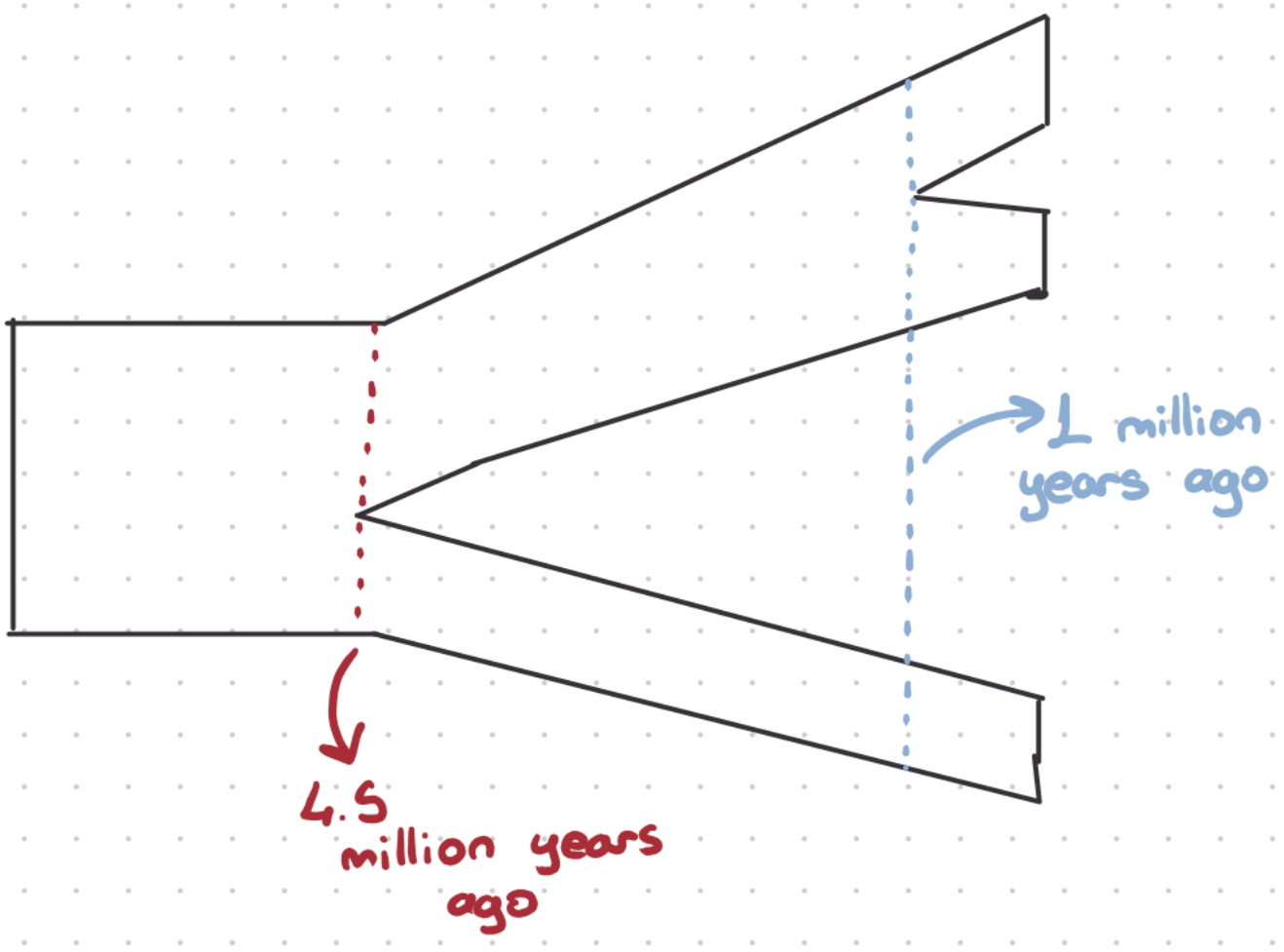
Özellik	Cladistics	Taxon
Ne tür bir kavram?	Yöntem / yaklaşım	Sınıflandırma birimi
Ne yapar?	Canlıları sınıflandırma **şeklini** belirler	Sınıflandırılan **grubun kendisi**
Evrimle ilişkisi	Doğrudan evrimsel akrabalık	Evrimsel olabilir veya olmayabilir
Örnek	"Kladlara ayırma"	Tür, cins, aile vb.

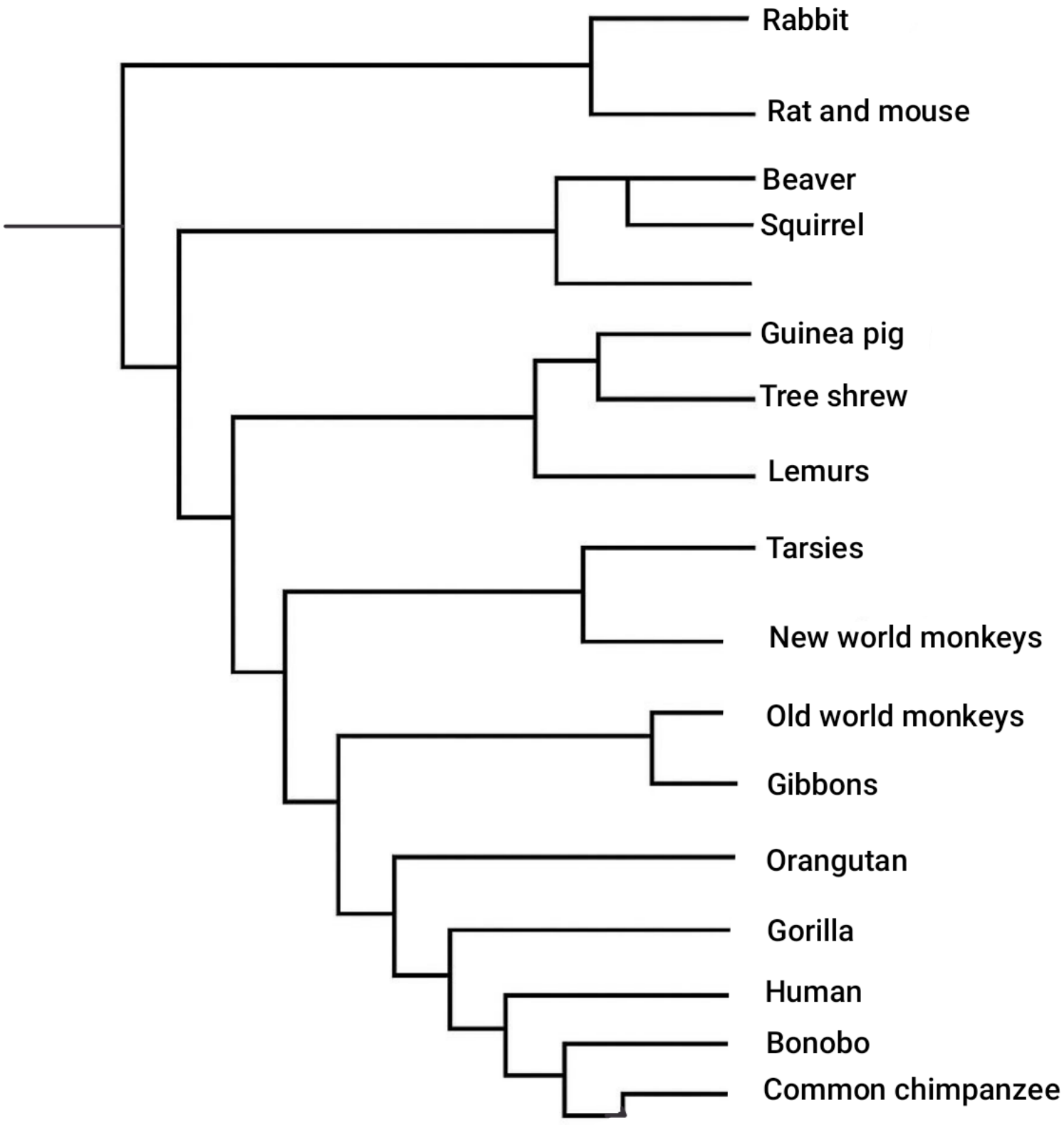
In a Cladogram:

- **Root**: The initial ancestor common to all organisms.
- **Nodes**: Each node shows a hypothetical common ancestor that gives rise to two daughter taxa.
- **Outgroup**: The most distantly related.
- **Clades**: A common ancestor and all of it's grandchilds.

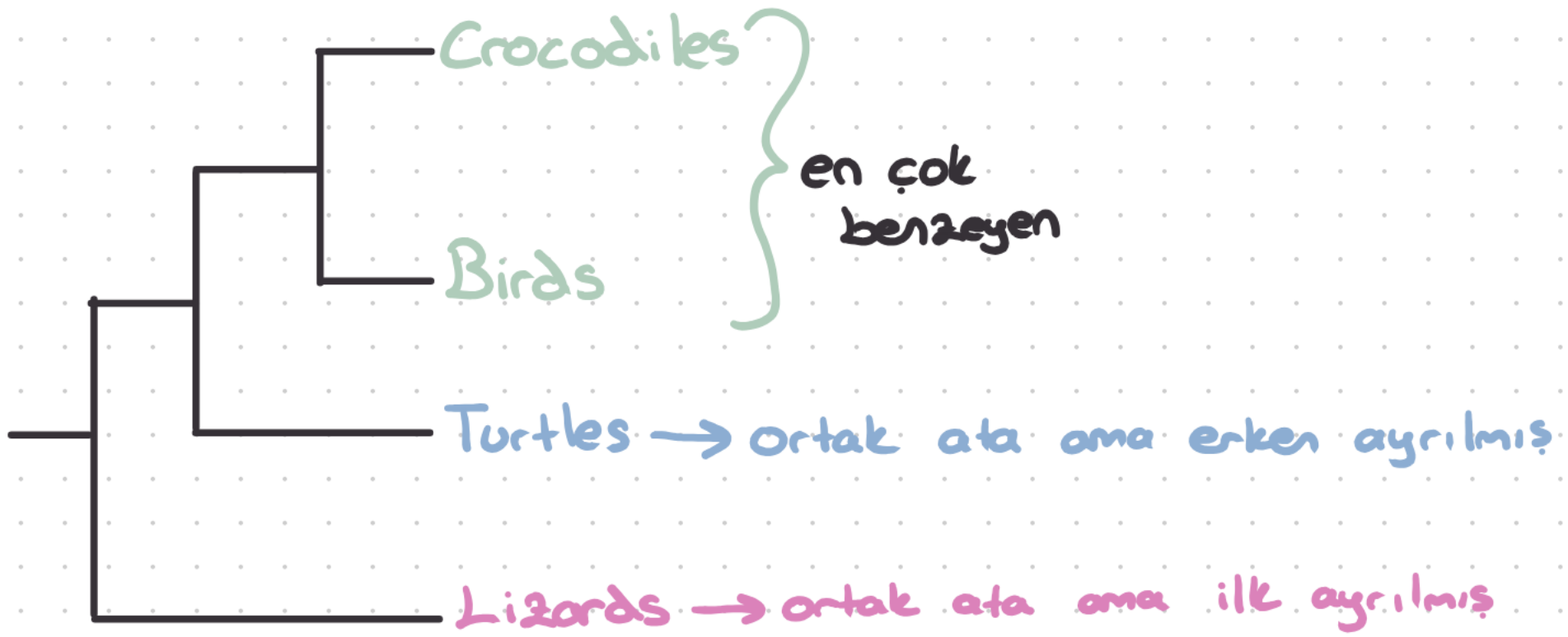








- What animal is most closely related to a squirrel? → Beaver
- What animals are more closely related to humans than old monkeys?
  ↳ bonobo, common chimpanzee
- Tarsiers share a common ancestor with which animal? → Every animal under tarsiers
- Elephants shrews, elephants, manatee and dugon all share a common ancestor. Which animal diverged first?
  → Elephant shrew



To conclude:

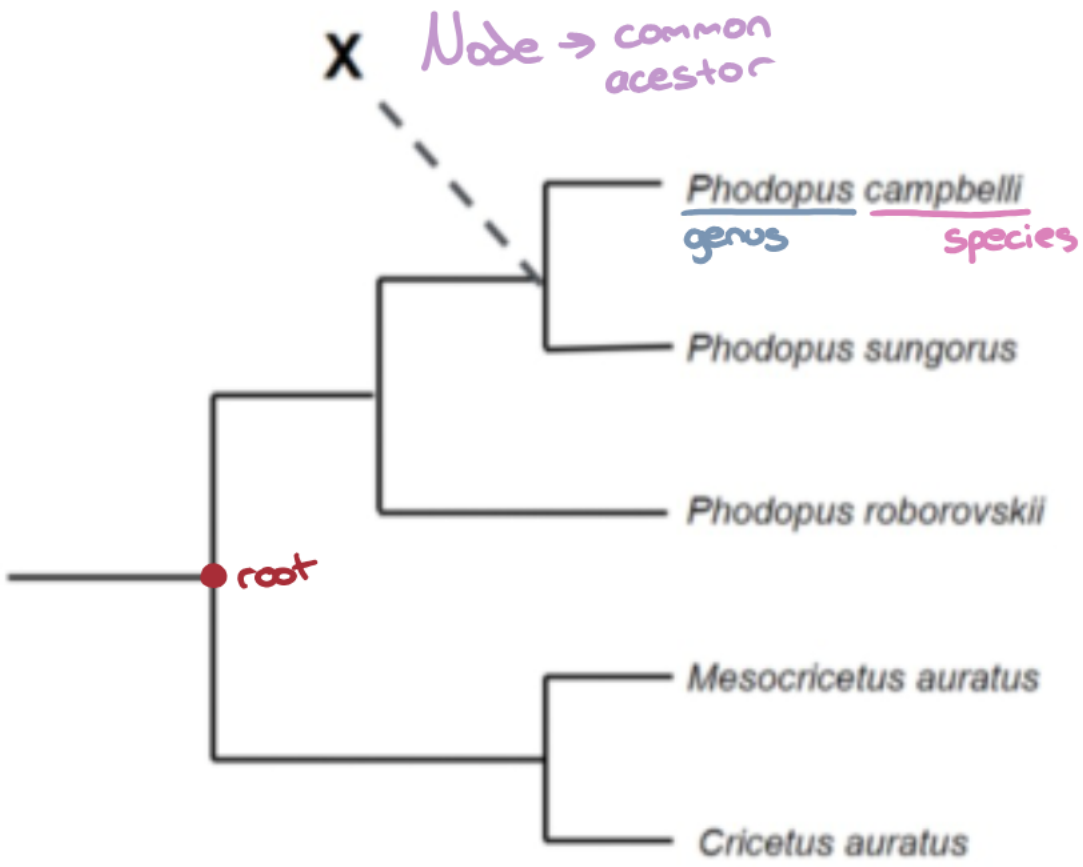
- The cladogram is used when comparing classifications because it visualizes evolutionary relationships with objective data, allows us to test different classification methods, and provides more scientifically accurate results using DNA, RNA, protein sequences or morphological features.

- Cladogram: answers the questions "Who is more closly related to whom?" "From which common ancestor did they descend?" It shows evolutionary relationships.

- Classification: answers the question "Which species belongs the which group?" Morphological, physiological and genetic similaritys also taken into account.

1)

The image shows a cladogram for several species of hamster.



1. State what is represented by the letter **X**

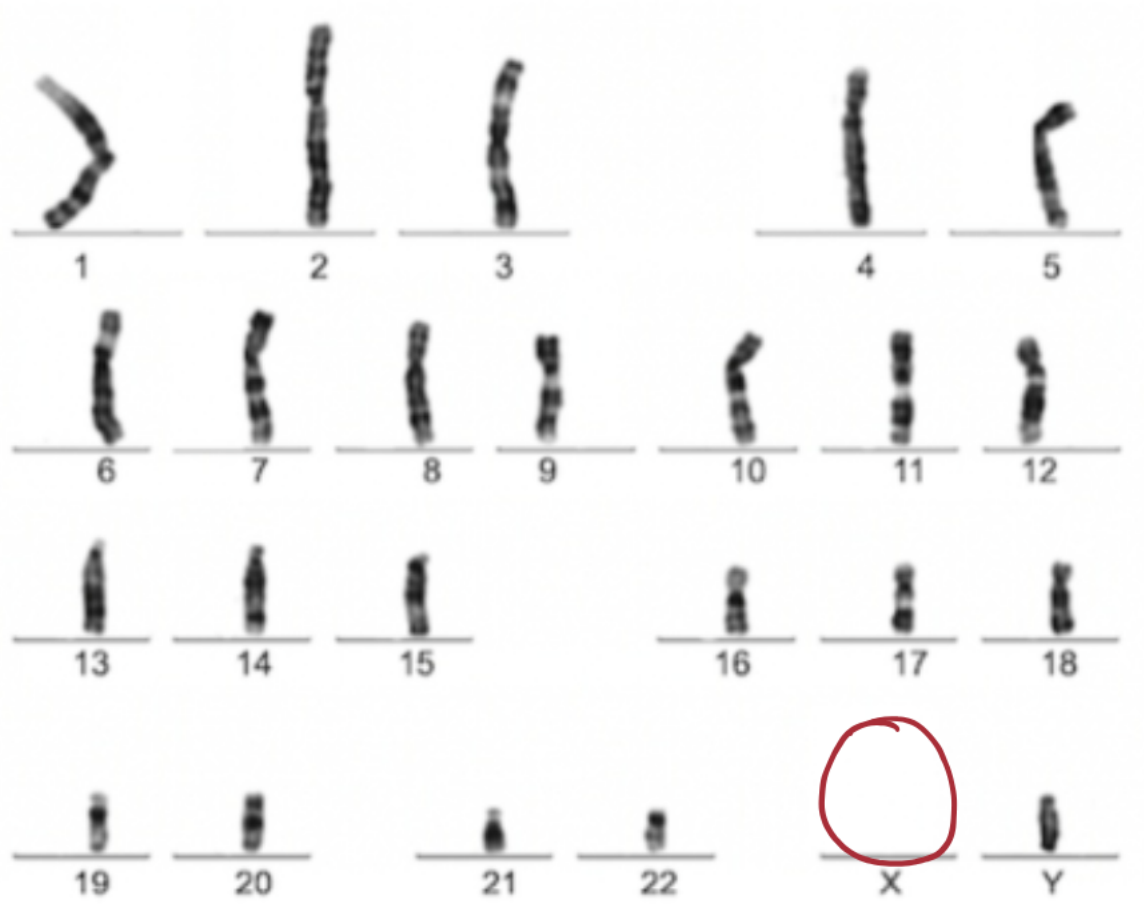
Node

2. Other than their positions on the cladogram, explain what information indicates that *Phodopus campbelli* and *Phodopus sungorus* are closely related.

Genus names are same

What type of human cell does the following karyogram represent?

X yok → male sex cell



3) Why does chromosome number affect hybrid fertility?

trisomy down syndrome

- A. Species with different chromosome numbers can always produce fertile offspring because meiosis is not affected by chromosome pairing.
- B. Hybrids with mismatched chromosome numbers have increased genetic diversity, making them more fertile.
- C. Chromosome number only affects physical traits, not reproductive ability.
- D. Hybrids with different chromosome numbers cannot produce functional gametes because homologous chromosomes fail to pair during meiosis.

according to anaphase

4) Which of the following could be used to identify different species?

I. Dichotomous key
II. Karyograms
III. Binomial naming system ✗ → identify in science

- A. III only
- B. I and II only
- C. I and III only
- D. I, II and III

5) Environmental DNA can be used to form which of the following?

↳ Su, toprakton örnek almak (skin cell, sperm cell)

↳ PCR'da çoğaltım

- A. Barcodes
- B. Karyotypes
- C. Dichotomous keys
- D. Binomial naming system

6) Which row in the table is correct for either the biological or morphological species concept?

	Concept	Species Definition	Proposed by…
A.	Biological	A group of organisms that can interbreed to produce fertile offspring	Linnaeus
B.	Biological	A group of organisms with shared traits	Mayr
C.	Morphological	A group of organisms that can interbreed to produce fertile offspring	Mayr
D.	Morphological	A group of organisms with shared traits	Linnaeus

7) This table shows the estimated number of genes in *E. coli* bacteria, fruit flies, mice, humans, and rice.

★ Kromozom sayısı gen sayısı ile ilgili değildir.

★ Her türün gen sayısı kendine özgüdür.

Species	Estimated number of genes
E.coli (bacteria species)	4,000
Drosophila melanogaster (fruit fly)	13,000
Canis lupis familiaris (dog)	20,000
Homo sapiens (humans)	30,000
Oryza sativa (rice)	40,000

What can you conclude from the above information?

- A. Species in the same kingdom of life have a similar number of genes
- B. Different species have different numbers of genes
- C. More complex species have more genes
- D. The number of genes is not a characteristic of a species

8) Which of the following is the correct format for species names according to the binomial naming system?

- A. Genus + Species
- B. Genus + species
- C. *Genus* + *species*
- D. *Genus* + *Species*

9) What is the best definition for a species?

- A. A group of individuals living in a defined area.
- B. A group of individuals of the same species living and interacting with one another in a given area.
- C. A group of individuals living in a given area and interacting within the environment.
- D. A group of individuals that can interbreed and produce fertile offspring.

10) What determines the overall size of a eukaryotic genome?

- A. The number of genes
- B. The number of chromosomes
- C. The amount of protein
- D. The total amount of DNA

Genome Size

Conservation of Biodiversity

Biodiversity as the variety of life and all its forms, levels and combinations

- **Biodiversity:** Variety of life

→ Ecosystem d. : The number of different ecosystems.
→ Species d. : Abundance of species.
→ Genetic d : Variety of gene pool in each species.

Comparisons between current number of species on Earth and past levels of biodiversity

- Currently species inhabiting the Earth are between 2-10 million.
- Levels of past diversity can be estimated by fossil evidences.
- There are 5 big extinctions in history with the most recent one being 66 million years ago.
- The other extinctions were due to volcanic activity and major climate changes.
- The extinction of some masses can lead to other new forms of life.
- Due to last extinction being 66 million years ago, the biodiversity probably is higher than ever.

Causes of anthropogenic species extinction

- Caribbean Monk Seal - (Marine Mammal)
→ hunted for it's oil (70 years ago.)

- Giant Moa - (A bird who cannot fly)
→ hunted for it's meat.

- Silphium - (Plant)
→ harvested for birth control.

} Over-harvesting

~Common causes of extinction other than over-harvesting~

- **Habitat Destruction**: Natural habitat being destroyed by agricultural reasons.

- **Invasive Species**: When alien species are introduced, native species can be in danger due to predation and illnesses. They can extinct if native species hybridize with alien species.

- **Pollution**: Chemical industries release chemical substances to the nature. Burning fossil fuels, mining etc. (agricultural)

- **Global Climate Change**: Human activities are currently causing very rapid changes in temperature, rainfalls and other climatic variables.

~Causes of Ecosystem loss~

- If enviromental conditions change, the replacement of one ecosystem is natural.
- This happens between glacial (warmer) and interglacial (colder) periods.

Mixed Dipterocarb forest of Southeast Asia

- **Dipterocarb**: Family of about 700 species of tropical hardwood tree.

- Mixed dipterocarb forests have an extremely high diversity of dipterocarb and other species.

- The highest diversity of tree species tends to occur on nutrent-poor sandy soils.

- Stressful environments reduces dominance



Loss of the Aral Sea - Ecological Disaster

- The Aral Sea: Was the 4. largest in the world. (Kazakhstan - Uzbekistan)
- It had higher salinity levels
- After 1960s due to a failed water management, it is now a desert.
- 24 species extinct because of this.

Direct or Undirect Causes of Ecosystem Loss

- Agriculture: Clearing forests and grasslands as humans.
- Urbanization: Buildings, factories, groundworks (roads etc.)
- Mining and smelting: Mines and their disposal waste damage nature.
- Water Management: Reservoirs created by building dams can flood natural ecosystems. Extraction of water for industrial use can reduce rivers.
- Overexploitation of natural resources: Gathering wood hunting animals and fishing.
- Drying of wetlands: Wetlands are drained for conversion to agriculture.
- Leaching: Anthropogenic climate change (most common)

Evidence for a Biodiversity Crisis

- **Biodiversity crisis:** The unprecedented losses of ecosystems and species.
  ↳ daha önce görülmemiş

- Evidence → IPBES
- Evidence for change in species:
  - Numbers in populations of the species
  - Genetic Diversity
  - Range of the species
- Evidence for change in ecosystems:
  - Species diversity
  - Richness and evenness of biodiversity
  - Area occupied
  - Extent of ecosystems degradation.
- For taxonomic group:
  - Number of threatened species within the group.

- **Citizen Science:** Opportunities for all citizens to contribute.

Causes of the current biodiversity crisis

- Over-hunting
- Urbanization
- Agriculture
- Pollution
- Alien Invasive species.

Need for several approaches to conservation of biodiversity

- Human Efforts to improve, managing natural areas:

→ National Parks
→ Rewilding
→ Nature reserves
→ Reclamation (ekolojik restorasyon)

- Human Efforts to improve, managing species outside their habitat

- Seed Banks (her seyi matuedersek burda depo var)
- Breeding programs
- Botanical gardens
- Animal tissue banks

Selection of evolutionarily distinct in EDGE existing programme

- EDGE uses two criteria to identify species that are most needing a conservation.

- Evolutionarily Distinct
- Globally endangered

Organic Compounds

Organic Compounds

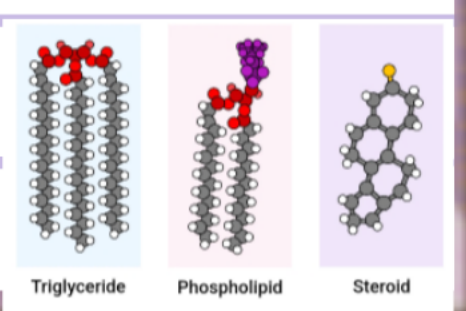
Life is basen on these (carbon) compounds

Carbohydrate	Lipid	Protein	Nucleic Acid
C, O, H	C, O, H	C, O, H, N	C, O, H, P
(4) (2) (1)	(4) (2) (1)	(4) (2) (1) (3)	(4) (2) (1)



Covalent is the strongest bond

Category	Subcategory	Example molecules
Carbohydrates	Monosaccharides	Glucose, galactose, fructose, ribose
•	Disaccharides	Maltose, Lactose, Sucrose
•	Polysaccharides	Starch, glycogen, cellulose, chitin
Proteins	•	Enzymes, antibodies, peptide hormones
Lipids	Triglycerides	Fats stored in adipose cells
•	Phospholipids	Lipids forming a bilayer in cell membranes
•	Steroids	Some hormones
Nucleic Acids	Nucleotides	DNA, RNA, ATP

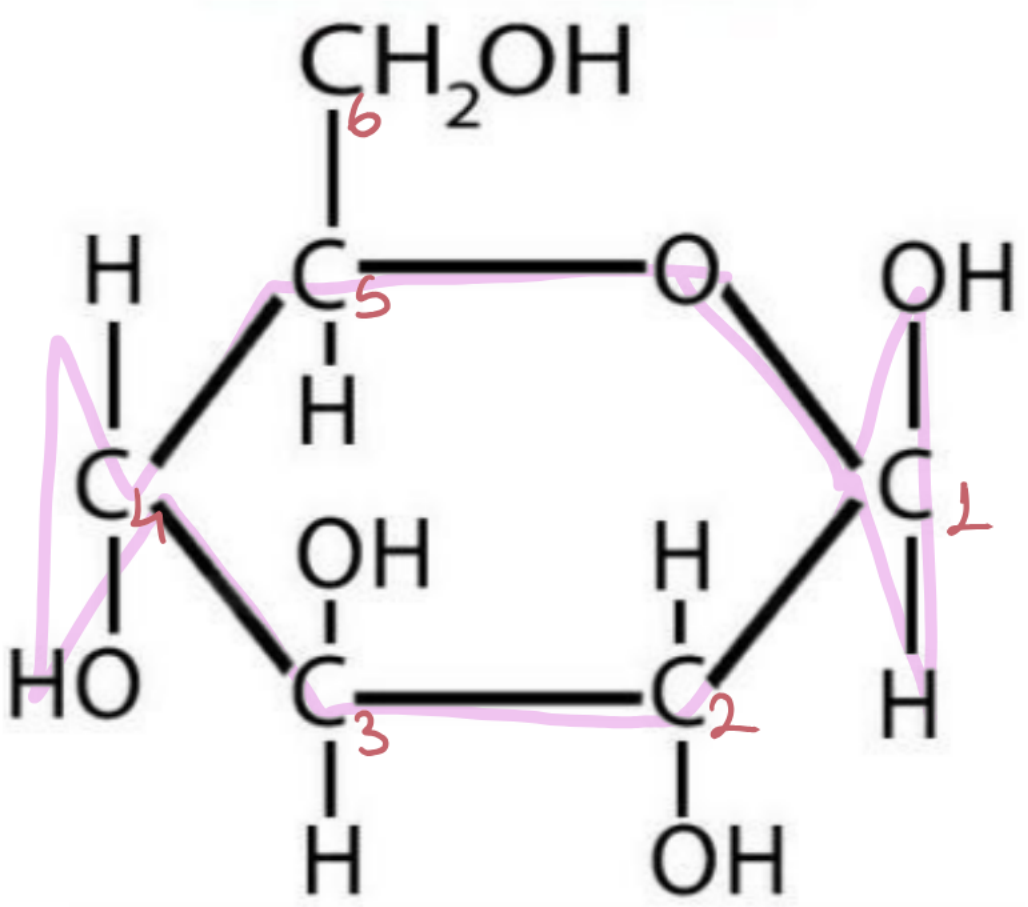


Monosaccharide + Monosaccharide $\underset{\text{hydrolysis}}{\overset{\text{condensation}}{\rightleftharpoons}}$ disaccharide + H_2OH

glucose + glucose → Maltose + H_2OH

galactose + glucose → lactose + H_2OH

fructose + glucose → Sucrose + H_2OH



Hexose

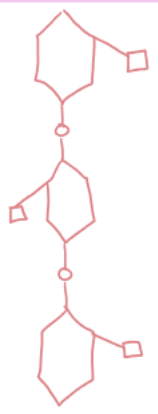
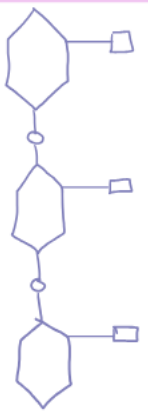
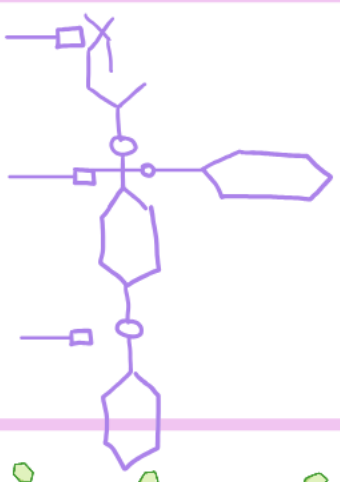
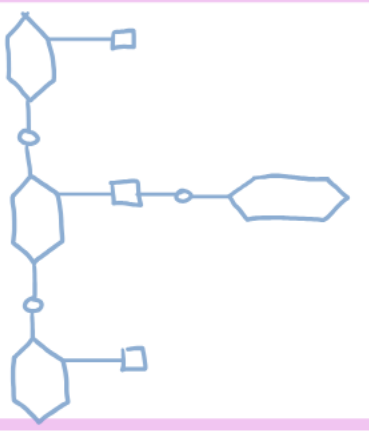
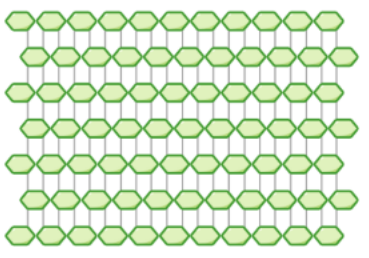
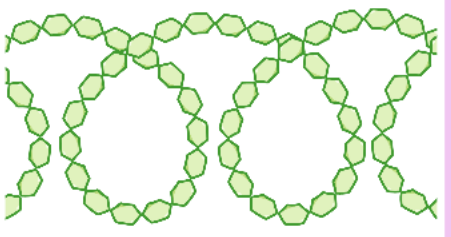
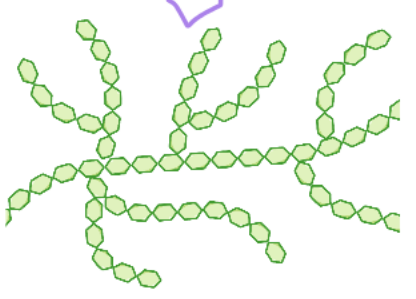
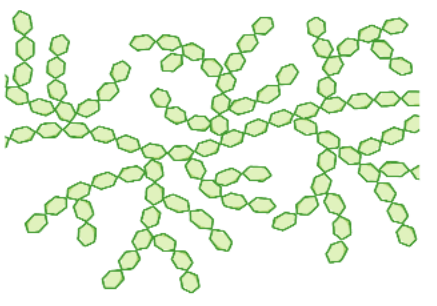
6 Carbon (sugar)

Looks like a candy

~Structure of glucose~

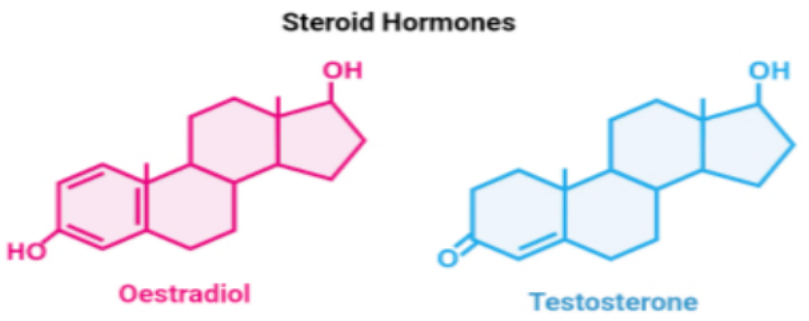
	Carbohydrates	Animal	Plants
Monosaccharide	glucose galactose fructose	glucose carried in blood, used for transporting energy.	fructose is used to make fruit sweet-tasting.
Disaccharide	maltose lactose sucrose	lactose is milk sugar, it provides babies energy.	sucrose transfers energy to cells through the plant.
Polysaccharide	glycogen starch cellulose	glycogen is used as a short-term energy.	cellulose is used for making fibres.

Polysaccharides of glucose

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-6	1-6
Branches	No	No	Yes (per 20 subunits)	Yes (per 10 subunits)
Diagram				
Shape	 CELLULOSE	 AMYLOSE	 AMYLOPECTIN	 GLYCOGEN

★ Ability of non-polar steroids to pass through the phospholipid bilayer.

- Steroids are mostly hydrophobic. This allows them to pass through phospholipid bilayers and enter or leave cells.



Carbohydrate (glycogen)	SODAS	Lipid (Triglyceride)
Short-term energy	Storage	Long-term energy
More effected on osmotic pressure	Osmality	Less effected on osmotic pressure
ready to digest, used for aerobic-anerobic respiration	Digestion	Less easy to digest, used for aerobic respiration
Stores half as much ATP	ATP	Stores twice as much ATP
Water soluble easy to transport	Solubility	Not water soluble difficult to transport

★ Role of glycoproteins in cell-cell recognition

Carbon Components	Type of conjugated molecule	
Lipid + Protein	Lipoprotein	Linked by glycosidic bonds
Carbohydrate + Lipid	Glycolipid	
Carbohydrate + Protein	Glycoprotein	

★ Glycoproteins and ABO blood types

A and B are antigens they trigger the immune system

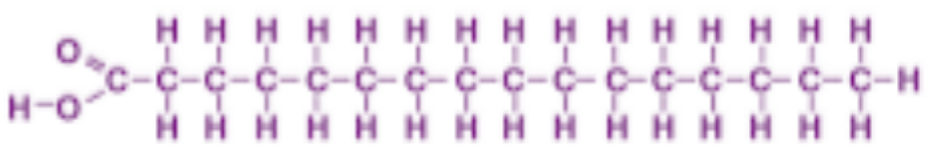
Blood Type	Glycoprotein found on red blood cell	Can receive	Can give
A	A	A - O	A - AB
B	B	B - O	B - AB
AB	A - B	AB, A, B, O	AB
O	Neither A - B	O	AB, A, B, O

$$\text{Glycerol} + 3\,\text{fatty acid} \underset{\text{hydrolysis}}{\overset{\text{condensation}}{\rightleftharpoons}} \text{Lipid} + 3H_2OH$$

Types of fatty acids

- **Saturated Fatty Acids (Butter)**

No double bond between carbon atoms.

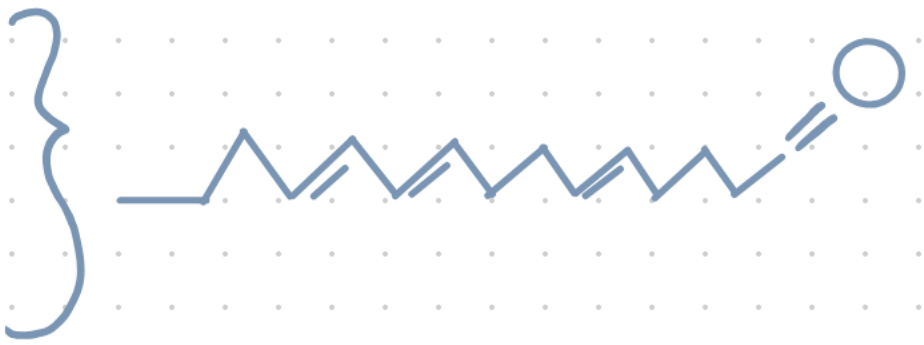




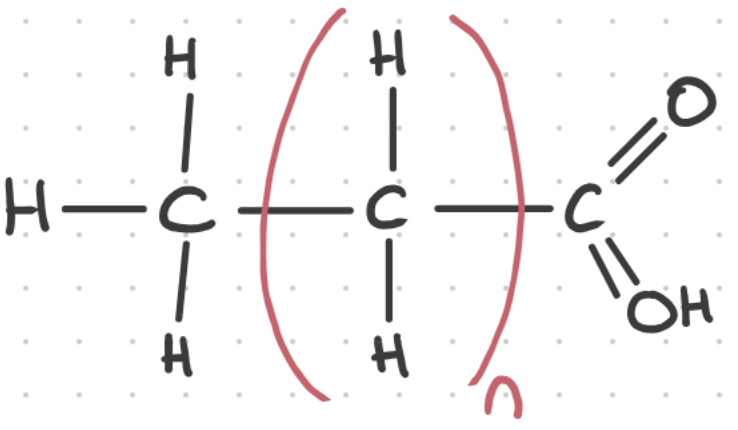
- **Unsaturated fatty acids (olive oil, avocados, almonds)**

Has double bond between carbon atoms.



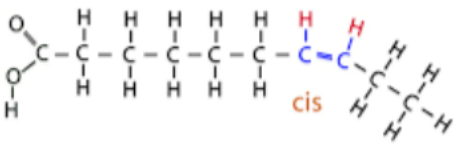
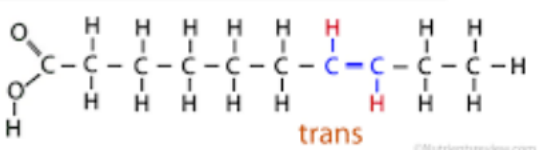


	Fats	Oils
Sources	◦ Animals (endotherms)	◦ Plants
Fatty Acids	◦ Saturated	◦ Unsaturated (*cis*)
Shape	◦ Straight chains	◦ Kinked chains
State	◦ Solid at room temperature	◦ Liquid at room temperature
Melting point	◦ Comparatively high	◦ Comparatively low



Structure of a fatty acid

Cis and Trans Isomers of Unsaturated Fatty Acids

Feature	Cis-Isomer	Trans-Isomer
Hydrogen atom position	H atoms on the **same side** of the double bond	H atoms on **opposite sides** of the double bond
Molecular shape	Double bond **causes a bend**	Double bond **does not cause a bend**
Physical state	Usually **liquid** at room temperature	Usually **solid** at room temperature
Occurrence	Found **commonly in nature** (e.g., nuts, fish, corn)	Found in **processed food**
Health effects	Considered **healthy**	Considered **unhealthy**
Structure example		

Degree of Saturation

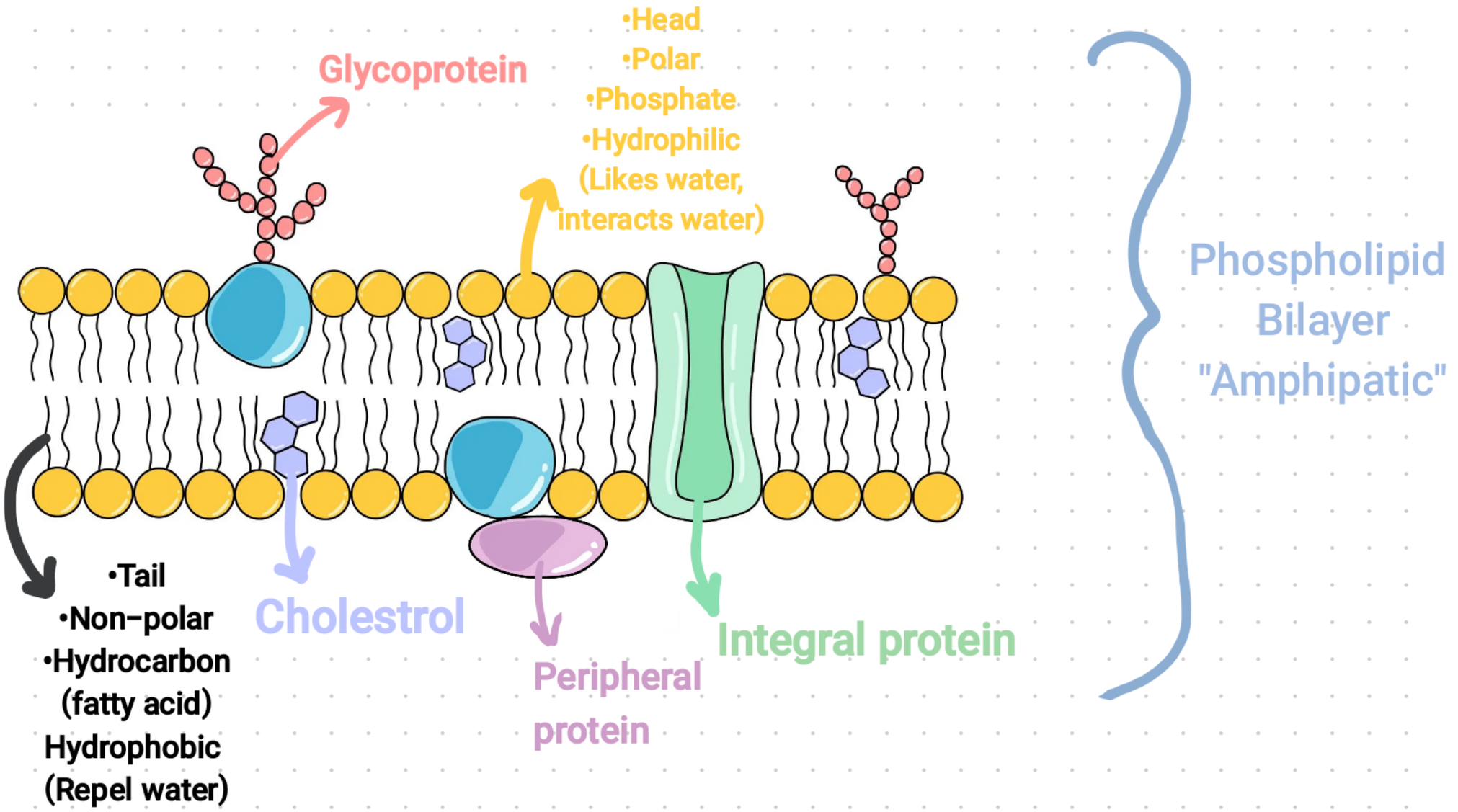
- **No double bonds** → **Saturated** fatty acid
- **1 double bond** → **Monounsaturated** fatty acid
- **2 or more double bonds** → **Polyunsaturated** fatty acid

Membrane and Membrane Transport

Membranes and Membrane Transport

- **Lipid Bilayers**: Membranes are an essential component of cells.

- **Fluid-Mosaic Model of Plasma Membrane**: A model by S.J. Singer and G. Nicolson in 1972 to describe the structural feature of biological membranes.



What's the function of Plasma Membrane?

- To control the entry and exit of substances.

- Large molecules and hydrophilic particles → low permeability due to hydrocarbon chains.

- Low membrane permeability makes it possible to maintain differences across a membrane.

- The plasma membrane holds useful substances inside the cell and prevents harmful substances from entering.

Plasma Membrane is Selectively Semi-Permeable

Examples of Low-Permeability:

- Large proteins: starch, glycogen, cellulose
- Polar: glucose, amino acids
- Ions: chloride, sodium, potassium, phosphate

Function of Membrane Protein

⭐ Hormone Binding Site:
Outside of the membrane — allows one specific hormone to bind.

⭐ Enzyme Action:
Enzyme located in the membrane (whether the active site is in or out on the surface), catalyzes reactions inside or outside the cell.

⭐ Electron Carrier:
In membranes, electrons pass through a chain so that electrons can move from one carrier to another.

⭐ Channel for Passive Transport:
Molecules pass through the center of the protein.
Each channel allows one specific molecule to pass.

⭐ Pumps for Active Transport:
Pumps release energy and use it to move a specific molecule.

⭐ Cell-to-Cell Communication:
Contains and attaches carbohydrate molecules. Provides identification.

⭐ Cell Adhesion:
When proteins hook together in various ways to provide permanent adhesion.

Passive Transport:

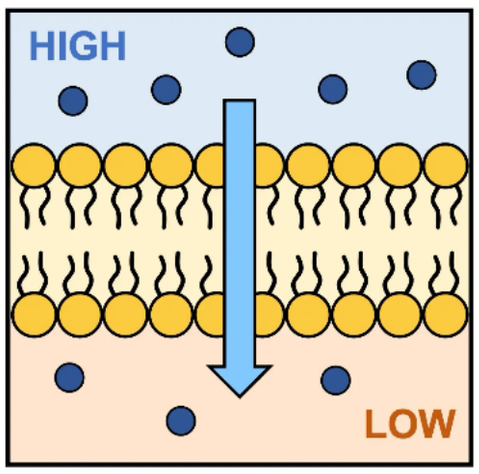
•Do not require energy

•To the high concentration --> low concentration

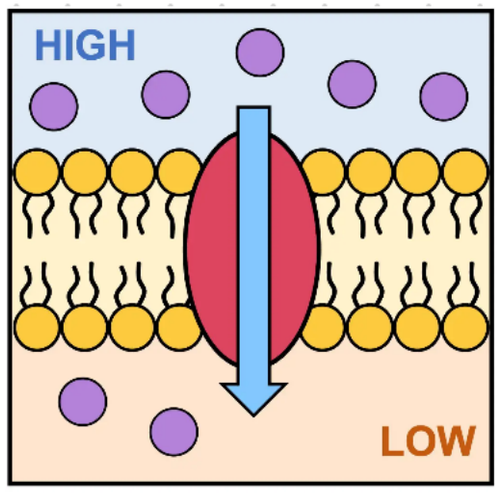
- There are 3 types of passive transport

•Simple Diffusion:

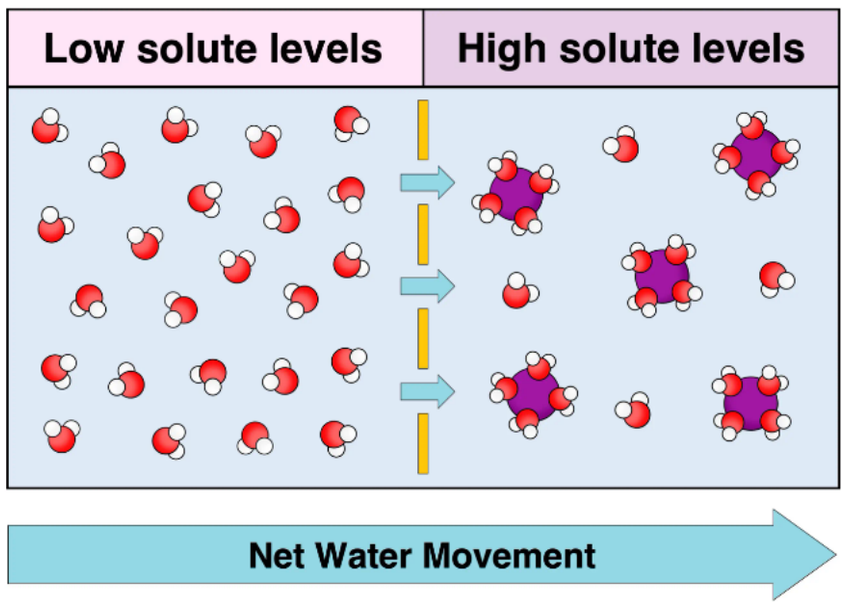
- Direct movement between the head and the tail
- Gas and oil soluble (non-polar)
- Passive çünkü natural consequence of particle movements.
- Hydrophilic ve large molecules cannot pass



- Faciliated Diffusion
- Use channel protein
- (Larger molecules) Monomers and ions can pass
- Uses channel proteins (Cells can select entering particles by controlling the type of the protein)



- Osmosis
- Uses aquaporin
- Water can pass (polar can pass)
- lower concentration --> higher concentration
- Hypotonic: The solution is a lower solute concentration then the cell. (bursting)
- Hypertonic: Higher solute concentration then the cell (shrink)



Integral and Peripheral Proteins in Membranes

1- Integral Protein: Transporting occur passive and active

2- Peripheral Protein: Protein do not extend (Hormone binding site, enzyme)

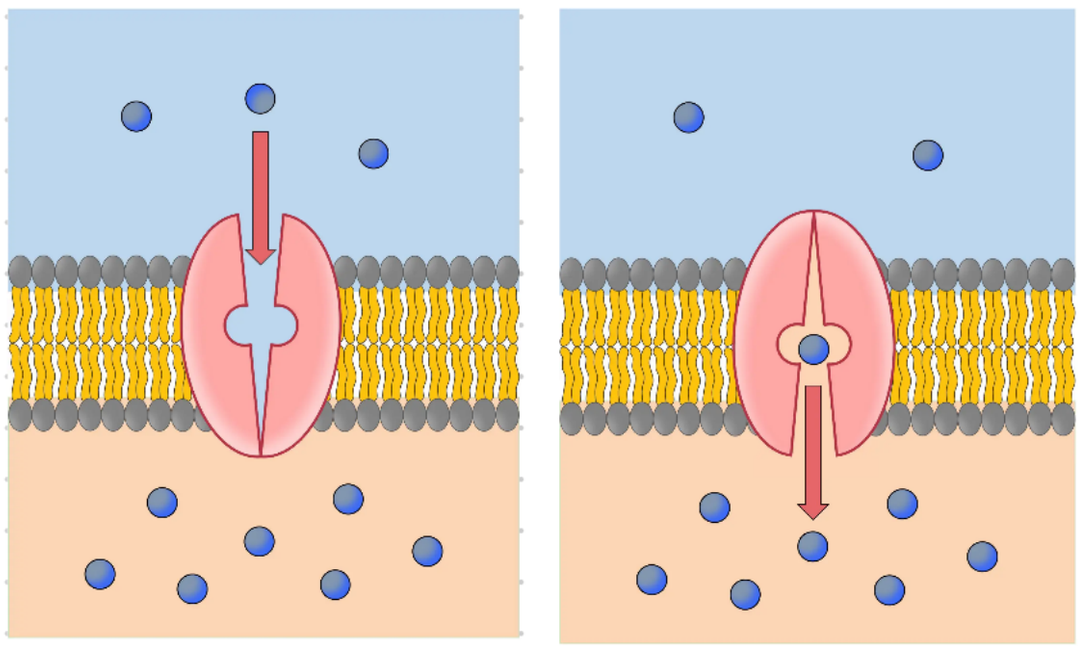
- Some proteins have carbohydrates "glycoprotein"
- Plasma membrane contain cholestrol. It's between the hydrocarbon tails.
- Membrane of the mitochondria have less cholestrol --> more fluid and permable to produce energy.

Pump Proteins And Active Transport

- Active transport is the movement of substances across membrane using energy.
- Lower --> higher concentration
- Work in a specific direction.
- Can generate concentration gradient (not equal)
- Selectively permable

Process:

- Pump close
- Substance enter the pump
- ATP binds to pump the change its shape
- Substance enter cell
- ATP leaves the pump and turns it into its original shape



Structure and Function of Glycoproteins and Glycolipids

Polypeptides + Carbohydrates → Glycoproteins

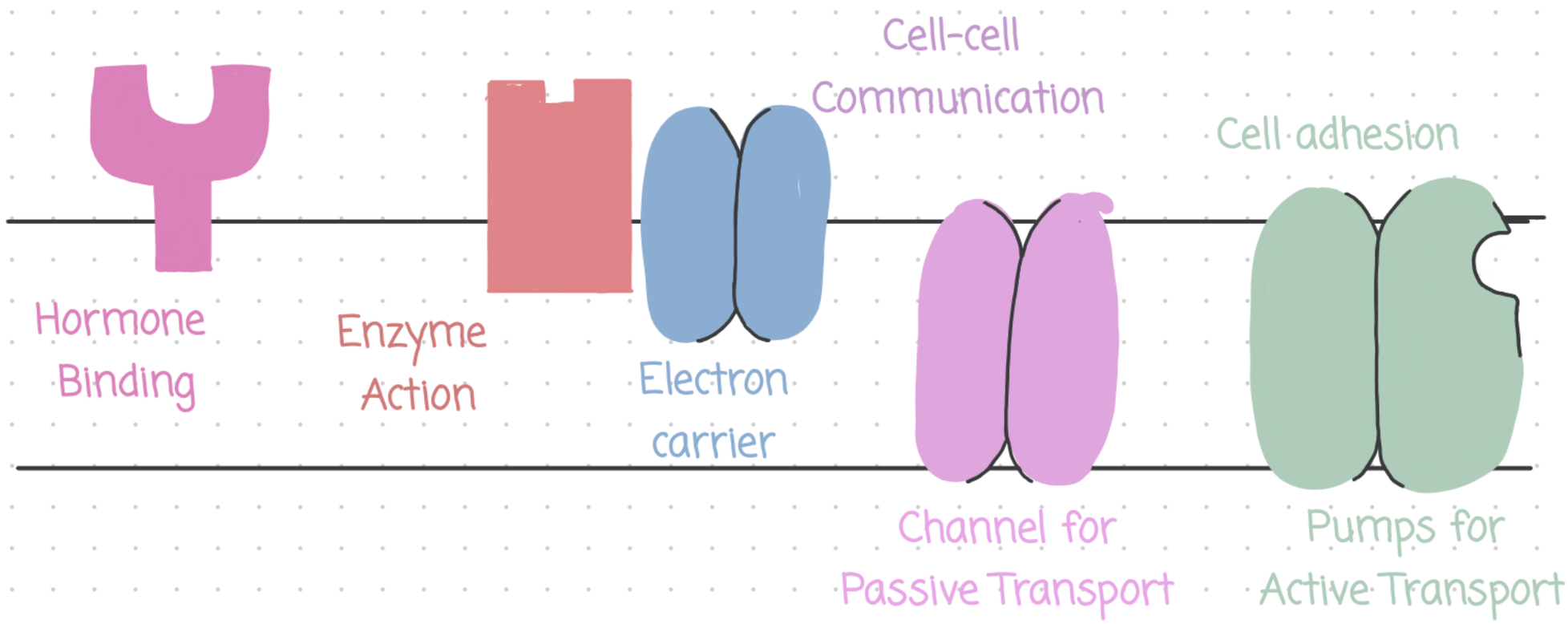
Polypeptides + Lipids → Glycolipids

} both component of plasma membrane

Two Main Roles:

- Cell Adhesion: Both glycoproteins and glycolipids form a carbohydrate-rich layer on the outer part of the animal cell membrane. This is called the glycocalyx. Prevents tissues from falling apart.

- Cell Recognition: Differences in glycoproteins and glycolipids in plasma membranes allow cells to recognize other cells. Allows the immune system to distinguish between self and non-self cells.



Relationship Between Fatty Acid Composition of Lipid Bilayers and Their Fluidity

Cold Temperatures → More unsaturated fatty acids in cell membranes
Hot Temperatures → Less unsaturated fatty acids

- Saturated Fatty Acids: Have straight chains, Allow phospholipids to pack tightly, This reduces membrane fluidity, flexibility, and permeability to simple diffusion

- Unsaturated Fatty Acids: Have more kinks, Phospholipids pack loosely, Membrane becomes more fluid, flexible, and permeable

Cholesterol and membrane fluidity in animal cells

♡ Cholesterol → %20 and %60 of the lipids

- The fluidity of membranes needs to be controlled

- Cold Temperature → Cholesterol makes sure that saturated fatty acid tails do not solidify → Prevents the cell from burst

- Hot Temperature → Cholesterol maintains the order of phospholipids → Prevents membrane from becoming fluid and remain impermeable

Membrane fluidity and the fusion and formation of vesicles

☆ Vesicles move materials around, inside the cell

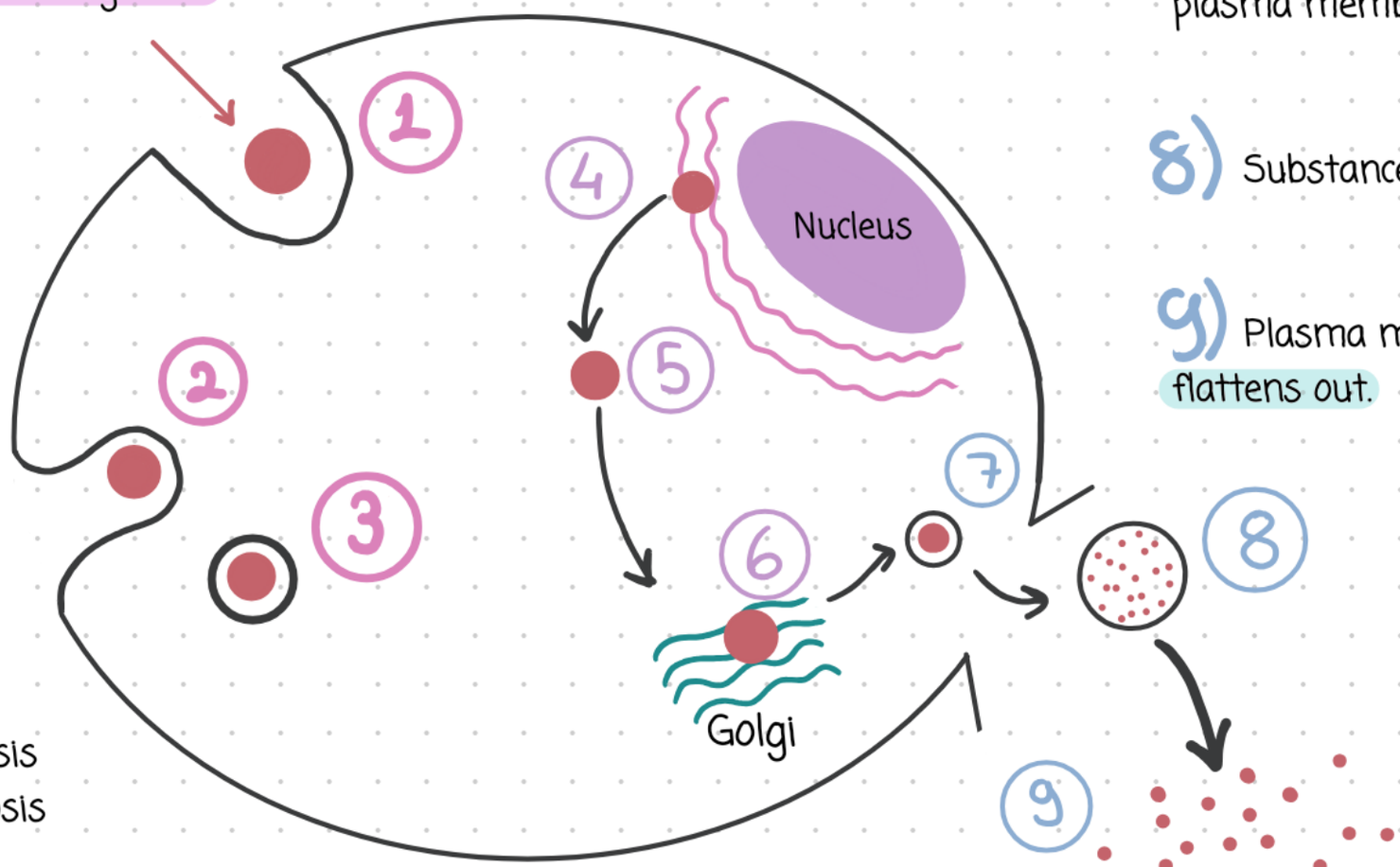
♡ Endocytosis (Organisms absorb large food particles)

1) Sustance pulled inward

2) Substance pinched off with plasma membrane

3) Substance enter the cell

- Solid substance --> Phagocytosis
- Liquid susbstance --> Pinocytosis



☆ Exocytosis:

7) Vesicles fuse with the plasma membrane

8) Substance expelled

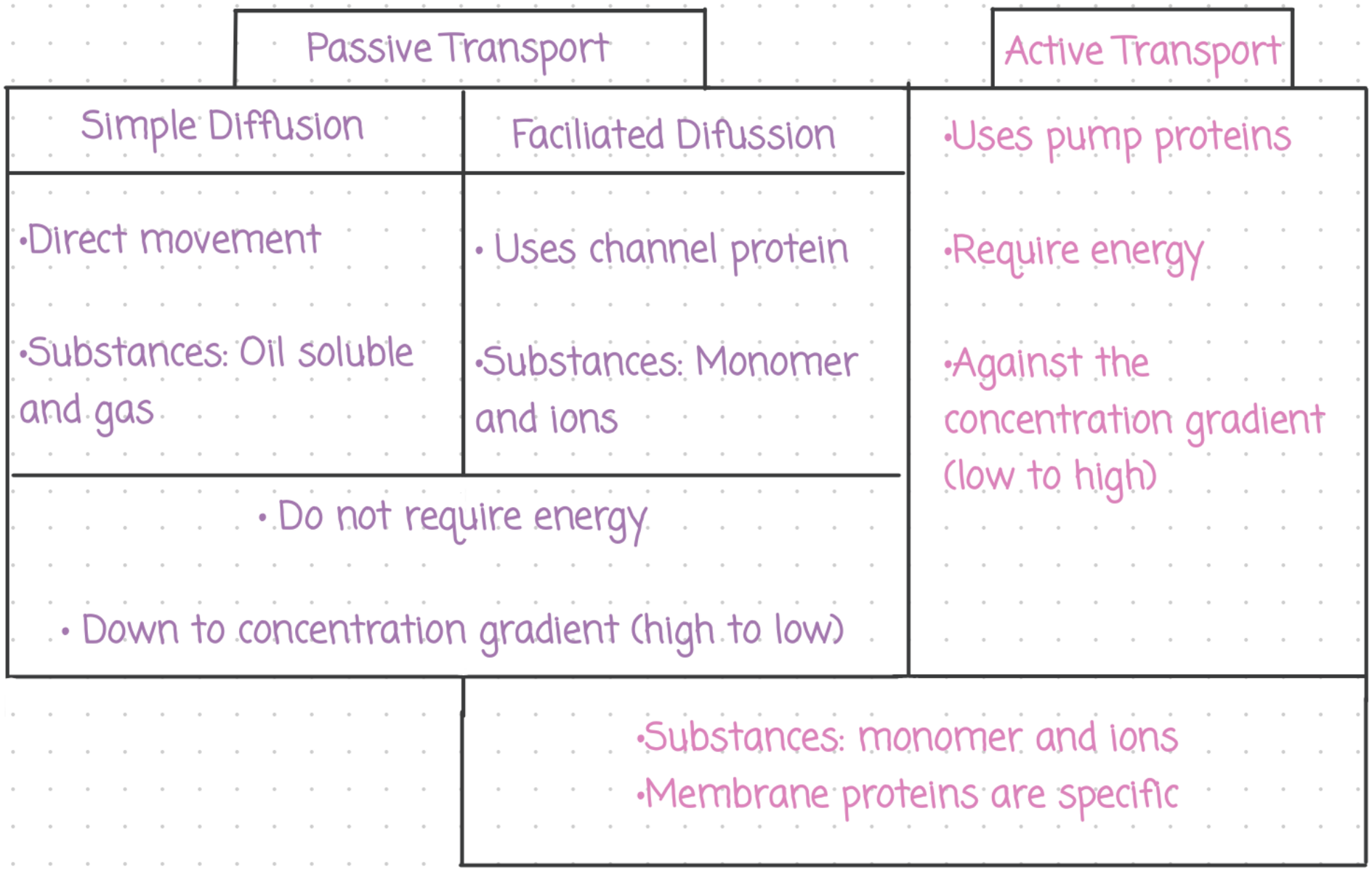
9) Plasma membrane flattens out.

☆Vesicle Transport in the Cytoplasm:

4) Rough ER produce protein and budding

5) Protein fuses with to the Golgi

6) Golgi modifies and packages and budding



Gated ion channels in neurons

- Gated ion channels open for a short time, allowing a pulse of ions to diffuse through, then close again → they're used in nerve impulses

- Voltage-gated sodium and potassium channels:
→ They're membrane proteins that can change shape

- Nicotinic acetylcholine receptors:
→ Used at synapses where acetylcholine is the neurotransmitter

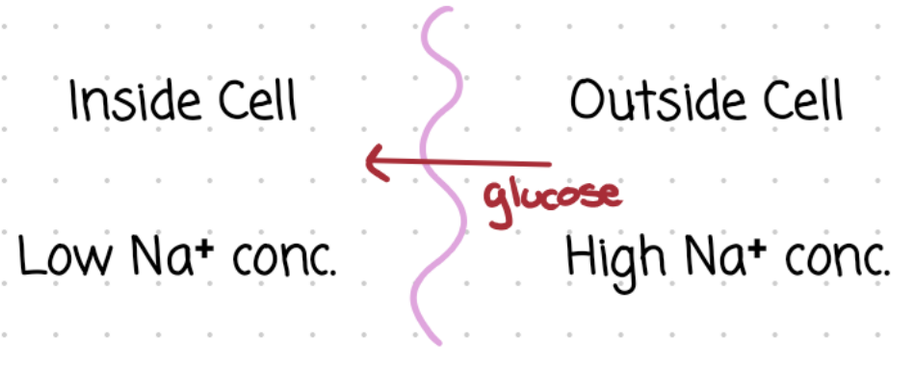
Sodium-potassium pumps as an example of exchange transporters

•Multi-taskers → They transport different substances in opposite directions across membrane

Example: Sodium-potassium pumps generate a concentration gradient

Sodium-dependent glucose cotransporter as an example of indirect active transport

• Sodium-glucose cotransporters are membrane proteins that move Na^+ and glucose together into a cell and Releases energy



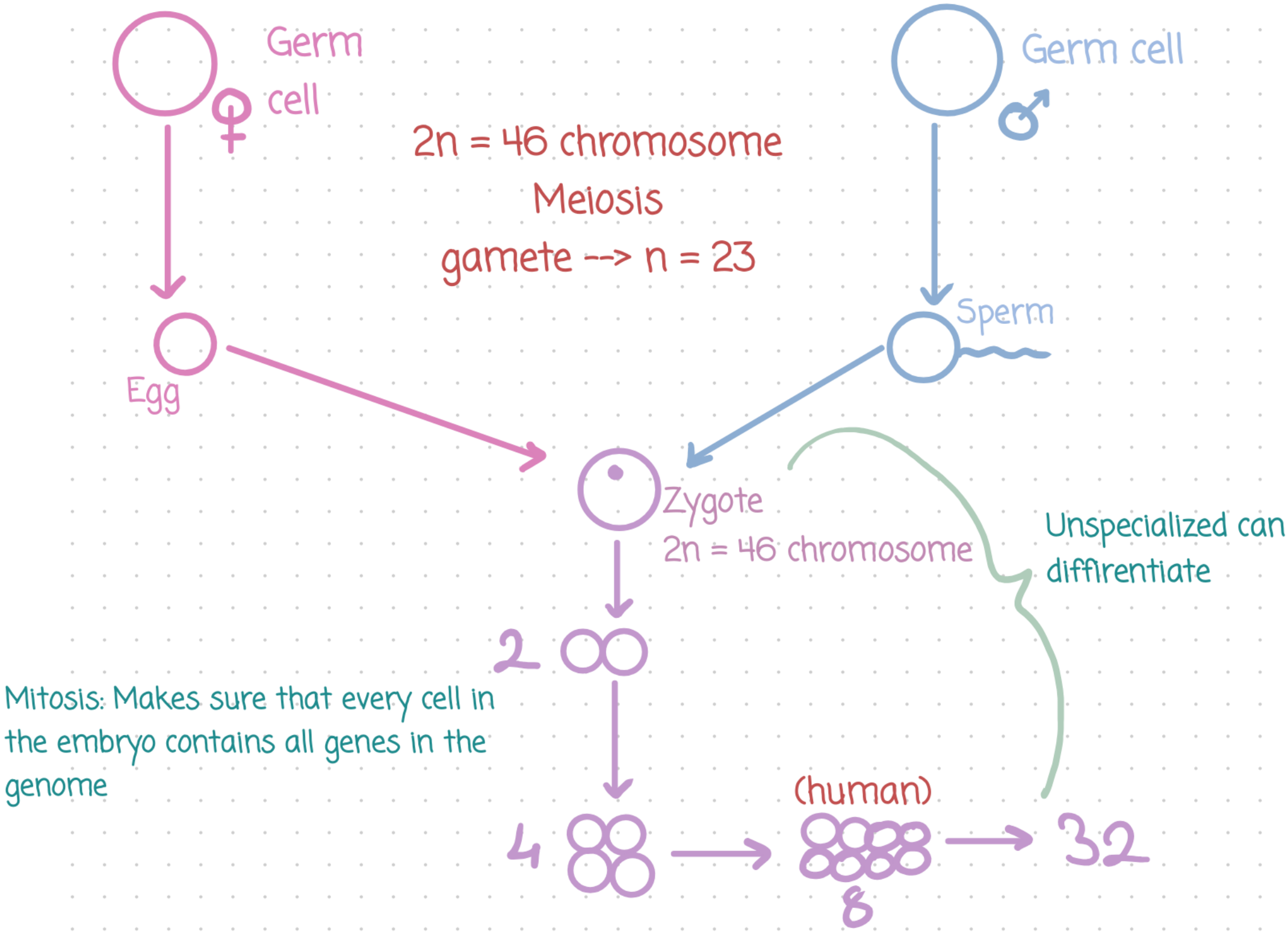
Adhesion of cells to form tissues

• Cell-cell adhesion molecules link adjacent cells in animals (CAMs)

• CAM: Integral membrane proteins
→ Link same type of cells in a tissue
→ Different cell types have different CAMs
→ to form organs

Cell Specialization

Cell Specialization



Production of unspecialized cells following fertilization and their development into specialized cells by differentiation

- Fertilisation: Fusion of a male gamete and female gamete to produce a zygote (single cell).

- Morphogens: Signal molecules that control cell differentiation.

- Sperm 7. günde rahme düşer → hücre farklılaşması başlar ve değişik organlar oluşur. 48 hour sonra human embryo oluşur.

Properties of Stem Cells

- Self-replicating: can divide endlessly
- Undifferentiated: it retains the capacity to differentiate along different pathways

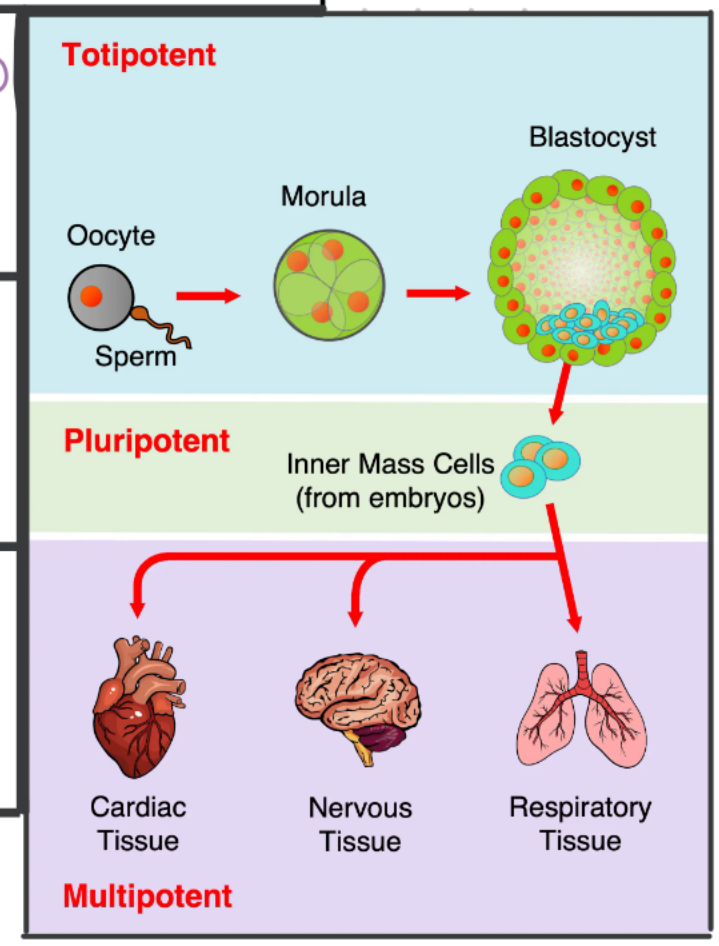
Location and function of stem cell niches in adult humans

- All cells in an embryo are stem cells. But only a small part of cells in an adult's body are stem cells. However they are present in many human tissues for power of regeneration and repair.

- Bone marrow: in femur, pelvis etc.
→ Contains haematopoietic stem cells → can develop into both blood cells

- Hair follicles: pores in the skin that hold hair
→ Divide repeatedly (hair growth) → They're multipotent

Stem Cell	Characteristics
Totipotent	• Large capacity of division and differentiation • Low number of cells are totipotent • Early stages of embryo, can form a complete organism
Pluripotent	• Arise from totipotents (early embryo stages) • Differentiate all cell types • Can not completely form organism
Multipotent	• Forms limited types of cells • Bone marrow, later embryotic stages • Present during the organism's life • Çoğalabilir, ama sadece kendisine dönüşür.
Unipotent	• Only forms one cell type (sperm etc.) • Later embryotic stages • Present during functioning organism



Cell sizes as an aspect of specialisation

- Male gametes: 3 μm → easier for a sperm to swim
- Red blood cells: 7 μm → large surface area → exit of oxygen's rapid

White blood cells: 10-12 μm → can grow when active, produce antibodies in bulk

- Female gametes: 140 μm → contains enough food to sustain the embryo
- Neurons: 20 μm → allows signals to carried far
- Striated muscle cells: 20-100 μm → large and powerful muscle contractions

Surface area-to-volume ratios and constraints on cell size

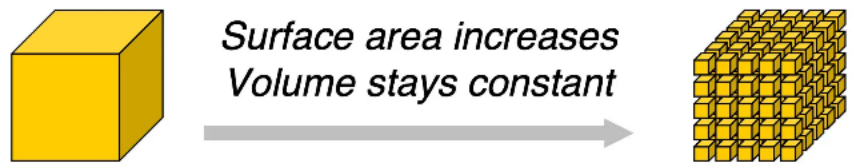
- The rate of metabolism of a cell = it's mass/volume

→ (larger cells need more energy)

- The rate of material exchange = it's surface area

→ (large surface allows more movement)

⭐ The surface area-to-volume ratio of cells decreases as the cell grows



5	Dimensions (width)	5 × 1
150	**Total surface area** (height × width × sides × number of boxes)	750
125	**Total volume** (height × width × length × number of boxes)	125
1.2	**SA:Vol ratio** (surface area ÷ volume)	**6**

Adaptations to increase surface area-to-volume ratios of cells

- Sphere (küresel): smallest surface area-to-volume ratio.

Any change in the sphere increases the ratio.

- Flattening: Wide and thin. Reduces diffusion distance

(Red blood cells, Type I pneumocytes)

Pneumocytes: Cells that form the walls of the alveoli.
Type I: Thin cells for gas exchange.
Type II: Produce surfactant to prevent alveolar collapse.

- Microvilli (finger-like)

→ (e.g. Kidney nephrons: reabsorb glucose/substances)

- Invagination (in-foldings of plasma membrane) → forms tubules or sacs

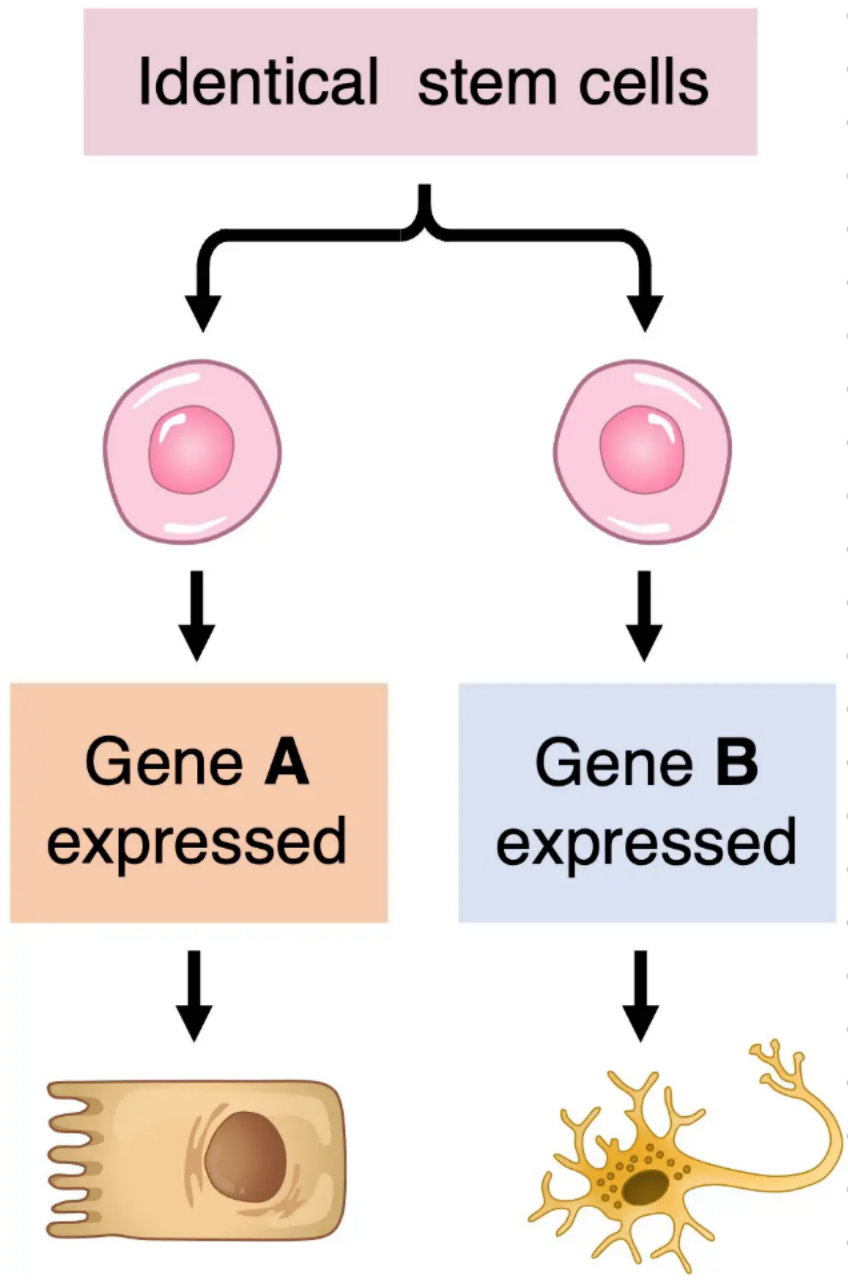
(Proximal convoluted tubules, basal channels → generate Na^+ concentration gradient)

Adaptations of Type I and Type II pneumocytes in alveoli

- The alveoli: Gas exchange occurs

Type I pneumocytes: 95% of the alveolus wall. Adapted to carry out gas exchange. (Very thin and permeable) (reduces diffusion distance)
~ İçindeki hava kana geçer, kanda: CO_2 alveole geçer.

- Type II pneumocytes: 5% of the alveolus wall, more numerous. Cytoplasm contains a fluid that is produced then secreted by exocytosis. Fluid keeps the alveolus moist and allows gases to dissolve (surfactant) (reduces surface tension)



Adaptations of Cardiac Muscle Cells and Striated Muscle Fibres

	Cardiac Muscle Cells	Striated Muscle Fibres
Branching	Branched, each is connected allows electrical stimuli	Unbranched
Junctions	Cell-to-cell junctions with discs allows electrical stimuli	No intercalated discs or special connections
Length	50-100 µm	30,000 µm
Number of nuclei	One per cell	Many per fibre

(Kalbin atması için discs lazım) (striated muscle kalbi çalıştıramaz)

Adaptations of Sperm and Egg Cell

- Male Gametes: Produced more than female to increase the chance of one of them getting fertilised.

- Tail: Allows movement and swimming.
- Midpiece of mitochondria: Provides ATP for swimming.
- Head: Resistance to movement is minimised.

Female Gametes: Larger, cytoplasm contains nutrition for the embryo.

- Zona pellucida: Layer of glycoproteins → sperm binds.
- Binding proteins: Allow sperm nucleus to enter the egg.
- Cortical granules: Makes it impenetrable.
- Yolk: Stores lipids and food.
- Mitochondria
- Centrioles

İKİSİNDE DE **mitochondria var**, kafa karıştıran yer bu 😭

Ama görevleri bağlama göre farklı düşün:

- **Sperm:** Mitochondria **midpiece'te yoğunlaşır** → ATP üretir → **flagellum/tail hareket eder, sperm yüzebilir.**
- **Egg cell:** Mitochondria **cytoplasm içinde bulunur** → hücrenin metabolizması ve **döllenmeden sonraki erken gelişim için ATP sağlar.**

Transport

nabız sadece arterden ölçülü. veins kalpten uzaktadır

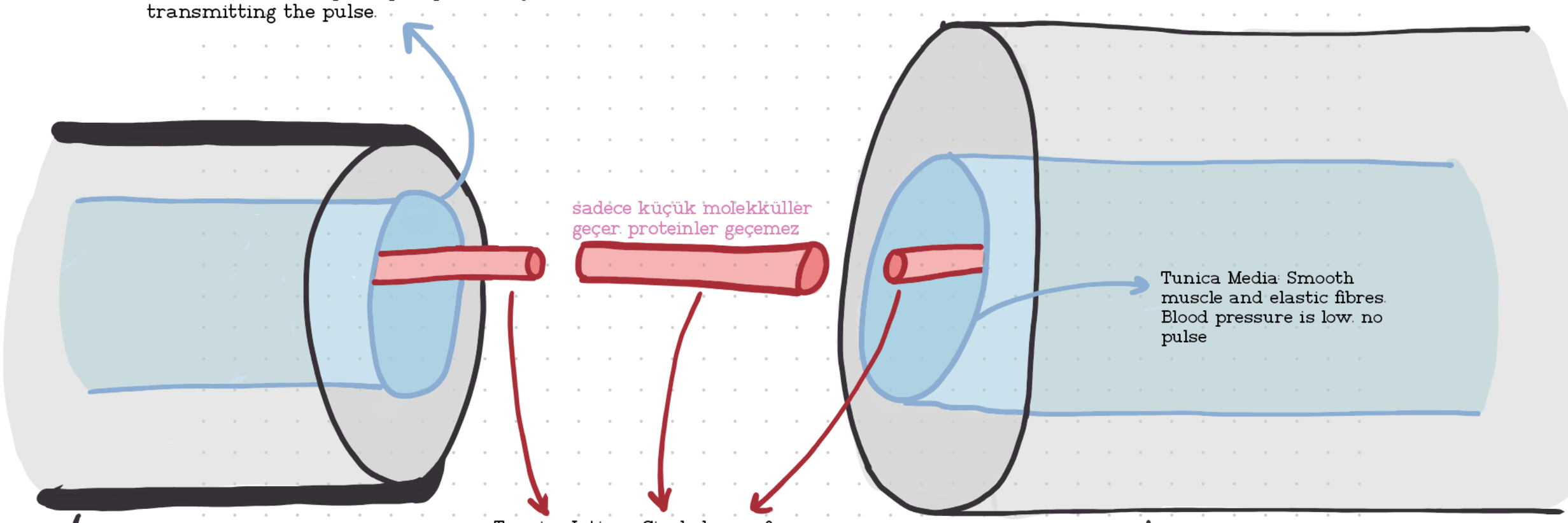
arter:

provides nutrient and gas exchange

Capillaries:

Veins:

Turnica Media: Contains smooth muscle and elastic fibres. It helps to pump blood by transmitting the pulse.



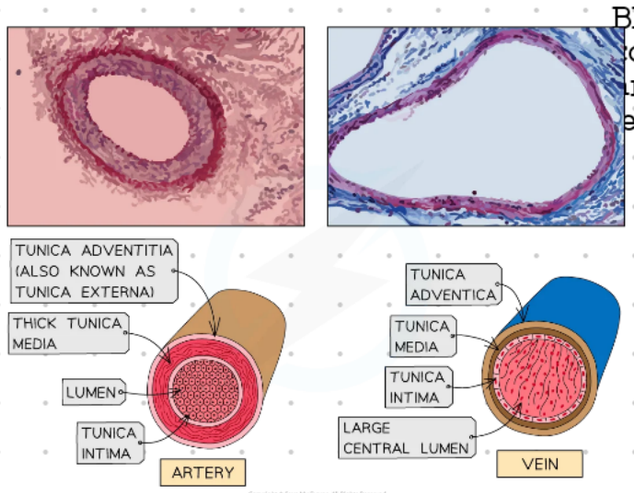
sadece küçük molekküller geçer. proteinler geçemez

Tunica Media: Smooth muscle and elastic fibres. Blood pressure is low. no pulse

Turnica Intima: Single layer of endothothelim to reduce resistance to slow

Trunica Externa: Thich enough to withstand the high blood pressure. Caused by contraction of the heart ventricles. It contains connective tissues. collagen and elastic fibres.

Tunica Externa: The blood vessel walls are thin. therefore their ability to contract and relax is limited. Blood pressure is low. It ontains connective tissues nd elastic fibres. It prevents eaks.



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Diameter: Vein > Arter > Capillaries

Blood Pressure: Arter > Capillaries > Vein

Capillaries are very small blood vessels. They are used to exchange materials between the blood and body cells or the outside environment (like lungs and intestine).

Blood comes → gives oxygen and nutrients → takes waste → leaves.

Where are capillaries?: They are in almost all tissues in the body and active cells are always close to a capillary

Some places have more capillaries (dense networks):
Lungs (exchange with air)
Small intestine (absorb nutrients)

3 main adaptations of capillaries

1. Large surface area: Capillaries are very narrow (about 10 µm). Blood cells move in single file
They branch and join many times → form a capillary network
This creates a large surface area → more exchange happens

2. Thin walls with pores
Wall = one layer of endothelial cells. This layer is very thin and permeable and Supported by extracellular fibrous proteins

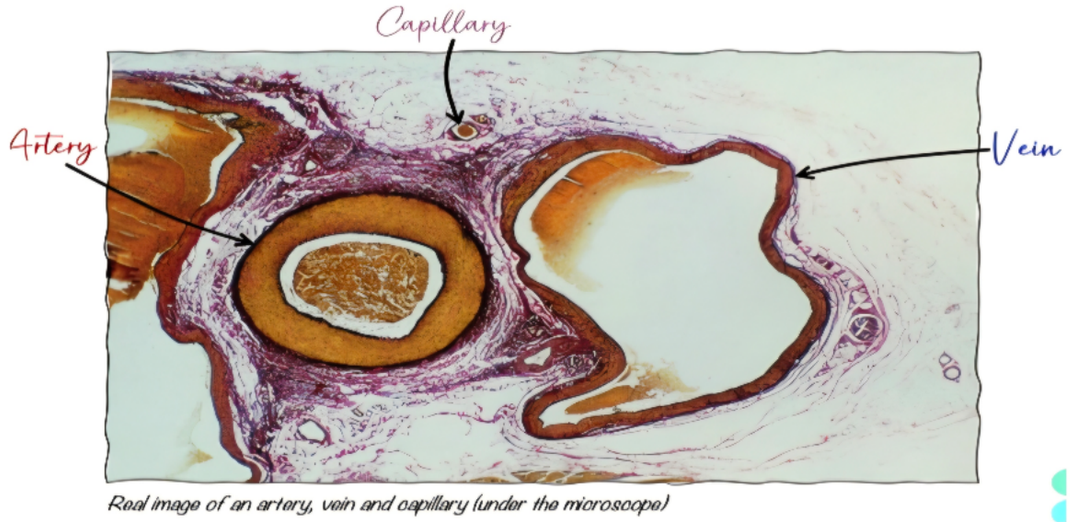
Has a basement membrane: Works like a filterand Lets small/medium particles pass Blocks macromolecules (like proteins)

What happens: Blood pressure › tissue pressure
Fluid leaves capillaries → called tissue fluid
Tissue fluid contains: oxygen and glucose and other small substances

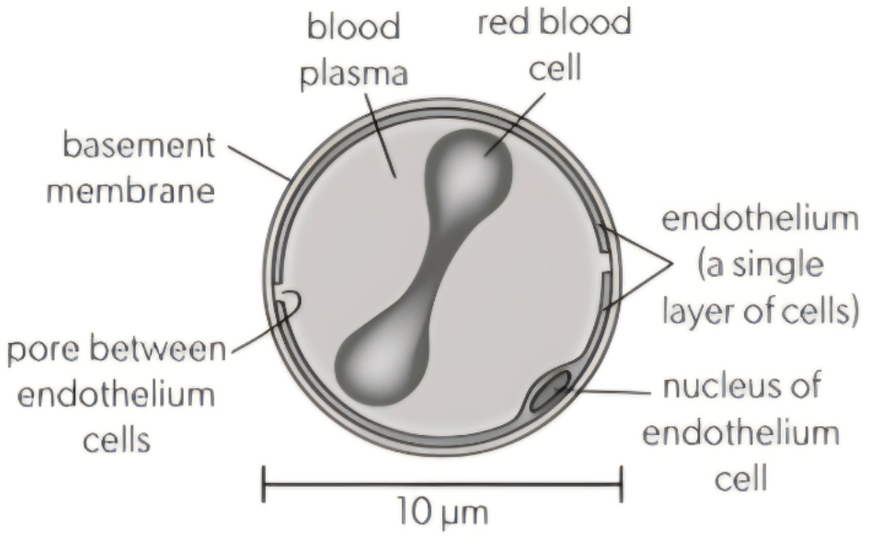
There's no plasma proteins: Tissue fluid moves between cells: Cells take useful substances and then release waste Then fluid goes back into capillaries: (Happens where pressure is lower) and Near veins (blood leaving tissue)

3. Fenestrations (large pores): Some capillaries have very large pores = fenestrations These allow more fluid to pass quickly So exchange is faster

Example: Kidney capillaries. Make large amounts of filtrate it's First step of urine production



Real image of an artery, vein and capillary (under the microscope)



Arteries and veins are blood vessels. They move blood in the body. but they have different structure and function.

Heart → arteries (away. high pressure) → capillaries → veins (back. low pressure) → heart

Arteries

Arteries
Away

Function: Carry blood away from the heart

- Blood is under high pressure: Blood moves in pulses
- Structure (adaptations):

- Thick wall ⟶ Strong to handle high pressure.
- Muscle layer (smooth muscle) ⟶ Can contract or relax to control blood flow.
- Elastic fibers ⟶ Stretch when blood is pumped
- Return to normal ⟶ helps keep pressure
- Small lumen (narrow inside) ⟶ Keeps pressure high

- No valves (not needed because pressure is high)

Veins

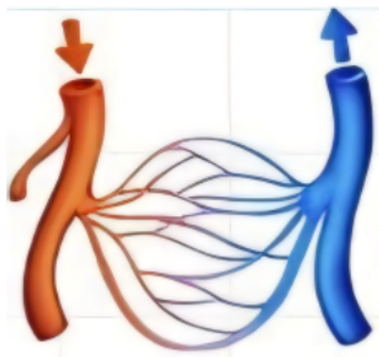
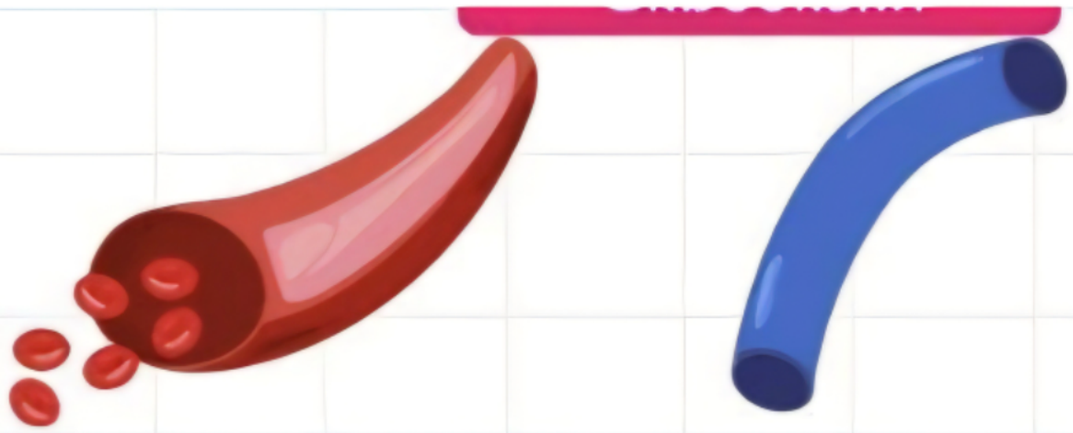
Function: Carry blood back to the heart

- Blood is under low pressure: No pulse

Structure (adaptations)

- Thin wall ⟶ Pressure is low. no need for thick walls
- Less muscle and elastic tissue
- Large lumen (wide inside) ⟶ Makes it easier for blood to flow

- Valves ⟶ Stop blood from flowing backwards


Feature	Arteries	Veins	Capillaries
Function	Carry blood away from the heart	Carry blood towards the heart	Connect arteries to veins
Type of Blood	Usually carry oxygenated blood (except pulmonary artery)	Usually carry deoxygenated blood (except pulmonary vein)	Exchange of gases, nutrients, and wastes
Wall Thickness	Thick and elastic	Thin and less elastic	Very thin (one cell thick)
Blood Pressure	High pressure	Very Low pressure	low pressure
Valves	No valves (except near the heart)	Have valves to prevent backflow	No valves
Lumen (inner diameter)	Narrow lumen	Wide lumen	Extremely narrow
Location	Usually deep under the skin	Closer to the skin surface	Present in almost all tissues
Pulse	Pulse felt	No pulse	No pulse

GKBOOKS

Arteries are built to carry high-pressure blood away from the heart safely and smoothly. Think of arteries as strong, flexible tubes that must handle very high pressure every time the heart pumps.

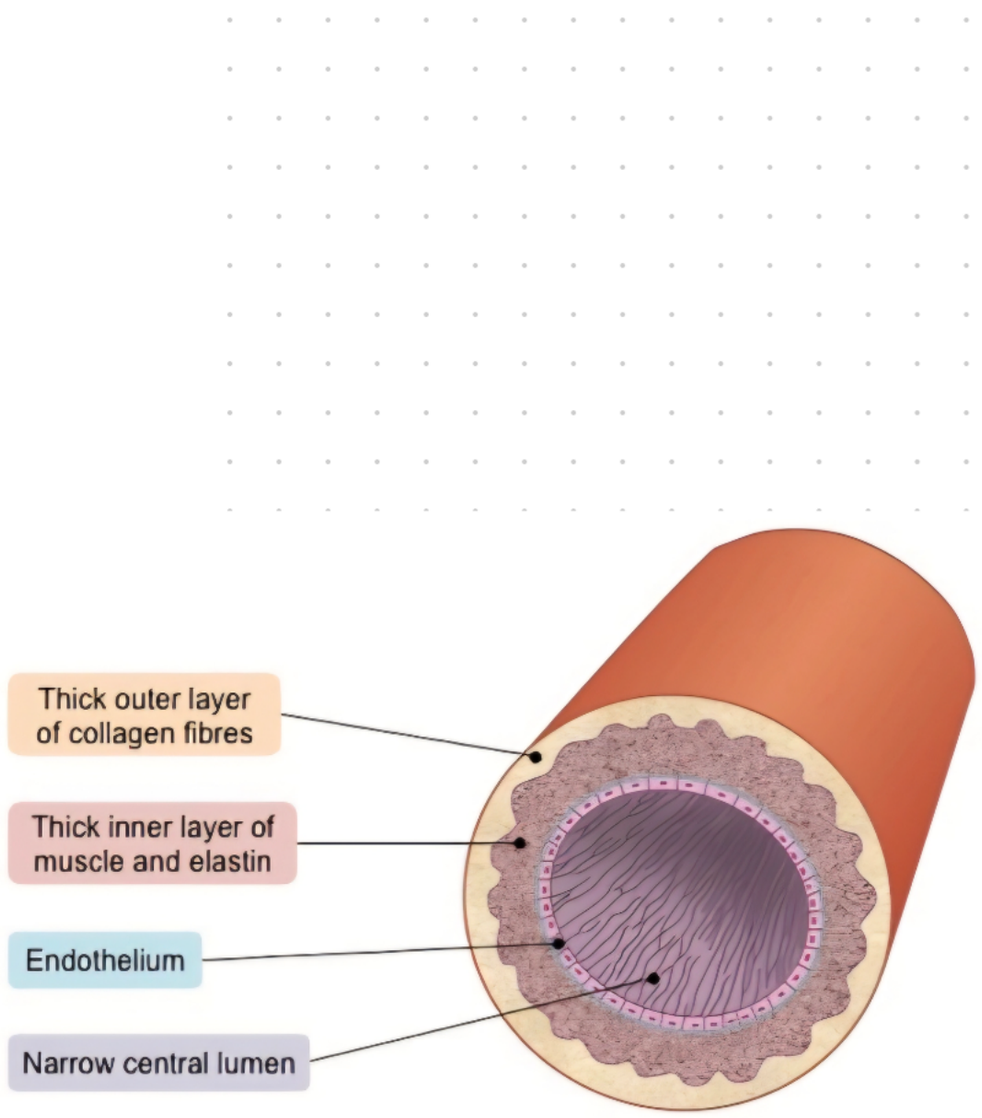
If they are not strong enough, they can bulge (aneurysm) or even burst.
If they are not flexible, blood flow becomes uneven.

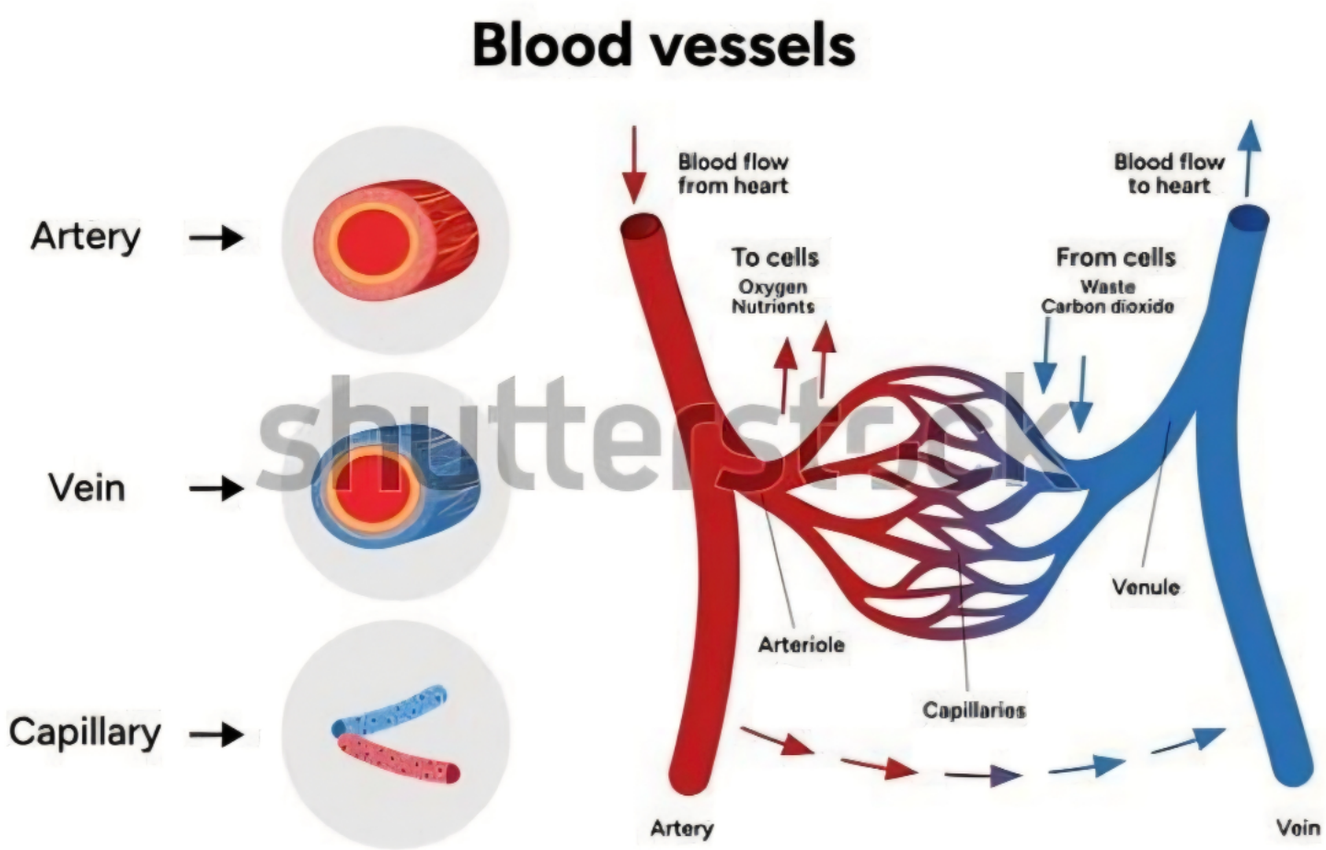
What happens during pumping:

When the heart contracts (systole), it pushes a burst of blood into the arteries at high pressure. This force makes the artery wall expand.
Inside the wall, elastic fibres stretch, and while stretching, they store potential energy.

Then the heart relaxes (diastole), and the pressure inside the arteries drops. At this moment, the elastic fibres recoil (go back to their original shape). This recoil pushes on the lumen (the inside space of the artery), so blood keeps moving forward even when the heart is not actively pumping.

Because of this, blood flow becomes more continuous and even, not just stop-start pulses.





Collagen fibres are hard rope-like proteins with high tensile strength. They make arteries strong enough to resist high and variable blood pressures without bulging outwards (aneurysm) or bursting.

Structure of artery wall (key parts)

1. Collagen fibres: The outer part of the artery wall contains collagen fibres. which are strong. rope-like proteins with high tensile strength. They prevent bulging (aneurysm) and prevent bursting when pressure is high or changes quickly.

2. Elastic fibres: Inside the wall. there are elastic fibres that can stretch and recoil. During high pressure (systole). they stretch and store energy. During low pressure (diastole). they recoil and release that energy. This maintain pulse flow and makes blood movement more smooth and continuous.

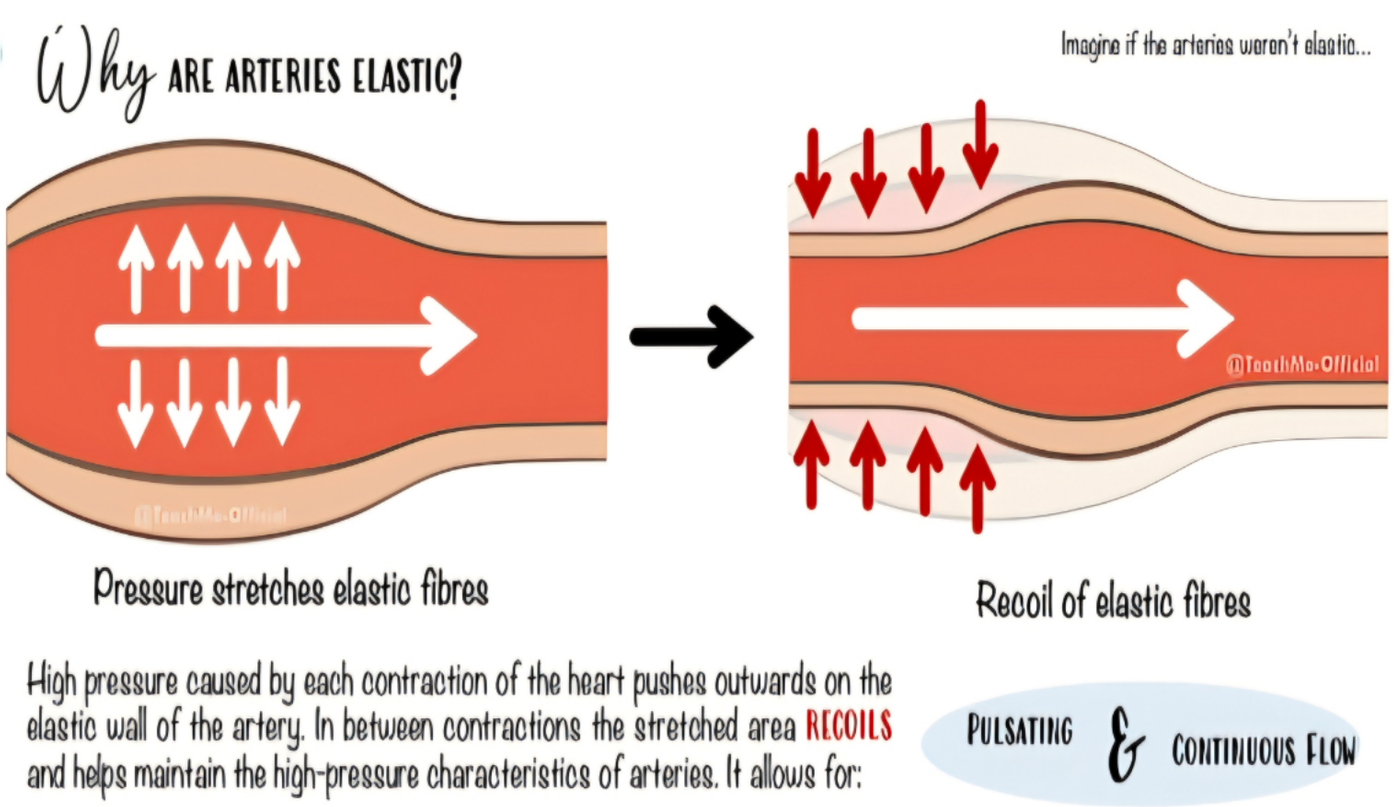
3. Smooth muscle (circular): They're in a circular shape around the lumen. Because of this arrangement. when the muscle contracts. it causes vasoconstriction (the lumen becomes narrower). When the muscle relaxes. it causes vasodilation (the lumen becomes wider). This allows arteries to control blood flow and blood pressure.

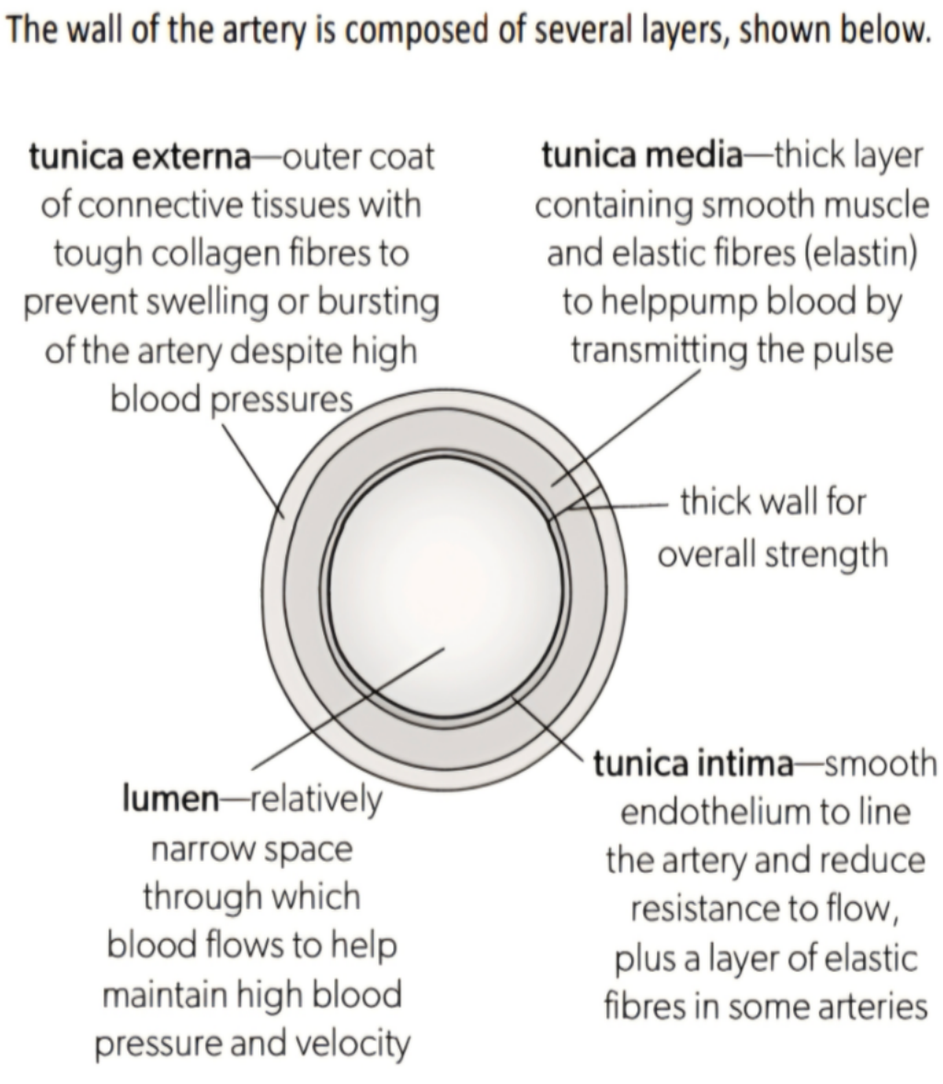
Special adaptations of arteries

Arteries have a narrow lumen (relative to wall thickness). This helps maintain a high blood pressure (about 80-120 mmHg). which is needed to push blood around the body.

They also have a thick wall. especially with collagen. to stop the artery from rupturing under high pressure.

The inner layers contain both elastic fibres and smooth muscle. so the artery can both stretch and contract. which is necessary to maintain pulse flow and adjust blood movement.





Measurement of pulse rates

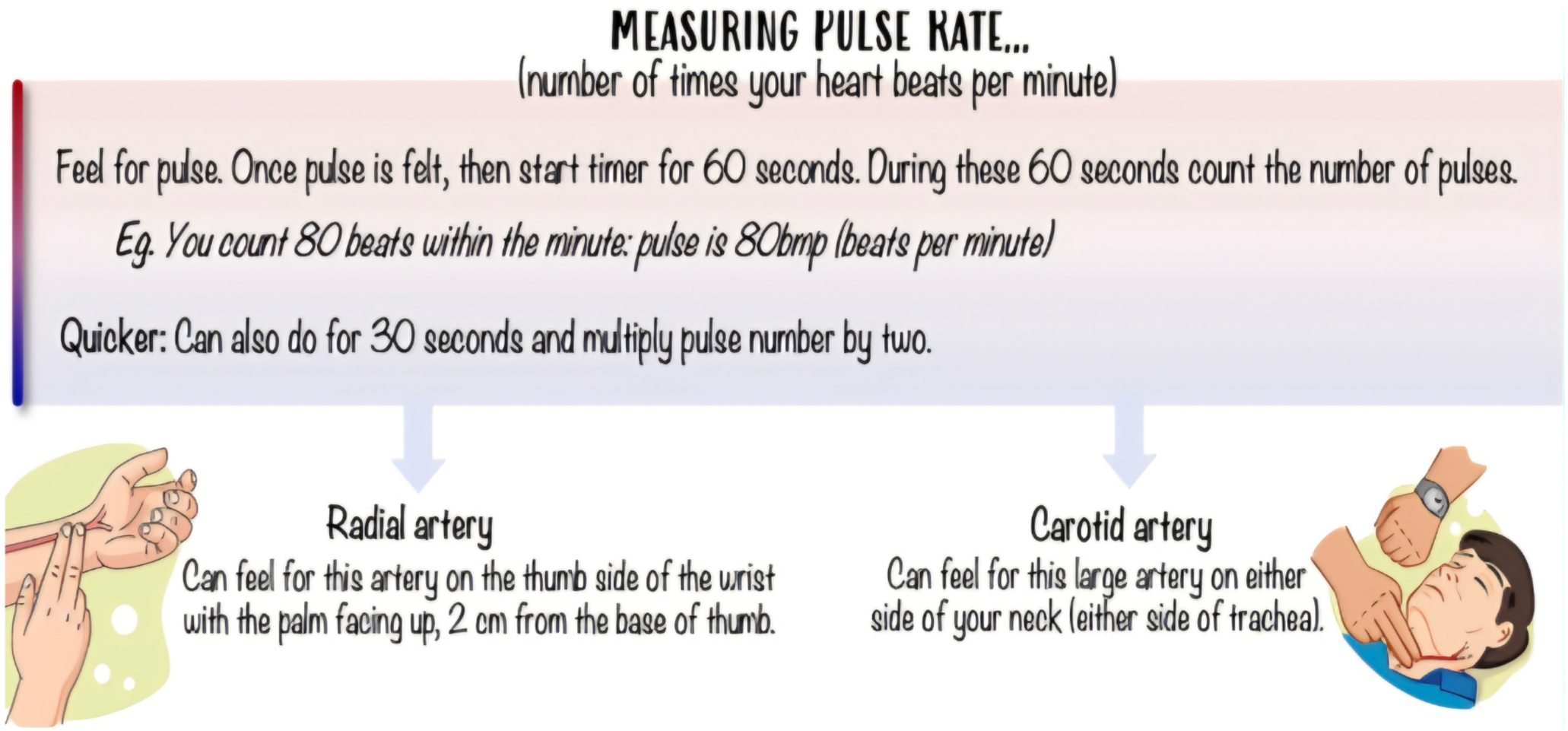
Every time the heart beats. it pushes blood into the arteries with high pressure.

This creates a wave that travels along the artery walls. The walls stretch and then recoil. When this happens in arteries close to the skin. you can feel it as a pulse.

You can feel this pulse in places like the carotid artery in the neck and the radial artery on the thumb side of the wrist. Each pulse is equal to one heartbeat. so the pulse rate = heart rate.

To measure it. you place your index finger and middle finger on the side of your neck. in the soft area next to the trachea. When you feel the pulse clearly. you use a timer and count how many beats you feel in one minute. You can also count for 30 seconds and multiply by 2 to get the pulse rate.

There are also digital methods to measure heart rate. One example is a pulse oximeter. This device is clipped onto a fingertip. It uses LEDs to shine light into the finger and has detectors to measure how much light is absorbed. The amount of light absorbed changes depending on how much blood is in the tissues. Using this. the device can calculate the pulse rate. and therefore the heart rate.



Adaptations of veins for the return of blood to the heart

Veins are blood vessels that collect blood from all organs and bring it back to the heart. After blood passes through capillaries. it enters veins slowly and continuously. so there is no pulse and the pressure is low (about 5-10 mmHg).

Because the pressure is so low. sometimes blood can slow down or even stop. and there is a risk that it might flow backwards toward the capillaries.

To stop this. veins have special valves. Each valve is made of three pocket-shaped flaps of tissue. When blood tries to go backwards. it gets trapped in these flaps. which fill up and close the valve. This blocks backflow.

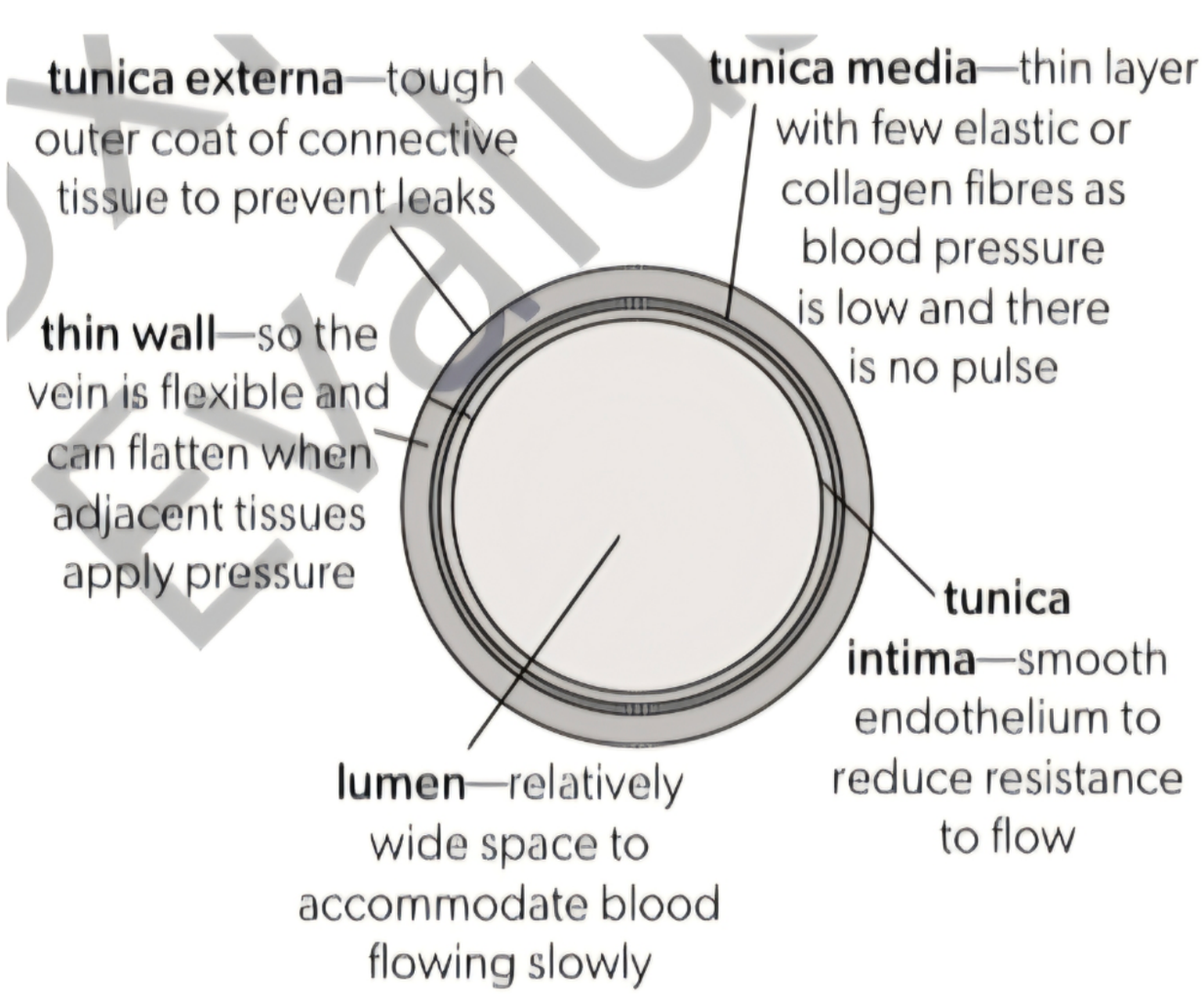
When blood moves in the correct direction. towards the heart. it pushes the valve open and continues flowing.

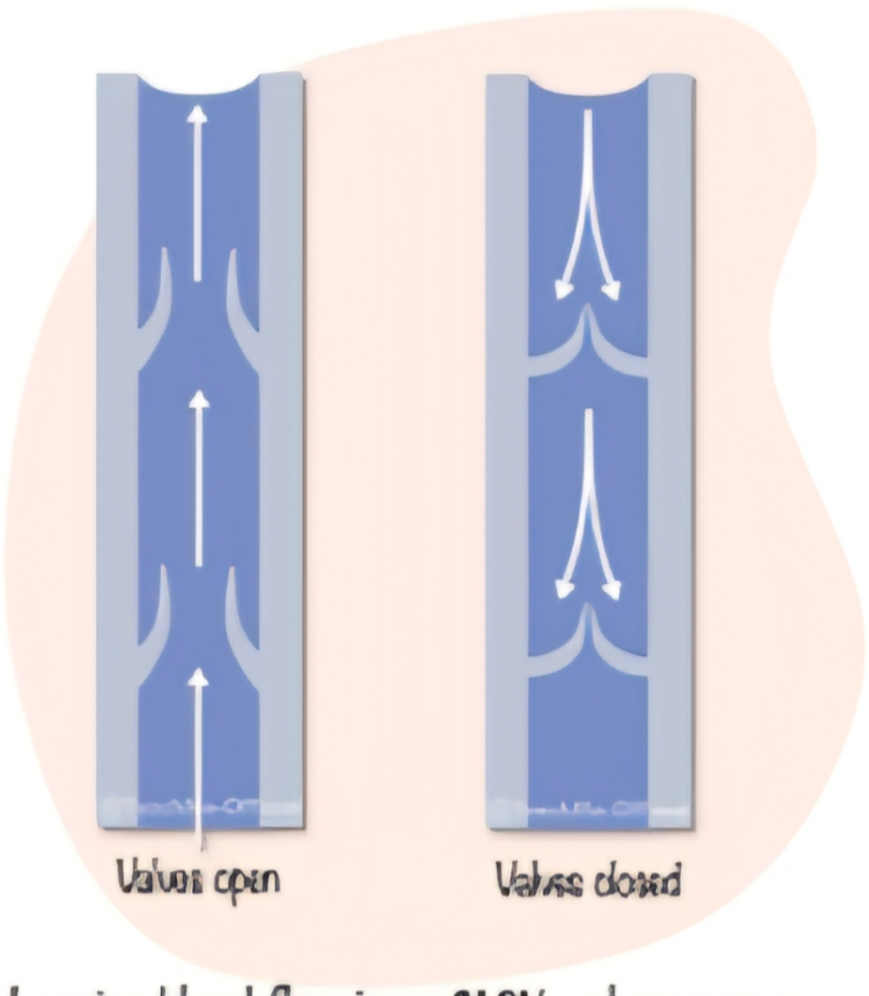
Blood movement in veins is also helped by skeletal muscles near them. When these muscles contract. they press on the veins. making them flatter and increasing the pressure inside. This helps push the blood forward.

The valves make sure that this pushed blood only goes towards the heart. not backwards.

To do this job well. veins have a special structure. They have a very wide lumen (compared to wall thickness). which makes it easier for blood to flow and improves return to the heart. Their walls are thin and contain less smooth muscle and fewer elastic fibres. because they do not need to handle high pressure.

Since pressure is low. valves are essential. They prevent backflow and stop blood from pooling in the lowest parts of the body.

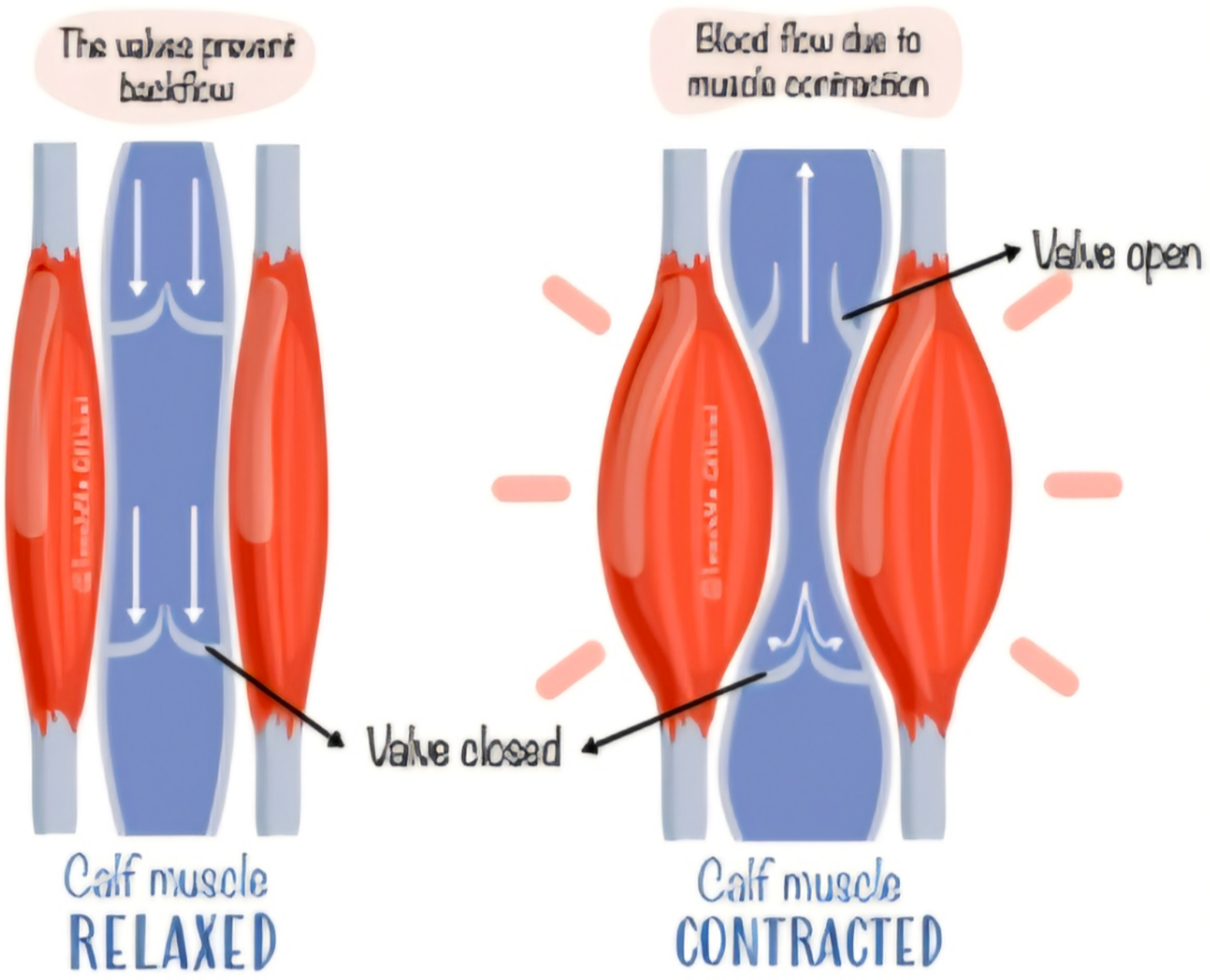


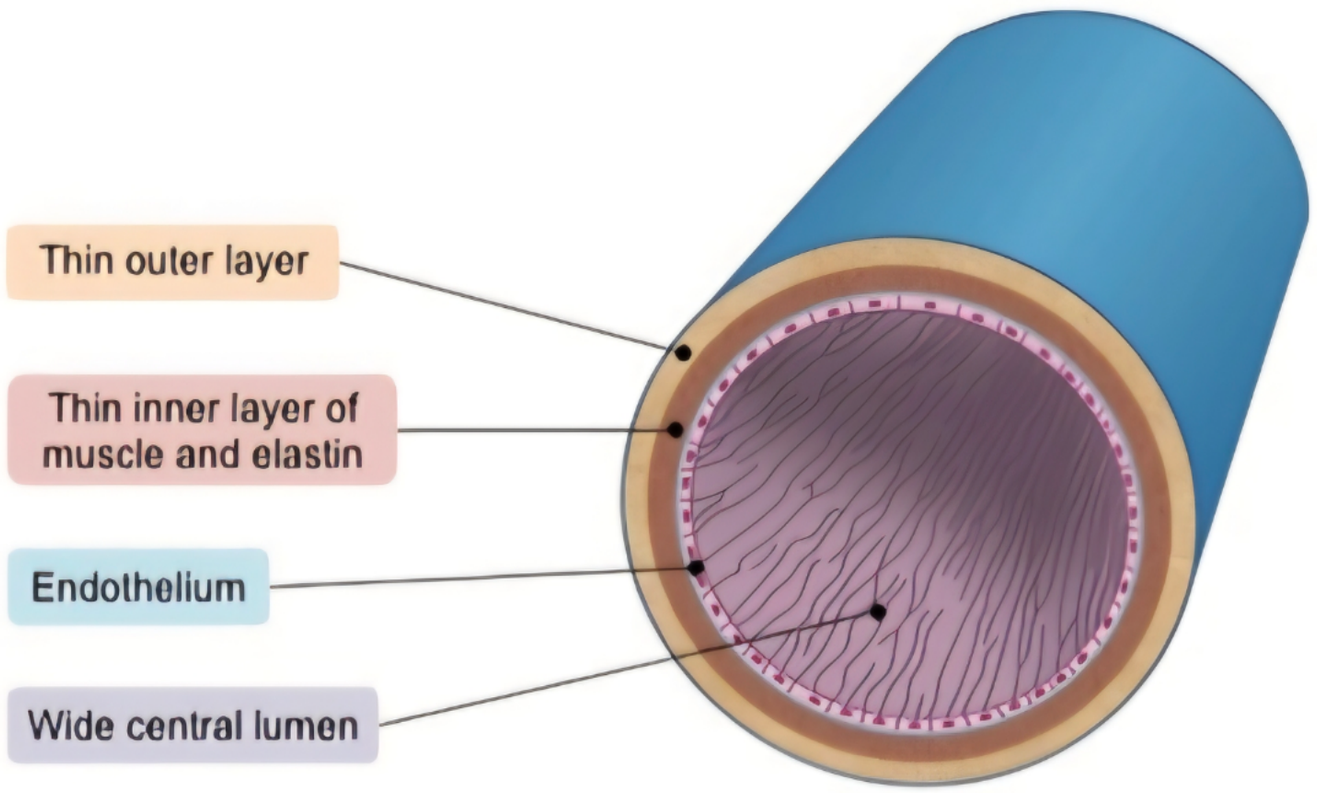


In veins blood flow is so **SLOW**: valves ensure **UNIDIRECTIONAL** blood flow (no backflow) back to the heart. It is a one-way valve.

CALF MUSCLES ACT AS PUMP FOR DEEP LEG VEIN

THIN wall allows compression by muscles to help blood flow return to heart.





Pressure in veins can drop so low that blood flow stops and there is a risk of backflow towards the capillaries. Valves in main veins prevent this. Each valve consists of three pocket-shaped flaps of tissue. If blood starts to flow backwards, it gets caught in the flaps, filling them and closing the valve. Blood flowing towards the heart pushes the valve open. Venous blood flow is aided by skeletal muscles adjacent to veins that become wider when they contract, pressing the vein flatter and raising blood pressure. Valves ensure that the resulting flow of blood is towards the heart.

Causes and consequences of occlusion of the coronary arteries

All blood from the left ventricle goes into the aorta. From there. blood is sent to the whole body (except the lungs).

The first two branches of the aorta are the coronary arteries. which carry oxygenated blood to the heart muscle itself.

One branch divides again. so there are three main coronary arteries. These branch many times to supply all parts of the muscular wall of the heart.

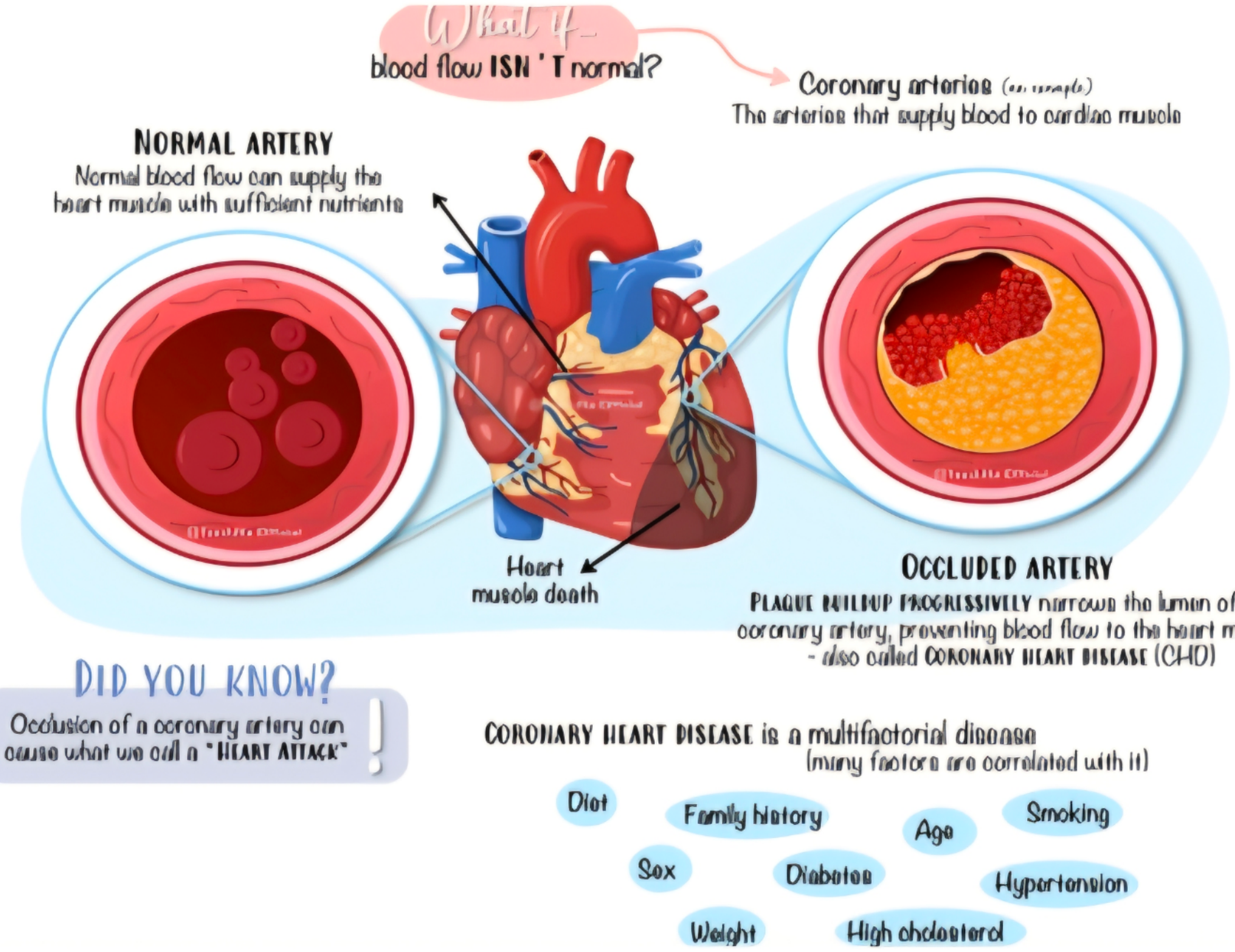
Over time. lipids (fats and cholesterol) can build up in the walls of arteries. These deposits are called atheroma (plaque).

As atheroma grows. it makes the lumen narrower. so blood flow is restricted. If the build-up continues. it can cause occlusion. which means a total blockage of the artery.

When coronary arteries are narrowed or blocked. the heart muscle does not get enough oxygen. This can cause chest pain (angina) or shortness of breath. especially during exercise when the heart needs more oxygen. These problems are part of coronary heart disease (CHD). which includes all medical conditions caused by reduced blood flow in coronary arteries.

Multiple risk factors for coronary heart disease (CHD) have been identified:

- High blood pressure (hypertension)
- Smoking
- Obesity (body mass index ≥30)
- Inactive lifestyle
- Family history of heart disease
- Old age
- High blood cholesterol concentration
- Diabetes



Transport of water from roots to leaves during transpiration

Plants move large amounts of water from the roots to the leaves. This water is carried in xylem vessels as part of xylem sap which has low concentrations of K^+ and other dissolved ions.

In the leaves. (In the spongy mesophyll cells) water evaporates from the cell walls. This water becomes water vapour and then diffuses out through stomata. This whole process is called transpiration. transpication = water vapour leaving from the leafs

When water leaves the leaf it creates a pull. To replace the lost water, more water is drawn up from the roots through the xylem.

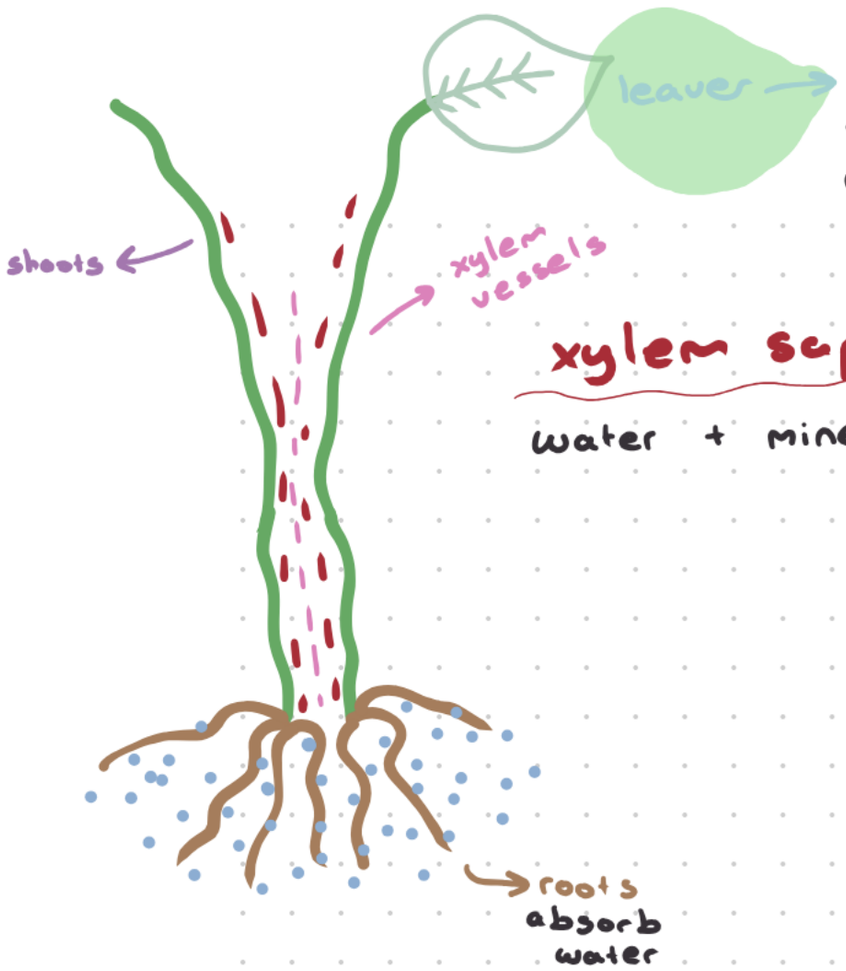
The walls of leaf cells are made of cellulose, which forms a mesh (a structure). Cellulose is hydrophilic, so it attracts water and forms hydrogen bonds with it. Because of this, water sticks to the cellulose (adhesion) and also sticks to other water molecules (cohesion).

These two forces allow water to move through tiny spaces (pores) in the cell walls. This movement is called capillary action. It helps pull water up from the roots all the way to the leaves, replacing the water lost by transpiration.

xylem walls → cellulose

cellulose + water = adhesion
↳ different

water + water = cohesion
↳ co (which means same i guess?)

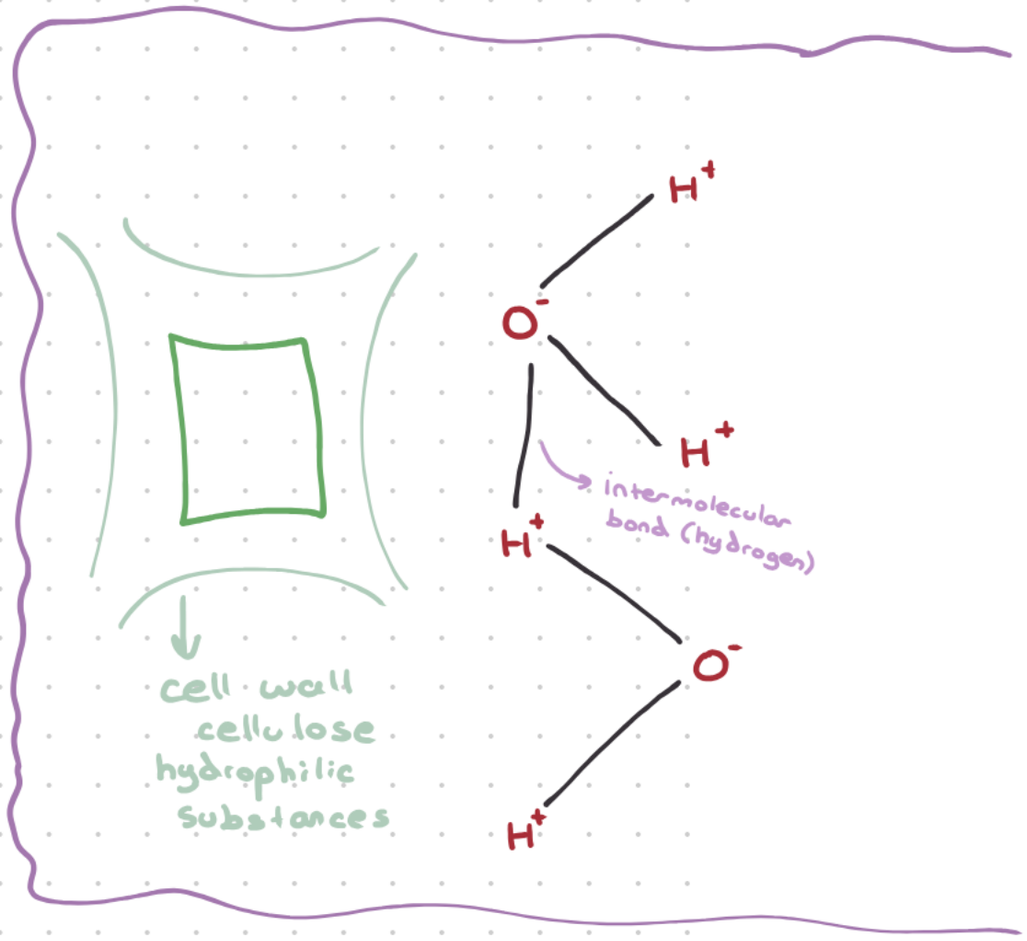


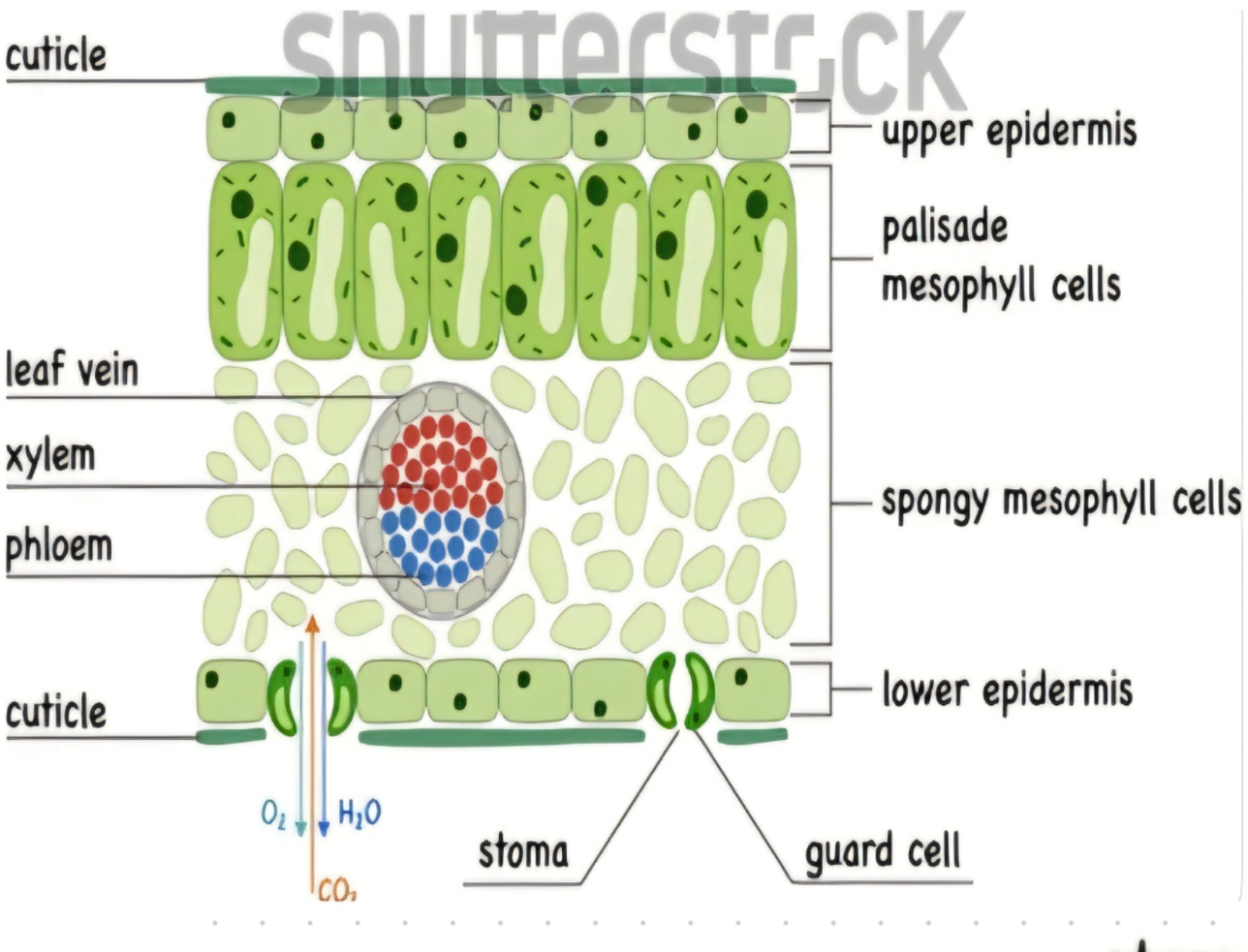
water evaporates from spongy mesophyll cells, then releases from stoma to atmosphere.

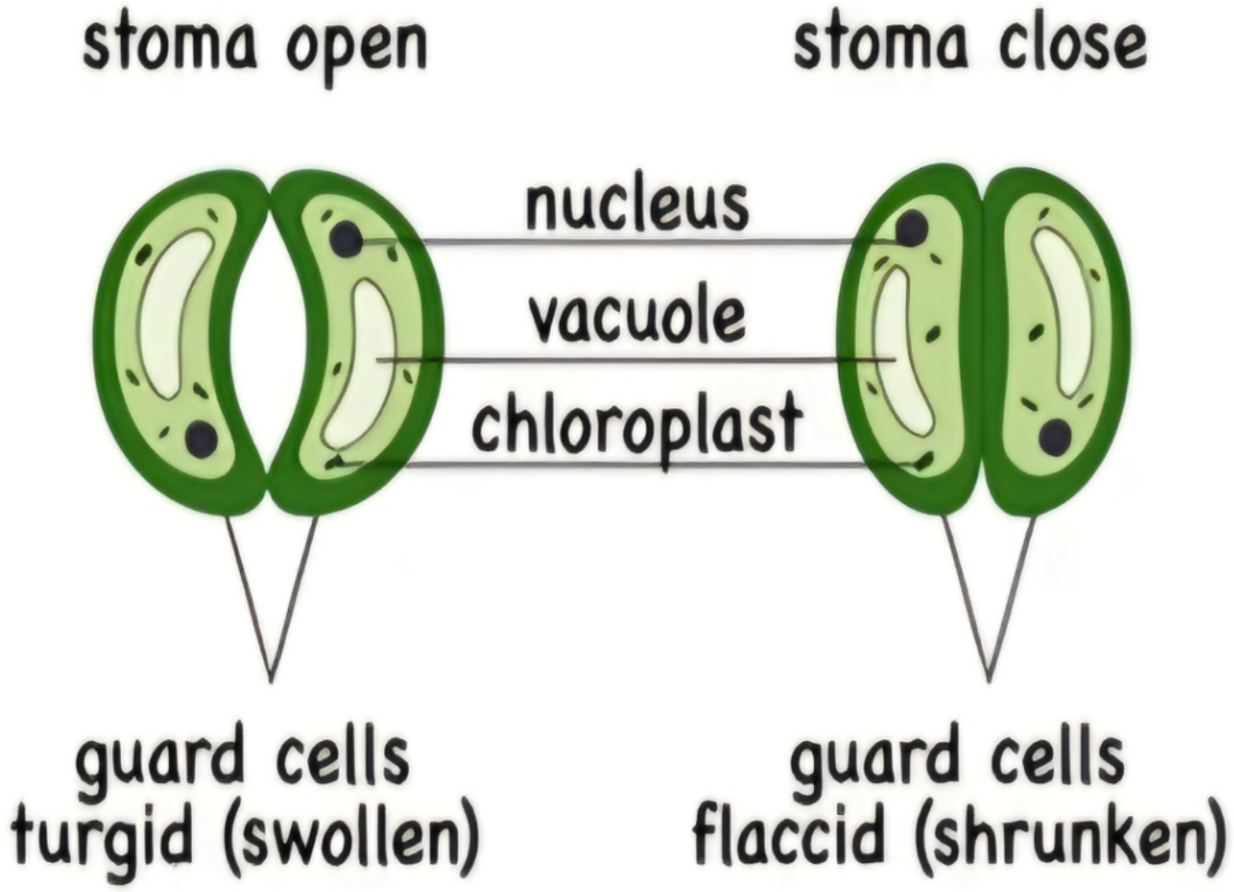
TRANSPIRATION

xylem sap

water + minerals







Transpiration pull and water movement in xylem

Water moves through leaf cell walls from xylem vessels in the leaf veins. When water leaves the xylem. it creates tension (a pulling force) inside the vessels.

Because water molecules stick together (cohesion). this tension is transmitted down the continuous column of water in the xylem all the way to the roots. This pulling force is called transpiration pull.

Transpiration pull is remarkable because it can move water upward against gravity. even to the top of the tallest trees. without any active pumping.

The energy comes from two sources:

Heat from the sun. which drives transpiration
Hydrogen bonds between water molecules. which act like rope-like connections that resist breaking and allow tension to be transmitted

TRANSPIRATION

the evaporation of water through an open stomata

1. Water uptake occurs at the root.
2. Water enter the xylem & moves up the xylem
3. Water moves from the xylem to leaf cells.
4. Water evaporates into empty spaces in the leaves.
5. Water transpires out of stomata into the air.

How?

The negative pressure created by the water transpired pulls water up the xylem: with the help of the **COHESIVE** and **ADHESIVE** properties of water (learned in A1.1)

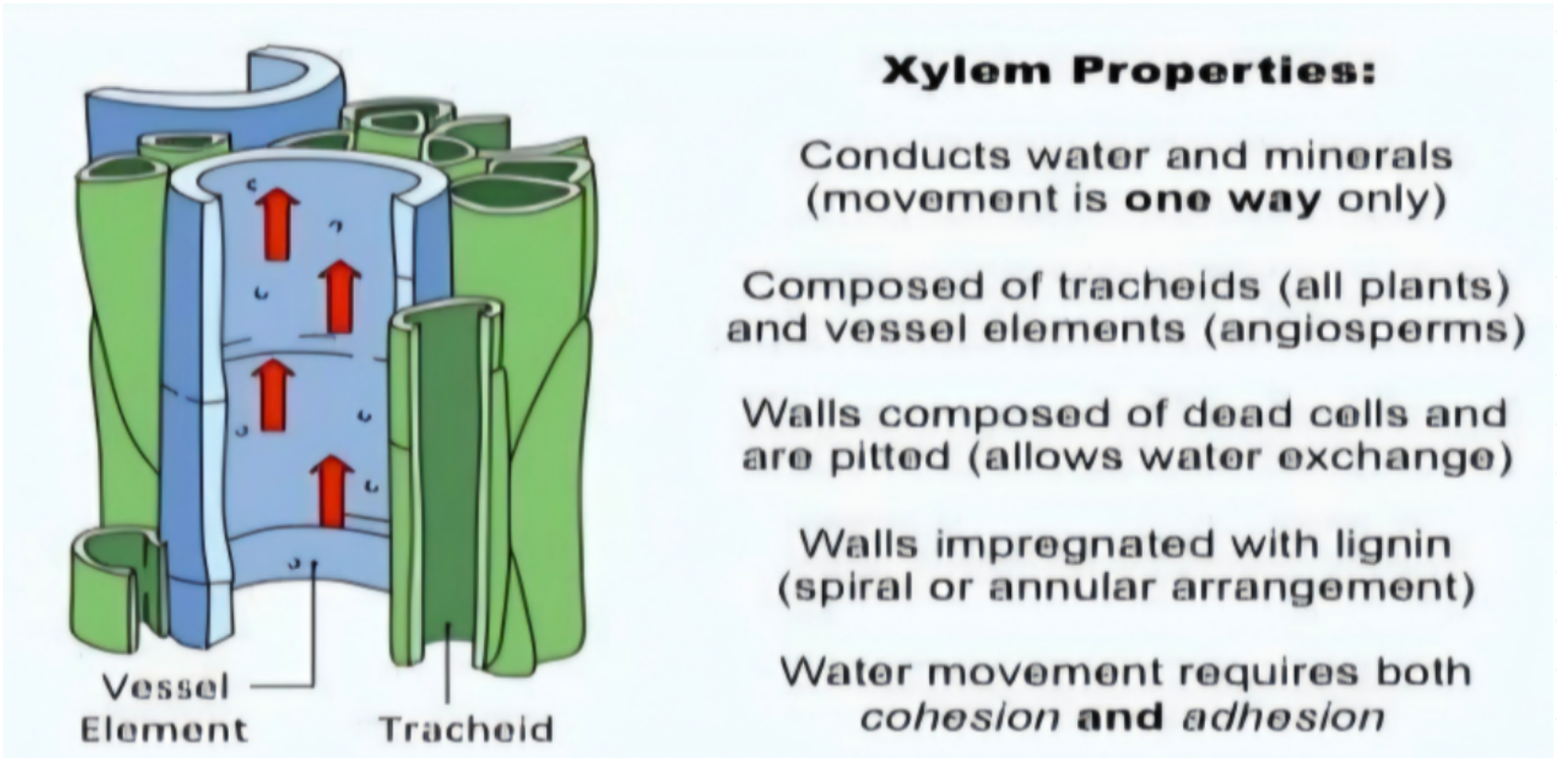
Adaptations of xylem vessels for water transport

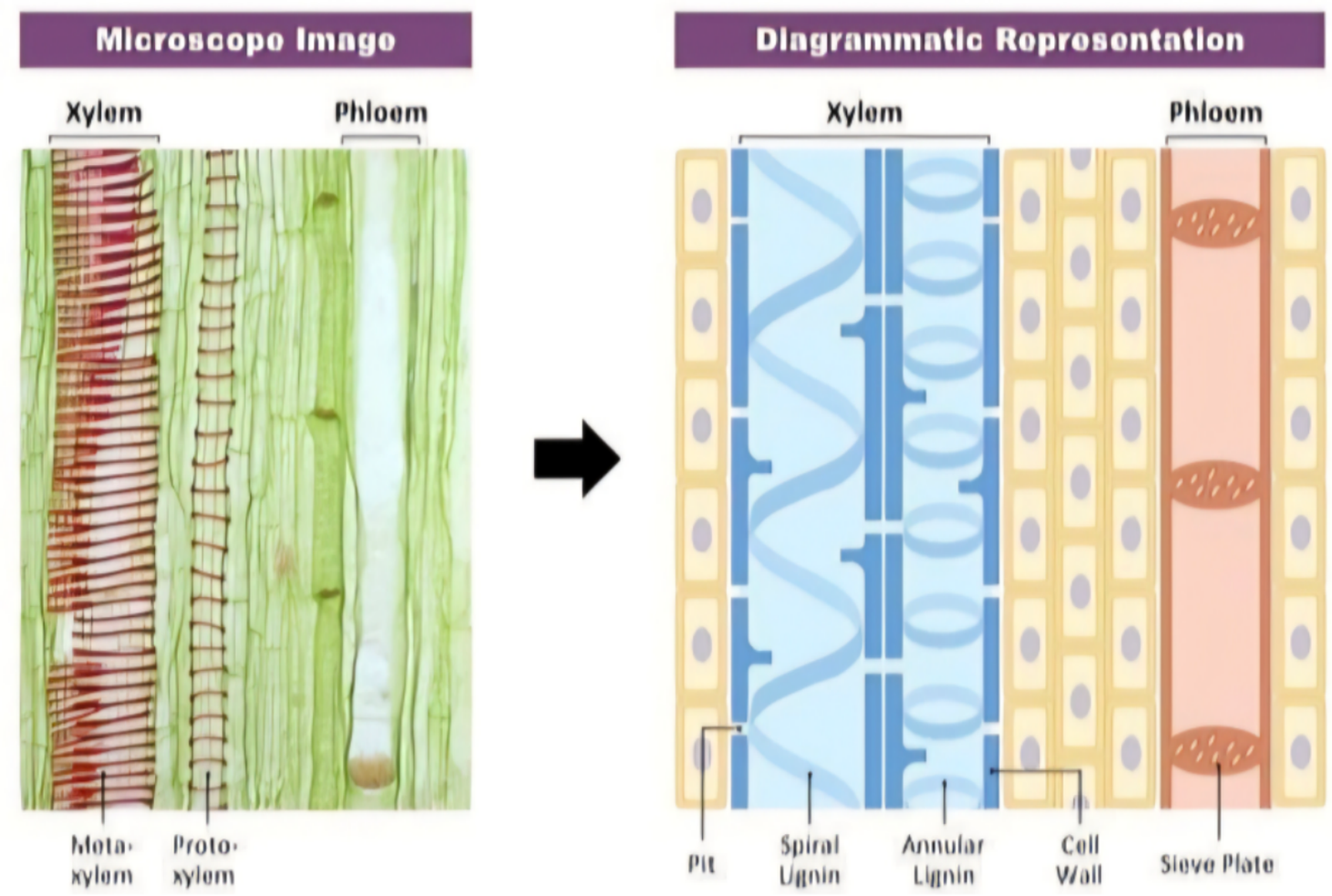
Xylem vessels are special tubes in plants that move water from roots to leaves. They are formed by columns of cells joined end-to-end.

Wall thickening and lignification: The side walls of xylem vessels are thick and strengthened with lignin, a strong polymer. This prevents the vessels from collapsing when the pressure inside is very low during transpiration.

Lack of end walls and cell contents: During development, the end walls between cells are removed and the cell contents and plasma membrane break down. This makes long, continuous tubes where water can flow freely. Since mature xylem vessels are non-living, water moves through them passively, without energy from the plant.

Pits for entry and exit of water: The lignified walls are waterproof, but there are always gaps for water to move in and out. In young plants, wall thickenings form rings or helices with large gaps for water. In older plants, thickenings are more complete, and water passes through small holes called pits.





Distribution of tissues in a transverse section of a dicot stem

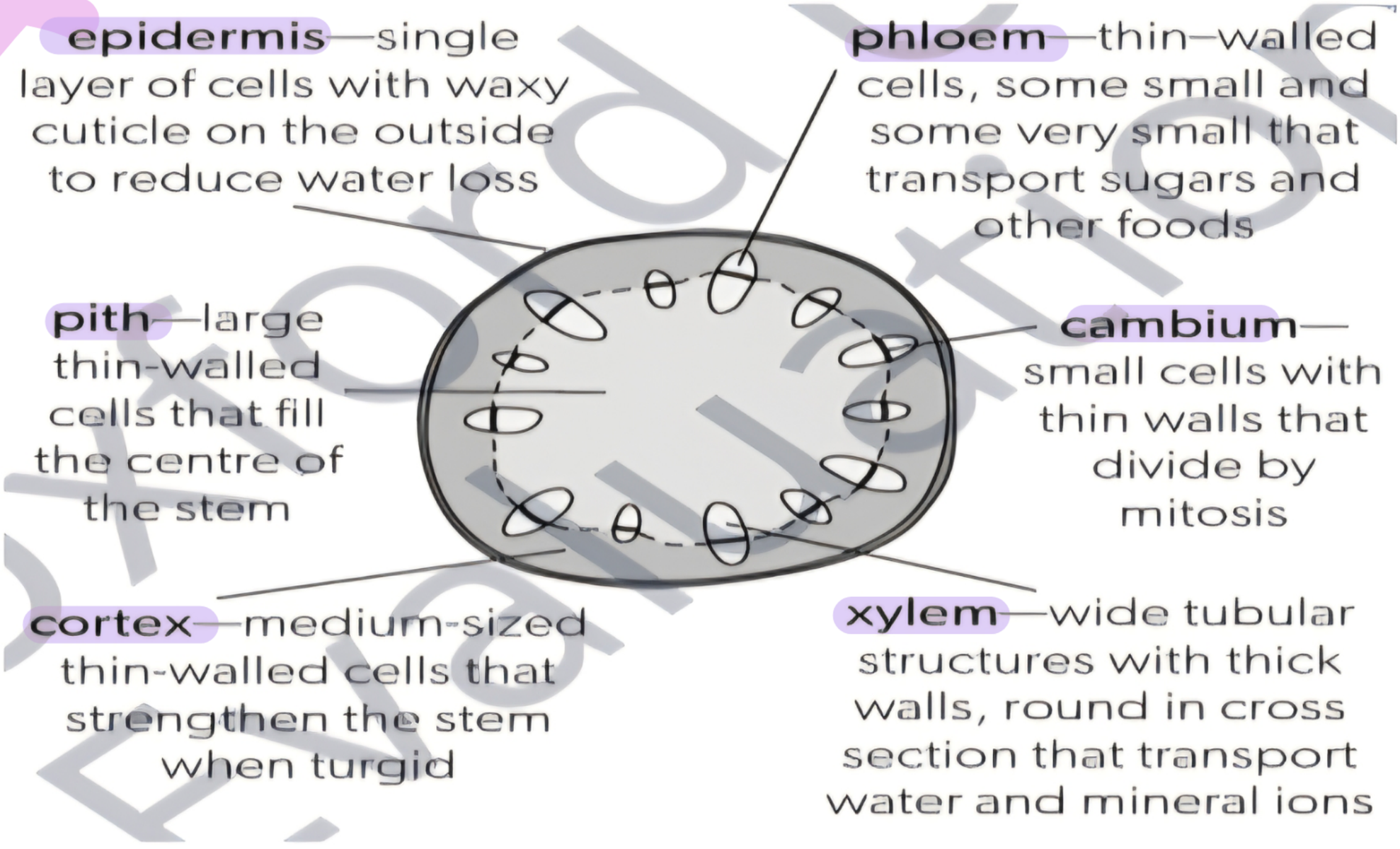
Dicotyledonous plants (dicots) are plants that have two seed leaves (embryo leaves). Their stems have a layered structure with different tissues arranged in a ring.

Stem tissues

Epidermis - the outermost layer. Protects the stem from damage and water loss.

Cortex - the layer just under the epidermis. Made of parenchyma cells. sometimes with supporting fibers. Stores food and helps support the stem.

Vascular bundles - arranged in a ring around the stem. Each bundle has:
Xylem - towards the inside of the stem: transports water and minerals from roots to leaves.
Phloem - towards the outside: transports sugars and nutrients from leaves to other parts of the plant.
Pith - the central region of the stem. Made of parenchyma cells. often stores food. Some stems have a hollow centre instead of pith.



Distribution of tissues in a transverse section of a dicot root

In dicotyledonous roots, the tissues are arranged differently from stems. The vascular tissue is grouped in the centre.

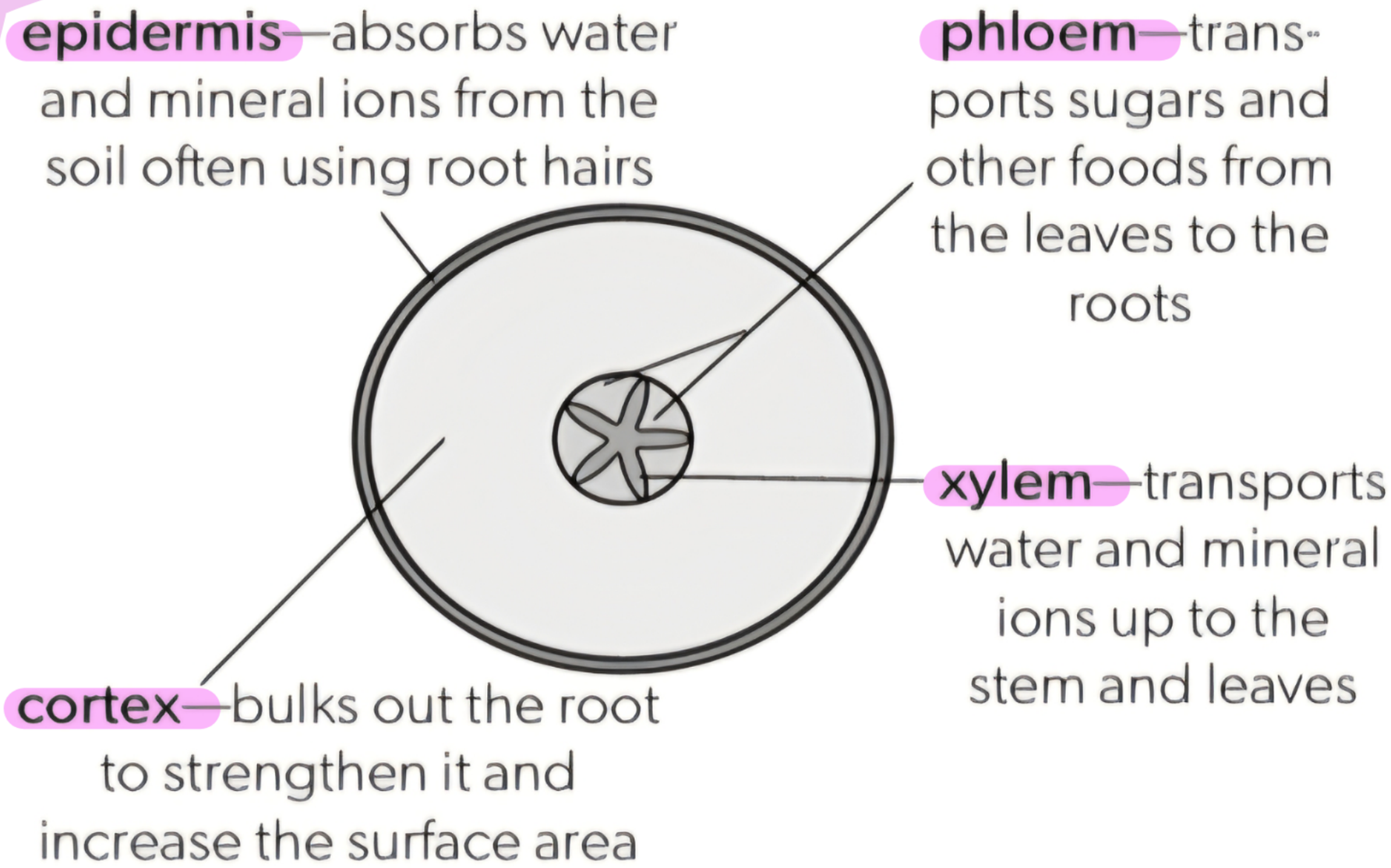
Root tissues

Xylem - forms a star-shaped pattern in the centre of the root. Transports water and minerals from the soil to the rest of the plant.

Phloem - located between the points of the xylem star. Transports sugars and nutrients from the leaves to the root and other parts of the plant.

Cortex - lies between the vascular tissue and the epidermis. Made of large, thin-walled parenchyma cells. Stores food and water.

Epidermis - the outer layer of small cells. Some cells may have root hairs, which increase the surface area for water and mineral absorption.



Release and reuptake of tissue fluid in capillaries

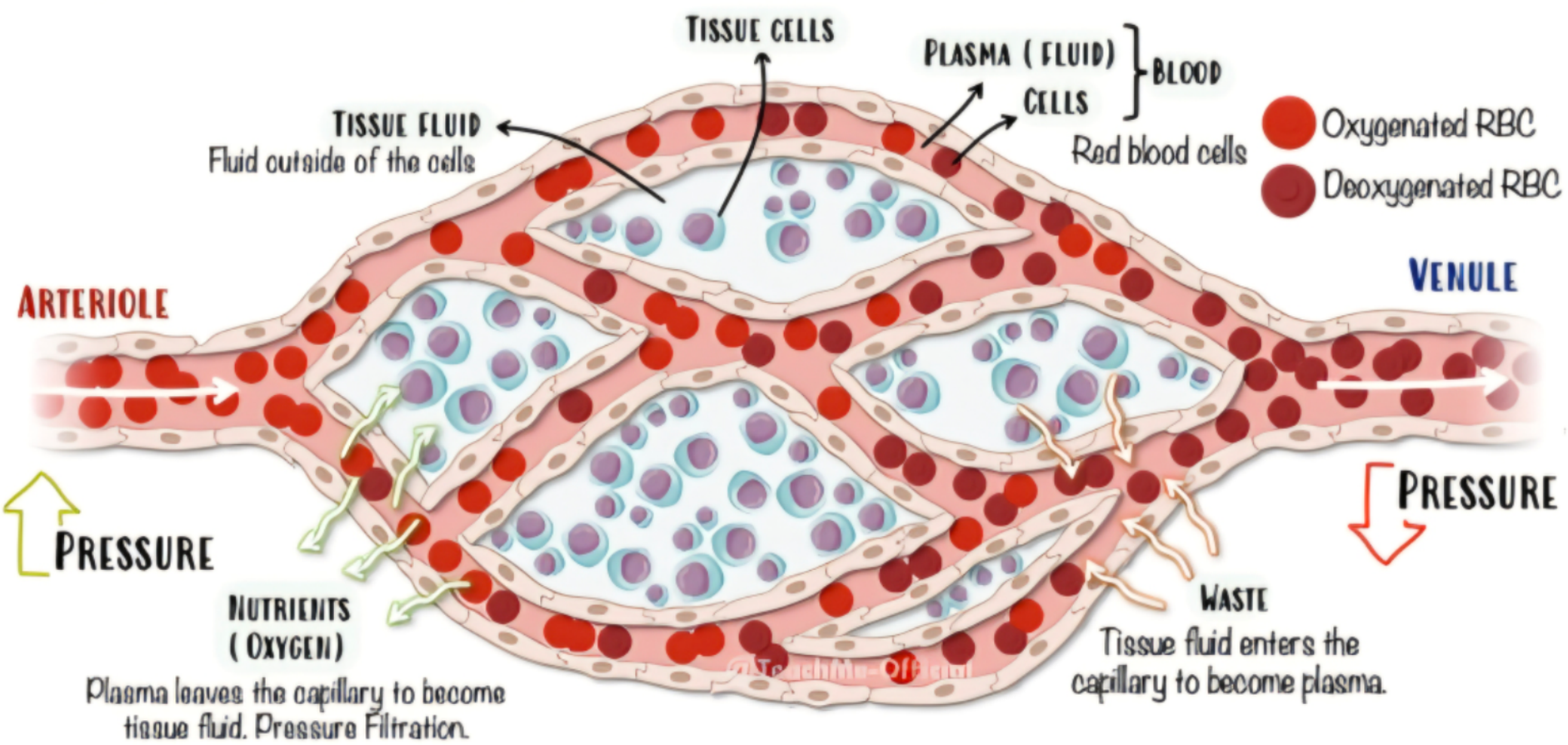
Blood carrying oxygen and nutrients enters capillary networks from arterioles. which are small branches of arteries.

Capillary walls are permeable. and blood pressure at the arterial end is high. This causes some plasma to leak out. forming tissue fluid. This process is called pressure filtration.

At any moment. a human body has about 14 litres of tissue fluid (around 20% of body mass).

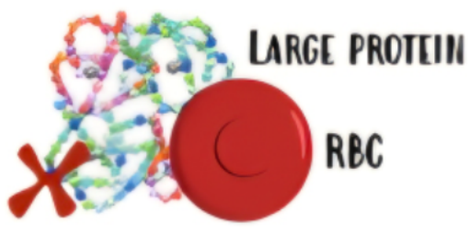
Blood then drains out of capillaries into venules. which are small vessels that join to form veins. Venules have low blood pressure. so the tissue fluid. now depleted of nutrients and oxygen. can re-enter the capillaries. This is how tissue fluid is reabsorbed.

Blood pressure. caused by the heart pumping. is the driving force for tissue fluid movement. Pressure is high at the arterial end of capillaries and drops toward the venous end. allowing filtration at the start and reuptake at the end.



- **Structure** – Very thin and permeable.
- **Purpose** – Site of nutrient exchange.

Red blood cells (**RBC**) & **LARGE PROTEINS** do **NOT** exit the capillaries, because they are too large to exit through the capillary walls. White blood cells (**WBC**) can exit at certain times, such as during an infection





Teach Me

Exchange of substances between tissue fluid and cells

Tissue fluid has oxygen. glucose. and other small substances from blood plasma. but not large proteins.

As tissue fluid moves through the spaces between cells. an exchange of substances happens:

Cells absorb oxygen. glucose. and other useful molecules from the fluid.
Cells release carbon dioxide and other waste products into the fluid.

When tissue fluid re-enters capillaries. it is low in oxygen and nutrients and high in waste products. Capillaries then merge to form venules. which carry these wastes away.

Finally: Carbon dioxide is removed by the lungs and other wastes are processed by the liver or excreted by the kidneys

Drainage of excess tissue fluid into lymph ducts

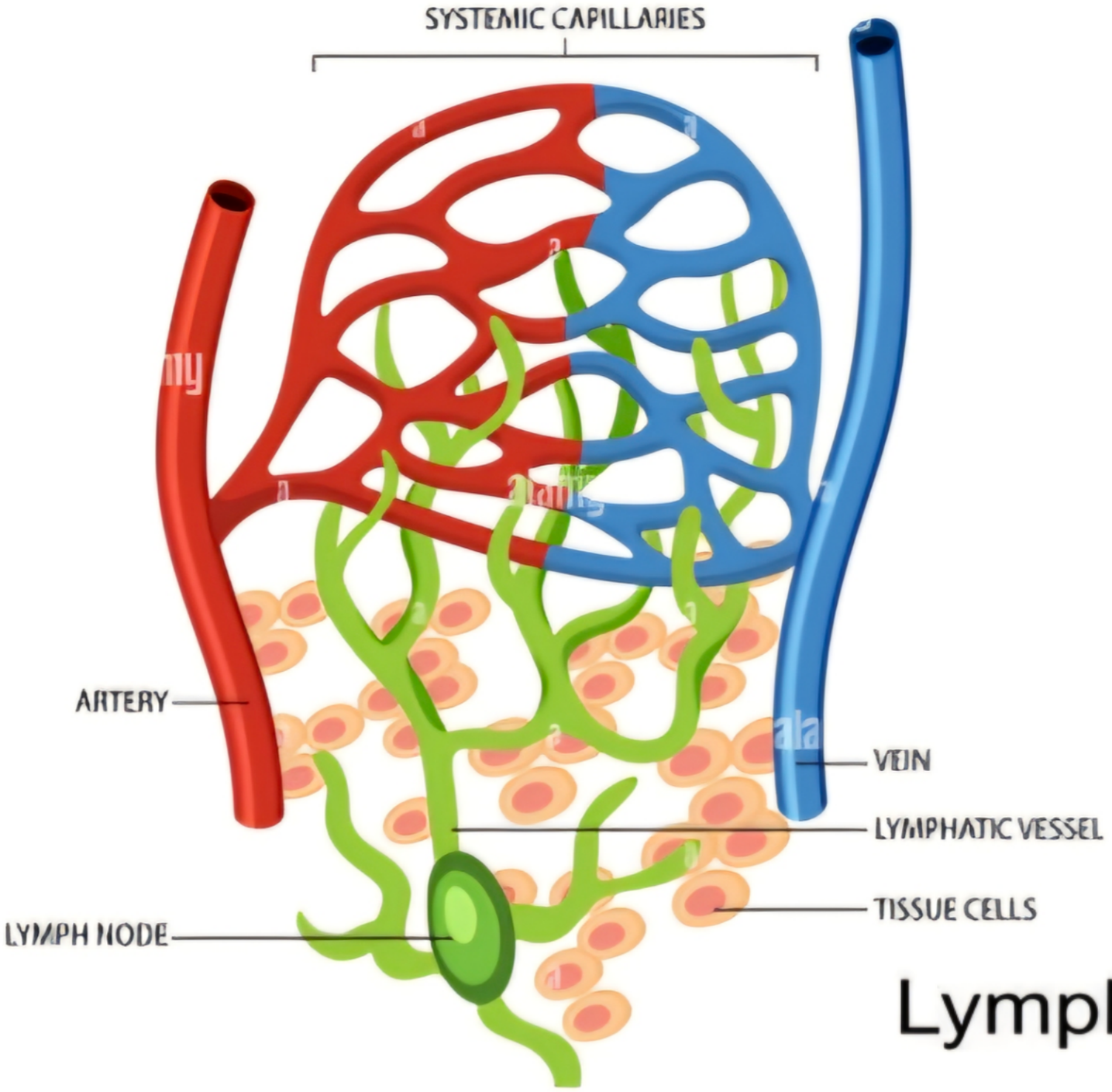
Not all tissue fluid that leaves capillaries returns to them. In an average adult. about 20 litres of tissue fluid are produced daily: 17 litres return to capillaries. but 3 litres do not. If this excess stayed in tissues. it would cause swelling. called oedema.

The body prevents this using the lymphatic system. All tissues have narrow. blind-ended lymphatic vessels with permeable walls. allowing tissue fluid to enter.

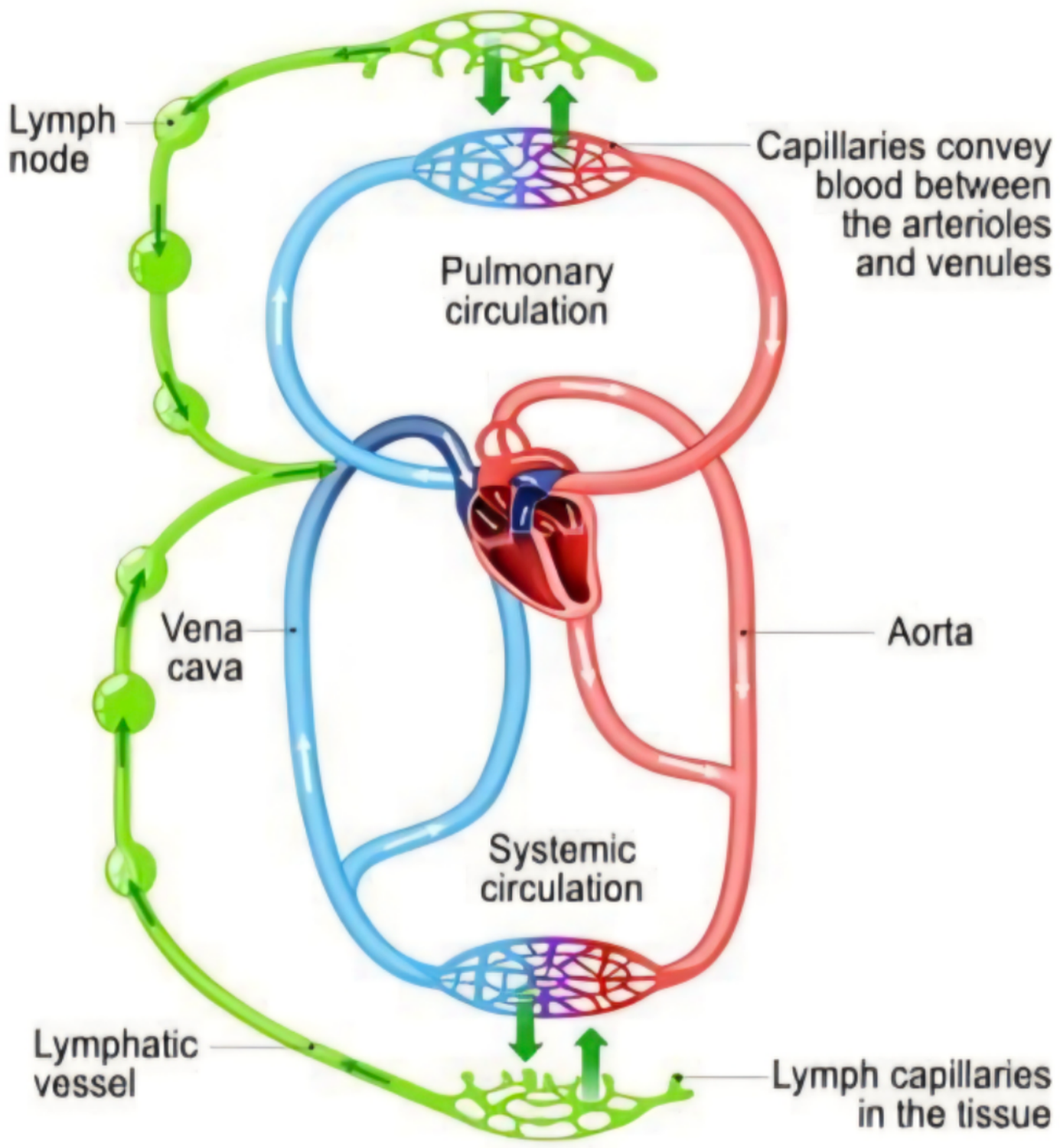
Once inside. the fluid is called lymph. These small lymph vessels join to form larger lymphatic vessels. which have valves to stop backflow.

All lymph eventually drains into the blood circulation through two large lymphatic ducts (left and right). which merge with the left and right subclavian veins. From there. blood flows into the vena cava and reaches the right side of the heart.

LYMPHATIC CIRCULATION



Lymphatic system

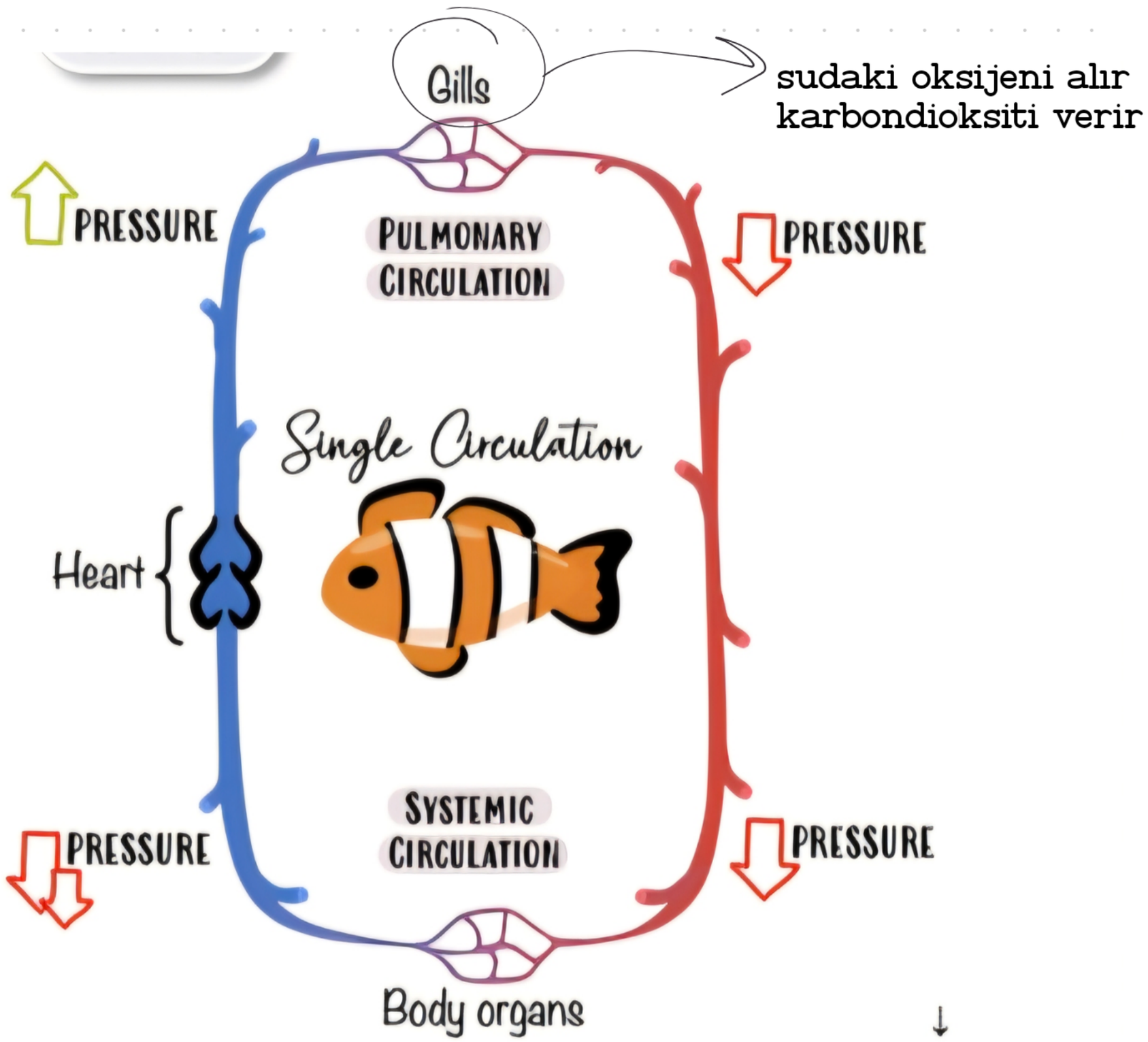


Differences between single circulation in fish and double circulation in mammals

In fish. the heart has one ventricle that pumps deoxygenated blood to the gills (solungaç). The surrounding water supports the gill capillaries. so blood can be pumped at high pressure without damage.

After picking up oxygen in the gills. blood still has enough pressure to flow directly to the body's organs. When blood passes through the organs. it loses oxygen and pressure. so it returns to the heart to be pumped again.

This is called single circulation. because blood passes through the heart only once in a full circuit.



In mammals. the heart has two sides (right and left). each with a ventricle.

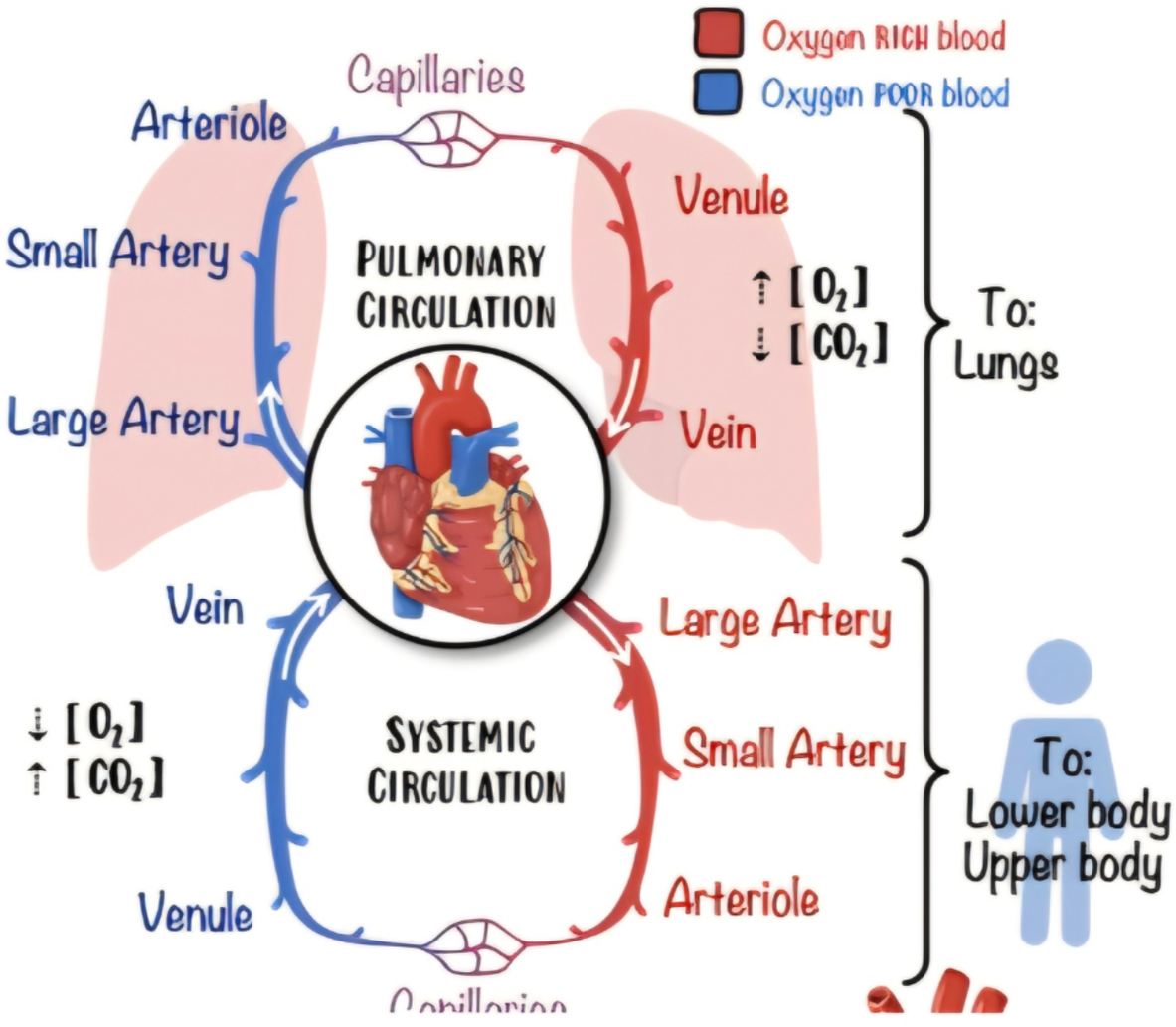
The right ventricle pumps deoxygenated blood to the lungs through the pulmonary arteries. Blood pressure must be low so delicate alveolar capillaries don't burst.

After oxygenation in the lungs. blood returns to the left side of the heart via the pulmonary veins. The left ventricle then pumps oxygenated blood through the aorta to the rest of the body at high pressure. needed for organs like the kidneys that require strong filtration.

After passing through body organs. blood is deoxygenated and low pressure and returns to the right side of the heart to be pumped again to the lungs.

Mammals have double circulation. meaning blood passes through the heart twice for a full circuit. The heart acts as a double pump. giving different pressures to the lungs and body.

These two circuits are called:
Pulmonary circulation → heart to lungs and back
Systemic circulation → heart to body and back



Fish: single circulation. one ventricle. blood passes through heart once

Mammals: double circulation. two ventricles. blood passes through heart twice

Pressure differences allow lungs to avoid damage and organs like kidneys to get high-pressure blood

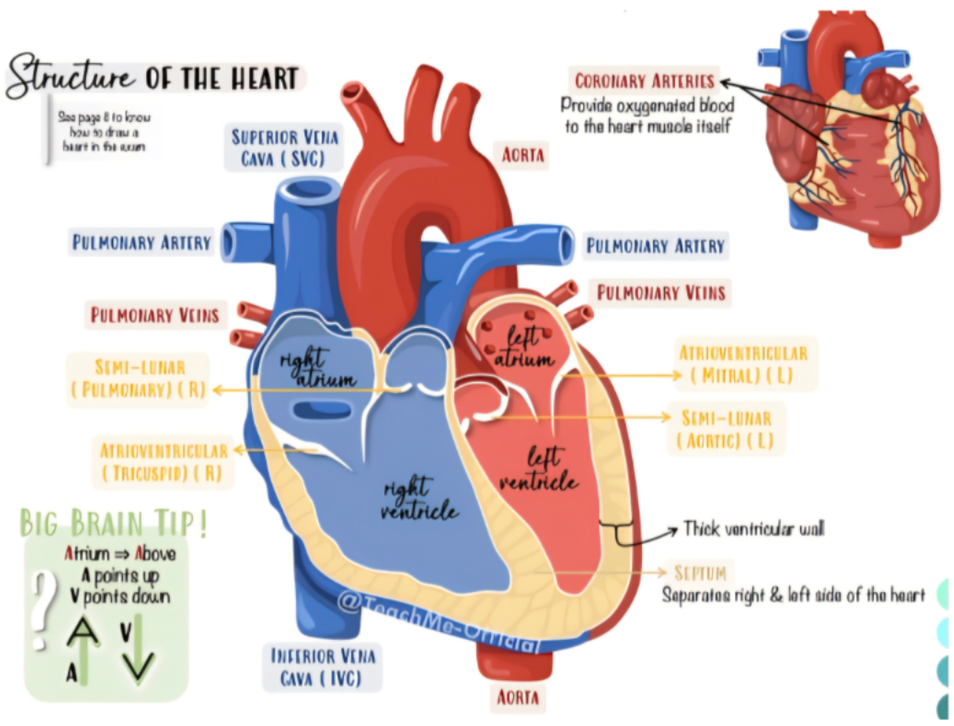
- The **left** side of the heart pumps *oxygenated* blood around the **body** (*systemic circulation*)
- The **right** side of the heart pumps *deoxygenated* blood to the **lungs** (*pulmonary circulation*)

Adaptations of the mammalian heart for delivering pressurized blood

The mammalian heart is built to pump blood efficiently and under pressure. Each part has a special role:

Atria are collecting chambers with thin walls. They slowly fill with blood coming back from veins and then push it into the ventricles.
Ventricles are the pumping chambers with thick muscular walls. They generate enough force to send blood into the arteries.
Septum is the wall between the left and right sides of the heart. It ensures the heart works as a double pump and keeps oxygenated and deoxygenated blood from mixing.

Valves: Atrioventricular valves between atria and ventricles
Semilunar valves between ventricles and arteries
These prevent backflow and make blood move in one direction.
Cardiac muscle can contract on its own without a nerve signal. a property called myogenic contraction. keeping the heartbeat regular.
Coronary vessels are capillaries in the heart wall that supply oxygen and glucose for energy and remove waste products. Coronary arteries bring blood in. and coronary veins take it away.
Pacemaker is a region of specialized muscle cells in the right atrium that starts each contraction. setting the heartbeat.



Blood returns to the **atria**, which slowly fill and push blood into the **ventricles**. Ventricles pump blood hard into the **arteries**. The **septum** keeps oxygen-rich and oxygen-poor blood separate. **Valves** stop blood from flowing backward. The heart muscle **contracts by itself** thanks to its **myogenic property**. **Coronary vessels** feed the heart, and the **pacemaker** sets the rhythm of each beat.

Key idea

- **Atria** → collect blood
- **Ventricles** → pump blood under pressure
- **Septum** → separates sides
- **Valves** → prevent backflow
- **Cardiac muscle** → myogenic contraction
- **Coronary vessels** → supply the heart itself
- **Pacemaker** → controls heartbeat rhythm

Stages in the cardiac cycle

The cardiac cycle is the repeated sequence of events in the heart that pumps blood. It happens in three main stages:
Atrial contraction:

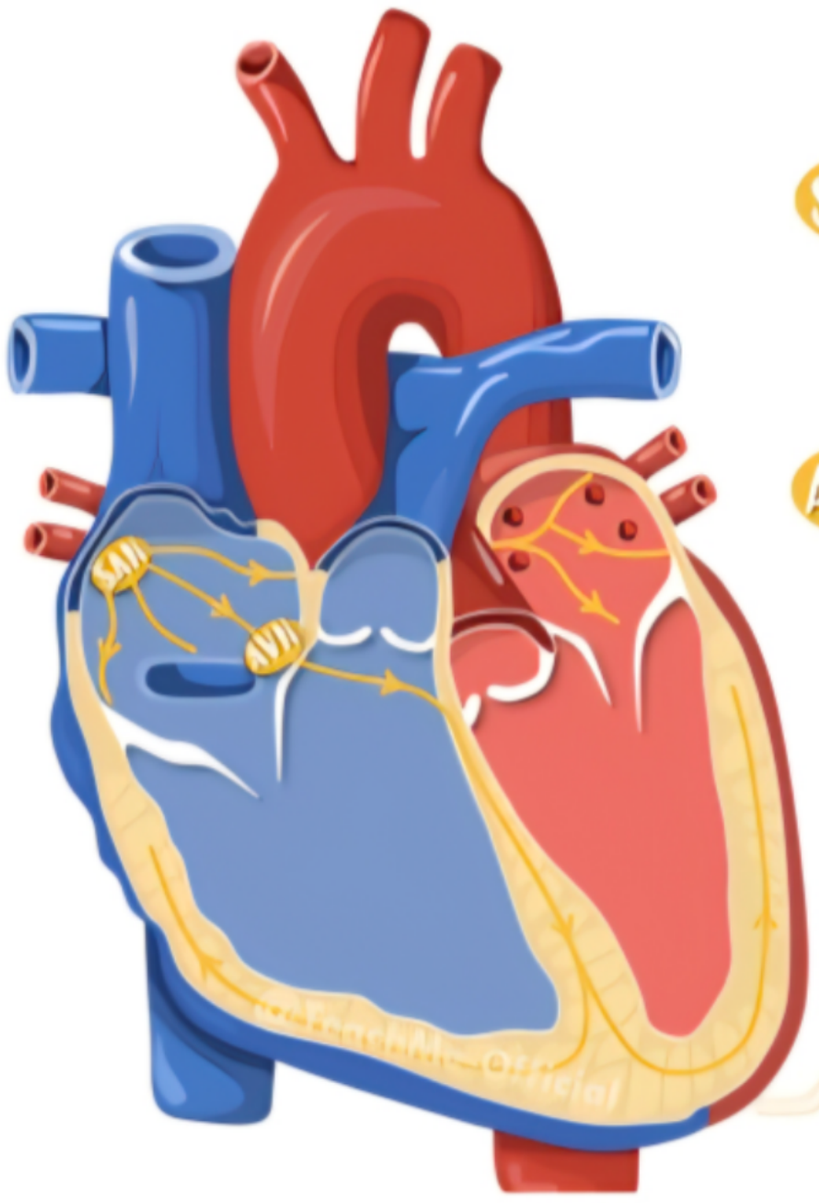
The atria walls contract. pushing blood into the ventricles through the atrioventricular (AV) valves. which are open. At this time. the semilunar valves are closed. so the ventricles fill with blood.

Ventricular contraction:
The ventricles contract strongly. causing blood pressure inside them to rise. This closes the AV valves. stopping blood from flowing back into the atria. and opens the semilunar valves. letting blood flow into the arteries. While this happens. the atria start filling again with blood from the veins.

Ventricular relaxation:
The ventricles stop contracting. so pressure drops. The semilunar valves close. preventing blood from flowing back from the arteries. When ventricular pressure falls below atrial pressure. the AV valves open. and blood flows from the atria into the ventricles. starting the next cycle.
How the heartbeat is controlled
Each heartbeat starts at the sinoatrial (SA) node or pacemaker. which sends an electrical impulse across the atrial walls. causing the atria to contract.
The impulse cannot go directly to the ventricles because of a fibrous tissue barrier. Instead. it travels to the ventricles through a second node and a bundle of conducting fibres that lead to the base of the ventricles. This delay allows atria to empty fully into the ventricles before they contract.
The impulse then spreads upwards from the base of the ventricles. making the ventricles contract and pump blood into the arteries.

Simple story version

Atria push blood into ventricles → ventricles squeeze and push blood into arteries → ventricles relax. valves reset → atria fill again. SA node starts the beat. impulse goes to ventricles with a delay → ventricles contract from base upwards → blood flows smoothly.
Key idea
Atrial contraction → fills ventricles
Ventricular contraction → pumps blood into arteries
Ventricular relaxation → valves reset. ventricles refill
SA node/pacemaker → controls heartbeat
Impulse delay → atria empty fully before ventricles contract



THE *Control* OF THE HEART BEAT

SAN SinoAtrial Node

A group of modified cardiac muscles located in the thin muscle wall of the right atrium that can generate **SPONTANEOUS** electrical impulse to start each heartbeat (myogenic).

AVN AtrioVentricular Node ⏰

Located in the right atrium, in the septum between the right and left atria.

ACTION POTENTIALS are sent from the SA node (SAN) and result in the almost instantaneous contraction of the atrias. These action potentials also reach the AV node (AVN) but this node **DELAYS** by **0.1** seconds the impulse before sending out the action potentials to the ventricles and causing them to contract. This mechanism ensure that both atrias contract **BEFORE** the ventricles.

Ensures blood flows in ONE direction!

BLOOD PRESSURE MEASUREMENT

Blood pressure (pressure inside the arteries) is measured using a machine with a cuff around the arm.

You may have seen blood pressure as:



120 / 80 mmHg

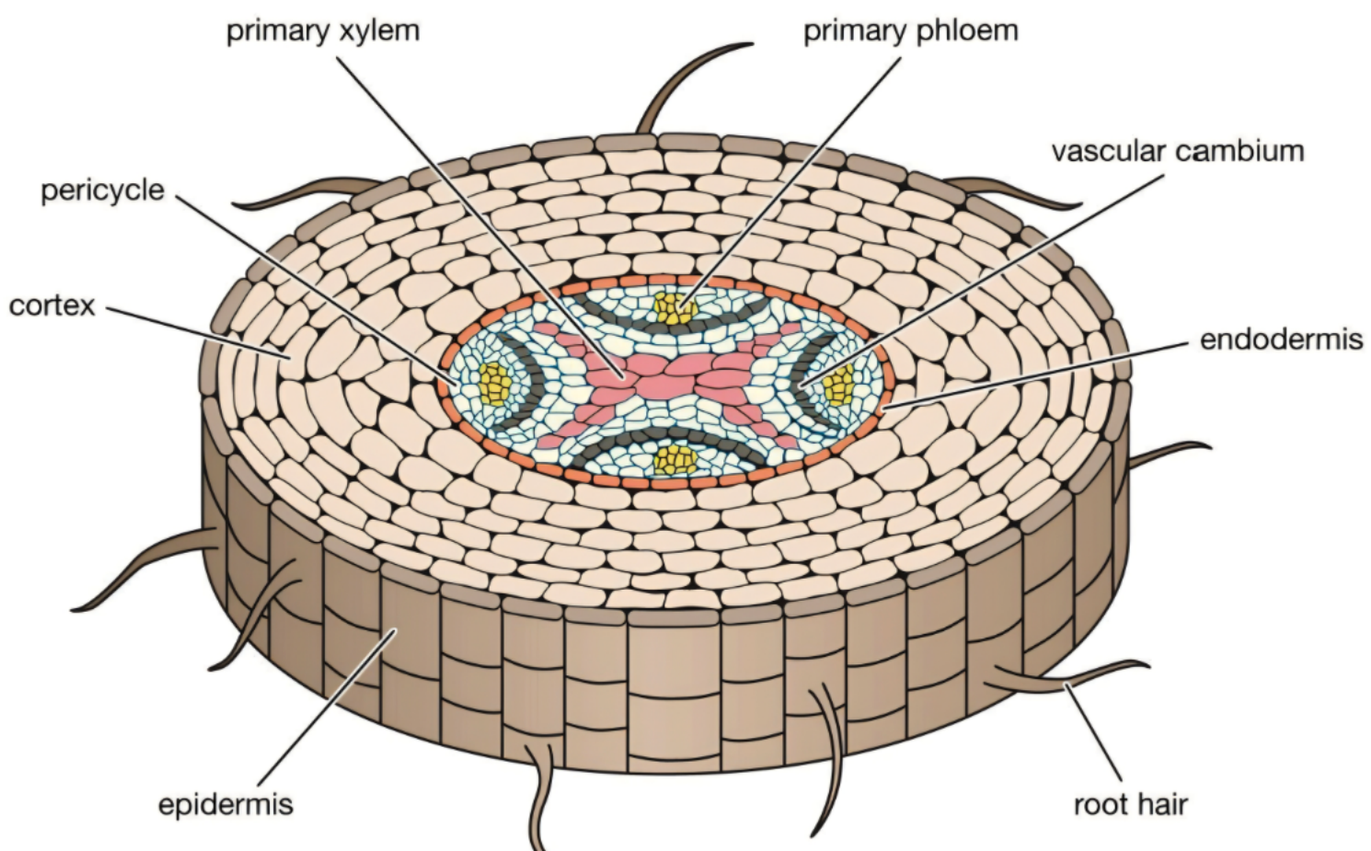
- **Systolic blood pressure** (active period of the ventricles)
- **Diastolic blood pressure** (rest period of the ventricles)
- **Millimeters of mercury** (the units)

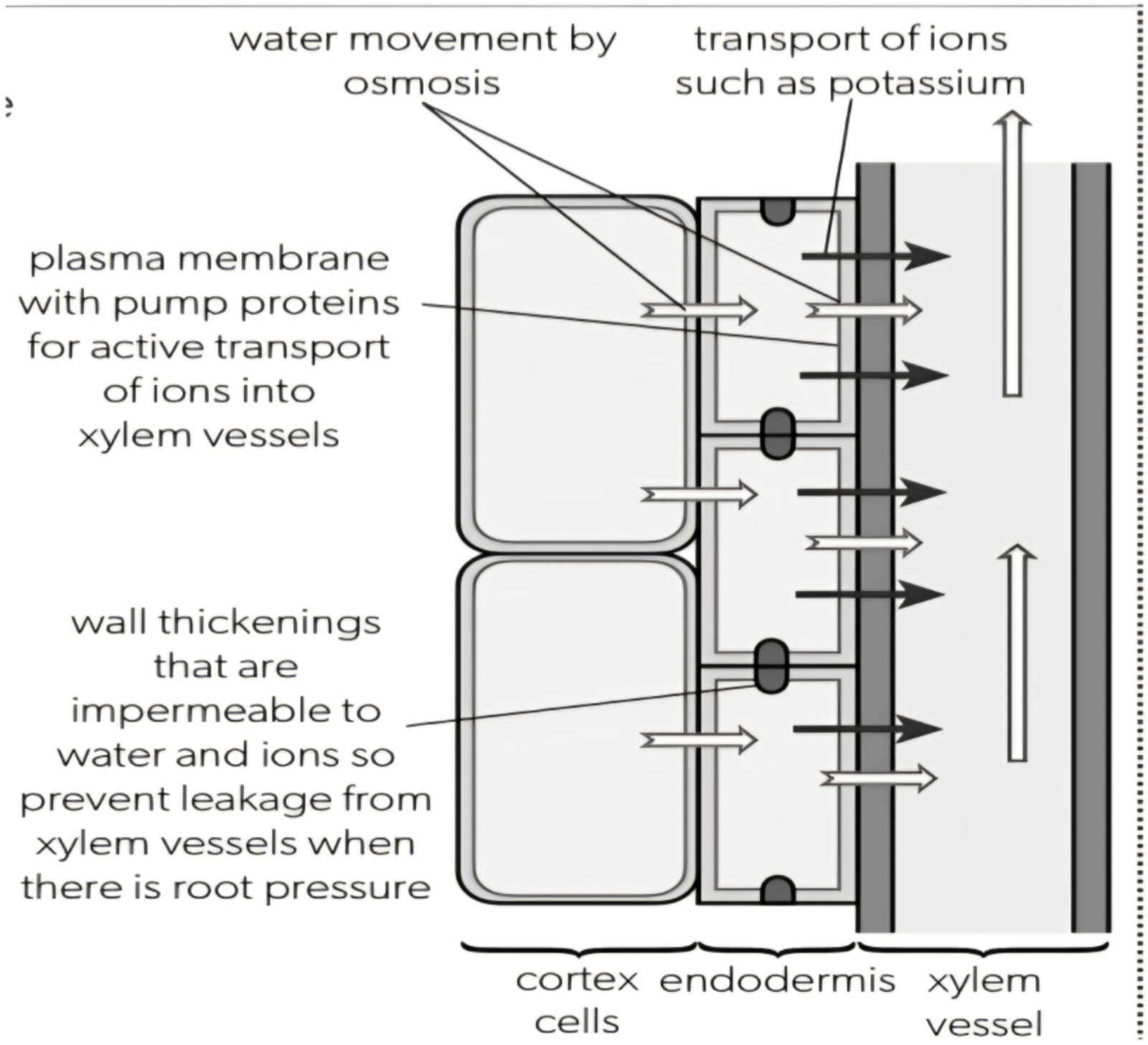
SYSTOLE - A name given to the active process (contraction) of a chamber

DIASTOLE - A name given to the inactive process (resting) of a chamber

Generation of root pressure in xylem vessels
Roots have root hairs that absorb water and minerals from the soil.
These absorbed substances travel to the xylem in two ways:
Between cells - water and minerals move through spaces outside cell walls without entering the cells.
Through cells - water and minerals pass from cell to cell via cytoplasmic connections.
Mineral ions in root hairs are more concentrated than in the soil. so roots use active transport to take them in.
Because of the higher mineral concentration in root cells. the water concentration in root cells is lower than in the soil. creating osmotic pressure. This osmotic pressure generates root pressure. which pushes water upwards from the roots into the xylem and up the stem.

Key idea
Root hairs → absorb water & minerals
Two pathways → between cells or through cells
Active transport → minerals enter root hairs
Osmosis → water moves into root cells
Root pressure → pushes water upward in xylem





Adaptations of phloem sieve tubes and companion cells for translocation

Plants move carbon compounds like sucrose using phloem tissue. This movement is called translocation and goes from sources to sinks.

Sources = places where sucrose is made or released (e.g. leaves. stems. storage organs releasing stores)

Sinks = places that need or store sucrose (e.g. roots. growing tissues. storage organs)

Sieve tubes

Phloem sieve tubes are formed from columns of cells joined end-to-end. During development:

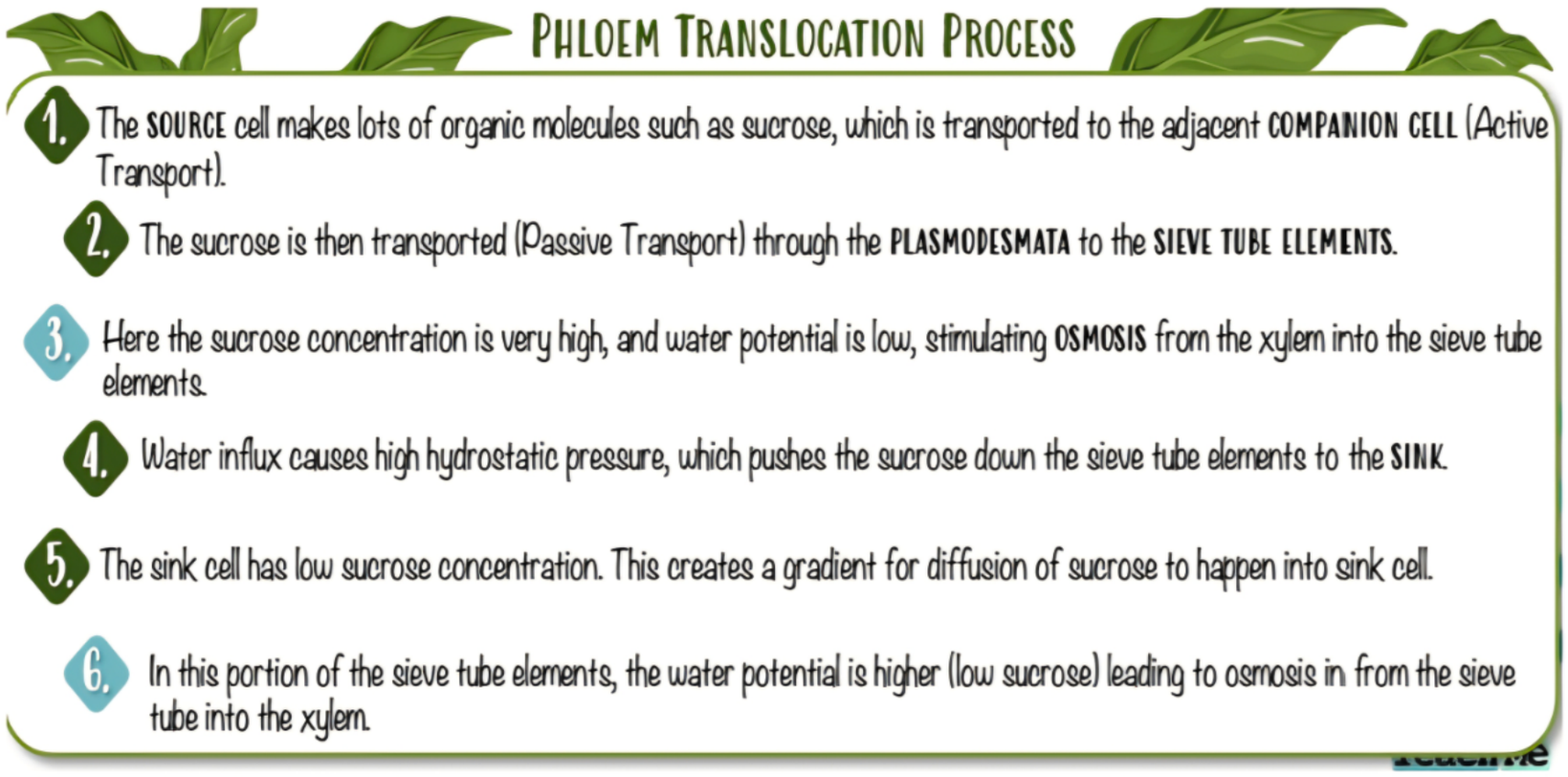
They lose their nucleus and most organelles. but stay alive

They keep a plasma membrane for active transport

The end walls are not fully removed. Instead. they form sieve plates with large pores. These pores allow sap (sucrose-rich fluid) to flow along the tube.

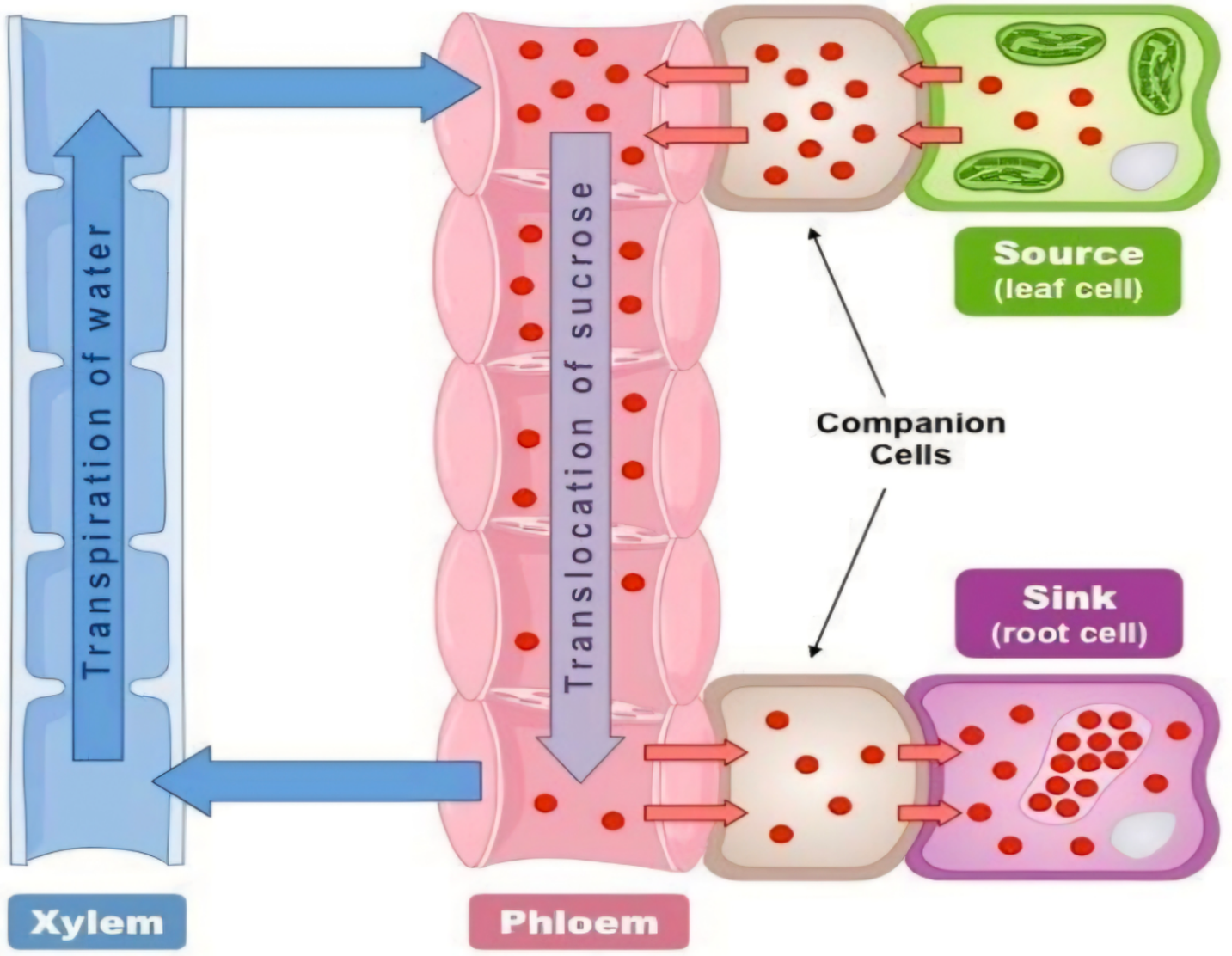
Because the end walls are still partly there. sieve plates act like cross-braces. helping the tube resist high pressure during translocation.

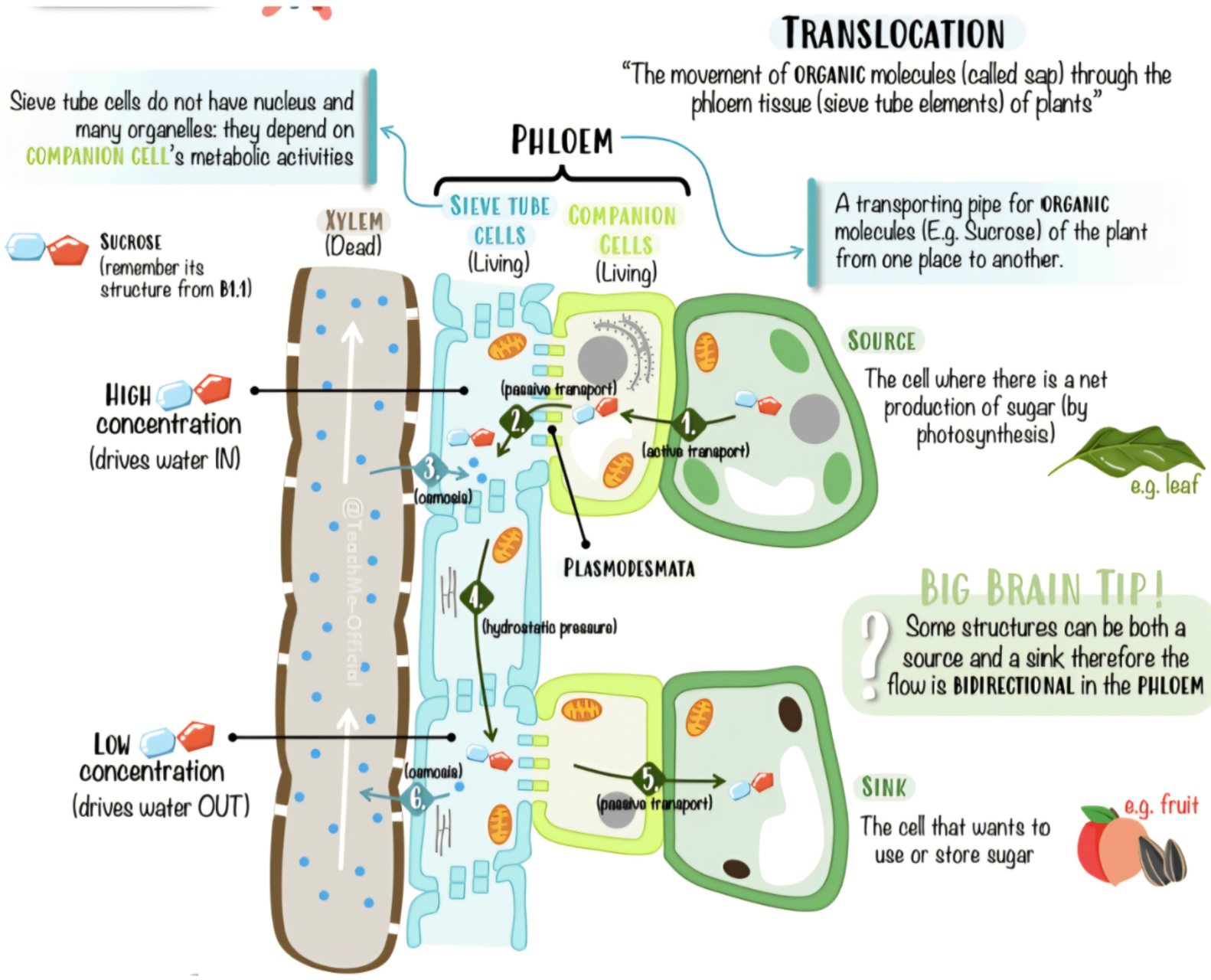
Companion cells
Next to each sieve tube are companion cells. which control and support it.
They are adapted for active transport:
Have many pump proteins in the plasma membrane → move sucrose into the cell
Have many mitochondria → produce ATP for active transport
Sucrose then moves from the companion cell into the sieve tube through plasmodesmata (cytoplasmic connections). This loads the sieve tube with sucrose-rich sap.

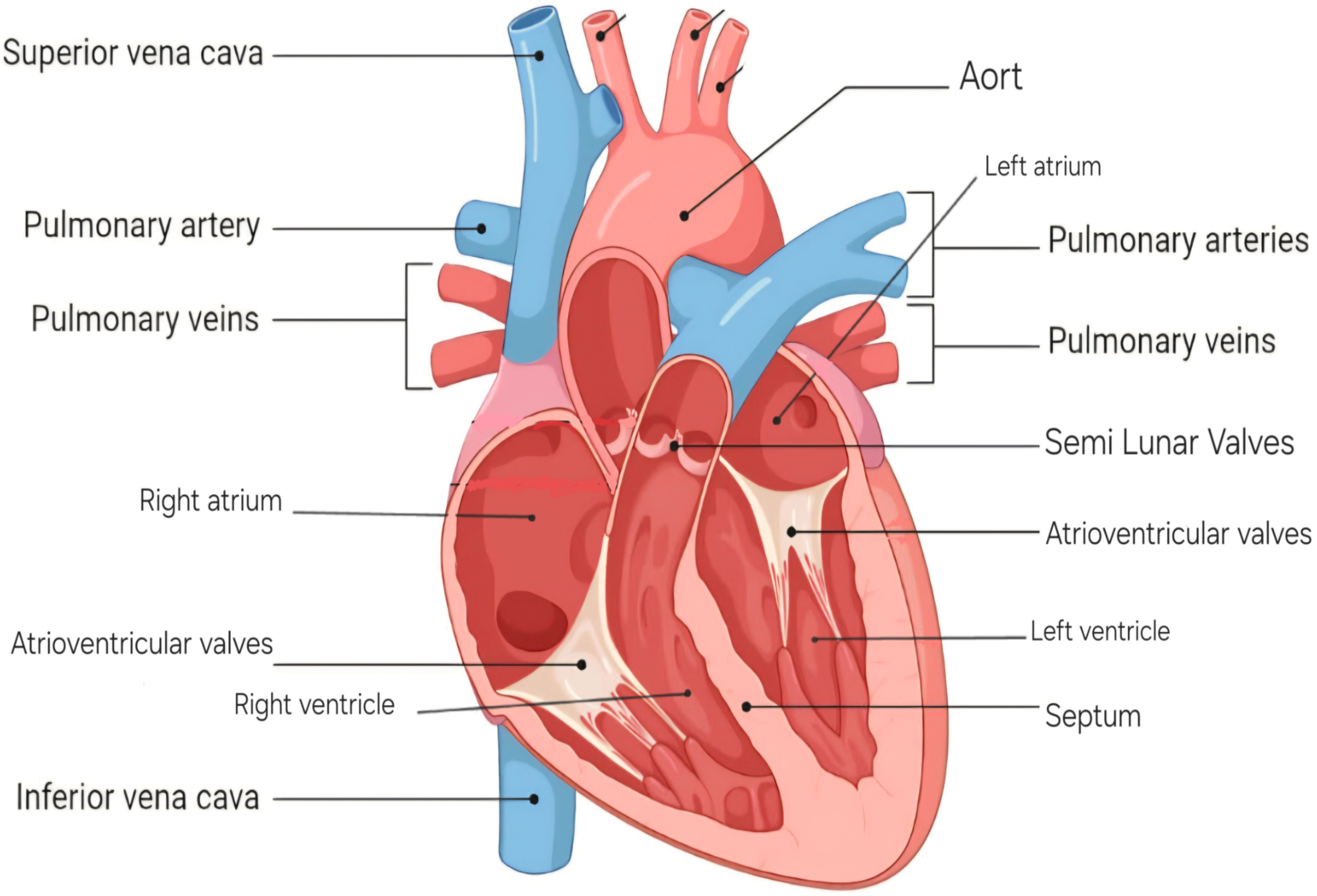


Phloem transports sucrose (translocation) from sources to sinks
Sieve tubes → living. no nucleus. have sieve plates for flow and strength
Companion cells → many mitochondria + pump proteins → active loading
Plasmodesmata → connect cells and allow sucrose transfer

	XYLEM	VS.	PHLOEM
Made of...	Dead (non-living) Cells		Living cells
Transports...	Water & Minerals		Food (organic things)
Carried to...	Leaves from root		Sink from source
Direction...	Upwards (Unidirectional)		Up and down (Bidirectional)


Transpiration of water
Translocation of sucrose
Source
(leaf cell)
Companion
Cells
Sink
(root cell)
Xylem
Phloem


TRANSLOCATION
"The movement of ORGANIC molecules (called sap) through the phloem tissue (sieve tube elements) of plants"
Sieve tube cells do not have nucleus and many organelles: they depend on COMPANION CELL's metabolic activities
PHLOEM
SIEVE TUBE CELLS (Living)
COMPANION CELLS (Living)
A transporting pipe for ORGANIC molecules (E.g. Sucrose) of the plant from one place to another.
XYLEM (Dead)
SUCROSE (remember its structure from B1.1)
HIGH concentration (drives water IN)
(passive transport)
(active transport)
(osmosis)
PLASMODESMATA
(hydrostatic pressure)
LOW concentration (drives water OUT)
(osmosis)
(passive transport)
SOURCE
The cell where there is a net production of sugar (by photosynthesis)
e.g. leaf
BIG BRAIN TIP!
Some structures can be both a source and a sink therefore the flow is BIDIRECTIONAL in the PHLOEM
SINK
The cell that wants to use or store sugar
e.g. fruit
@TeachMe_Official


Superior vena cava
Aort
Left atrium
Pulmonary artery
Pulmonary arteries
Pulmonary veins
Pulmonary veins
Semi Lunar Valves
Right atrium
Atrioventricular valves
Atrioventricular valves
Left ventricle
Right ventricle
Septum
Inferior vena cava

Chemical Signaling

• Autoinducers are signaling molecules that enable bacteria to regulate collective gene expression by sensing cell density.

1-) Vibri fischeri bacterias produce the auto inducer inside the cell.

2-) Vibrio fischeri releoses outo inducers outside the cell.

3-) Auto inducers accumulate in the environment.

4-) When the number of autoinducer molecules reach a threshold level, they re-enter the Vibrio fischer's cytoplasm.

5-) Autoinducers bind to Lux-R (receptor) in the cytoplasm.

6-) Initiates gene expression.

"Neuron signaling is faster than chemical signaling."

"Chemical signaling's persisting time is longer than neuron signaling."

Receptors as proteins with binding sites for specific signalling chemicals

• Cells communicate with each other using signals, which can be chemical or electrical.

• In chemical signalling, one cell produces signalling molecules that move to another cell called the target cell.

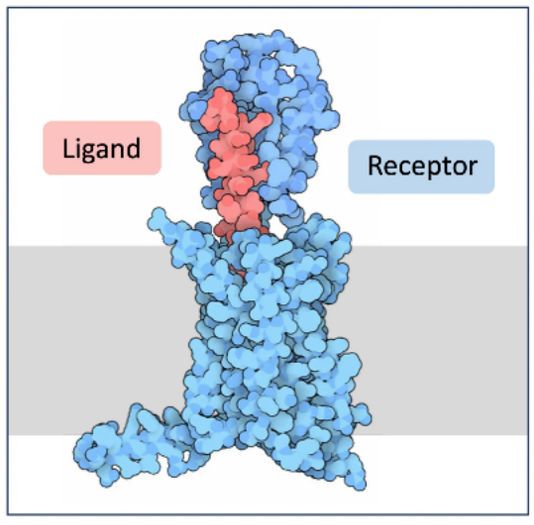
• The target cell has receptors, which are specific protein molecules. A receptor allows the cell to detect a signal and respond to it.

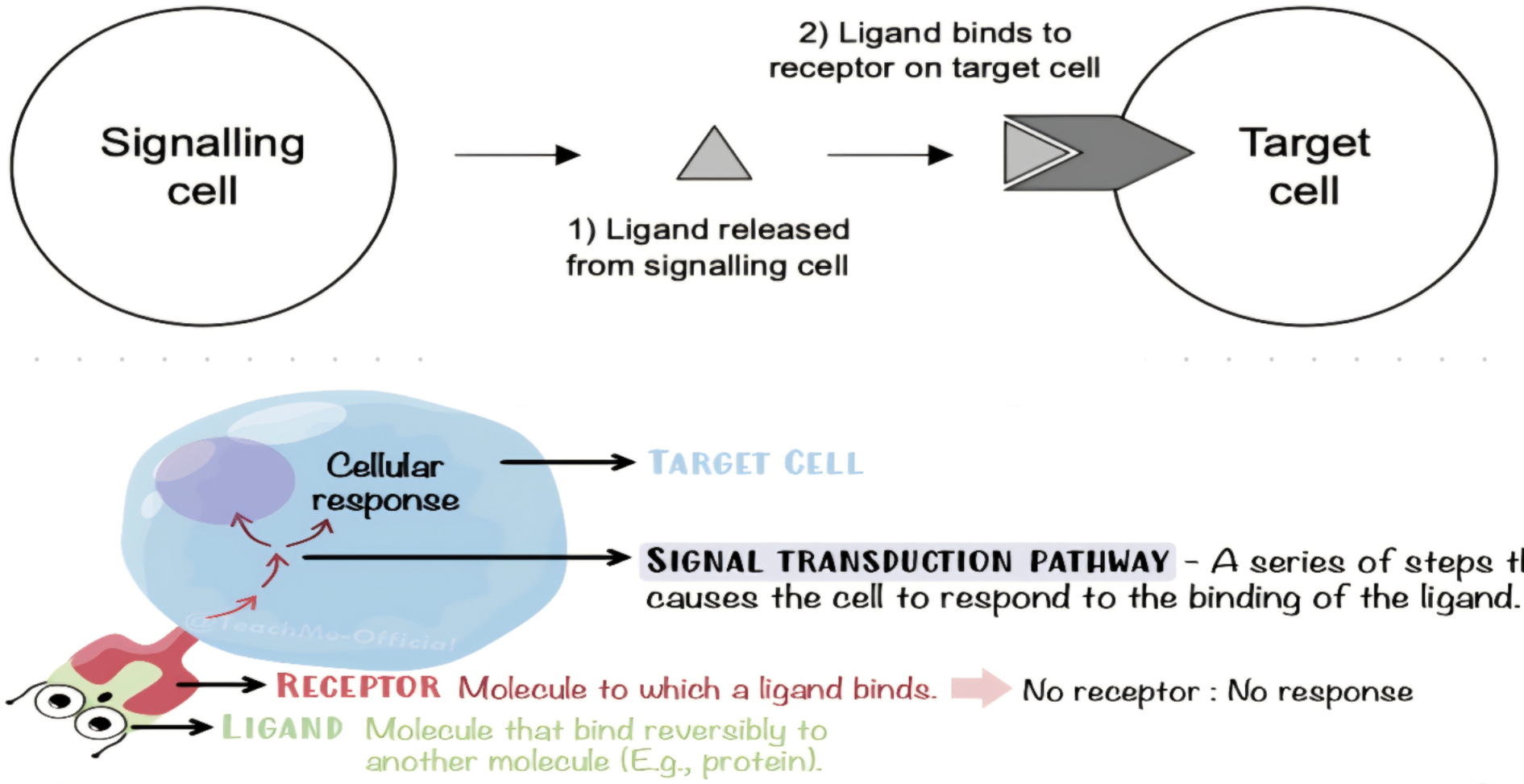
• When a signalling molecule binds to its receptor, the receptor initiates changes inside the target cell. A molecule that binds to a receptor is called a ligand.

• Each receptor has a ligand–binding site, which is the specific region where the ligand binds.

• Binding is specific: only the correct ligand can bind to its receptor.

• This specificity is similar to enzyme–substrate specificity, where only a specific substrate fits into an enzyme's active site.





Cell signalling by bacteria in quorum sensing

• Unicellular organisms, such as bacteria, can communicate using chemical signals. This communication allows bacteria to adjust their activity according to population density. Each bacterial cell secretes a chemical signal at a low, constant rate. The signal diffuses freely between cells. Each cell has receptors that can bind to the signalling molecule.

• Quorum sensing is an intercellular communication mechanism in which bacteria detect population density and collectively regulate gene expression. In simple terms, it answers the question: “Are there enough of us to act together?”

• Example: Vibrio fischeri and bioluminescence
• Vibrio fischeri secretes a signalling molecule called an autoinducer. The autoinducer diffuses freely between cells and enters the cytoplasm. It binds to a receptor protein called LuxR. The LuxR–autoinducer complex binds to a specific region of DNA.

• This binding induces transcription of genes that code for luciferase. Luciferase catalyses an oxidation reaction that releases energy as greenish–blue light (bioluminescence). At low population density, the autoinducer concentration is low, so light is not produced. Producing light at low density would waste energy and be ineffective.

• Mutualism with the bobtail squid
• Vibrio fischeri lives at high population density in the squid’s light organ. High density leads to a high autoinducer concentration, so bioluminescence is induced. The light helps camouflage the squid in moonlight, reducing predation. The squid supplies the bacteria with sugars and amino acids.

•This shows interaction, because signalling molecules pass between cells, and interdependence, because bacteria cannot act effectively as individual cells.

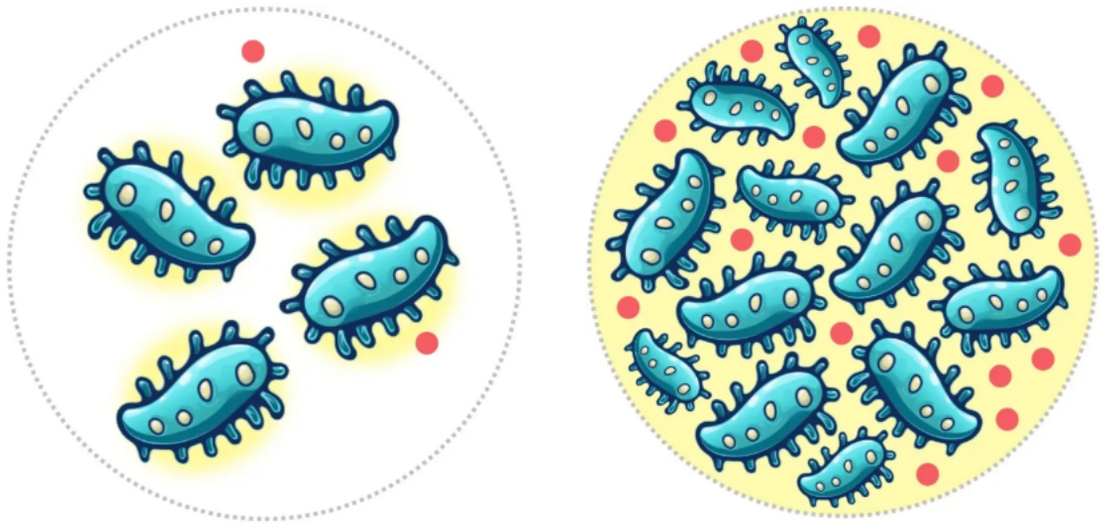
Quorum sensing is a communication system used by bacteria to coordinate their behavior based on population density.
Individual bacteria release small signaling molecules called autoinducers into the environment.
As the bacterial population increases, the concentration of autoinducers increases.
When the concentration reaches a threshold level, the molecules bind to specific receptors in the bacteria.
This binding activates or represses gene transcription.
As a result, the whole bacterial population changes behavior simultaneously.

Autoinducers are small signaling molecules released by bacteria during quorum sensing.
Key features:
produced continuously by bacterial cells
diffuse into the surrounding environment
their concentration reflects cell density
When autoinducers reach a threshold concentration, they bind to regulatory proteins, which then activate specific genes.
Thus autoinducers act as chemical messengers between bacterial cells.

Vibrio fischeri is a marine bacterium commonly used as an example of quorum sensing.
It lives symbiotically in the light organ of certain squid and fish.
When the population density is low:
little autoinducer is present
genes for light production are not expressed
When population density increases:
Autoinducers accumulate.
They bind to the LuxR regulatory protein.
This activates the lux operon.
Genes responsible for light production are transcribed.
This leads to bioluminescence.

Bioluminescence is the production of visible light by living organisms through a biochemical reaction.
In Vibrio fischeri, the reaction involves:
the enzyme luciferase
a substrate called luciferin
oxygen.
Reaction:
luciferin + O_2 → oxyluciferin + light
The emitted light helps the host organism (e.g. squid) with camouflage or communication.

Quorum Sensing in Bacteria



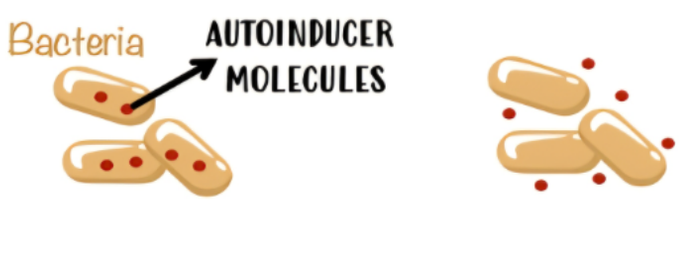
Low Density

High Density

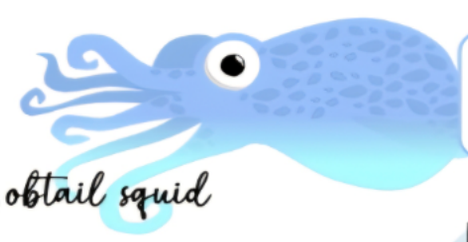
QUORUM SENSING

Mechanism by which bacteria can alter group behavior depending on population density. Examples are bioluminescence, virulence...

Bioluminescence: refers to the production of light by an organism







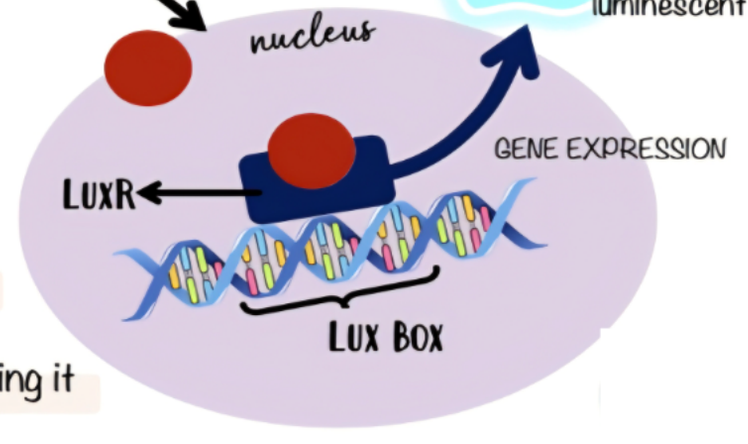
Bacteria is consumed by the squid and provides a safe environment for it to proliferate and grow

Mutualism (symbiotic relationship) between the squid and the bacteria

Protects squid against predators as they get perceived as sunlight

LUCIFERASE
luminescent protein

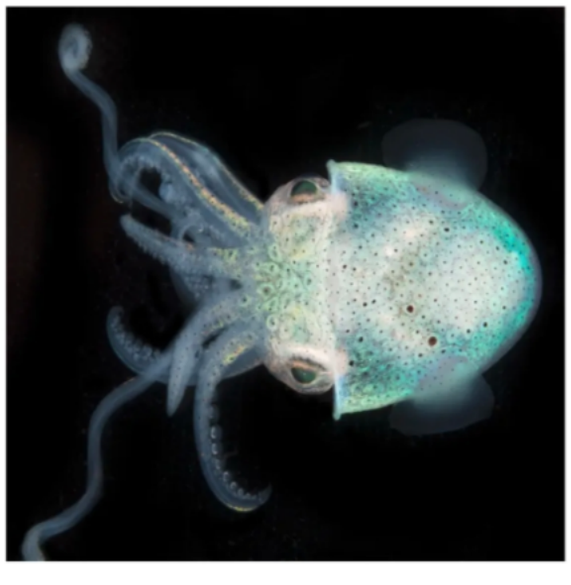
- During the reproductive cycle of the *V. fischeri* bacteria, they produce **AUTOINDUCER MOLECULES.**
- As the number of these bacteria increases, the concentration of autoinducer molecules increases in the surroundings.
- When the number of autoinducer molecules reach a threshold level, the move into the bacteria and bind to an intracellular receptor: **LUXR.**
- The bounded receptor then bonds to a DNA binding site called a **LUX BOX**, activating it and thus causing the production of a luminescent protein: **LUCIFERASE.**



Bioluminescence Example



Vibrio fischeri



Bobtail squid

Functional categories of signalling chemicals in animals

• Animal cells use different categories of signalling chemicals with different speed, distance, and duration of effects.

1. Hormones: Produced by specialized cells in glands.

• Glands are endocrine (ductless) and secrete hormones directly into blood capillaries. Transported by the blood to all parts of the body (may take up to about 1 minute).

• Bind to receptors inside the cell or on the cell surface. Trigger changes in cell activity by promoting or inhibiting specific processes.

• Persist for minutes or hours, so effects are long–lasting. May target one or multiple cell types, in one or multiple body regions. Therefore, one hormone can have complex and widespread effects.

• Examples: insulin, thyroxine, testosterone.

2. Neurotransmitters: Transmit signals across synapses (junctions between neurons). Released when a nerve impulse reaches the end of a presynaptic neuron.

• Diffuse across a very narrow synaptic gap in 0.5–1.0 ms. Bind to receptors in the plasma membrane of the postsynaptic neuron. Can excite or inhibit transmission of a new impulse.

• Persist only for a fraction of a second, so effects are short–lived. Usually act on one specific postsynaptic neuron only (do not diffuse away).

• Examples: acetylcholine, norepinephrine, dopamine.

3. Cytokines: A group of small protein signalling molecules. Secreted by a wide range of cell types. One cytokine can be produced by different cell types.

• One cell type can produce several cytokines. Usually act on the same cell (autocrine) or a nearby cell (paracrine). Do not enter cells; bind to receptors in the plasma membrane.

• Binding triggers intracellular signalling cascades, leading to changes in gene expression and cell activity. One cytokine can bind to multiple receptor types, causing multiple effects.

• Important in inflammation, immune responses, cell growth and proliferation, and embryonic development.

• Examples: erythropoietin (EPO), interferon, interleukin.

Receptors...

Molecules (proteins) to which a ligand binds. Complementary. Binding cause the receptor shape change

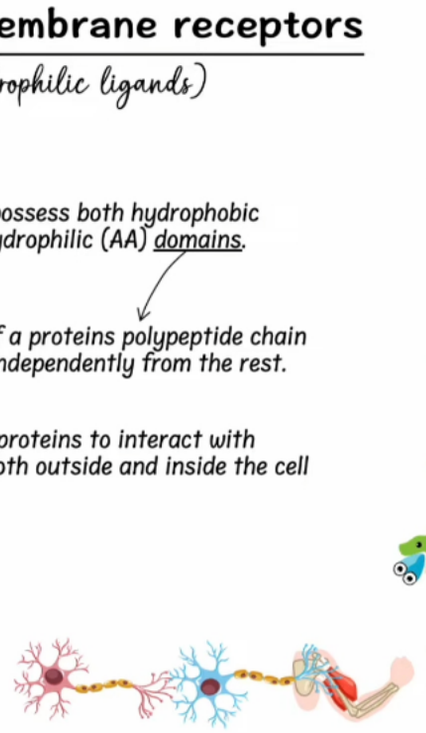
Transmembrane receptors

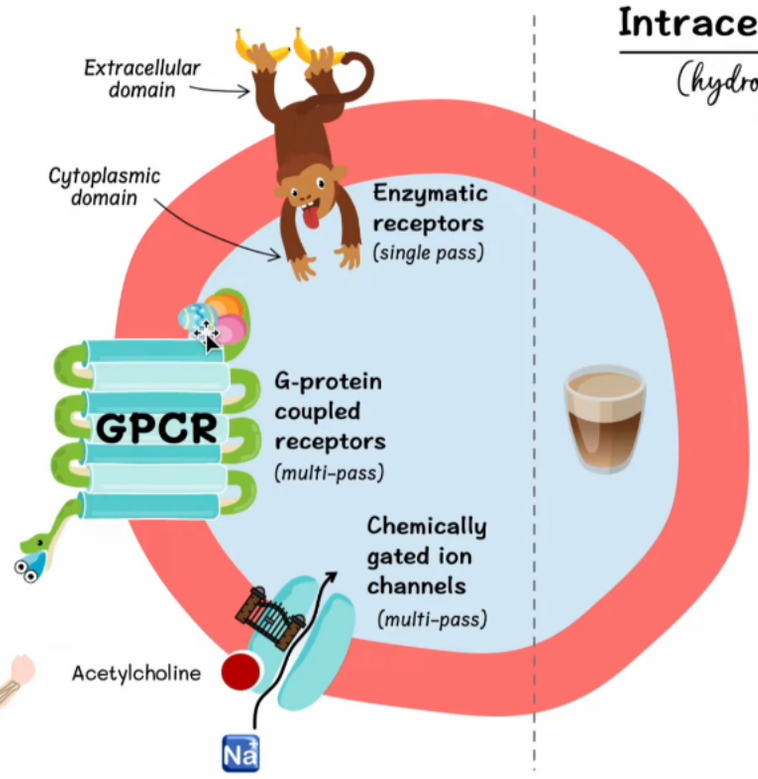
(hydrophilic ligands)

Receptors possess both hydrophobic (AA) and hydrophilic (AA) domains.

A portion of a proteins polypeptide chain that folds independently from the rest.

This allows proteins to interact with molecules both outside and inside the cell





Intracellular receptors

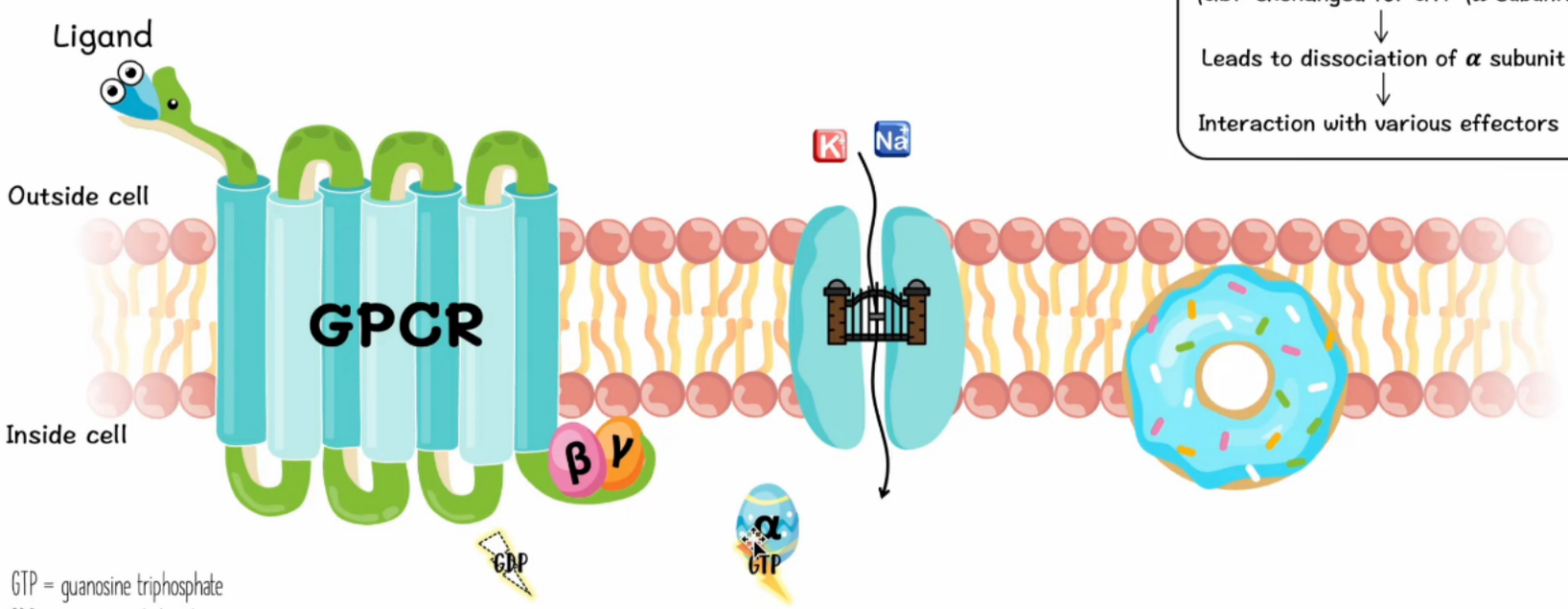
(hydrophobic ligands) or small

G-PROTEIN COUPLED RECEPTORS (GPCR)

Mechanism: Acts indirectly on enzymes or ion channels with the the aid of a protein called G protein.

Summary of mechanism:

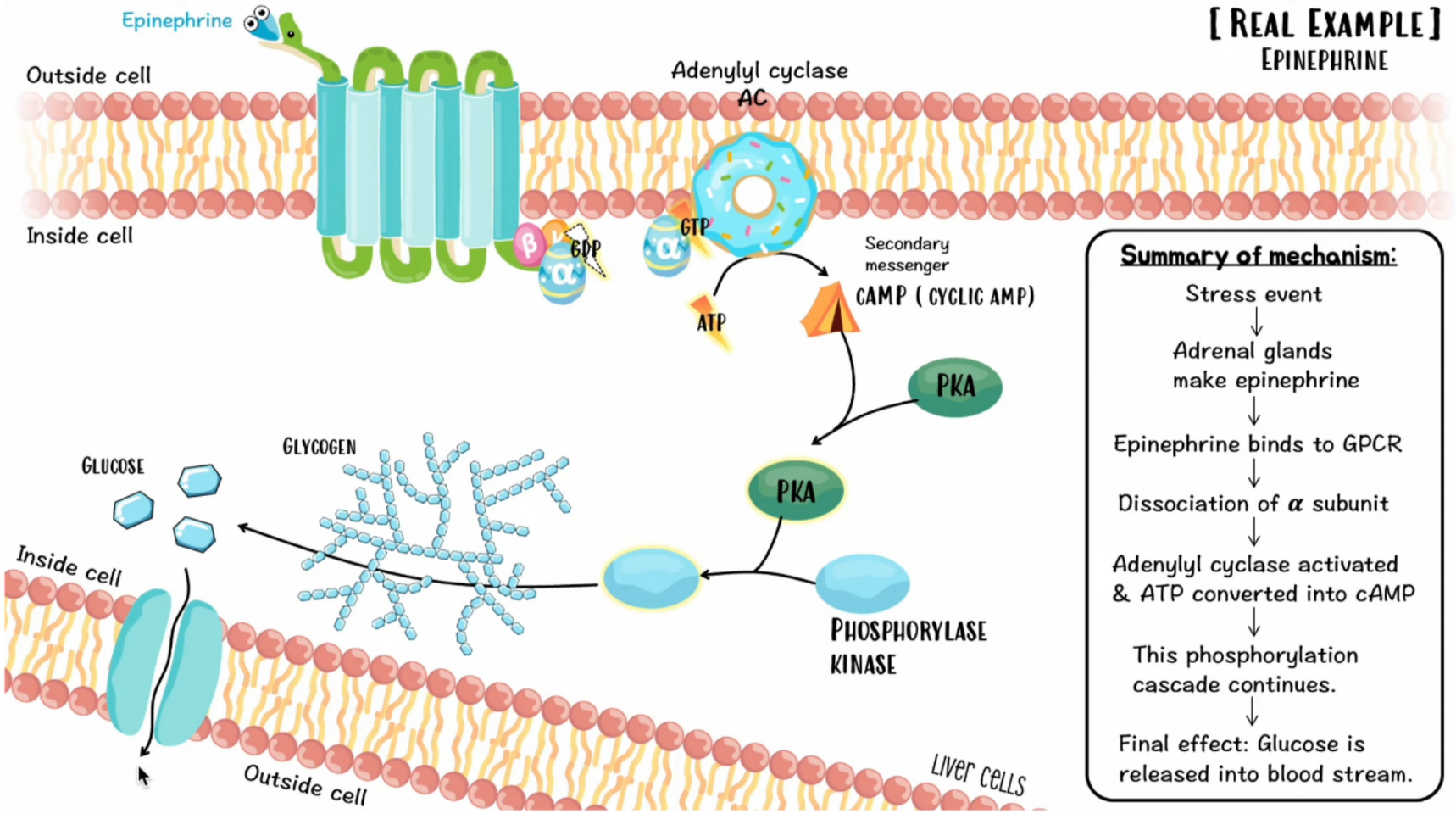
Ligand binds to GPCR
↓
Receptor is activated (Conformational change)
↓
Interaction with G-protein (GDP exchanged for GTP (α subunit)
↓
Leads to dissociation of α subunit
↓
Interaction with various effectors



GTP = guanosine triphosphate
GDP = guanosine diphosphate

[REAL EXAMPLE]

EPINEPHRINE



Summary of mechanism:

Stress event
↓
Adrenal glands make epinephrine
↓
Epinephrine binds to GPCR
↓
Dissociation of α subunit
↓
Adenylyl cyclase activated & ATP converted into cAMP
↓
This phosphorylation cascade continues.
↓
Final effect: Glucose is released into blood stream.

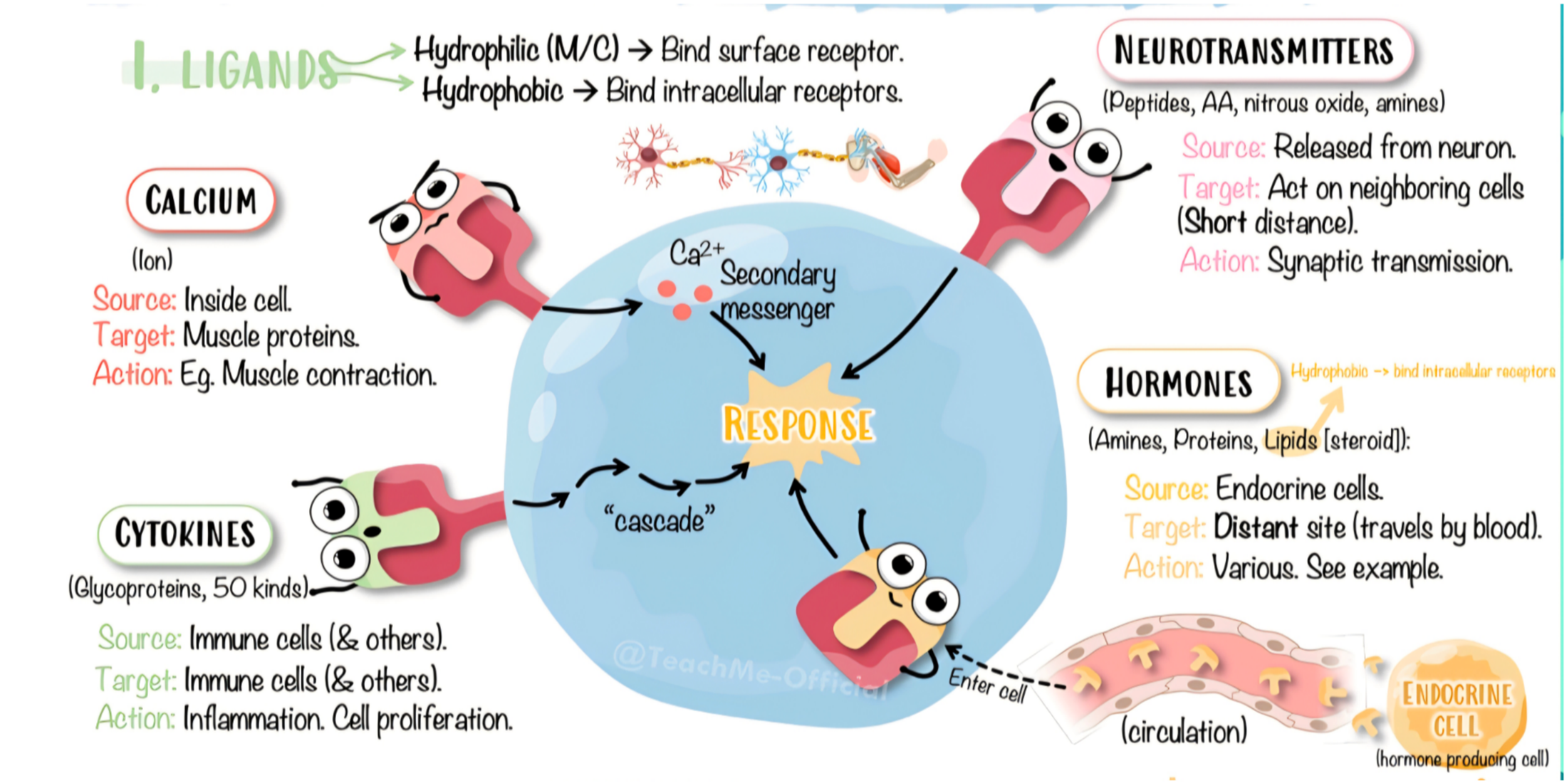
4. Calcium ions (Ca^{2+}): Normally kept at low intracellular concentration by calcium pumps in the plasma membrane.

• Enter cells through voltage–gated or ligand–gated channels. Act as intracellular signalling molecules.

• In muscle cells, cause muscle fibre contraction.

• In neurons, trigger release of neurotransmitters from presynaptic neurons into the synapse.

Feature	Hormones	Neurotransmitters	Cytokines	Calcium ions
Distance	Long (blood)	Very short (synapse)	Local	Inside cell
Speed	Slow	Very fast	Moderate	Very fast
Duration	Long-lasting	Very short	Variable	Very short



Chemical diversity of hormones and neurotransmitters

• For a molecule to function as a signalling chemical, it must:

• Have a distinctive shape and chemical properties, so its receptor can distinguish it from other molecules.

• Be small and soluble enough to be transported (for example in blood or across a synapse).

• This explains why hormones and neurotransmitters show chemical diversity but still share these basic requirements.

Hormones		Neurotransmitters	
Amines	• melatonin • thyroxin • epinephrine	**Amines**	• dopamine • norepinephrine
Peptides	• insulin • glucagon • ADH	**Gases**	• nitrous oxide
Steroids	• oestradiol • progesterone • testosterone	**Amino acids**	• glutamate • glycine
		Esters	• acetylcholine

Localized and distant effects of signalling molecules:

• Signalling molecules differ in how far they travel, which determines how widespread their effects are.

• Some act locally (for example neurotransmitters at synapses or cytokines acting on nearby cells).

• Some act at long distances (for example hormones transported in blood).

• The distance travelled determines whether the effect is:
• Localized (specific target cell)
• Widespread (multiple tissues or organs)

Characteristics	Hormones	Neurotransmitters	Cytokines
Distance travelled	Large	Very small	Small
Affected area	Widespread	Very small	(Very) small
Signalling cells	Glands	All neurons	Many cells
Target cells	Many cells	One neuron	Same cell or nearby ones
Method of transportation	Bloodstream or ducts	Synapse	Bloodstream

Transmembrane vs intracellular receptors

• Signalling chemicals act in two main ways:

• Bind to receptors in the plasma membrane (do not enter the cell)
• Enter the cell and bind to intracellular receptors (cytoplasm or nucleus)

--> 1. Transmembrane (extracellular) receptors
• Located in the plasma membrane. Are transmembrane proteins.

• Have:
• A region exposed outside the cell
• A region protruding into the cytoplasm
• They stay in the membrane because:
• Two regions contain hydrophilic amino acids, which interact with aqueous solutions inside and outside the cell.
• The middle region contains hydrophobic amino acids, which interact with the non-polar fatty acid tails of phospholipids in the membrane core.
• The signalling molecule does not enter the cell.
• Binding triggers intracellular signalling pathways.

--> 2. Intracellular receptors
• Located in the cytoplasm or nucleus.
• Bind hydrophobic signalling molecules, such as steroid hormones.
• Hydrophobic ligands can passively diffuse through the hydrophobic plasma membrane.

• Intracellular receptors:
• Have hydrophilic amino acids over their entire surface
• Remain dissolved in the aqueous cytoplasm
• Binding often leads to direct effects on gene expression.

Feature	Transmembrane receptor	Intracellular receptor
Ligand type	Hydrophilic	Hydrophobic
Ligand enters cell?	No	Yes
Membrane structure	Hydrophilic ends + hydrophobic middle	Fully hydrophilic surface
Typical effect	Signalling cascade	Gene expression change

Initiation of signal transduction pathways by receptors

● Signal transduction is the process by which:
• A cell receives a signal,
• Intracellular changes occur,
• The cell changes its activity or behaviour in response. It explains how an external signal leads to a specific cellular response.

--> 1. Intracellular receptors
• Bind to hydrophobic ligands that enter the cell.
• The receptor–ligand complex acts to alter gene expression. This leads to production of specific proteins and therefore a specific cellular activity.
• So the response is usually direct regulation of transcription.

--> 2. Extracellular (transmembrane) receptors
• Located in the plasma membrane.
• The ligand does not enter the cell.
• Binding causes a conformational change (change in shape) of the receptor.
• This activates intracellular signalling pathways.

● These pathways involve:
• Effectors (proteins that carry out actions)
• Secondary messengers (small intracellular signalling molecules)
• The result is a specific cellular response.

● Three categories of transmembrane receptors

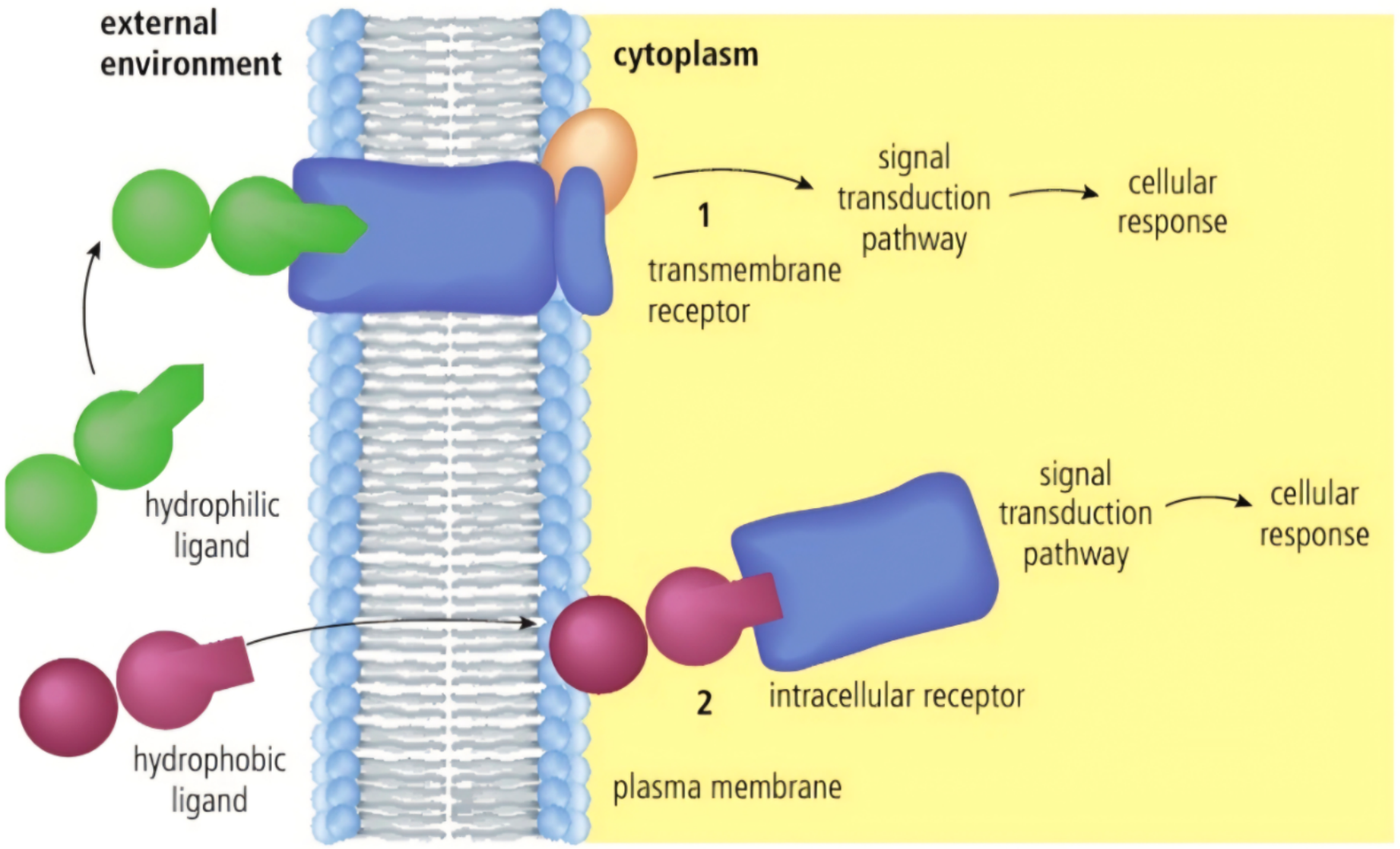
• G–protein–coupled receptors (GPCRs): Activate a G–protein inside the cell.
Often involve secondary messengers.

• Enzyme–coupled receptors: Have an enzymatic function or activate enzymes after ligand binding.
Often involved in regulation of cell growth and differentiation.

• Ion–channel–coupled receptors: Open or close an ion channel when a ligand binds.
Cause rapid changes in ion concentration inside the cell.

Type of transmembrane receptor

Type	Structure	Function
Chemically gated ion channel receptors	Multi-pass protein with a central pore	Possess gates that open and close
Enzymatic receptors	Single-pass protein	Bind ligands extracellularly, activate enzymes intracellularly
G protein-coupled receptors (GPCRs)	Multi-pass protein with intracellular binding site for G protein	Bind with ligands that activate the G protein



Transmembrane receptors for neurotransmitters and changes to membrane potential

● Receptors for neurotransmitters are located in the plasma membrane of:
• Postsynaptic neurons
• Muscle fibres

• When a ligand (neurotransmitter) binds: The receptor undergoes a conformational change. This opens a membrane ion channel.
• Positively charged ions pass through by facilitated diffusion. The movement of ions changes the membrane potential.

• This change in membrane potential can: Stimulate or inhibit a nerve impulse in a postsynaptic neuron.
• Trigger contraction in a muscle fibre.

• Example: Acetylcholine: Acetylcholine (ACh) is released from the presynaptic neuron.
• It binds to receptors on the postsynaptic membrane. This opens ligand–gated sodium (Na^+) channels. Na^+ diffuses into the cell. This causes depolarization of the plasma membrane. Depolarization allows the neural signal to pass between neurons.

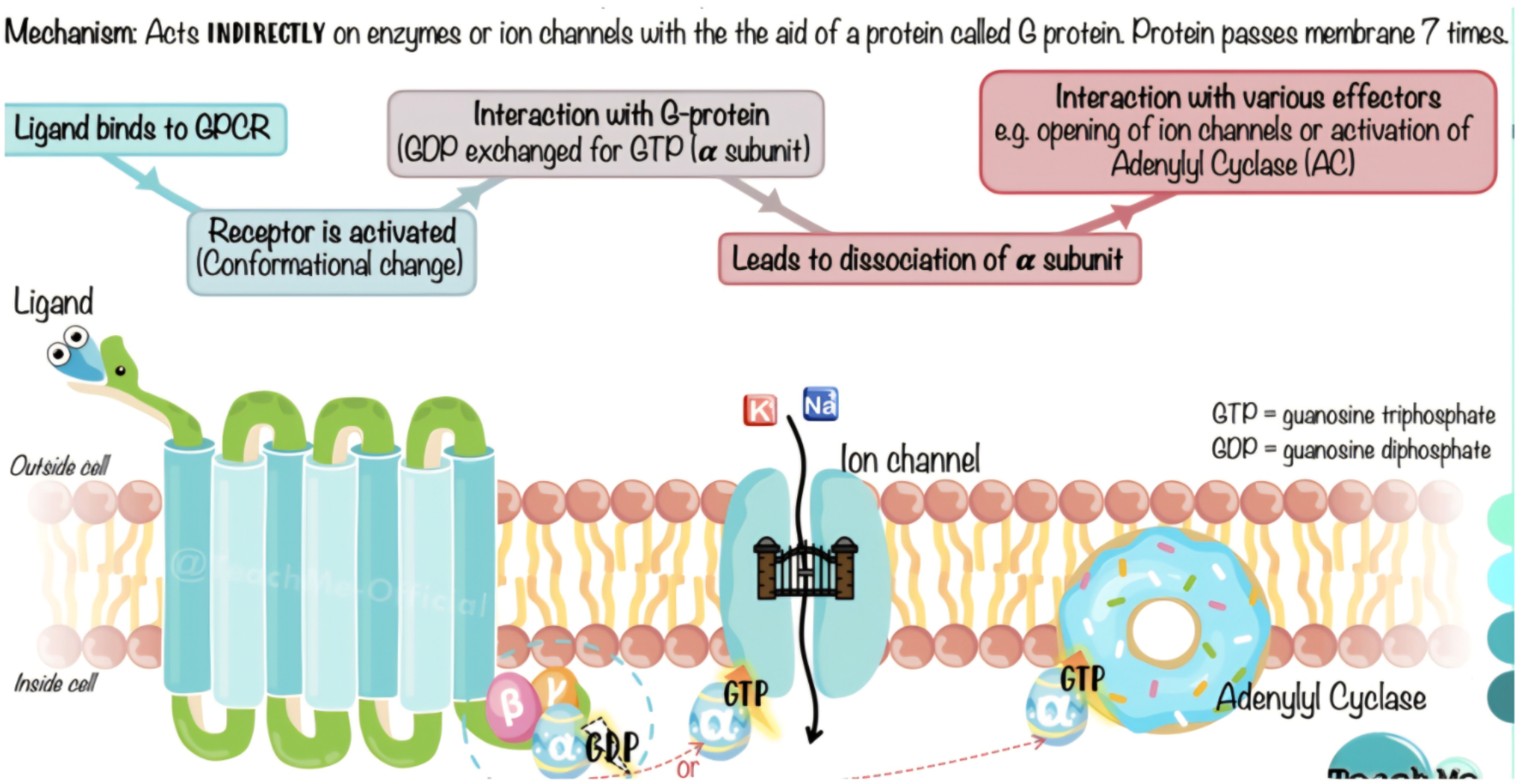
Transmembrane receptors that activate G proteins

• G protein–coupled receptors (GPCRs): Large and diverse group of transmembrane receptors. Transmit signals using a second membrane–associated protein called a G protein.

• Structure of G protein
• Has three subunits: α (alpha), β (beta), γ (gamma)
• The G protein is located on the cytoplasmic side of the receptor.

• Inactive state: GDP is bound to the α subunit. (This keeps the G protein inactive.)
• Activation mechanism: A ligand binds to the extracellular side of the receptor. The receptor undergoes a conformational change. This causes changes in the associated G protein.
• GDP dissociates from the α subunit.
• GTP binds to the α subunit.
• Binding of GTP activates the G protein.
• The G protein separates into subunits. The activated subunits dissociate from the receptor.
• These subunits interact with other intracellular targets. This leads to the cellular response.

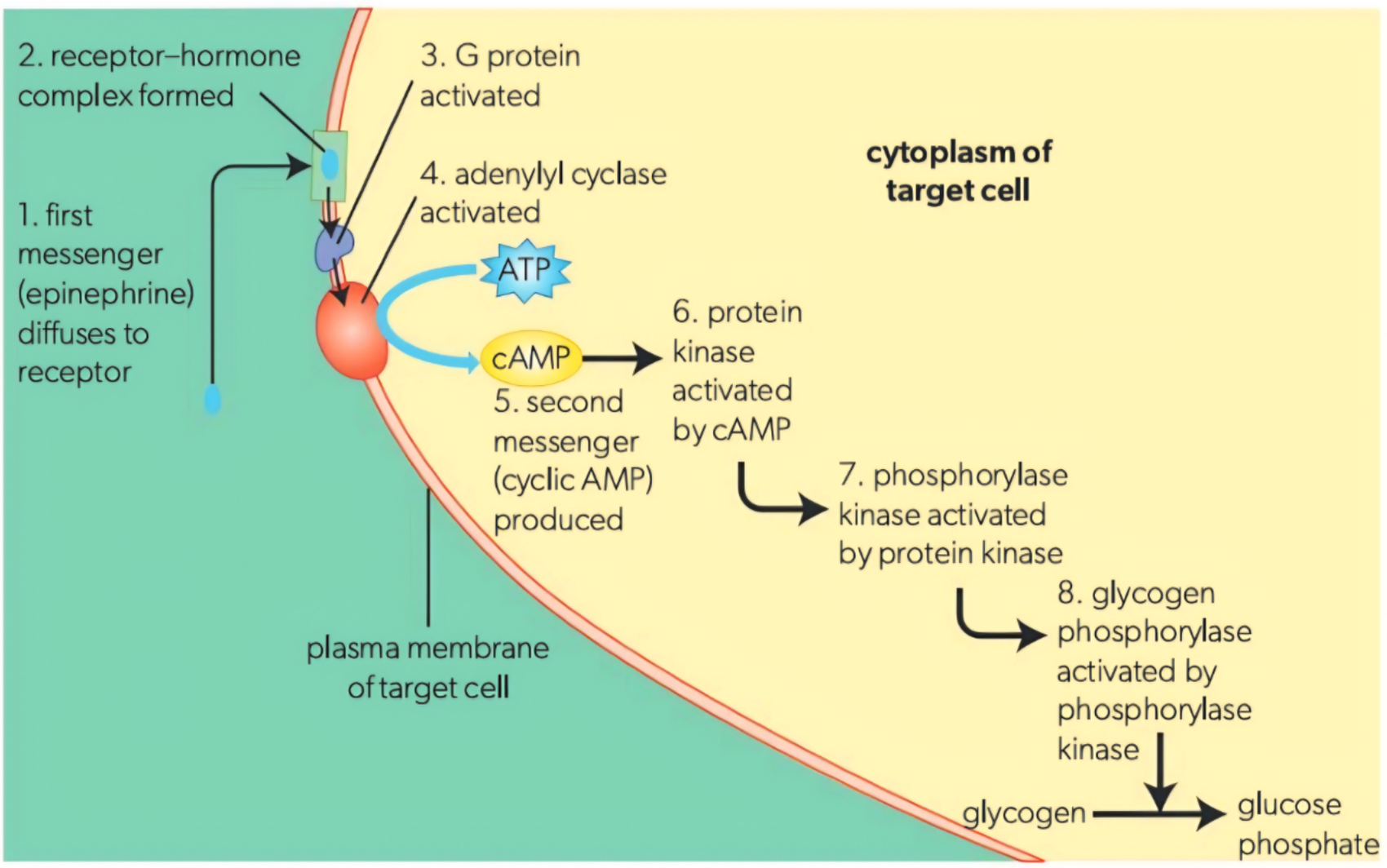
Ligand → receptor shape change → GDP replaced by GTP → G protein activated → subunits separate → intracellular interactions → response.



Mechanism of action of epinephrine (adrenaline) receptors

• Epinephrine (adrenaline) receptors are located in the plasma membrane of target cells.
• They are an example of G protein–coupled receptors (GPCRs).
• Step–by–step mechanism
• Epinephrine binds to its receptor on the plasma membrane. The receptor undergoes a conformational change.
• This activates the associated G protein. The activated G protein activates the enzyme adenylyl cyclase in the membrane.
• Adenylyl cyclase converts ATP into cyclic AMP (cAMP) in the cytoplasm. cAMP acts as a secondary messenger. cAMP initiates a cascade of intracellular reactions.
• The signal is amplified, meaning one epinephrine molecule leads to a large cellular response.

• Example: Effect in liver cells In liver cells, the signalling cascade causes: Breakdown of glycogen and release of glucose into the blood. This happens within seconds of receiving the epinephrine signal.



• The hormone known as adrenaline and epinephrine is the same molecule. The two different names were given by different research groups around the late 19th or early 20th century. Both names persisted instead of one being universally adopted.

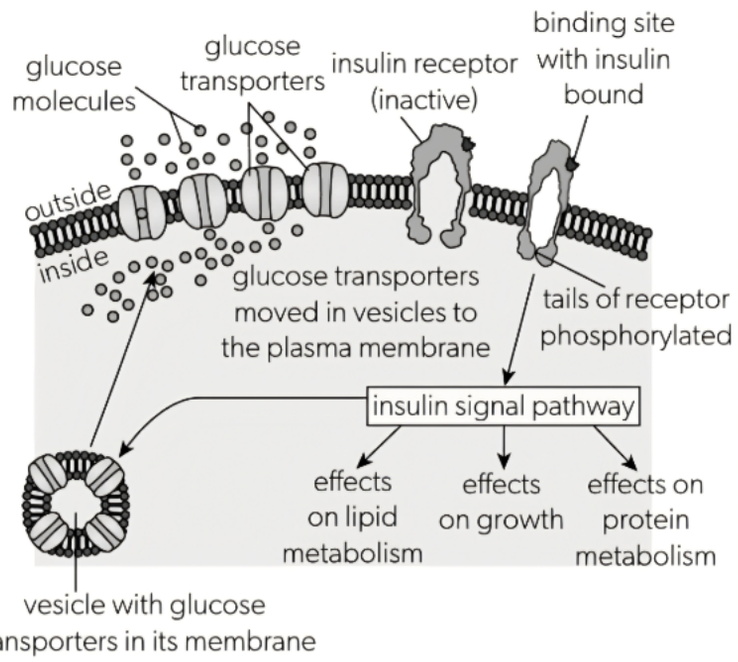
• Adrenaline is used more commonly in Europe.
• Epinephrine is more commonly used in North America.

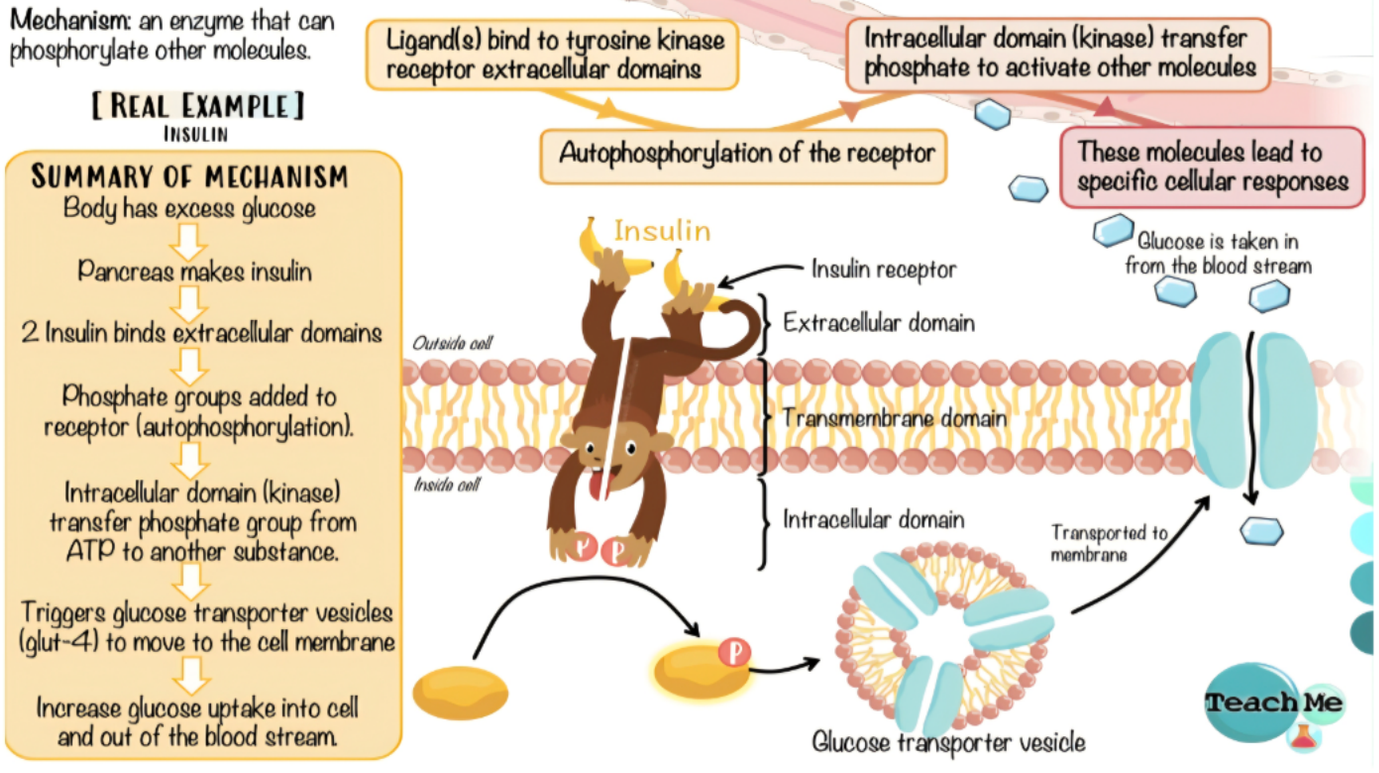
• Link to international cooperation in science: Scientific naming usually involves international agreement to ensure clarity and consistency. Naming conventions are an example of international cooperation for mutual benefit. In this case, lack of agreement led to two names for the same hormone, which can cause confusion.

Transmembrane receptors with tyrosine kinase activity

• Protein kinases: Protein kinases are enzymes that transfer phosphate groups from ATP to proteins.
• This process is called phosphorylation.
• Tyrosine kinase specifically transfers phosphate groups to the amino acid tyrosine in target proteins.
In many cases:
• Phosphorylation activates proteins. Removal of the phosphate (dephosphorylation) makes them inactive again

• Example: Insulin receptor The insulin receptor is a large transmembrane protein.
• Structure: Has two intracellular tails extending into the cytoplasm. These tails have tyrosine kinase activity.
• Mechanism of action: Insulin binds to the extracellular part of the receptor. A conformational change occurs.
• The two intracellular tails come together to form a dimer. Each tail phosphorylates the other tail (cross–phosphorylation). This activates the insulin receptor.
• Signal transduction outcome. Activation triggers a signal transduction pathway inside the cell.
• Vesicles containing glucose transporters move toward the plasma membrane. The vesicles fuse with the membrane.
• Glucose transporters are inserted into the membrane. These transporters act as channel proteins. Glucose enters the cell by facilitated diffusion. The glucose is then used as a substrate in cell respiration.





Intracellular receptors that affect gene expression

• Steroid hormones are hydrophobic and lipid soluble. Because of this, they can diffuse through the plasma membrane.

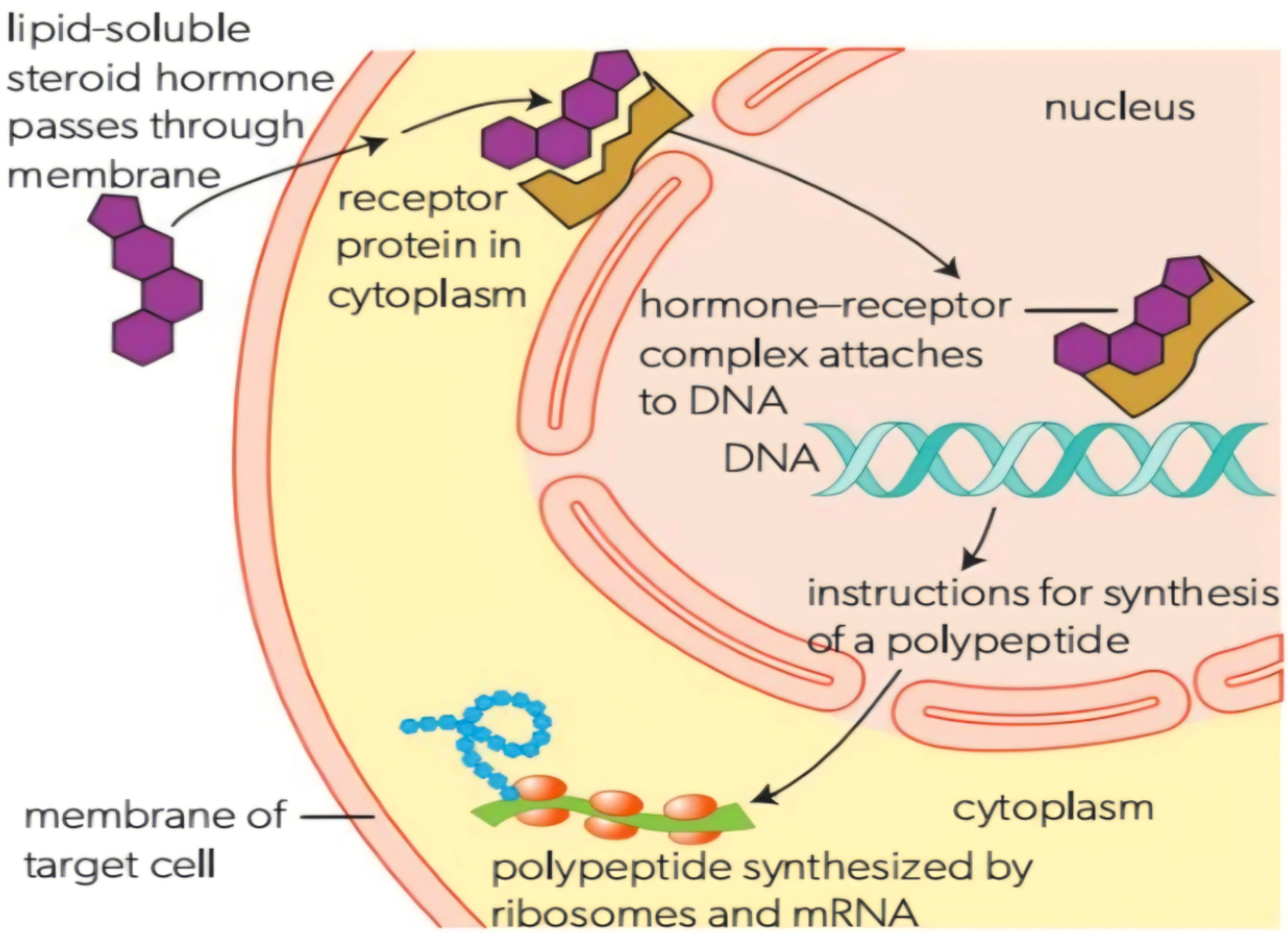
• Inside the cell, they bind to receptors in the cytoplasm.

• The hormone–receptor complex then enters the nucleus and it binds to DNA.

• This activates transcription and leads to production of a specific polypeptide.

• So the mechanism is:

Steroid hormone → cytoplasmic receptor binding → complex enters nucleus → gene transcription → specific protein production.



Effects of oestradiol and progesterone on target cells

• General features: Oestradiol and progesterone are female sex hormones.

• Secreted by: Cells in the ovary, The corpus luteum, The placenta during pregnancy

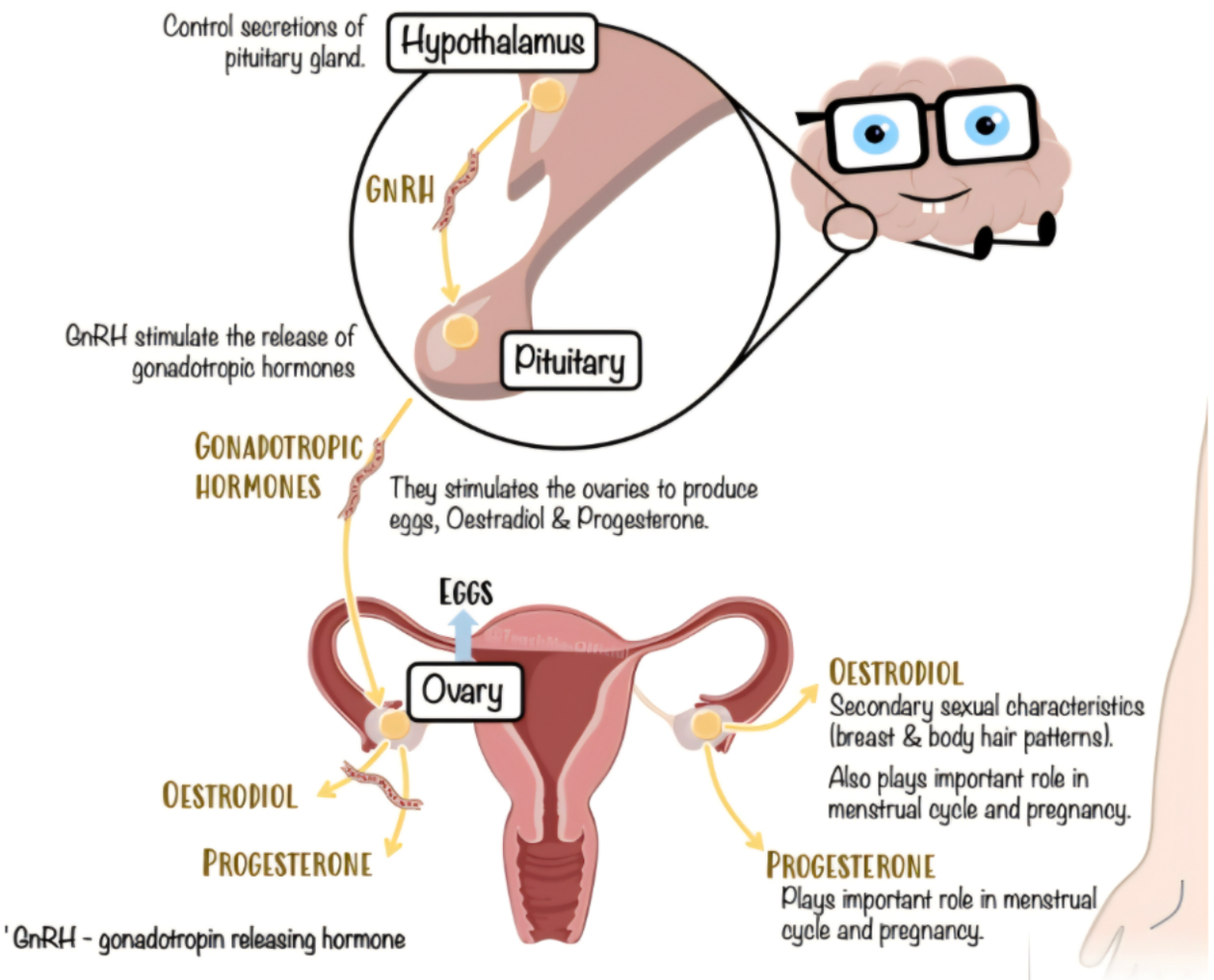
• Both are steroid hormones, so they: Diffuse through the plasma membrane, Bind to specific cytoplasmic receptors, Form hormone–receptor complexes, Enter the nucleus, Alter gene expression

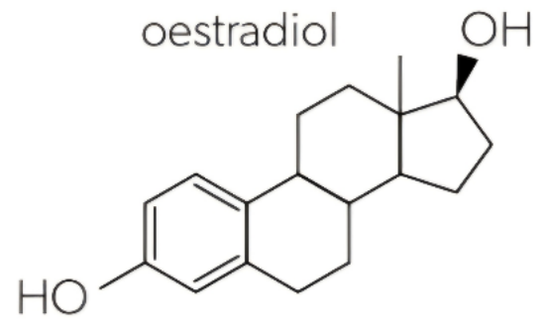
• Effects of Oestradiol: Has a broad range of effects in The ovary and The uterus, Also affects the hypothalamus in the brain.

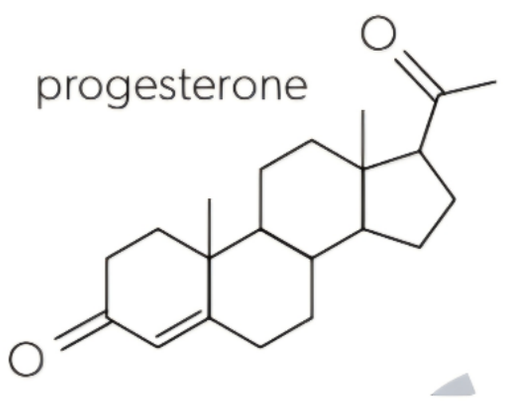
• Around ovulation: Oestradiol binds to receptors in cytoplasm of hypothalamus cells. The oestradiol–receptor complex enters the nucleus. It enhances transcription of GnRH mRNA. Increased GnRH stimulates the anterior pituitary gland.
• The anterior pituitary secretes: LH (luteinizing hormone) and FSH (follicle–stimulating hormone)
• These hormones regulate the menstrual cycle and ovulation.

• Effects of Progesterone: Promotes development and maintenance of the endometrium (uterine lining). Ensures the uterus can support a developing foetus.

• Mechanism: Progesterone binds to receptors in cytoplasm of uterus cells. The progesterone–receptor complex enters the nucleus. It activates transcription of specific genes.
• Changes in gene expression cause: Repeated cell division in the uterus wall and Thickening of the endometrium







Regulation of cell signalling pathways by positive and negative feedback

• In both positive and negative feedback: The product of a pathway affects how much more product is made. The product usually acts on an early stage of the pathway. So the system regulates itself.

• Negative feedback: The product inhibits its own production.
• More product → less production
• Less product → more production
• This maintains homeostasis.

• Example: Regulation of thyroxin
• The hypothalamus secretes TRH (thyrotropin–releasing hormone): Stimulates the anterior pituitary gland.
• The anterior pituitary secretes TSH (thyroid–stimulating hormone): Stimulates the thyroid gland.
The thyroid secretes thyroxin.

• Regulation: High thyroxin levels inhibit TRH secretion. Low thyroxin levels stimulate TRH secretion.
• So thyroxin controls its own production through inhibition of an earlier step.

• Positive feedback: The product stimulates its own production.
• More product → more production
• Less product → less production
• This amplifies a process until a specific event occurs.

• Example: Oxytocin during childbirth (parturition): Uterine wall contractions stimulate release of oxytocin.
• Oxytocin increases the strength of uterine contractions. Stronger contractions cause more oxytocin release. This amplification continues until parturition (birth).

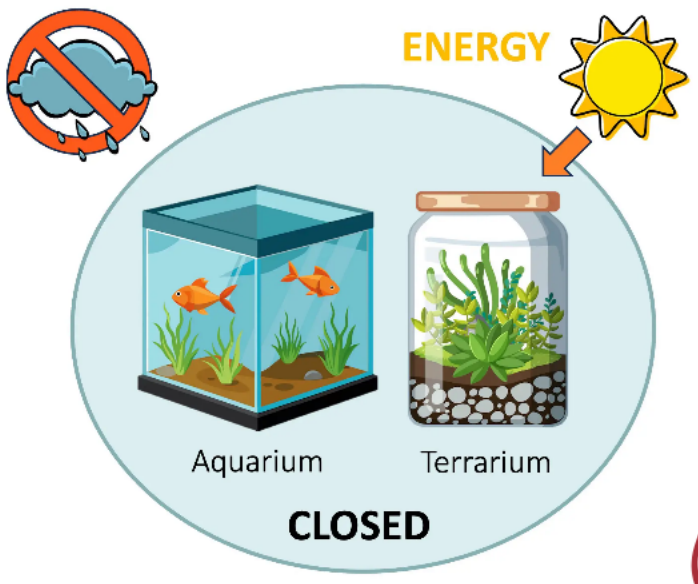
Feature	Negative Feedback	Positive Feedback
Effect of product	Inhibits production	Stimulates production
Function	Stabilizes system	Amplifies process
Example	Thyroxin regulation	Oxytocin in labour

Transfer of energy and organic matter

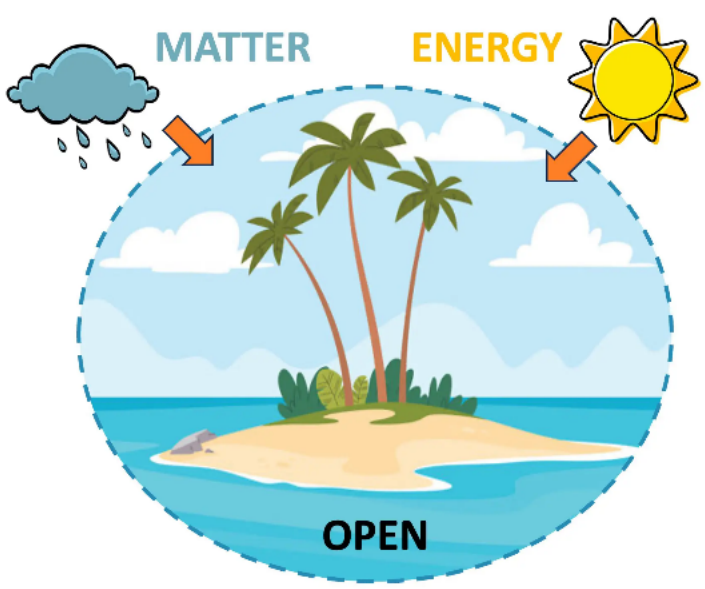
Ecosystem as open systems in which both energy and matter can enter and exist

Living organisms cannot live alone. They depend on interactions with other organisms for supplies of energy and chemical resources

- Open systems where resources can enter or exit including both chemical substances and energy.
- Closed systems where energy can enter or exit, but chemical resources cannot be removed or replaced.



- A system where only energy can pass. (Earth)



- A system where both energy and matter can exist and enter.

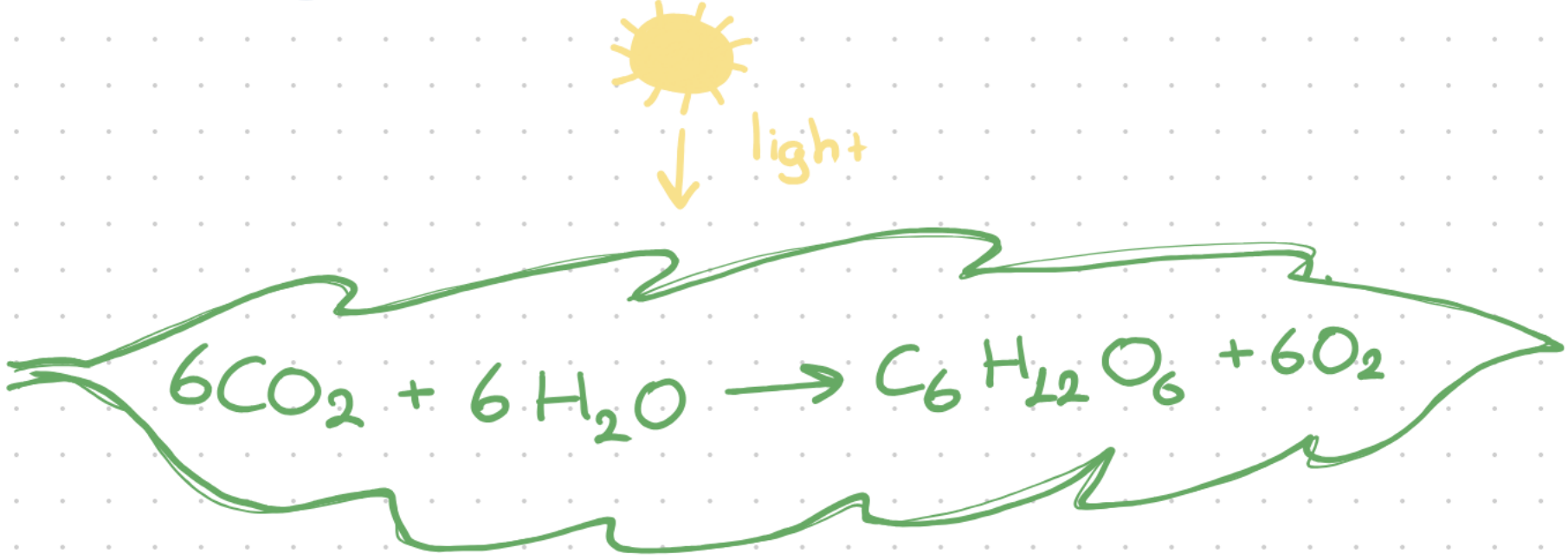
(By migration, deforestation)

Sunlight as the principle source of energy that sustains most ecosystems

- Organisms that use an external energy source to make carbon compounds are producers. Energy fixed by producers in carbon compounds is available to other organisms, so sustain the whole ecosystem.

principle source of energy → carbon compounds

Sunlight — photsynthesis



Light energy ⟶ chemical energy

Inorganic molecules ⟶ Organic molecules

Feature	Scientific Theory	Scientific Law
Definition	• Well supported explanation why and how? occur based on evidance, observations and experiments.	• A statement or a mathematical relationship, describes what happens in nature and consistently observed.
Main Question	• Why does it happen?	• How can this happen?
Purpose	• Explains the mechanisms and causes behind natural events.	• Describes patterns or relationships found in nature.
Change over time	• Can be modified or expanded when new evidance is found	• Changes rarely
Based On	• Multiple confirmed hypotheses and vast supporting evidance	• Repeated observations or mesurements
Example	• Theory of evolution Cell theory Atomic theory Plate tectonics theory	• Law of gravity Boyle's Law Ohm's Law
Question type	• Why does an apple fall? Gravity theory explains	• How does it fall? Newton's law of gravity explains

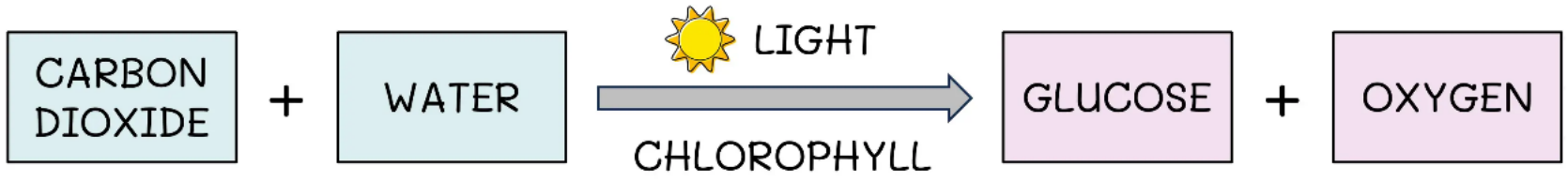
Chemical Energy Flows through food chains

Food chain: A sequence of organisms feeding on eachother

Trophic level 1	Producer
level 2	Primary consumer
level 3	Secondary consumer
level 4	Tertiary consumer

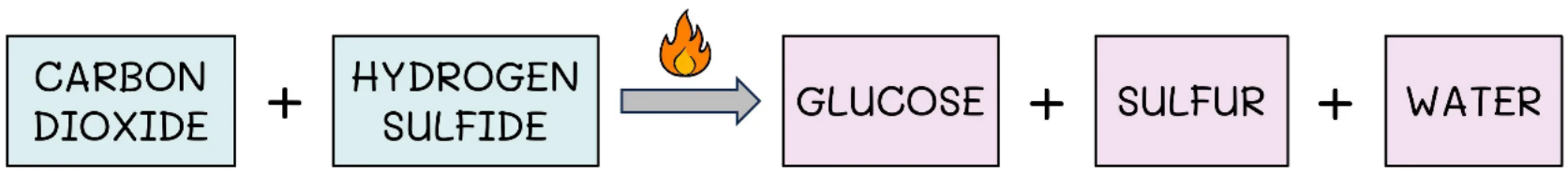
★ Sometimes at the top of the food chain there may be parasites that feed on the blood of the host organisms instead of carnivores.

Photosynthesis Equation

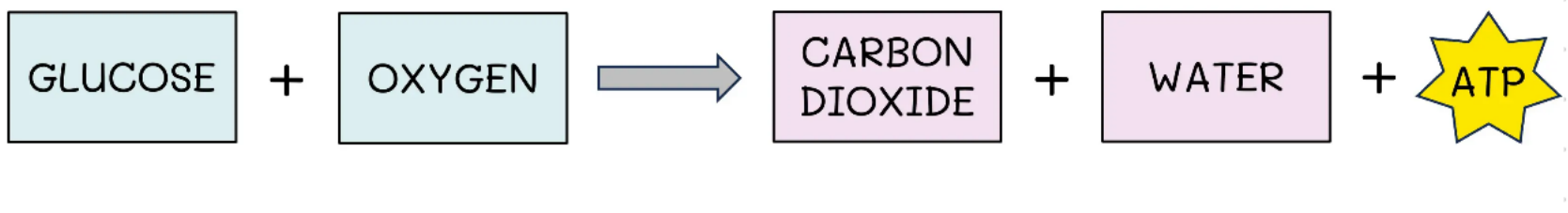


$$CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$$

Chemiosmosis Equation



Cell Respiration Equation

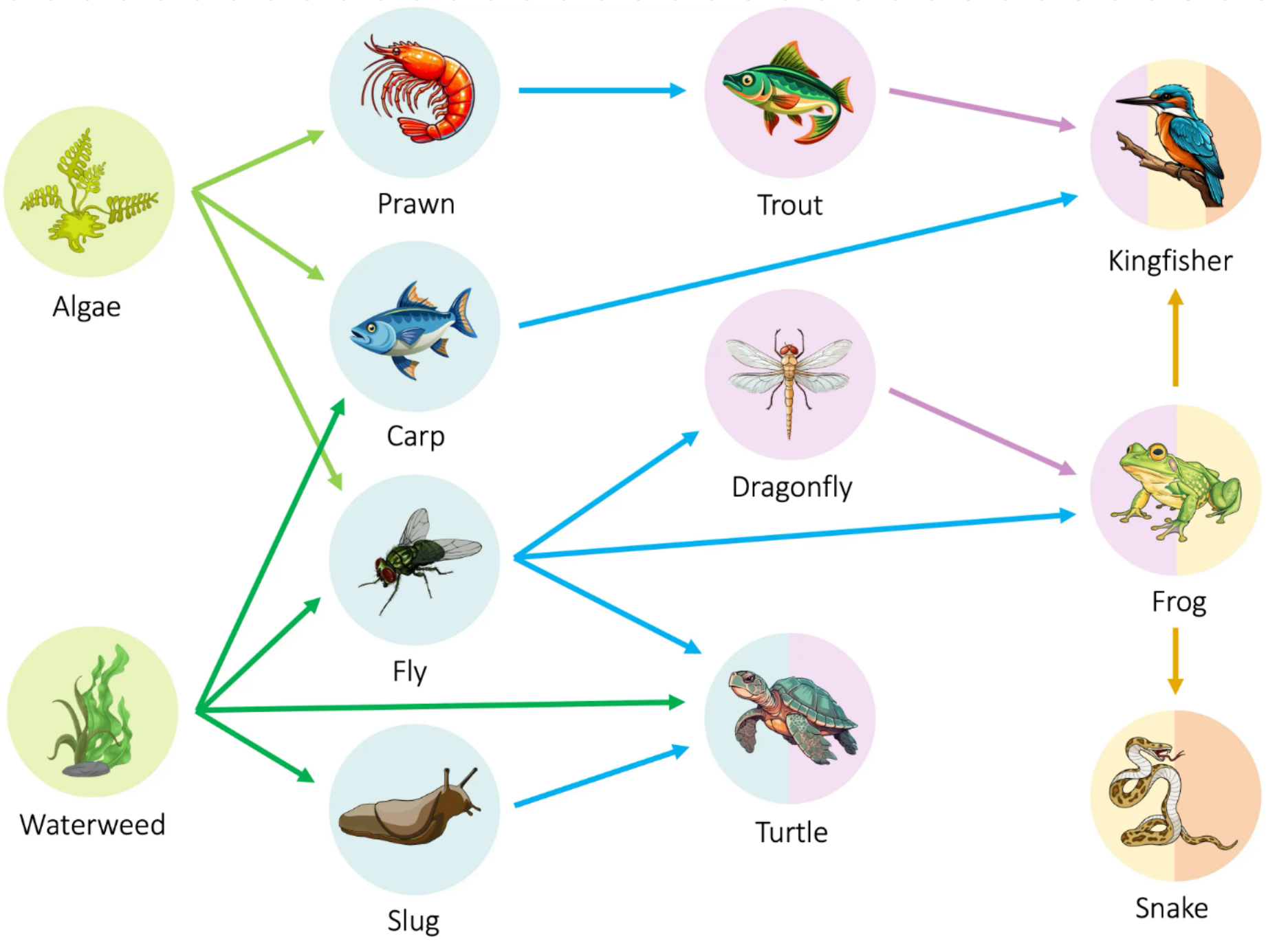


Food Chain



Constraction of food chains and food webs to represent feeding relationship

- Most living things can participate in more than one food chains. These relationships formed by different food chains are called food webs.



Supply of energy to decomposers as carbon compounds in organic matter coming from dead organisms

- Dead organic matter is generated by these processes:

  - Death of whole organisms
  - Defecation (removal of feaces from the gut)
  - Shedding of leaves, skin cells, hairs etc. ⟶ et cetera

- Dead organic matter supplies saprotrophs with a.a glucose and other carbon compounds

  → They're used for growth and energy which released by cell respiration.

Saprotrophs

- What: Decompose (break down) dead organic matter.
- How: Releasing enzymes onto their food (external digestion)
- Fungi, Bacteria

Detritivores

- What: Decompose (break down) dead inorganic matter
- How: By direct consumption (internally digestion.)
- Earthworms, woolice etc.

Decomposing (breaking down): Converting dead organic organic matter into simpler organic and inorganic matter. (recycling)

→ Decomposers use some of the dead organic matter for cellular respiration. NOT all of it is decomposed.

Autotrophs as organisms that use external energy sources to synthesize carbon compounds from simple inorganic substances

- **Autotrophs:** Making their carbon compounds themselves using CO_2 or HCO_3
- A **reduction reaction** inside autotrophic cells converts the simple inorganic carbon sources into an initial carbon compound (**carbon fixation**)
- This initial carbon compound is then built up into a wide variety of other carbon compounds by **anabolic reaction or assimilation.**
- Carbon fixation and anabolic reactions in autotrophs require an **external energy source.**
  - inorganic chemical reactions
  - Sunlight

Light → external energy source in photoautotrophs

Oxidation → energy source in chemoautotrophs

Photoautotrophs + Sunlight —photosynthesis→ carbon compounds

Chemoautotrophs use exothermic inorganic chemical reactions which is a substrate in a reduced state (sulfur, hydrogen sulfide) these are absorbed and then oxidized. (releases energy)

- Use this energy to synthesize carbon compounds.
- Archaea, bacteria

- Essential a.a in human body → 9
- Other a.a → 11

Heterotrophs as organism that use carbon compounds obtained from other organisms to synthesize the carbon compounds that they requaire

- Assimilation : The process of absorbing carbon compounds and making them part of the body (by feeding on others.)

- Assimilation requires absorption of carbon compounds into cells, so the molecules must be small and soluble.

Externally and internally digesting heterotrophs

- Saprotrophs secrete hydrolytic enzymes
- detrivores

- Consumers: Ingest their food.
- Multicellular organisms: Swallow → gut → (food + enzymes)
- Uni cellular organisms: (Paramecium → endocytosis → (digest inside the phagocytic vacuoles)

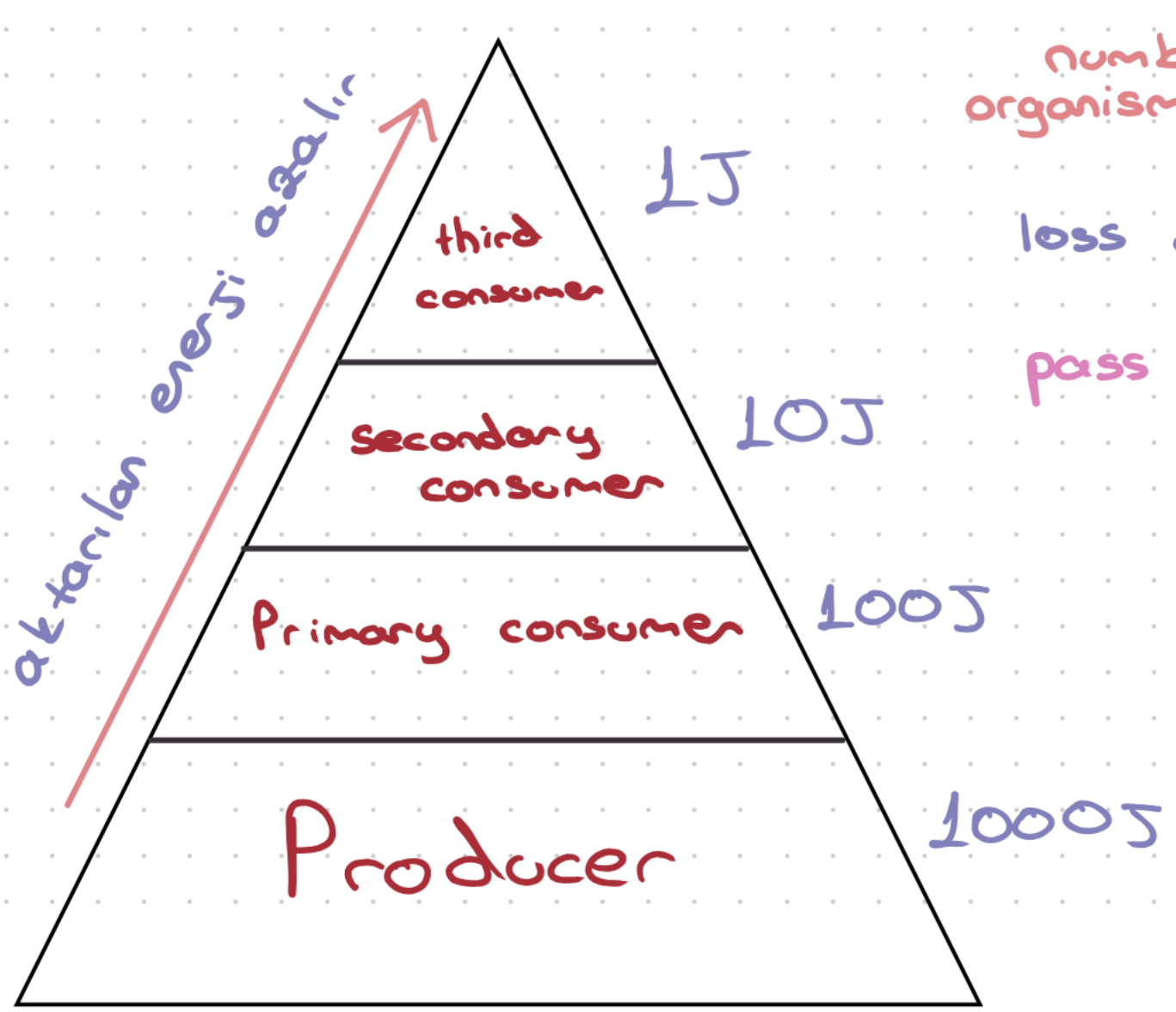
Release of energy in both autotrophs and heterotrophs by oxidation of carbon compounds in cell respiration

~ATP is needed for:~

%30
- Anabolic reactions to synthesize molecules (proteins (polysaccharides, triglycerides and nucleic acids.)
- Active transport
- Movement of vesicles and other stuctures inside the cell.

%70←
- Maintaining body temperature (birds and mammals)

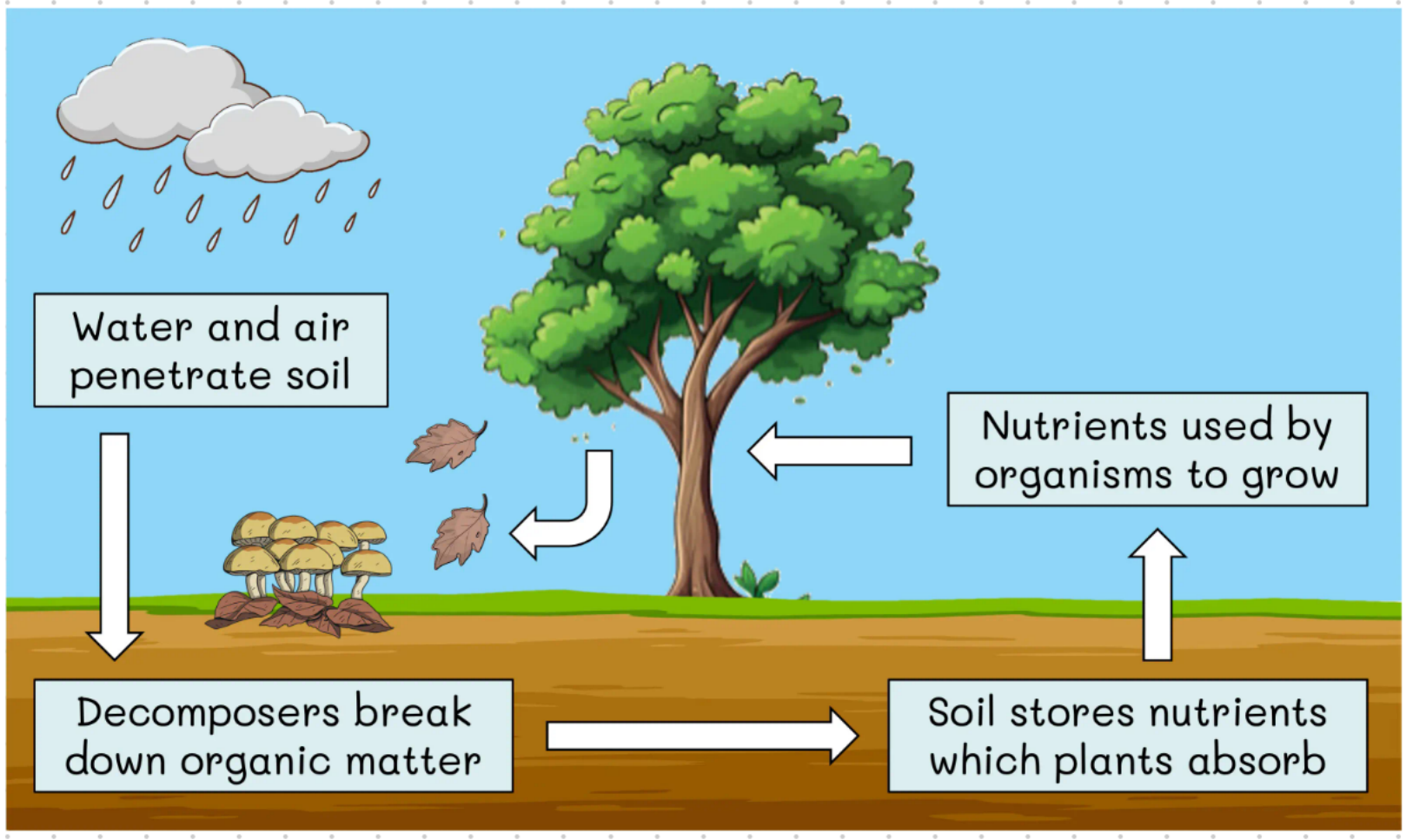
→ Both autotrophs and heterotrophs, ATP is produced by Cell Respiration



Reduction in energy availability at each successive stage in food chains due to large energy losses between trophic level

- Not all energy stored in organic molecules is transfered via heterotrophic feeding, some of the chemical energy remains indigested.
- Living organism cannot convert heat energy into other useble forms
- Energy is lost between trophic levels, as the energy content of a unit of mass does not change
- Energy transfers are not % 100 efficient, when energy is released by oxidizing substrates in cell respiration, some of the heat energy is converted to heat. So energy cannot be recycled (but chemical elements can)

autotrophs and heterotrophs



Restrictions on the number of trophic levels in ecosystems due to energy losses

- Food chains are limited in length because so much energy is lost between each trophic levels. For this reason the number of trophic levels in ecosystems is restricted to a four or five.

Primary production as accumulation of carbon compounds in biomas by autotrophs

- Production in ecosystems = accumulation of carbon compounds
- Primary production : mass of carbon compounds synthesized from CO_2 and other simple substances by autotrophs.

- Gross primary production : Total biomass of carbon compounds made by autotrophs. (energy kaybı olmadan)

- Net primary production : minus the biomass lost due respiration of the plant. Amount of biomass available to consumers.

→ Biomass vary in their capacity to accumulate depending on rates of photosynthesis

- Cooler bioms → Lower biomass
- Warmer biomes → higher biomass

Primary production = bitkilerin (ve alglerin) fotosentezle ürettiği organik madde miktarı.

Yani:

- $CO_2 + H_2O \rightarrow$ **şeker, nişasta, selüloz vb.**
- Bu maddeler **bitkinin biyokütlesi (biomass)** olur.

Enerji konuşuyor gibi yapıyorlar ama aslında **karbon** sayıyorlar. Çünkü:

- Enerji ölçmek zor
- Karbon miktarı → biomass → enerjiyle doğrudan bağlantılı

Primary production

- Ototrofların fotosentezle ürettiği organik madde

Gross primary production (GPP)

- Fotosentezle üretilen **toplam** biomass
- Solunum kaybı **dahil**

Net primary production (NPP)

- Tüketicilere kalan biomass

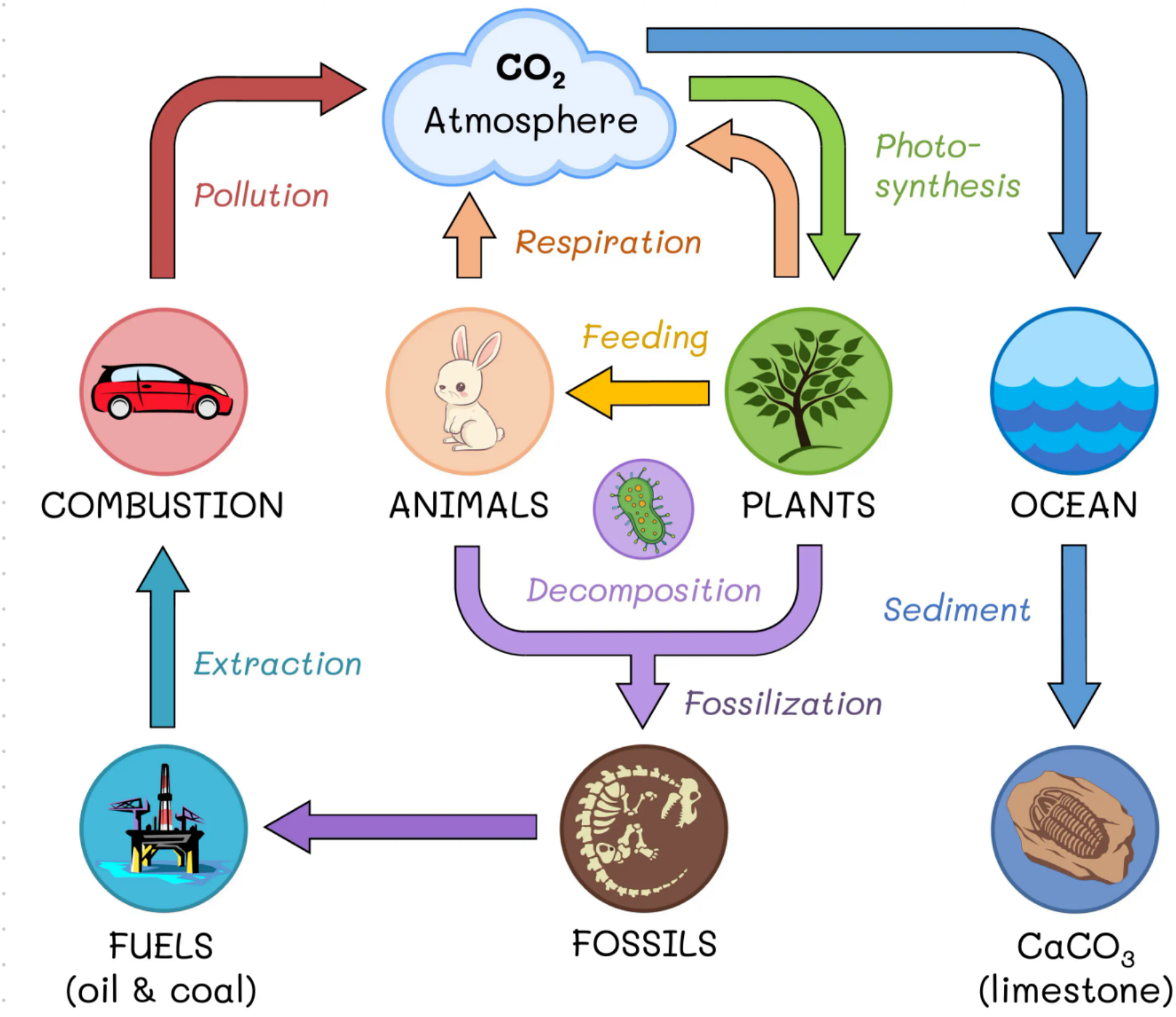
Secondary production as accumulation of carbon compounds in biomass by heterotrophs

- Conversion of one carbon molecule to other. (glucose → lipid)

- Heterotrophs use carbon compounds in growth and reproduction. (biomass is lost between levels.)

Constructing Carbon Cycle Diagrams

- Carbon Cycle: Biogeochemical cycle that describes the movement of carbon.
- Recycled and reused throughout the biosphere.



Ecosystems as carbon sinks and carbon sources

- Photosynthesis is more than respiration → net take of CO_2
- Respiration is more than photosynthesis → net release of CO_2
- Carbon sink: Reservoir that stores CO_2 more than it releases. It can be an any organism plant, ocean soil or an entire ecosystem.
- Carbon source: Opposite but can be both an organism and a process.

Release of CO_2 into the atmosphere during combustion of biomass, peat, coal, oil and gas

- Combustion (burning) of organic compounds releases CO_2.
  → Forest fires, lightning strikes, volcanic eruptions
- Anthropogenic factors (human activities) increases combustion rates.
  → Biomass: organic waste of agriculture
  → Peat: partially decomposed organic matter
  → Coal: Peat that has been converted by heat.
  → Oil: decayed marine organisms → hydrocarbon liquid
  → Natural gas: decayed marine → Methane gas
- Due to Industrial revelution human have developed some ways to burn oil, coal and natural gas to produce energy

combustion of fossil fuels ⟶ CO_2

- Carbon sink: Reservoir (Store more carbon than release

- Carbon sources: Release more than store

→ Volcanic eruption

→ Agricultural Activity → Industrial process

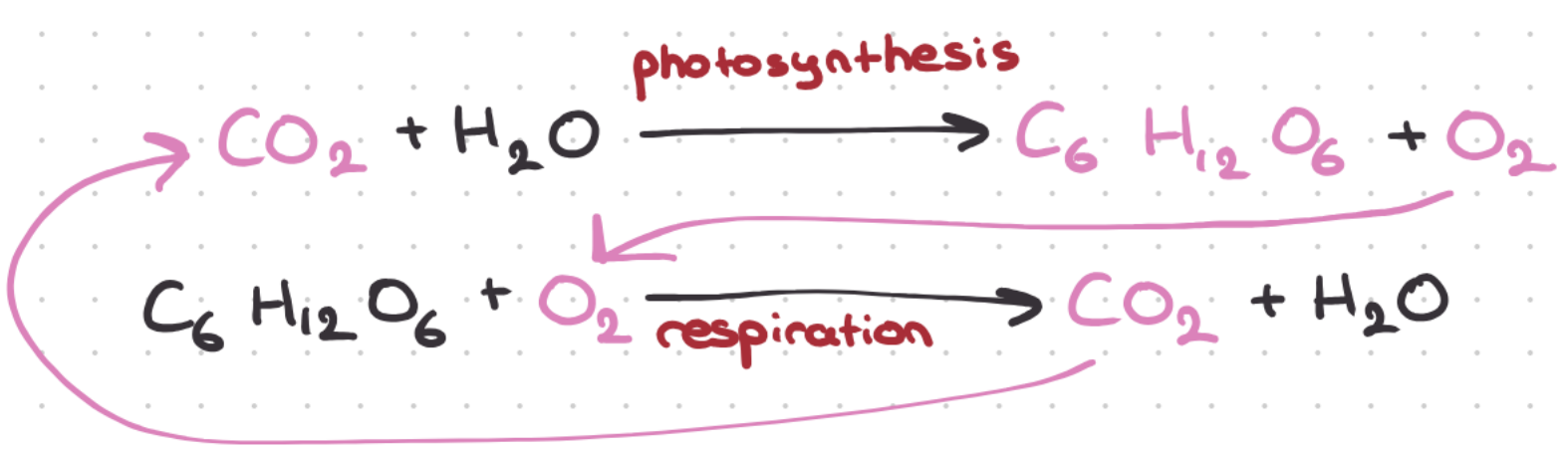


Analysis of the Keeling Curve in terms of Photosynthesis, respiration and combustion

- Keeling Curve: Atmospheric CO_2 concentrations.

1. Trend → Annual Fluctuations

- Seasonal changes:
- Summer and spring → More absorption of CO_2 by plants
- Winter and fall → Less absorption of CO_2



- Opposite of eachother but they're each others substrates so they need each other to occur.

- Interdependent → product → Substrate

2. Trend → Long Term

- Due to burning of fossil fuels by humans.
- Mainly anthropogenic reasons → Deforestation.

Dependence of aerobic respiration on atmospheric oxygen produced by photosynthesis on atmospheric CO_2 produced by respiration

- Autotrophs split water molecules → photosynthesis
  release O_2
- Heterotrophs Oxidise carbon compounds → respiration
  release CO_2

Recycling of all chemical elements required by living organisms in ecosystems

- Living organisms contain large amounts C, H, O, N and P in their molecules.
- About 15 other elements have been used in our body. Even though the elements are finite, they do not run out.
- This is because all water and elements are being recyled due to Earth being a closed system.

Decomposers → nutrient cycling → no longer needed nutrients → available for who need them

Neural Signaling

Neurons as cells within the nervous system that carry electrical impulses

• **Stimulus:** A stimulus is any change in the internal or external environment that can be detected by an organism. Examples include heat, light, humidity, pressure, and chemicals.

• **Receptor:** Receptors are specialised cells located in sensory organs that detect stimuli.

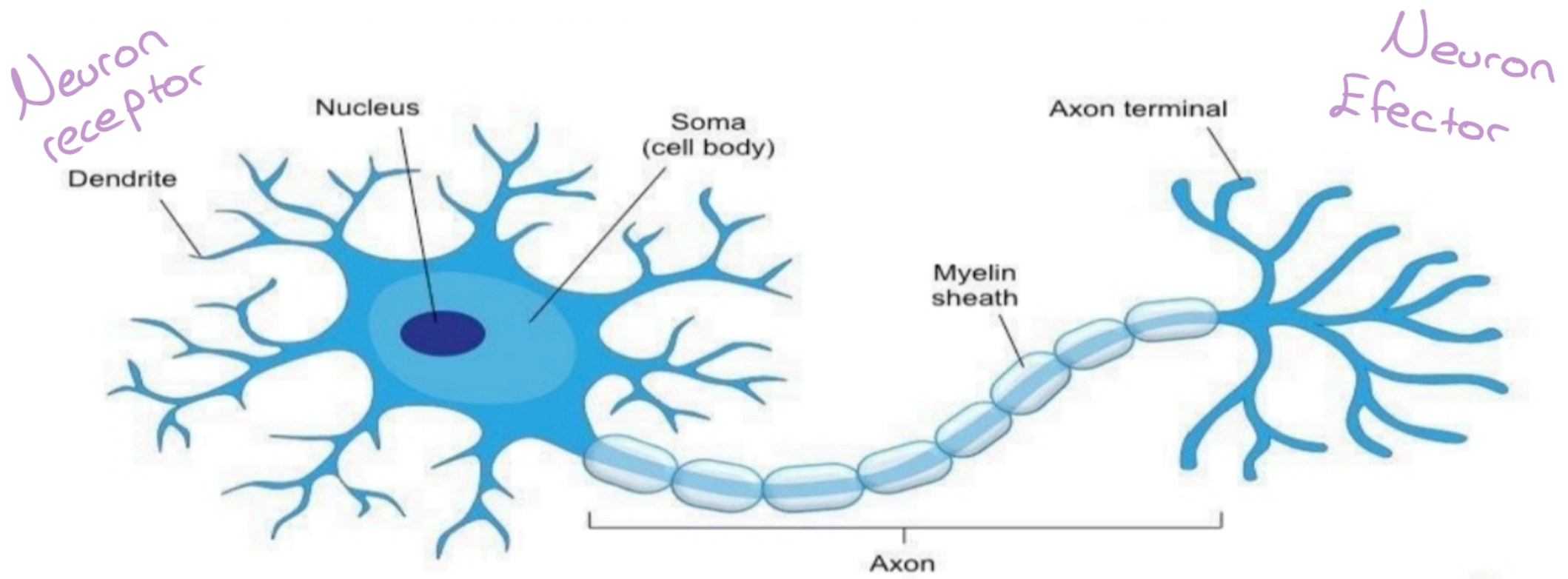
• A stimulus causes the initiation of an electrical impulse in the receptor cell. This impulse is transmitted to neurons and carried to the brain or spinal cord, where it is interpreted. The response is then transmitted to effector organs such as muscles or glands.

- The nervous system converts sensory information into electrical impulses to allow rapid detection of and response to stimuli.

- Nervous tissue makes up the nervous system and consists of neurons and glial cells.

- Neurons are specialised cells that transmit electrical impulses within the nervous system.

- Glia cells (from Greek glia meaning “glue”) are supporting cells that help neurons carry out their functions, such as protection, insulation, and nourishment.



Stimuli → Receptor (sensory organ) → sensory Organ → Inter Neuron → Motor Neuron → Response

Pressure

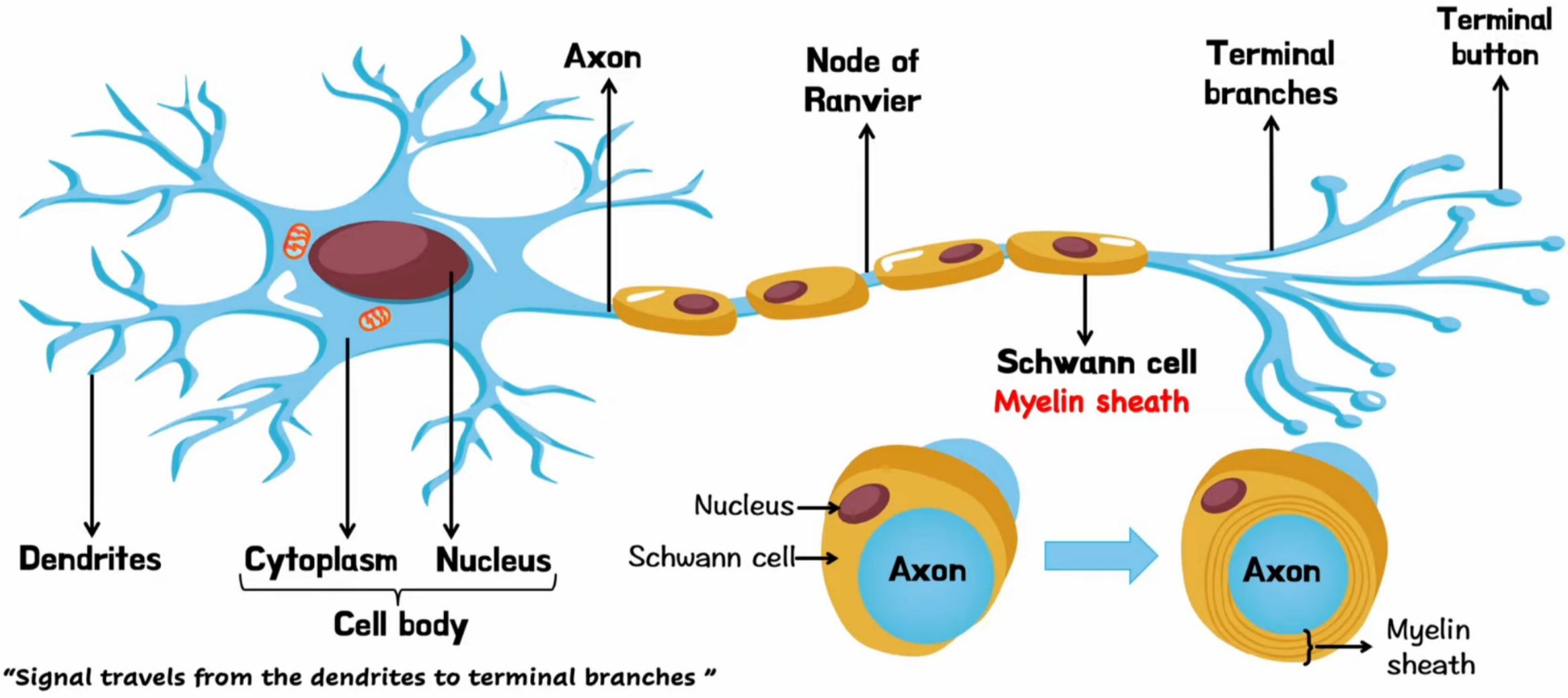
efector organ → Gland, Muscle

[Structure]

Neuron

An individual cell that carries electrical impulses (signals) from one point in the body to another.

"Some long (1m) some short"

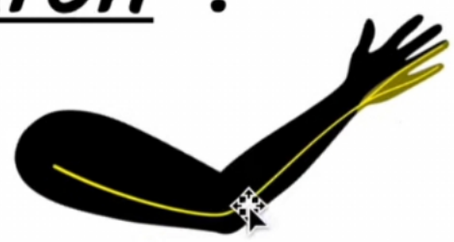


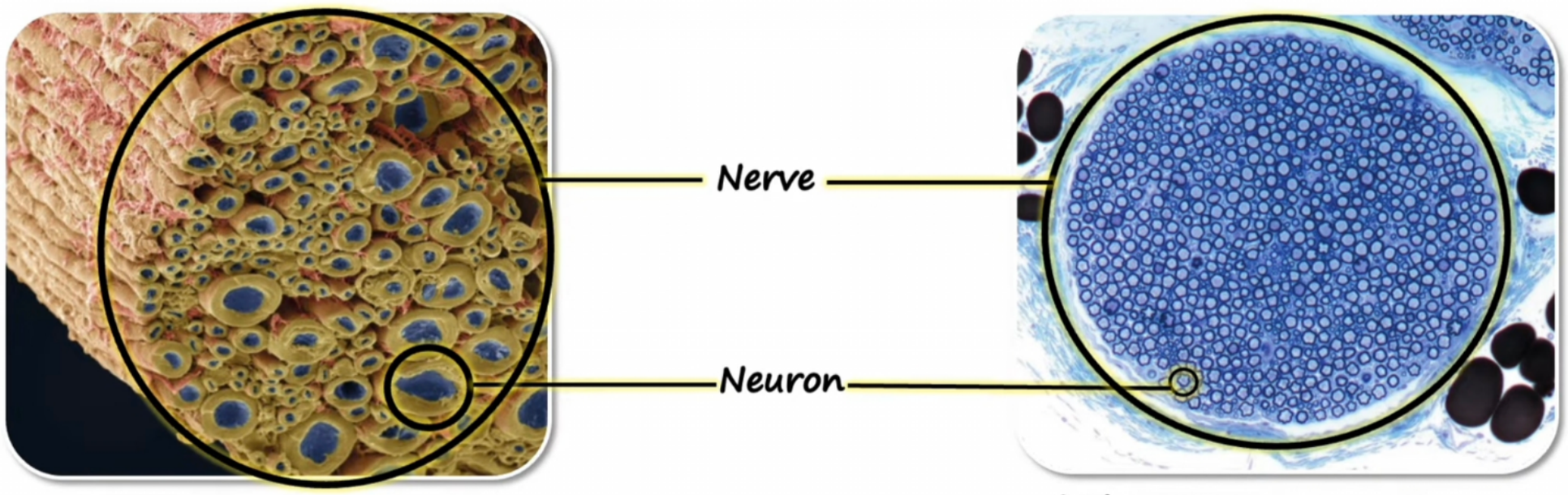
"Signal travels from the dendrites to terminal branches "

[Structure]

Difference between a "nerve" & a "neuron"?

When many individual neurons grouped or bundle together it forms a nerve.





SEM (Scanning electron microscope):
Blue = axons
Yellow/Green = Myelin Sheath

Light microscope:

Structure of a neuron

Neurons have three basic components:

- Soma (cell body): Contains the nucleus and organelles. Site of essential metabolic processes required for cell survival.

- Dendrites: Short, branched fibres that receive information from other neurons or receptor cells. They convert chemical signals into electrical signals.

- Axon: A single long extension that carries electrical impulses away from the cell body to other neurons or effector organs. Some axons (in the brain and spinal cord) are surrounded by a myelin sheath.

> In myelinated neurons, impulse transmission speed is 120 m/s. → CNS (Brain, spinal cord)

> In unmyelinated neurons, impulse transmission speed is 12 m/s. → PNS

> The myelin sheath speeds up impulse transmission by providing electrical insulation.
Gaps in the myelin sheath are called Nodes of Ranvier, where myelin is absent. Myelin → lipids

Synapse

- A synapse is the region where the axon of one neuron meets the dendrite of another neuron.

- In neurons, impulse transmission occurs in one direction: dendrite → soma → axon.

Glial cells

• Glial cells are supporting cells of the nervous system that protect, insulate, and maintain neurons.

• Glial cells are divided into two groups based on their location:

• Glial cells in the CNS (Central Nervous System) → Oligodendrocytes:
• Found in the brain and spinal cord. Produce the myelin sheath around axons of neurons in the CNS.
• One oligodendrocyte can myelinate multiple axons.
• The myelin sheath increases the speed of impulse transmission by providing electrical insulation.

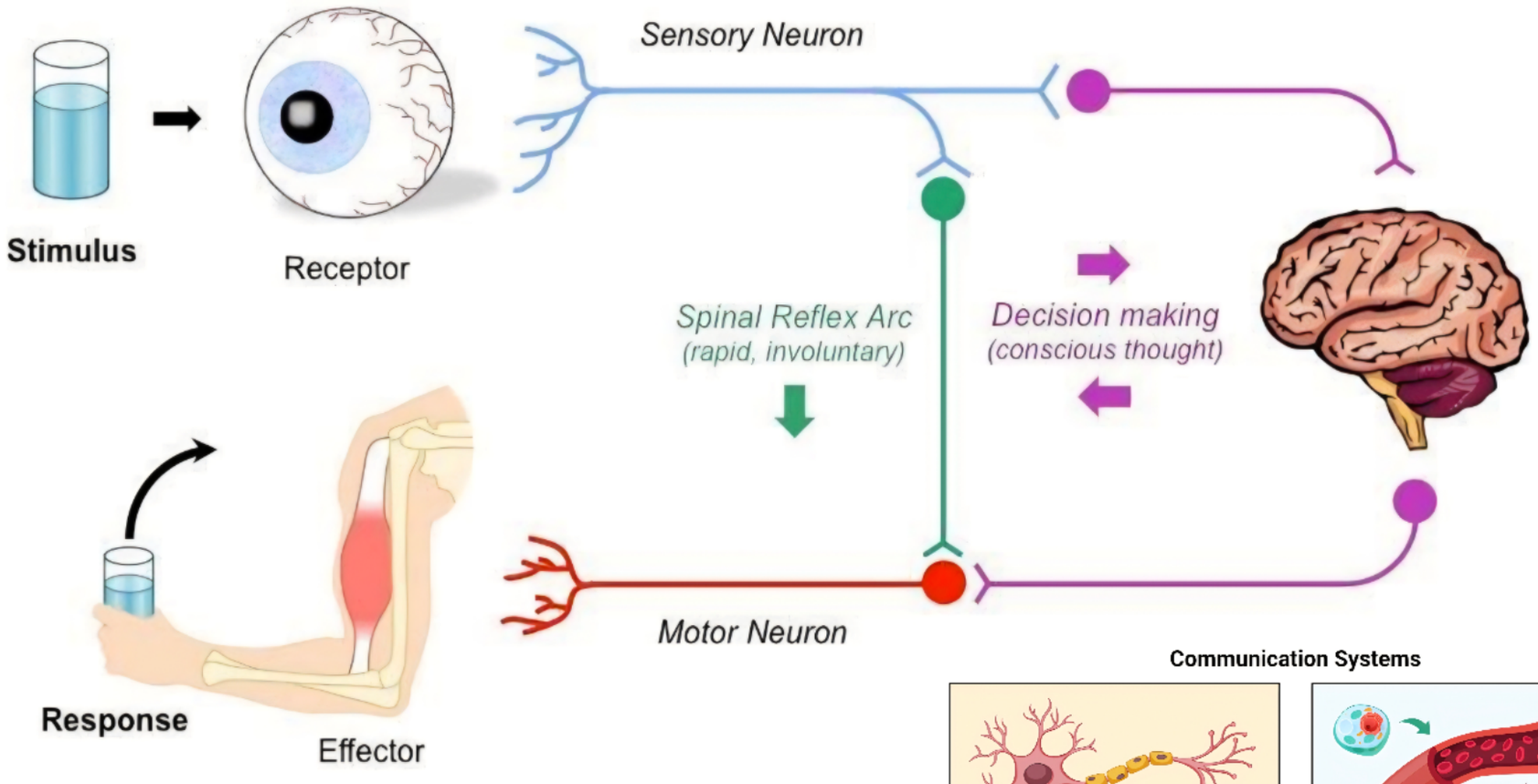
• Glial cells in the PNS (Peripheral Nervous System) → Schwann cells:
• Found in the peripheral nervous system. Produce the myelin sheath around axons of neurons in the PNS.
• Each Schwann cell myelinates one section of one axon.
• They also play a role in axon regeneration after injury.

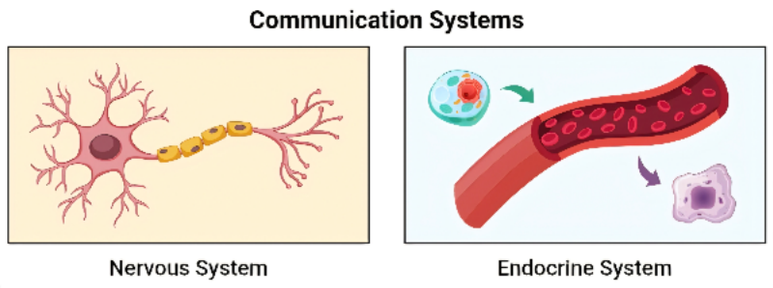
Types of neurons

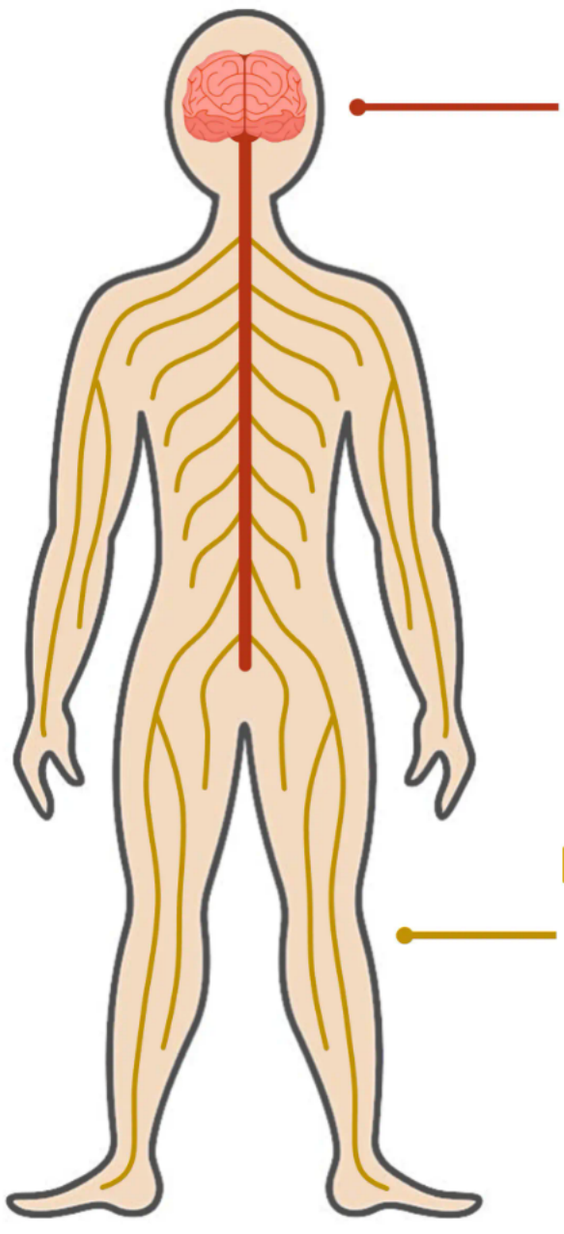
Sensory neuron: Carry electrical impulses from receptors to the central nervous system (CNS), which includes the brain and spinal cord.

Interneuron: Located entirely within the central nervous system.
They process and evaluate impulses from sensory neurons and transmit signals to motor neurons.

Motor neuron: Carry electrical impulses from the central nervous system to effector organs, such as muscles or glands, to produce a response.







The central nervous system integrates information received from peripheral nerves and coordinates bodily responses

The majority of this integration occurs within the brain, however certain responses can be autonomously mediated by the spinal nerves (reflex actions)

The peripheral nervous system relays signals between the central nervous system and the organs of the body

Signals within the body tissues are detected by receptors and transmitted to the CNS via sensory neurons

Responsive signals from the CNS are transmitted to effectors (muscles and glands) via motor neurons

Generation of the resting potential

• Electricity is the phenomenon associated with stationary or moving charged particles.
In neurons, electrical signals are produced by the movement of charged ions across the plasma membrane.

• The plasma membrane restricts ion movement, so concentration gradients can be maintained between the inside and outside of the cell.

• Differences in the concentrations of positively and negatively charged ions create a potential difference (voltage) across the membrane.
The inside of the neuron is electrically negative compared with the outside, so the membrane potential is negative.

~~ Resting state:
• When a neuron is not transmitting a signal, it has a resting membrane potential of about −70 mV. This means the cytosol is more negatively charged than the extracellular fluid.

• Potassium ions (K^+) are mainly concentrated inside the cell, while sodium ions (Na^+) are mainly concentrated outside the cell. This ion distribution is essential for normal neural function.

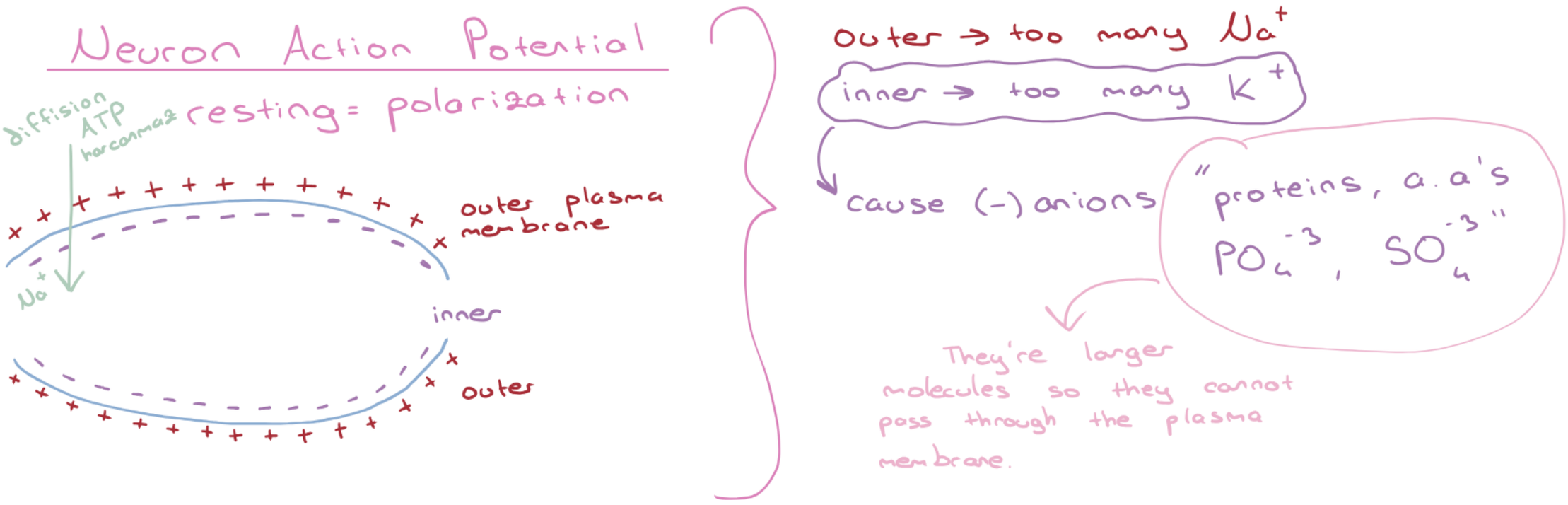
• The resting potential is maintained by the following mechanisms:

• The sodium–potassium pump uses active transport and ATP to move 3 Na^+ ions out of the cell and 2 K^+ ions into the cell. Because more positive ions leave than enter, the cytoplasm becomes more negative.
• This pump also maintains the concentration gradients of Na^+ and K^+.

~ Two additional factors contribute to the resting potential:

• Leakage of ions by diffusion: Na^+ and K^+ ions leak across the membrane.
The membrane is about 50 times more permeable to K^+ than to Na^+, so K^+ leaks out faster.

• Organic anions: There are more negatively charged organic anions (such as proteins and amino acids) inside the cell than outside.
These contribute to the negative charge inside the neuron.



Nerve impulses as action potentials

• Impulse: The electrical and chemical change that occurs in a neuron in response to internal or external stimuli.

• Threshold value (threshold intensity): The minimum stimulus strength required to trigger an impulse in a nerve cell.

• Electrical signals can involve the movement of ions or electrons. Nerve impulses are electrical signals because they involve the movement of positively charged ions.

• A nerve impulse is a brief reversal of the resting membrane potential of a neuron. This occurs due to facilitated diffusion of Na^+ and K^+ ions across the membrane.

• Action potential: The changes in voltage that occur during a nerve impulse.

• Membrane potential is the difference in electrical charge across the plasma membrane.

○ There are two stages in an action potential:

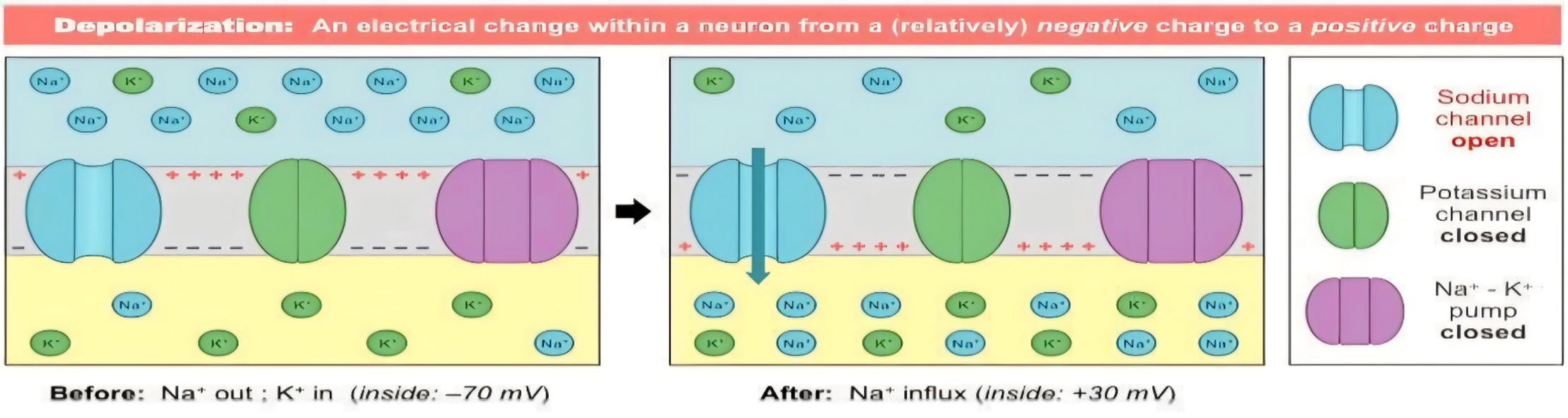
~~ I. Depolarization

• When a neuron receives a stimulus and the threshold value is reached, an action potential is triggered.

• Voltage–gated sodium ion channels open, allowing Na^+ ions to diffuse into the cell.

• This causes depolarization, which is a decrease in the voltage difference between the inside and outside of the cell. The membrane potential becomes positive and reaches approximately +40 mV.

• During depolarization, voltage–gated potassium ion channels remain closed.



~~ II. Repolarization

• Repolarization restores the membrane potential to its resting value of −70 mV after depolarization reaches its peak.

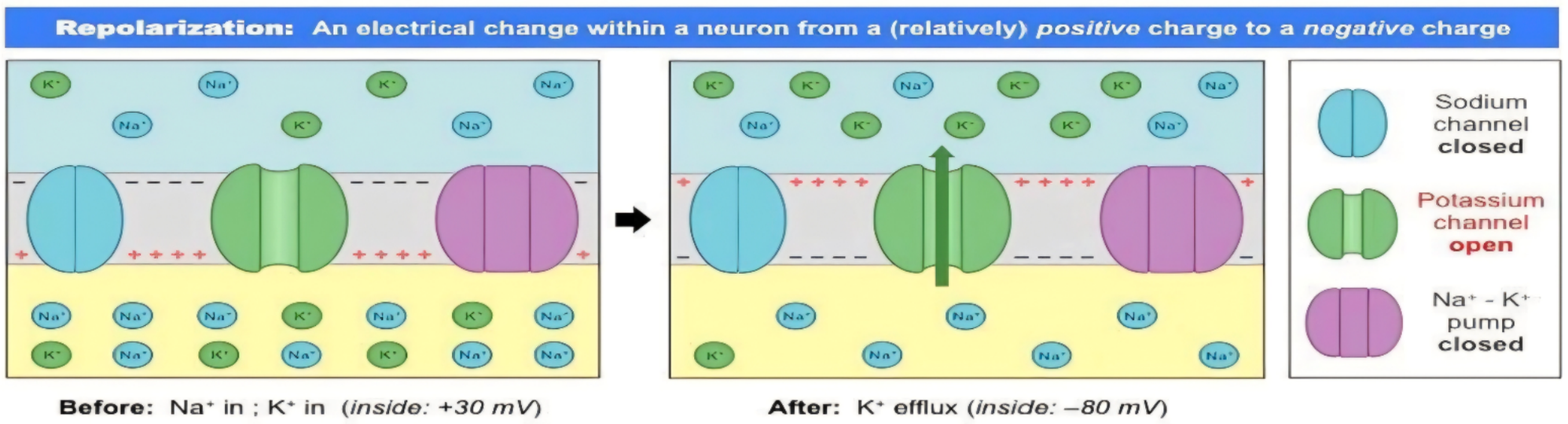
• At the peak of the action potential, voltage–gated sodium ion channels close. At the same time, voltage–gated potassium ion channels open, allowing K^+ ions to diffuse out of the cell.

• The loss of positively charged K^+ ions causes the membrane potential to become negative again.

• For a short time, the membrane becomes hyperpolarized at about −80 mV.

• This occurs because potassium ion channels remain open slightly longer than needed.

• The potassium ion channels then close, and the membrane potential is gradually returned to −70 mV by the sodium–potassium pump.

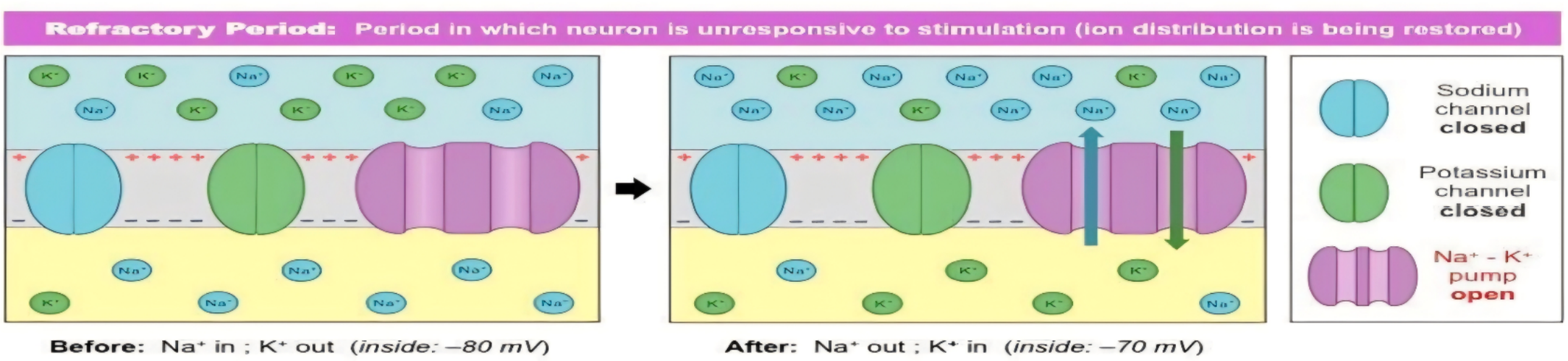


~~ III. Rebuilding gradients --> Resting State

• Until the resting potential is fully restored, the neuron enters a refractory period.

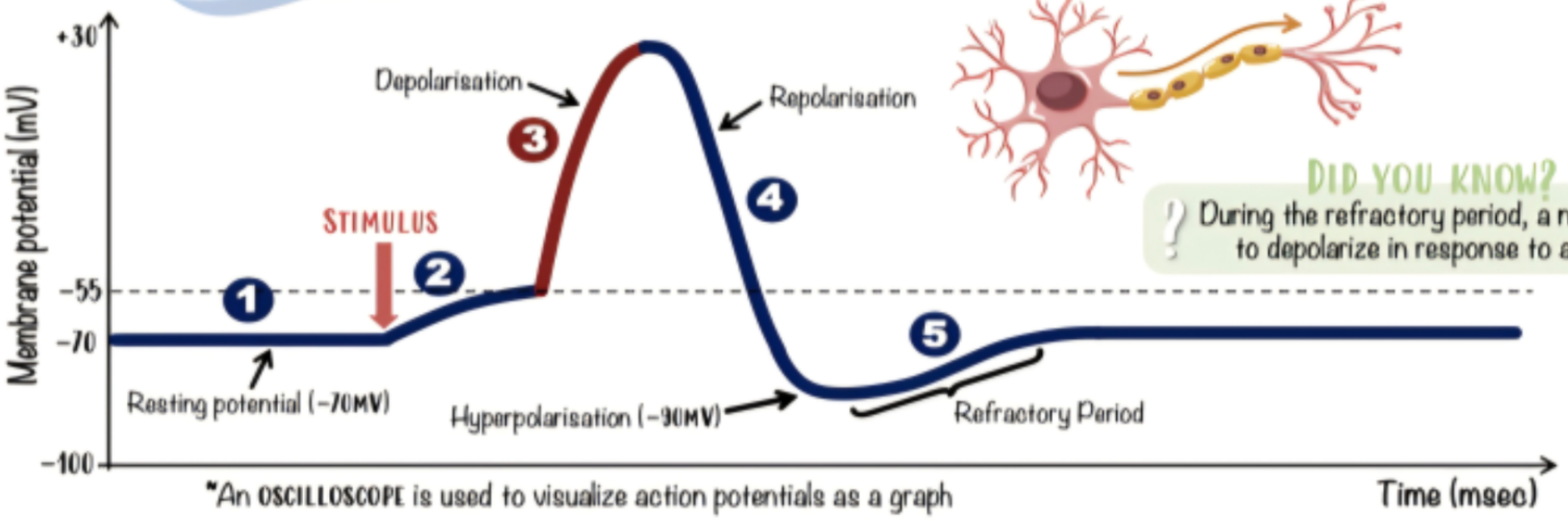
• During the refractory period, another action potential cannot be produced.

• After an action potential, the sodium–potassium pump actively transports ions to re–establish Na^+ and K^+ concentration gradients. This prepares the neuron for the next nerve impulse.



NERVE IMPULSE GENERATION

The detailed mechanism!



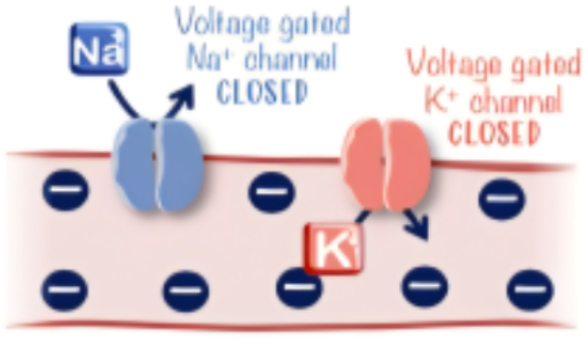
A signal is transmitted from the neuron's **DENDRITES**, along the **AXON** all the way to the **TERMINAL BRANCHES.**

DID YOU KNOW?

During the refractory period, a neuron is unable to depolarize in response to any stimulus.

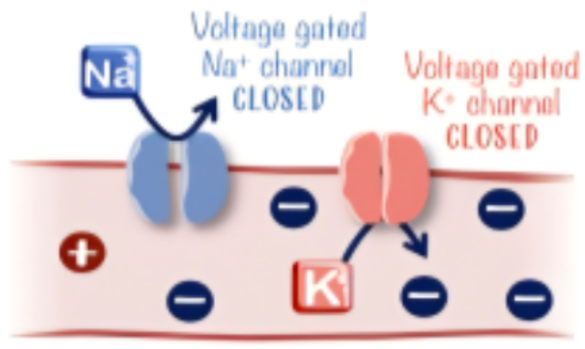
We now see the exact mechanism how an **ACTION POTENTIAL** can be represented as the curve seen above in **5** simple steps.

1 RESTING STATE (POTENTIAL)



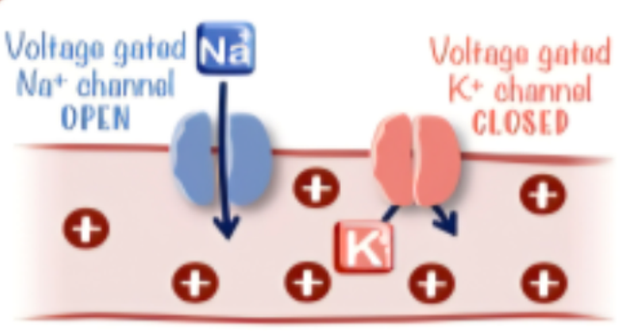
- High [Na^+] outside axon.
- High [K^+] inside axon.
- Membrane potential is negative.

2 STIMULUS ARRIVES



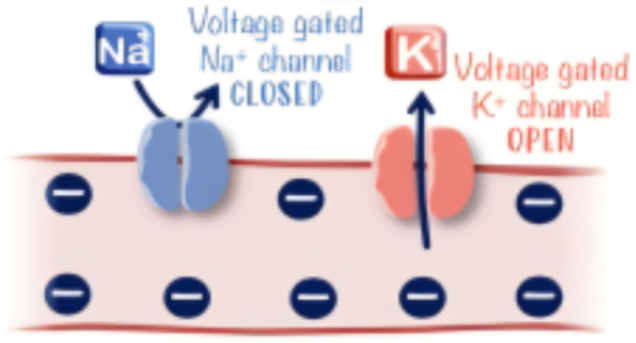
- Signal in the form of a positive charge arrives.
- Axon is slightly more positive.

3 DEPOLARIZATION



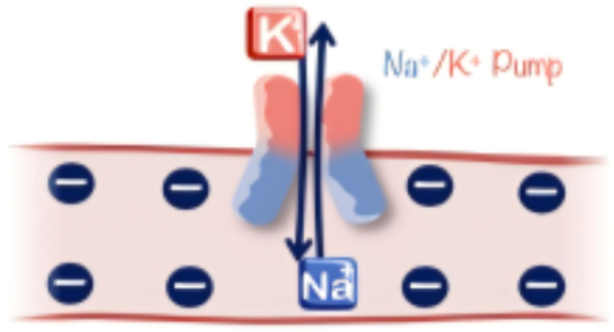
- If threshold potential is reached, voltage gated Na^+ channels open.
- Sodium diffuses into the axon to **DEPOLARIZE** the membrane.
- Membrane potential is positive.

4 REPOLARIZATION & HYPERPOLARIZATION



- Voltage gated K^+ channels open.
- Potassium diffuses out of the axon to **REPOLARIZE** the membrane.
- Membrane potential is negative, but even lower than resting potential.

5 RESETTING THE RESTING POTENTIAL



- Na^+/K^+ Pump pumps sodium out and potassium into the axon.
- Resets resting membrane potential.
- Na^+ & K^+ are returned to their original locations.

Key Terms

ACTION POTENTIAL – the sequence of events that allows an impulse (electrical signal) to be generated in a neuron.

RESTING POTENTIAL – When the neuron is not transmitting an impulse; **NEGATIVELY** (-70mV) charged inside compared to the outside.

THRESHOLD POTENTIAL – The minimum potential needed to initiate an action potential (-55mV).

BEAUTIFUL TIP!

Na^+ = Nah = 3

K^+ = K (okay) = 2

Variation in the speed of nerve impulses

• In some neurons, the axon is covered by a fatty white substance called myelin, which acts as an insulating layer.

• Myelin is made of proteins and phospholipids and is produced by glial cells.
• In the PNS, myelin is produced by Schwann cells.
• In the CNS, myelin is produced by oligodendrocytes.

• The myelin sheath acts as an electrical insulator between the axon membrane and the extracellular fluid. It prevents ions from entering or leaving the axon membrane. Because ions cannot move across myelinated regions, depolarization cannot occur there. This reduces the surface area of the axon membrane that must depolarize. As a result, myelinated axons depolarize only at the Nodes of Ranvier, which are small gaps in the myelin sheath.

• The main function of the myelin sheath is to increase the speed of nerve impulse transmission by saltatory conduction.

Saltatory conduction

• In unmyelinated neurons, action potentials propagate continuously along the entire axon membrane as a wave of depolarization.

• In myelinated neurons, action potentials jump between the Nodes of Ranvier. This hopping mechanism greatly increases conduction speed, by up to 100–fold.

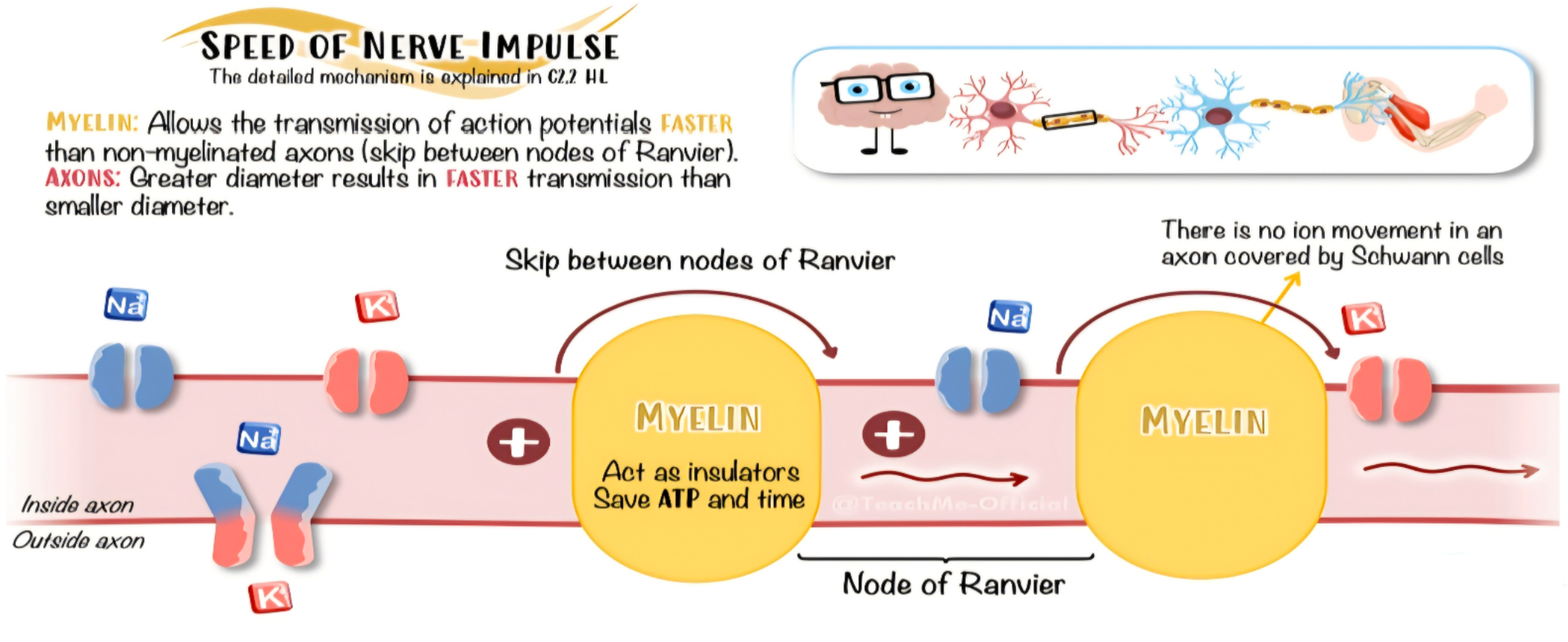
Exp: Squids have giant axons with a diameter of about 500 μm. These axons are unmyelinated but allow a conduction speed of about 25 m/s. This enables rapid escape responses using jet propulsion.

Factors affecting the speed of action potentials

• Myelination: Myelinated axons can conduct impulses at speeds of up to 150 m/s, while unmyelinated axons conduct impulses at about 0.5–10 m/s.

• Axon diameter: Larger axon diameters allow faster transmission because ions face less resistance.

• Ion channel density: A higher density of voltage–gated sodium ion channels at the Nodes of Ranvier allows faster depolarization and quicker signal transmission.



Synapses as junctions between neurons and effector cells

• A synapse is a junction between two cells in the nervous system.

• Synapses are mainly located in the brain and spinal cord.

• Signals can pass across a synapse in one direction only.

• One neuron brings the signal to the synapse in the form of a nerve impulse (action potential).
• This neuron is called the presynaptic neuron, and it has a presynaptic membrane.

• The second neuron carries the signal away from the synapse, also as a nerve impulse.
• This neuron is called the postsynaptic neuron, and it has a postsynaptic membrane.

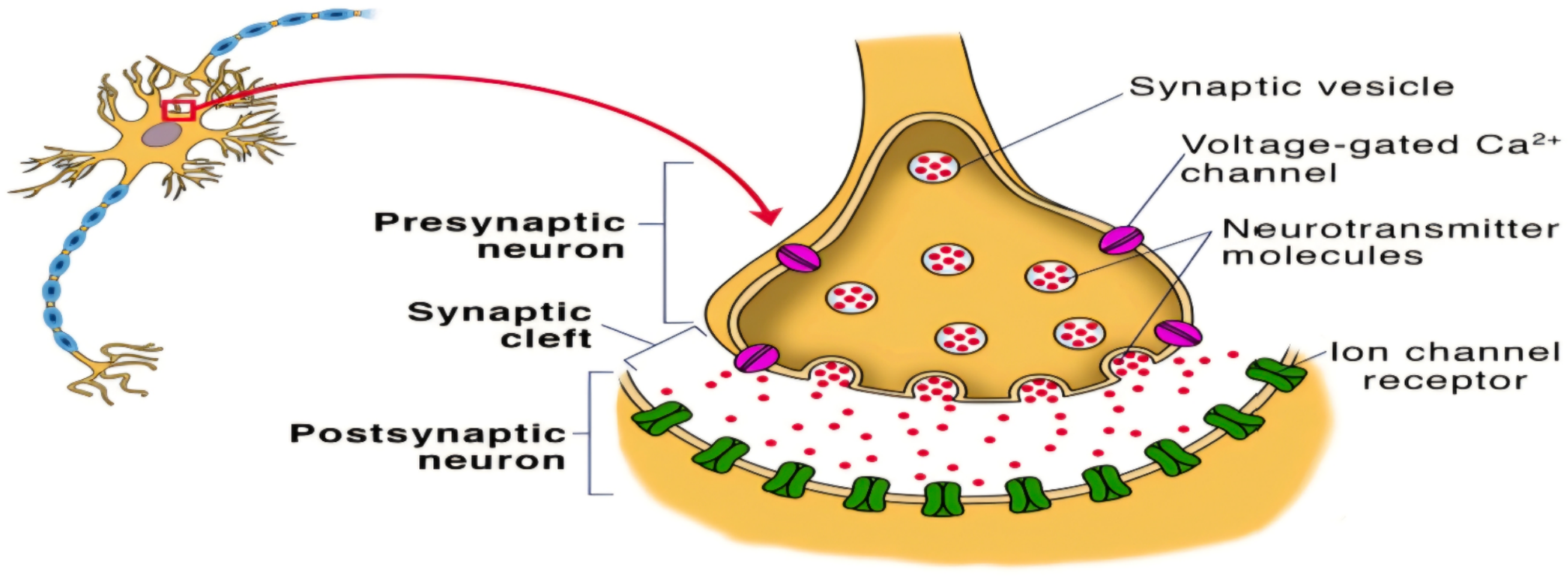
• Between the presynaptic and postsynaptic membranes is a narrow, fluid–filled gap called the synaptic cleft, which is about 20 nm wide.

• The signal crosses the synapse using a chemical substance called a neurotransmitter.
The neurotransmitter transfers the signal from the presynaptic membrane to the postsynaptic membrane.

• Synapses are not only found between neurons.

~~ They also occur:
• Between sensory receptor cells and neurons
• Between neurons and effector cells

• Effector cells are cells that carry out responses in the body.
~~ The two main types of effector cell are:
• Muscle fibres
• Gland cells



Release of neurotransmitters from a presynaptic membrane

• Synaptic transmission: The sequence of events from the arrival of a nerve impulse at the presynaptic membrane to the initiation of an impulse in the postsynaptic membrane.

• The early stages of synaptic transmission result in the release of neurotransmitter.

• When a nerve impulse arrives at the presynaptic membrane of the transmitting neuron, the membrane becomes depolarized.

• Depolarization causes voltage–gated calcium (Ca^{2+}) channels to open.

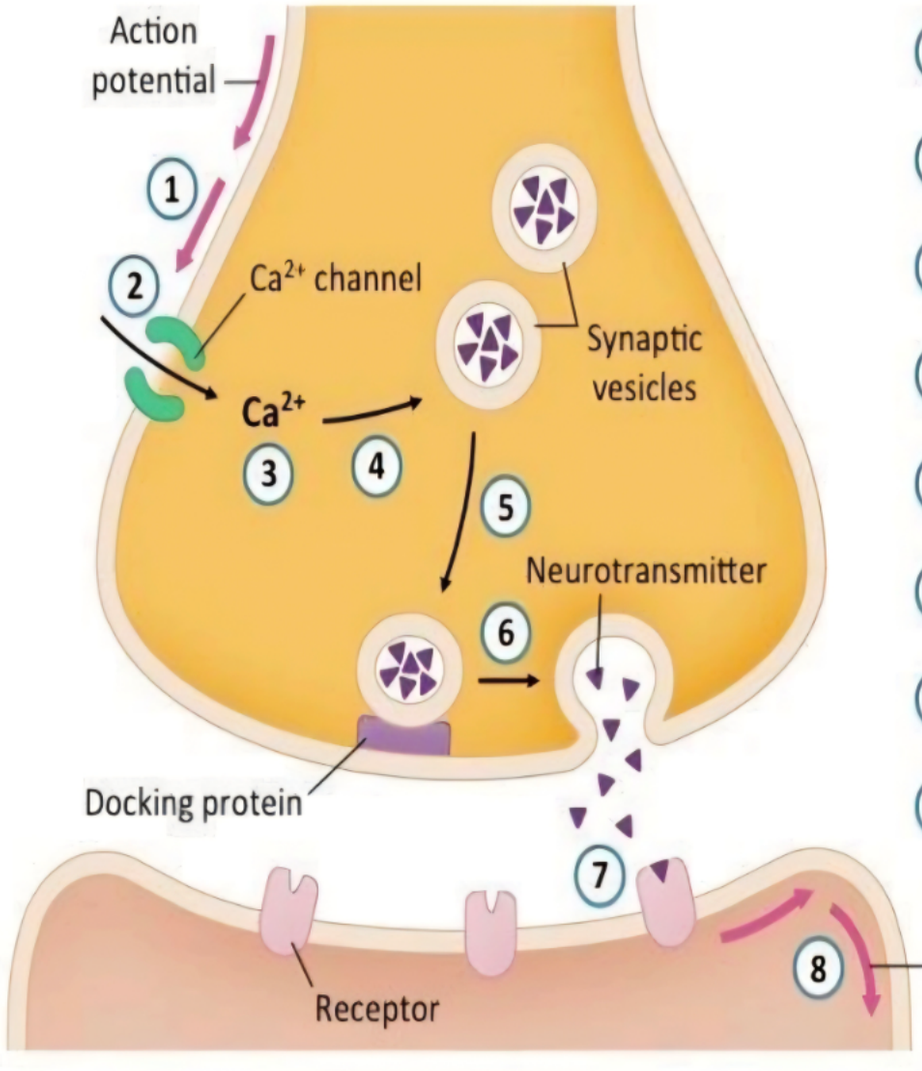
• Because the concentration of Ca^{2+} ions is higher outside the presynaptic membrane, Ca^{2+} diffuses into the presynaptic neuron.

• The influx of Ca^{2+} ions causes synaptic vesicles containing neurotransmitter to move towards the presynaptic membrane.

• The vesicles fuse with the presynaptic membrane and release the neurotransmitter into the synaptic cleft by exocytosis.

~~ Sequence of events

1. A nerve impulse arrives at the presynaptic membrane and depolarization occurs.
2. Depolarization opens voltage–gated calcium channels.
3. Calcium ions diffuse into the presynaptic neuron, causing vesicles to move to the membrane.
4. Neurotransmitter is released into the synaptic cleft by exocytosis..



1. Action potential arrives at axon terminal
2. Voltage-gated Ca^{2+} channels open
3. Ca^{2+} enters the presynaptic neuron
4. Ca^{2+} signals to neurotransmitter vesicles
5. Vesicles move to the membrane and dock
6. Neurotransmitters released via exocytosis
7. Neurotransmitters bind to receptors
8. Signal initiated in postsynaptic cell

Generation of an excitatory postsynaptic potential (EPSP)

• Release of a neurotransmitter from the presynaptic membrane triggers the final stages of synaptic transmission that can lead to an action potential in the postsynaptic neuron.

~~ After neurotransmitter release:

5. Neurotransmitter molecules diffuse across the synaptic cleft. This happens very rapidly because the distance is short, about 20–40 nm.

6. The neurotransmitter binds to specific receptors on the postsynaptic membrane. This binding opens ligand–gated Na^+ channels. Na^+ ions diffuse into the postsynaptic neuron, causing depolarization of the postsynaptic membrane.

7. To allow the postsynaptic neuron to respond to another signal, the neurotransmitter must be removed from the synaptic cleft. This occurs by DRD:

• Degradation by enzymes in the synaptic cleft
• Recycling (reuptake) by the presynaptic neuron
• Diffusion away from the synaptic cleft

• If the membrane potential rises from −70 mV to −50 mV, an action potential is triggered in the postsynaptic neuron and is propagated away from the synapse.

• A depolarization that is sufficient to trigger an action potential is called an excitatory postsynaptic potential (EPSP).

Example: Acetylcholine is an excitatory neurotransmitter at neuromuscular junctions. It binds to receptors on muscle cells and causes depolarization and muscle contraction. Acetylcholine is then degraded by acetylcholinesterase, and the breakdown products are recycled by the presynaptic neuron.

Depolarization and repolarization during action potentials

• The threshold potential is a critical membrane potential, usually around −50 mV. This threshold must be reached for voltage–gated sodium ion channels to open and depolarization to occur.

• A neuron only fires an action potential if the EPSP is strong enough to reach the threshold potential.

• Voltage–gated potassium ion channels have a similar structure to sodium ion channels.

• The opening and closing of sodium and potassium channels occurs in response to changes in membrane voltage.

• This mechanism is called voltage–gating.

• Both sodium and potassium channels remain open for only a short time, making action potentials brief and rapid.

• Threshold potentials and all–or–nothing principle. A nerve impulse is all–or–nothing. If the threshold potential is not reached, no action potential occurs.

• Small depolarizations, such as from −70 mV to −60 mV, do not open voltage–gated sodium channels. Instead, the sodium–potassium pump restores the resting potential of −70 mV.

~ Important distinction

• Ligand–gated Na^+ channels initiate the synaptic signal at the postsynaptic membrane.

• Voltage–gated Na^+ channels convert this signal into an action potential and transmit it along the axon.

Propagation of an action potential along a nerve fibre by local currents

• A nerve impulse: An action potential that travels along an axon from one end to the other.

• This movement occurs because an action potential in one region of the axon triggers an action potential in the adjacent region.

• This process is called "Propagation of the nerve impulse."

• Propagation occurs due to local currents. Local currents are movements of Na^+ ions by diffusion between a region of the axon that is depolarized and a neighbouring region that is still polarized.

• Depolarization occurs due to an influx of Na^+ ions, which increases the sodium ion concentration inside the axon and decreases it outside.

• As a result, Na^+ ions diffuse along the axon:

• Inside the axon, diffusion occurs from the depolarized region to the polarized region
• Outside the axon, diffusion occurs in the opposite direction

• These local currents cause the membrane potential of the adjacent polarized region to become less negative.

• If the membrane potential rises from −70 mV to the threshold potential of −50 mV, voltage–gated sodium ion channels open.

• This triggers a new action potential, allowing the nerve impulse to continue along the axon.

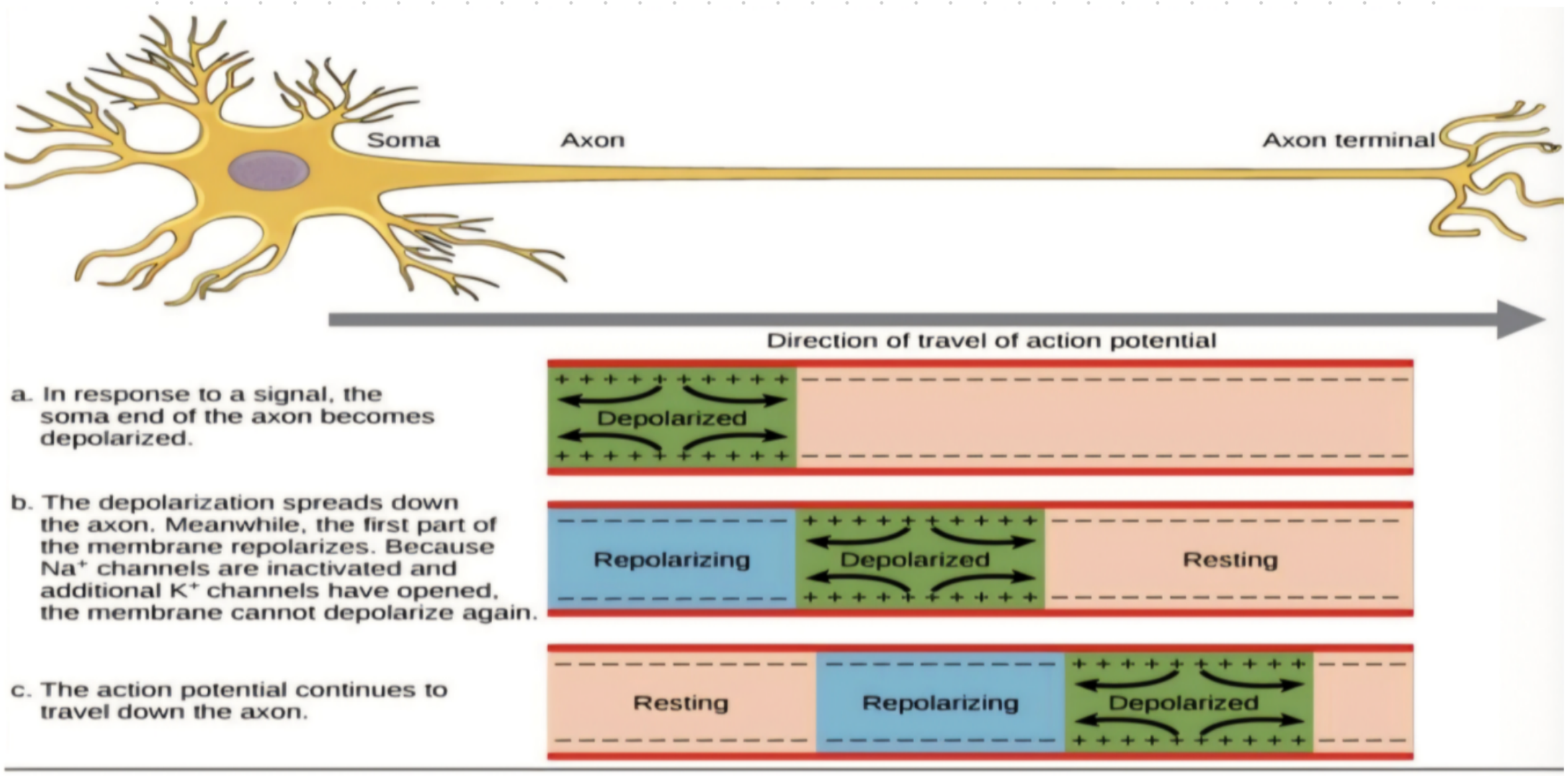


Figure: propagation of action potential an axon through local currents

Oscilloscope traces of resting and action potentials

• Membrane potential is measured using microelectrodes placed inside and outside an axon.

• The electrical signal is displayed using an oscilloscope.

~~ On an oscilloscope:
• The x–axis represents time
• The y–axis represents voltage (membrane potential)
• A horizontal line on the trace shows the resting potential (about −70 mV).
• A spike on the trace represents an action potential, showing rapid depolarization and repolarization.
• Oscilloscopes therefore show how membrane potential changes over time.

Saltatory conduction in myelinated fibres

• In myelinated axons, the myelin sheath prevents the movement of Na^+ and K^+ ions across the axon membrane.

• Voltage–gated sodium channels, voltage–gated potassium channels, and sodium–potassium pumps are concentrated at the Nodes of Ranvier.

• Nodes of Ranvier are gaps between Schwann cells where the axon membrane is exposed. Because ions cannot move across the myelinated sections, action potentials occur only at the Nodes of Ranvier.

• In unmyelinated axons, action potentials are propagated continuously along the entire axon membrane.

• In myelinated axons, the nerve impulse jumps from one Node of Ranvier to the next instead of travelling continuously.

•This process is called saltatory conduction.

• Saltatory conduction greatly increases the speed of nerve impulse transmission. In myelinated fibres, conduction speeds can reach up to 100 m s^{-1}, compared with about 1 m s^{-1} in unmyelinated axons.

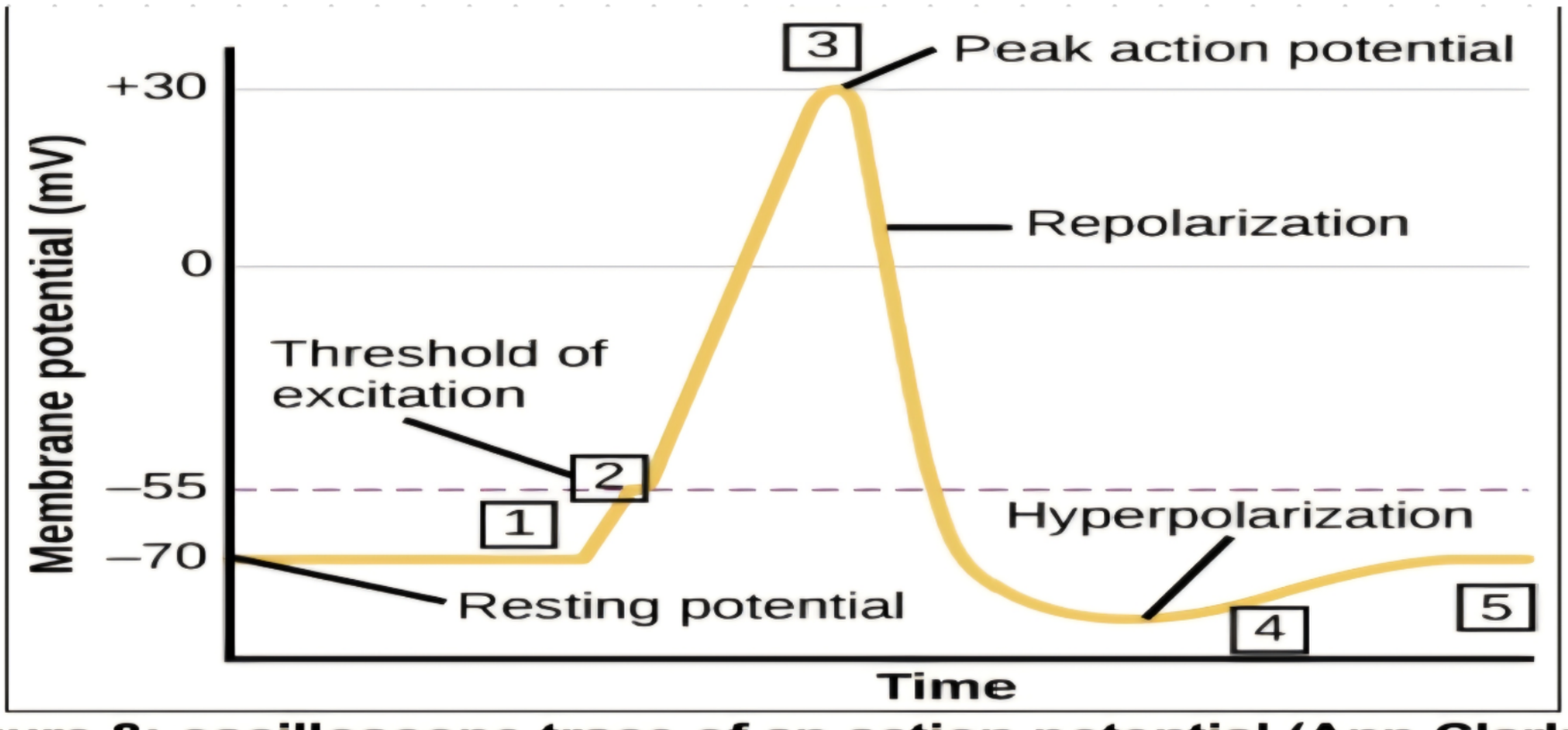


Figure 8: oscilloscope trace of an action potential (Ann Clarks).

Effects of exogenous chemicals on synaptic transmission

• Exogenous chemicals are chemicals that come from outside the body.
• They can enter the body through: The skin, The lungs, The gut, Injection.

• Two important groups of exogenous chemicals are pesticides and drugs.

• Some exogenous chemicals affect synaptic transmission by blocking or enhancing it.

~~ Examples include neonicotinoids and cocaine.

• Neonicotinoid pesticides: Synthetic chemicals that are similar to nicotine. They bind to acetylcholine receptors in cholinergic synapses in the central nervous system of insects.

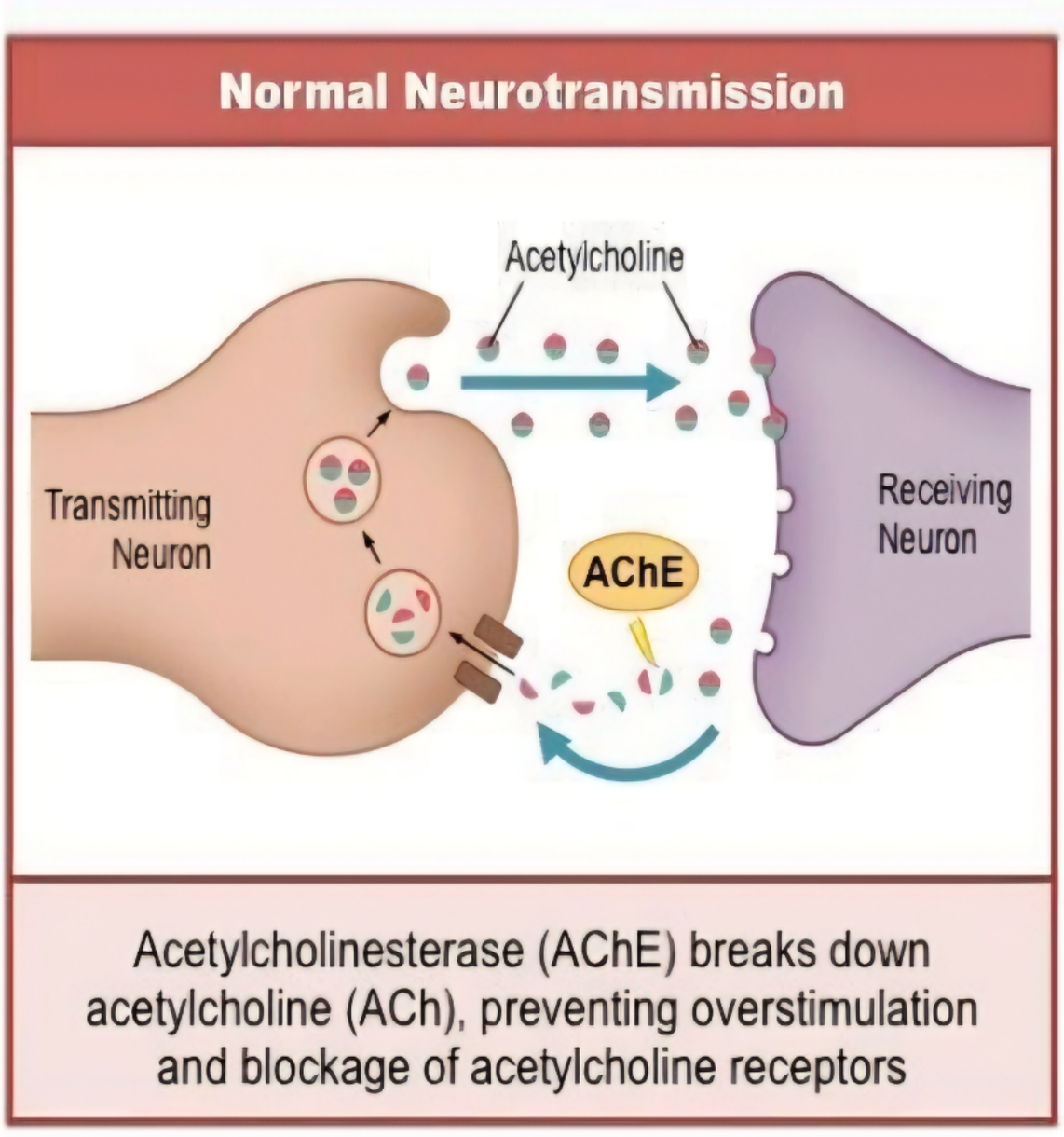
• Binding causes the Na^+ channel in the receptor to open.

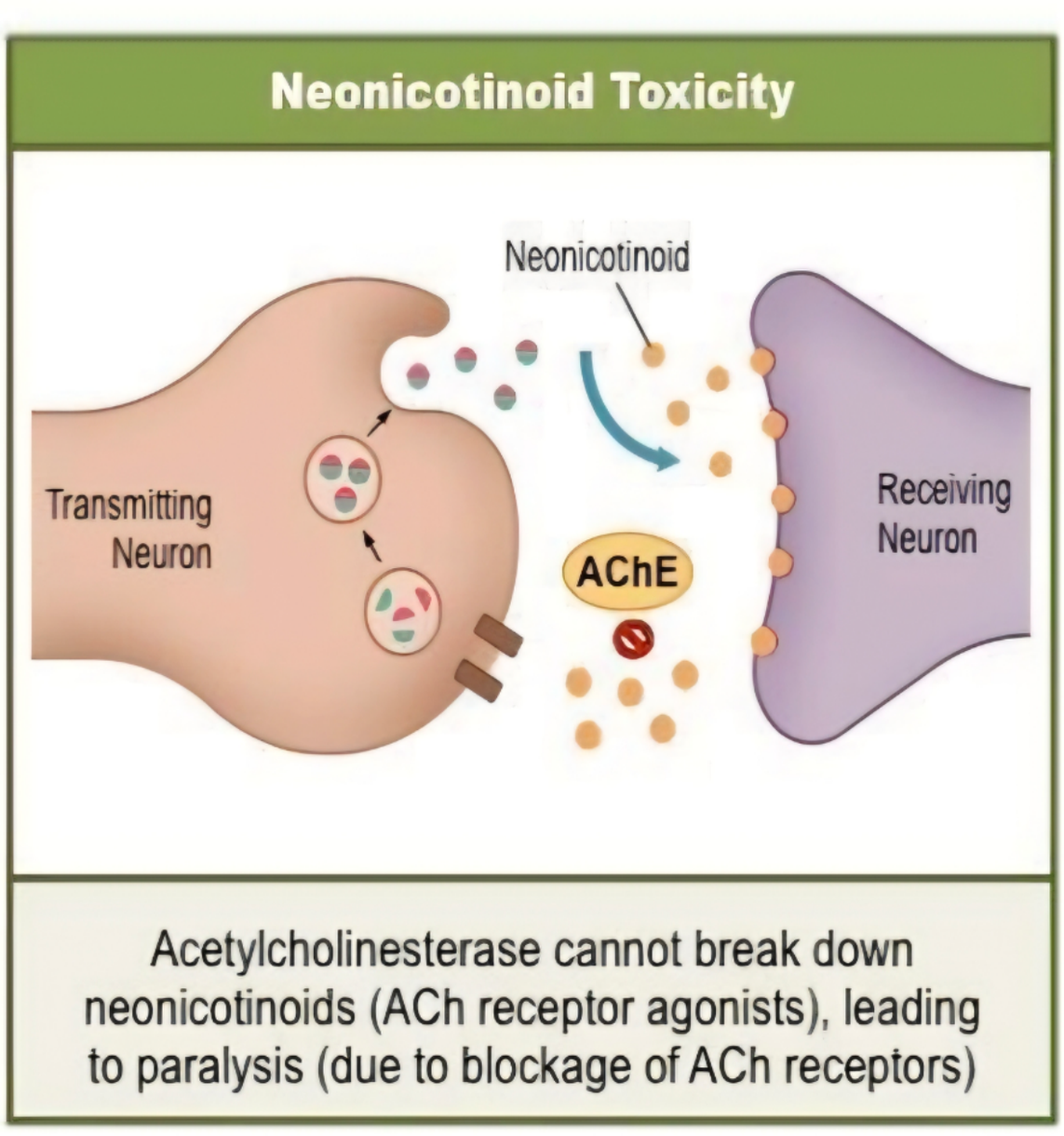
• Acetylcholinesterase cannot break down neonicotinoids, so the binding is irreversible.

• As a result, the Na^+ channel remains open, allowing excessive Na^+ ions to enter the postsynaptic neuron.

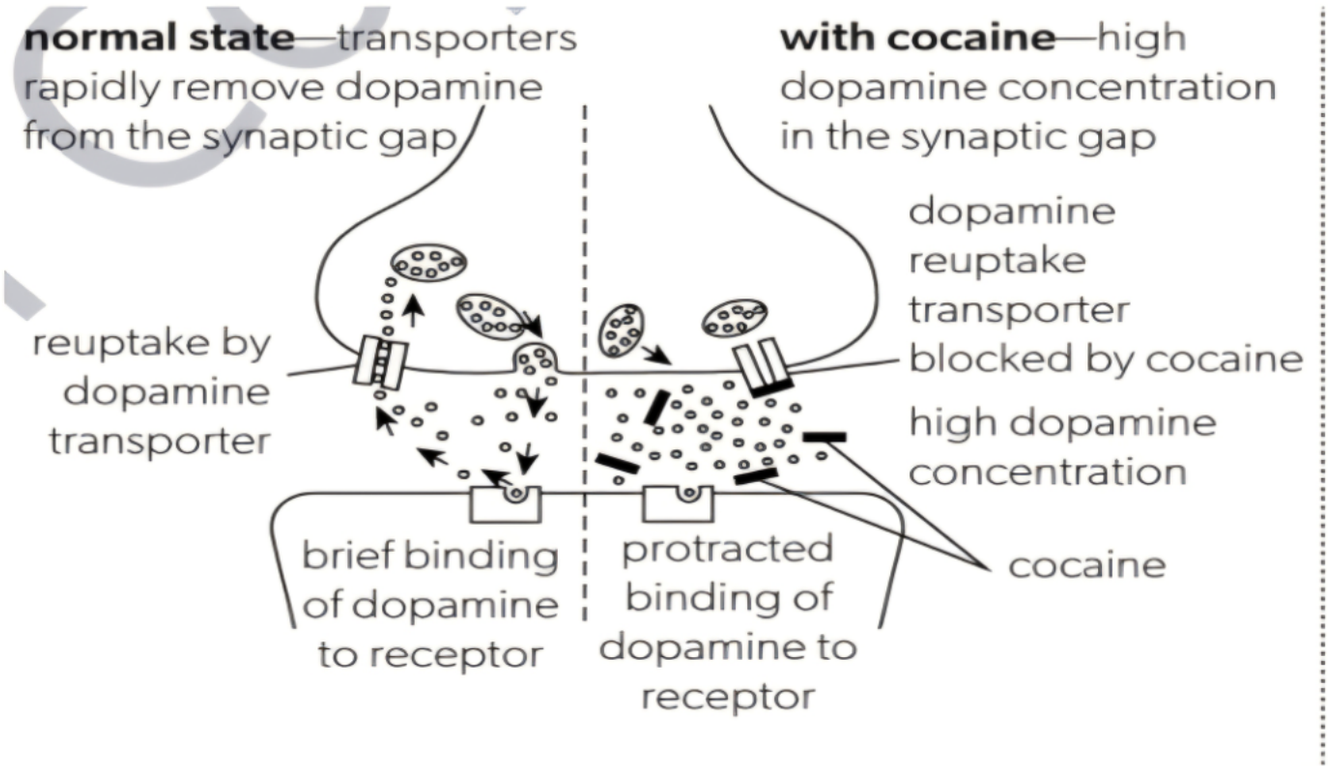
• This causes overstimulation, which blocks normal synaptic transmission. The effect in insects is paralysis and death.

• Neonicotinoids are therefore effective insecticides, but they can also harm bees and other beneficial insects, affecting ecosystems and agriculture.





Cocaine is a stimulant psychoactive drug that prevents dopamine reuptake into the presynaptic neuron, causing it to accumulate in the synaptic cleft and leading to continuous excitation of the postsynaptic neuron. This gives false feelings of euphoria and pleasure.



Inhibitory neurotransmitters and inhibitory postsynaptic potentials (IPSPs)

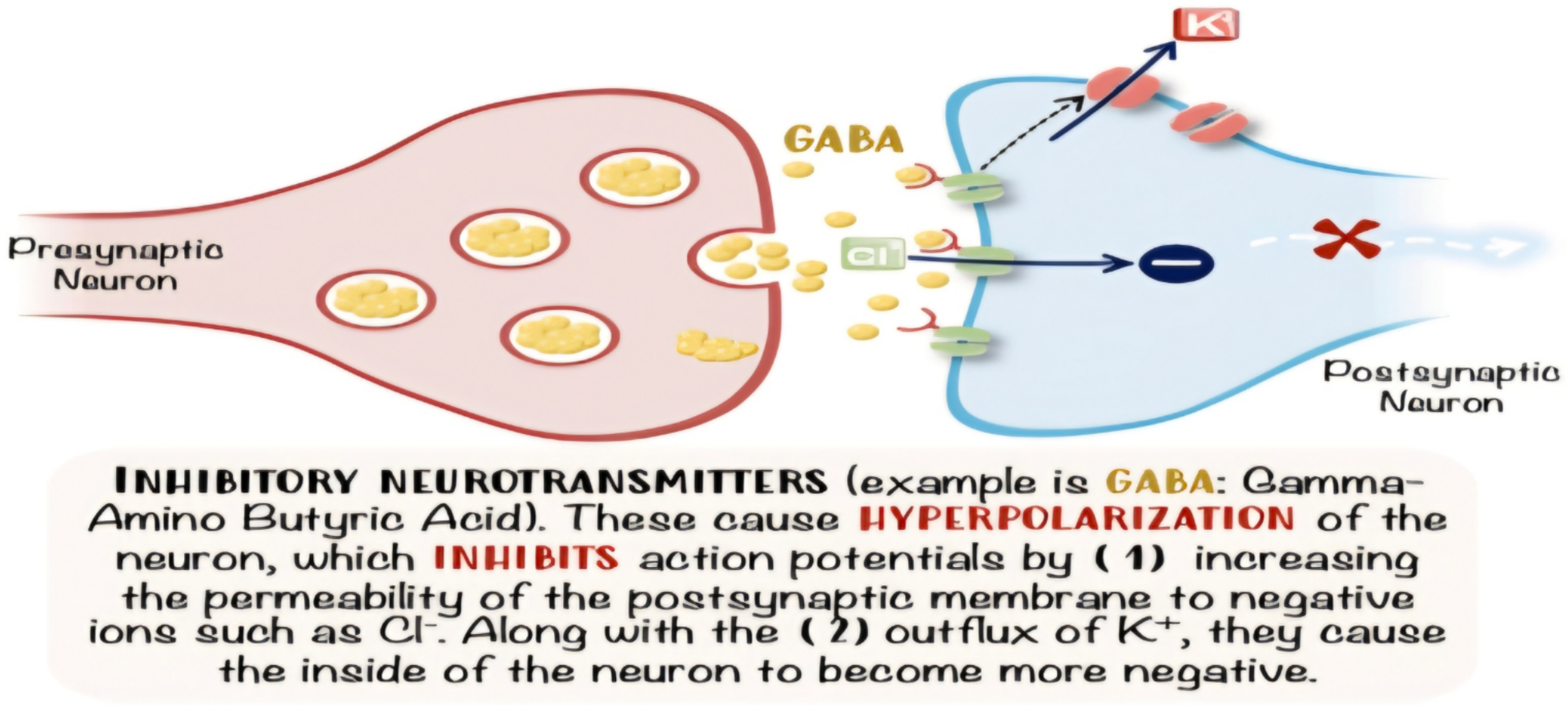
• Inhibitory neurotransmitters bind to receptors on the postsynaptic membrane. This binding causes chloride ion (Cl^-) channels to open.

• Cl^- ions diffuse into the cytoplasm of the postsynaptic neuron.

• The influx of negatively charged chloride ions makes the membrane potential more negative. This change in membrane potential is called "Hyperpolarization."

• Hyperpolarization increases the amount of Na^+ ions needed to depolarize the membrane to the threshold potential. As a result, the postsynaptic neuron is less likely to fire an action potential.

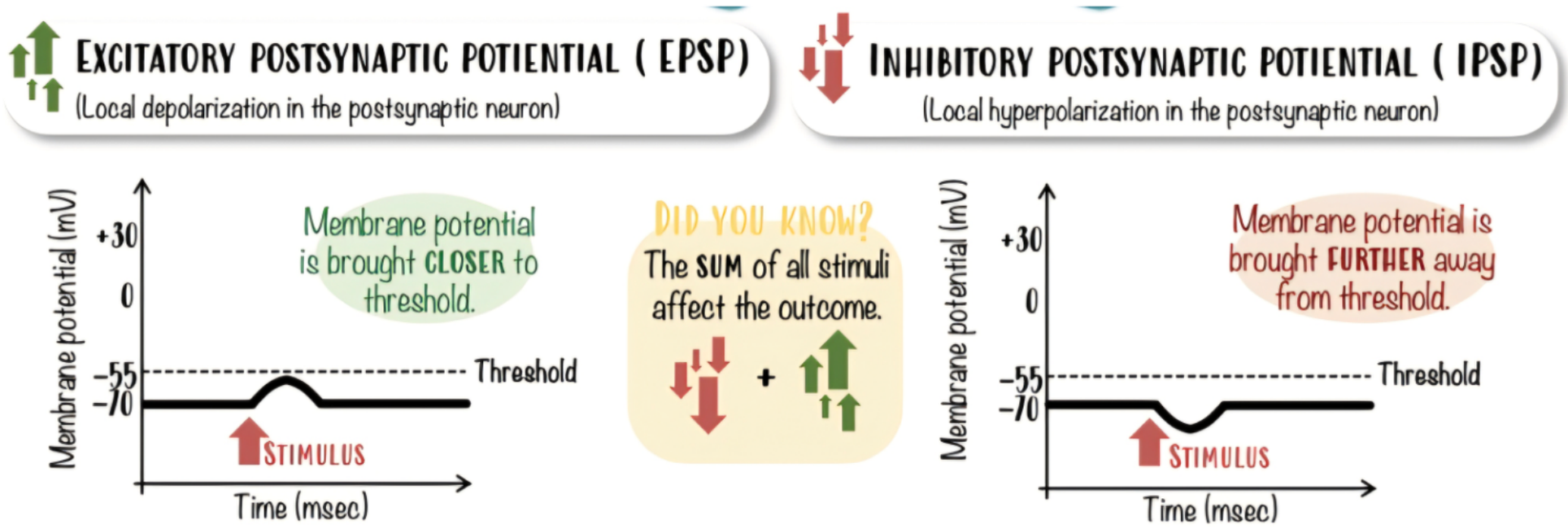
• The change in membrane potential caused by inhibitory neurotransmitters is called an inhibitory postsynaptic potential (IPSP).

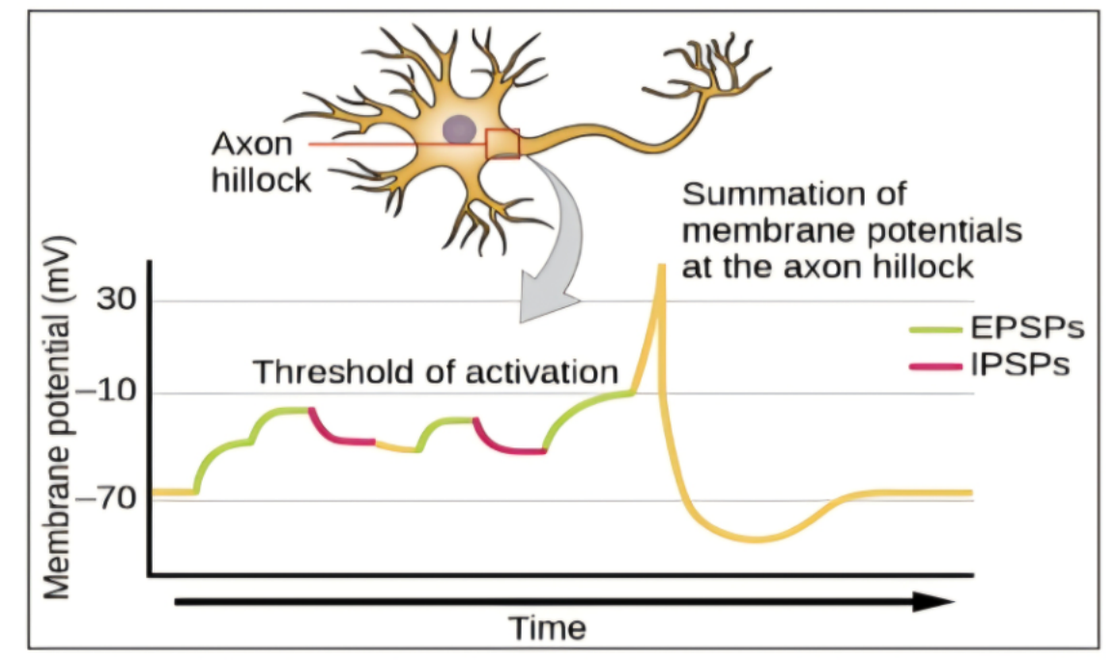


Effects of excitatory and inhibitory neurotransmitters

	Excitatory	Inhibitory
Channel opened in postsynaptic membrane	Channel for positively charged ions, usually Na^+	Channel for negatively charged ions, usually Cl^-
Effect on postsynaptic membrane potential	Rises from −70 mV so becomes less negative; may reach threshold potential (−50 mV)	Falls from −70 mV to −80 mV or lower so more negative than the resting potential (hyperpolarization)
Effect on postsynaptic neuron	Excites an impulse if threshold potential reached	Inhibits impulses but does not make them impossible
Example	Acetylcholine	GABA

Summation of excitatory and inhibitory neurotransmitters





Summation of excitatory and inhibitory neurotransmitters

• Neurons receive signals from multiple presynaptic neurons.

~ These signals can be:

• Excitatory postsynaptic potentials (EPSPs)

EPSPs cause depolarization of the postsynaptic membrane

• Inhibitory postsynaptic potentials (IPSPs)

IPSPs cause hyperpolarization of the postsynaptic membrane.

• EPSPs and IPSPs can cancel each other out.

• For example, if an EPSP increases the membrane potential by +10 mV and an IPSP decreases it by −10 mV, the net change is 0 mV.

• All incoming postsynaptic potentials are added together at the axon hillock.
This process is called "Summation."

• If the combined EPSPs are strong enough to overcome IPSPs and raise the membrane potential to the threshold potential, an action potential is triggered and propagated along the axon.

• If IPSPs dominate, the membrane remains hyperpolarized and no action potential occurs.

• Although many presynaptic neurons contribute to the signal, the response of the postsynaptic neuron is all−or−nothing.

Perception of pain by neurons with free nerve endings

• Sensations such as pain, taste, and smell are detected by receptors in nerve endings. In the skin, free nerve endings act as pain receptors.

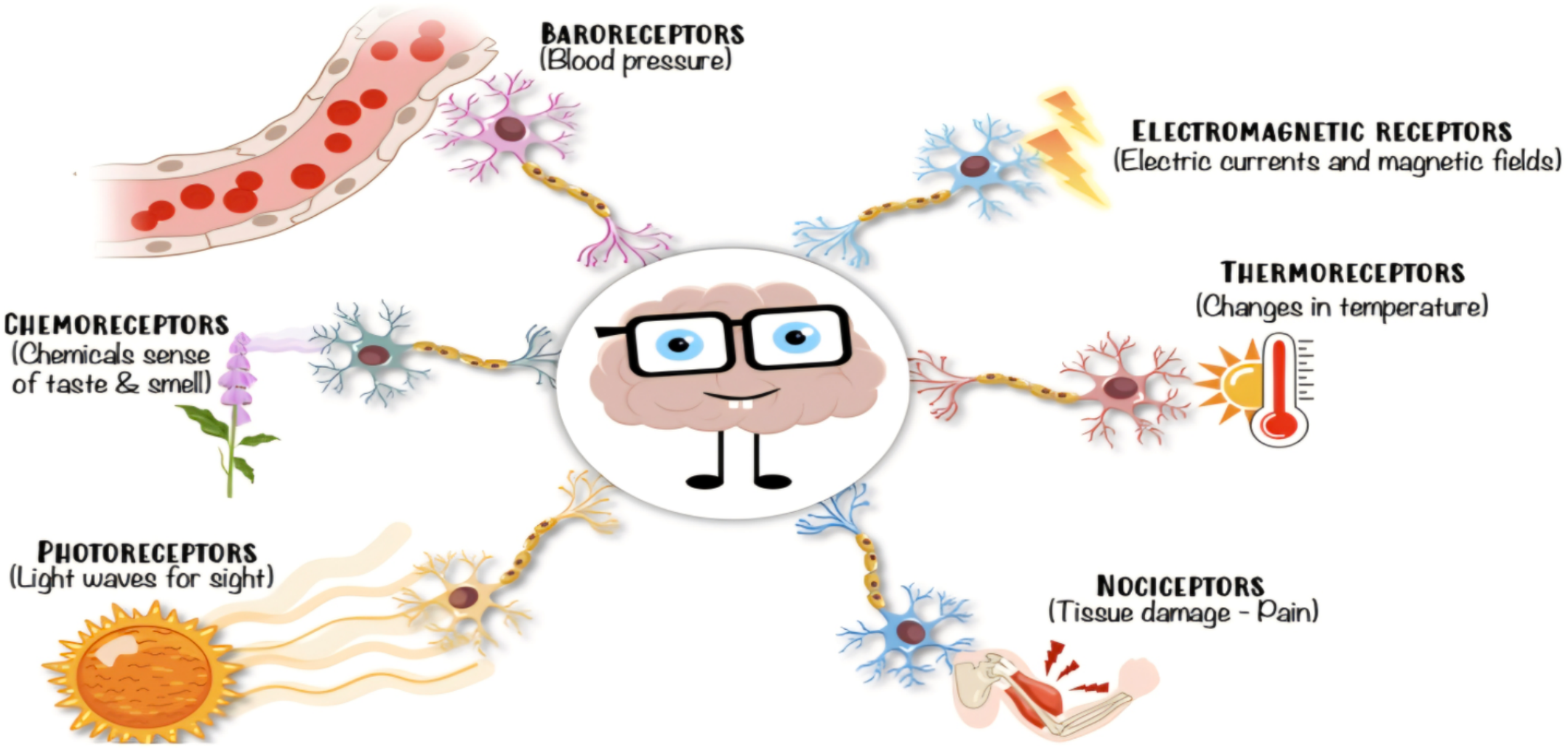
• These receptors detect specific stimuli, for example chemicals in hot spices. When the receptor is stimulated, ion channels open in the neuron membrane.

• This allows positively charged ions to flow into the neuron.

• The influx of positive ions causes depolarization of the membrane.

• If the threshold potential is reached, action potentials are generated. The nerve impulses travel through neurons to the brain, where pain is perceived.

Sensory nerves can specialise to sense various types of stimuli such as light for sight, or chemicals which can be interpreted as taste, other for pressure or even pain. When a nerve acts as a receptor, different names will be given:



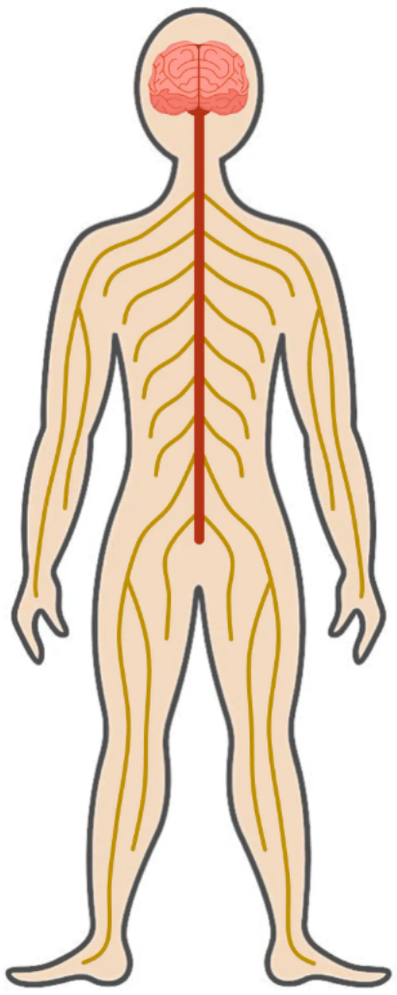
Consciousness as an emergent property

• Consciousness is a property of the human body that emerges from the interaction of neurons in the brain.

• It is not produced by a single neuron. Consciousness arises from the interaction and interdependence of billions of neurons.

• This makes consciousness an emergent property.

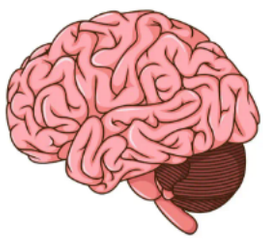
• Like other emergent properties, it only exists because many individual components work together.



Central Nervous System

Brain and Spinal Cord

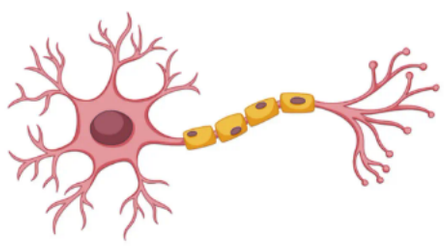
Central Processing



Peripheral Nervous System

Afferent = Sensory Neurons

Efferent = Motor Neurons

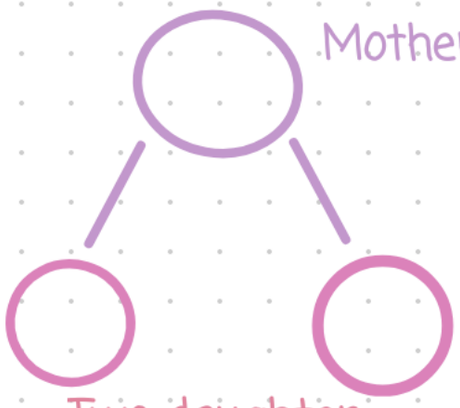


COMPONENTS OF THE NERVOUS SYSTEM

- **Central Nervous System** — Brain and Spinal Cord
- **Peripheral Nervous System** — Cranial and Spinal Nerves
  - **Somatic Nervous System** — Voluntary Responses
  - **Autonomic Nervous System** — Involuntary Responses
    - **Sympathetic Division** — "Fight or Flight"
    - **Parasympathetic Division** — "Rest and Digest"

Cell and Nuclear Division

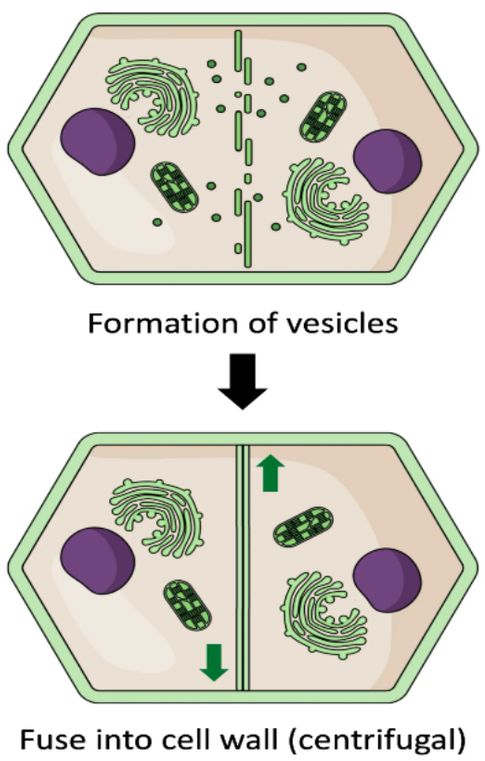
Cell and Nuclear Division



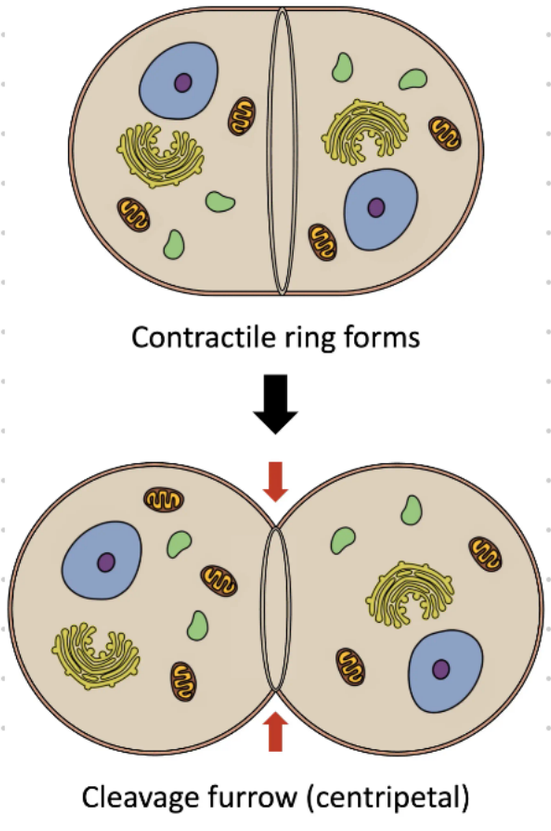
Mitosis produces two genetically identical twins
→ "for growth and repair"

Cytokinesis as splitting of cytoplasm in a parent cell between the daughter cells

• Cytokinesis: The division of a cell's cytoplasm to form two cells. Occurs after mitosis and happens differently in animal and plant cells.



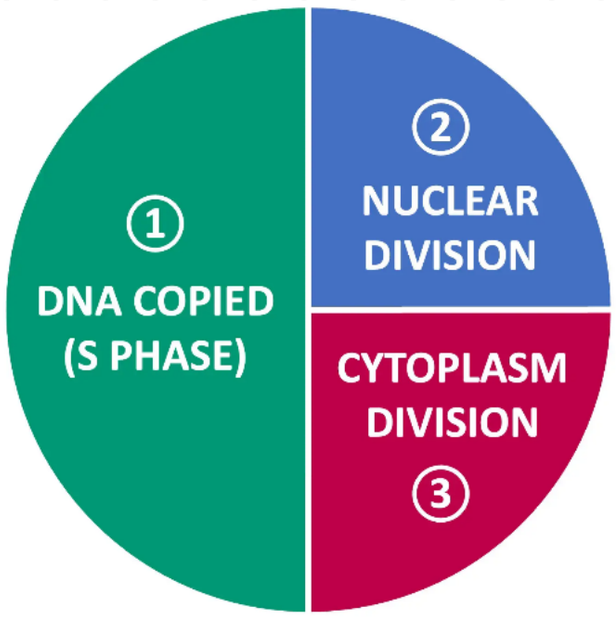
Plant Cell (Cytokinesis):
In plant cells, pectin (vesicles) is linked to the equator to form middle lamella.
Cellulose is then added to form the cell wall.



Animal Cell (Cytokinesis):
In animal cells, mixing of cytoplasm occurs by narrowing the plasma membrane because of the proteins myosin and actin adjacent to the membrane.

Cleavage furrow at the equator with circular actin filaments → splits the cell.

Animal Cell	Plant Cell
Contractile protein (microfilaments) pulls the membrane inward	Telophase: vesicles (from Golgi) to the center of the cell. Then the vesicles fuse to form tubular structures
Cleavage furrow forms	Then the vesicles fuse to form tubular structures.
Cells pinched apart into two daughter cells	Cell plate connects with the existing cell membrane → Cell division completed. Each daughter cell secretes cellulose to form cell wall.

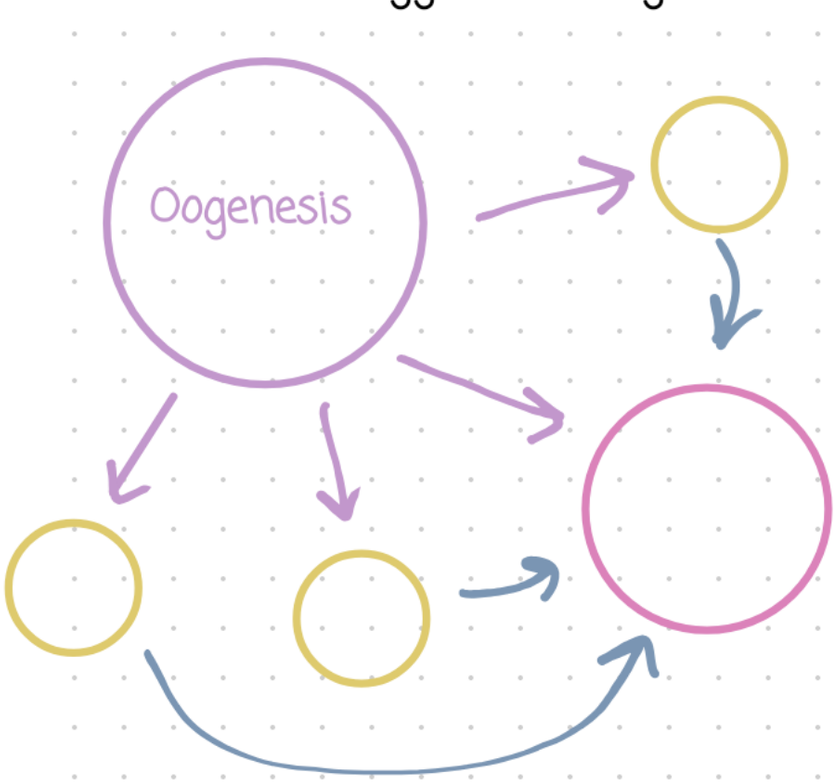


Equal and Unequal Cytokinesis

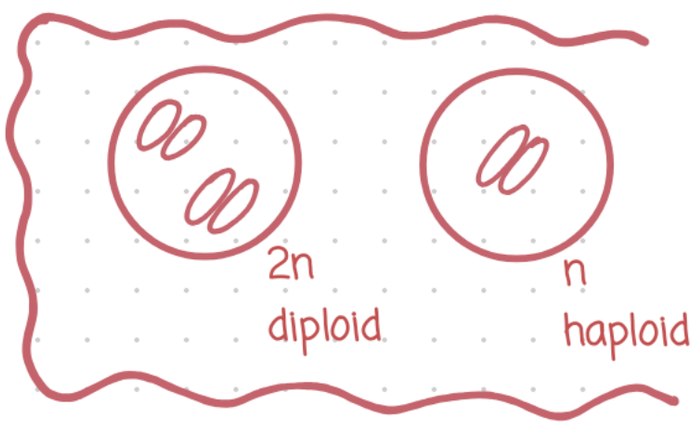
• Equal: Each cell receives a full copy of the parent cell's DNA and some essential organelles. If all the mitochondria from the parent cell stay in only one daughter cell, the other would not be able to survive.
Same for the chloroplasts in photosynthetic prokaryotes.

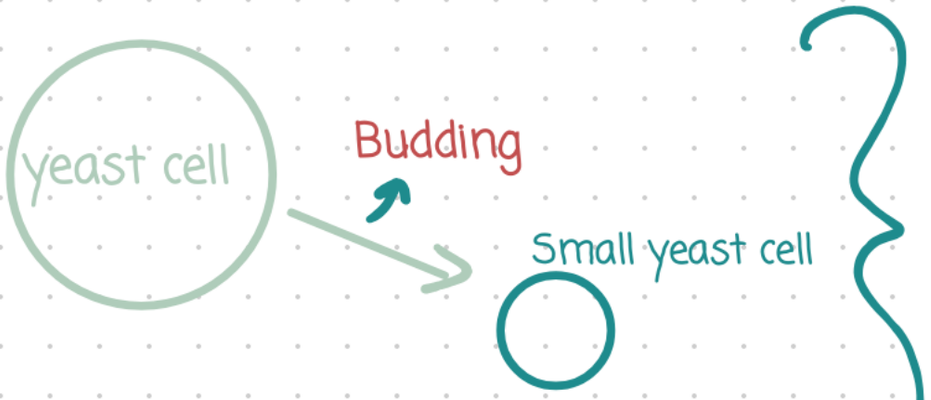
Red Blood Cells:
- Anucleated
- Cannot synthesize proteins
- Have a short lifespan

• Unequal: Daughter cells are not identical.
Production of eggs called oogenesis.

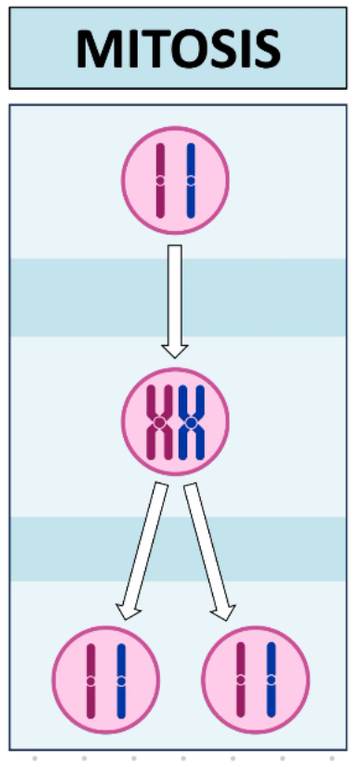
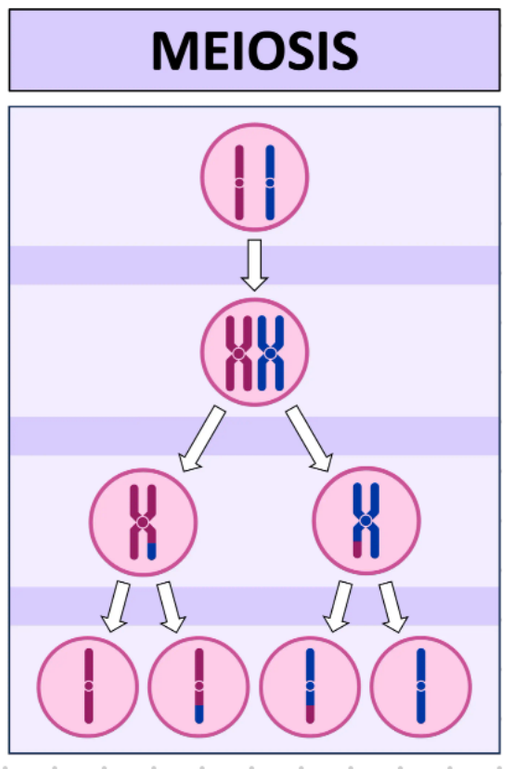


Three haploid cells donate their cytoplasm and organelles because they do not used as eggs and cannot form zygot





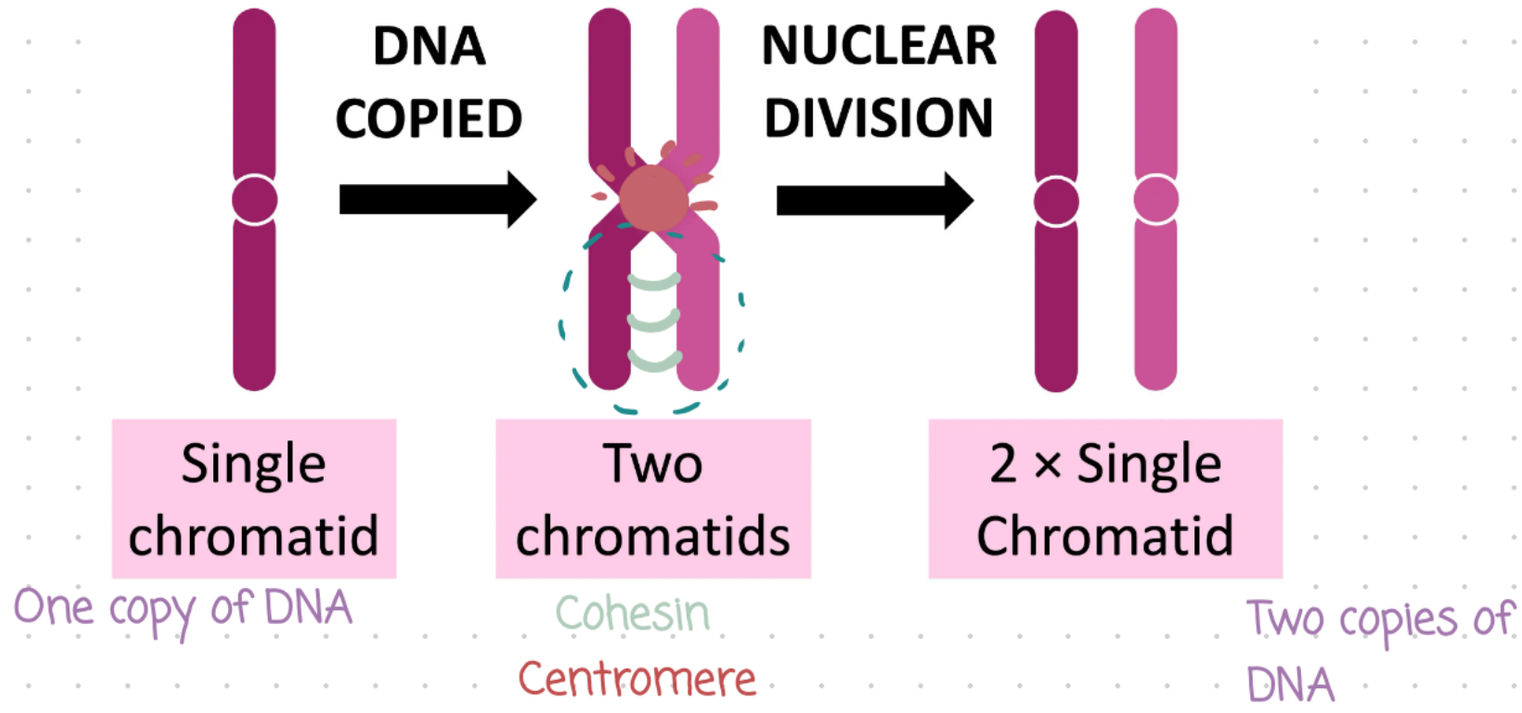
Asexual reproduction. Small cell buds off → when the small cell is big enough to survive, cytokinesis closes the membranes.

Mitosis	Meiosis
Daughter cells receive all the chromosomes and genes. Chromosome number unchanged.	A nucleus divides into haploid nuclei, halving the chromosome number. This allows gametes to be produced in sexual life cycles.
Asexual reproduction. Produces genetically identical body cells.	Generates genetic diversity.
Usually, nuclear division happens before cytokinesis, so that each cell can receive a nucleus. Two types of nuclear division: mitosis and meiosis.	
	

DNA Replication for Mitosis and Meiosis

• Cells replicate their DNA before the start of meiosis and mitosis. In mitosis (at the S phase), two daughter cells receive the entire genome.

• DNA replication provides enough DNA for two daughter cells. Cells divide twice in meiosis, producing 4 haploid cells. Provides enough DNA for crossing over.



Movement of Chromosomes as a Shared Feature

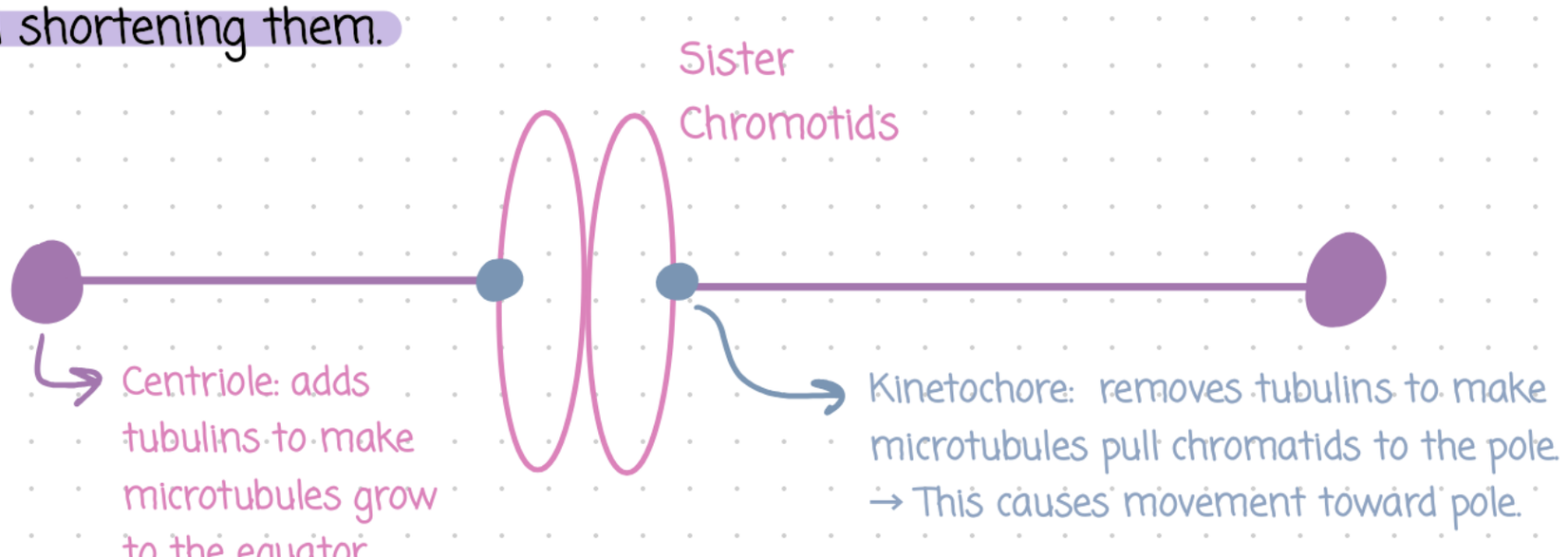
• In mitosis and meiosis, chromatids are separated and moved to opposite ends (poles). Then packed up to form fatter/shorter chromosomes (condensation).

• This is called supercoiling → later stages of condensation, chromosomes become shorter and fatter. (input: relaxed DNA /// output: condensed chromosome)

• Chromosomes are moved by microtubules at the poles of the cell. These microtubules extend and form a spindle shape, called spindle microtubules.

Microtubule motors

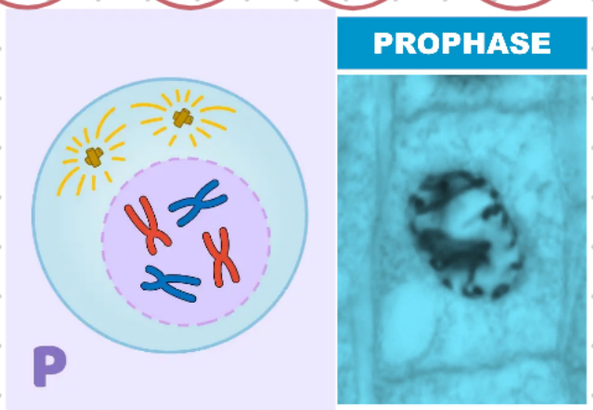
- Cause movement by removing tubulin subunits from the ends of microtubules and shortening them.



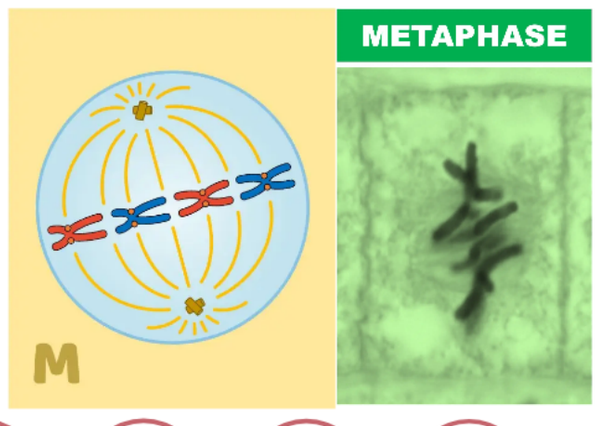
Phases of Mitosis

- Preparation (Interphase): The cell is growing and preparing to divide.
- Phases: G1 - S - G2
- DNA is in chromatin form (not condensed).
- S phase: DNA is replicated. Later, condensation & supercoiling occur.

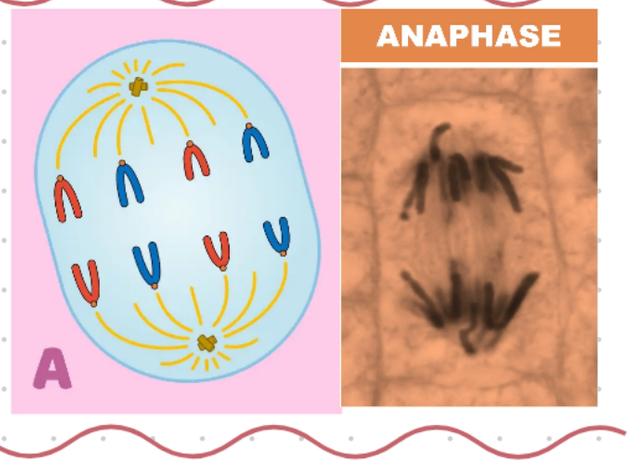
- PROPHASE : Condensed chromosomes become visible.
- Nucleolus disappears. Nuclear envelope gets smaller and dissappears.
- Mitotic spindle forms: spindle fibers form from centrosomes.
- Kinetochore (a region on chromosome) attaches to the spindle.
- Centrosomes move to opposite poles, lengthening microtubules.



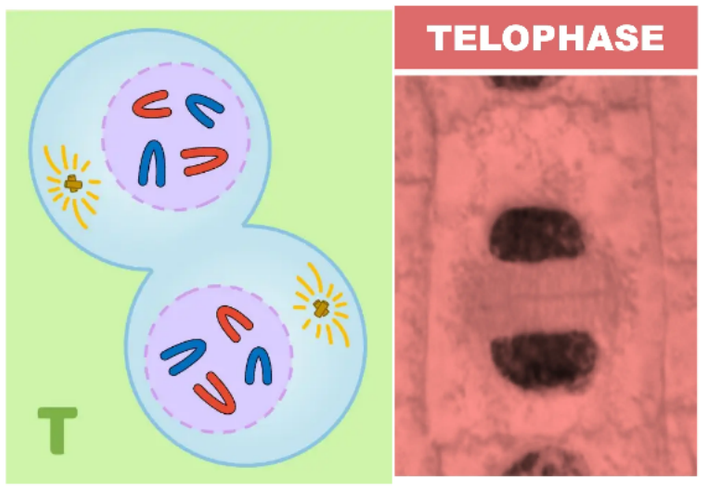
- METAPHASE : Chromosomes move to the middle of the cell (metaphase plate).
- Centrosomes align on the plate.
- Chromosomes move because of the microtubules.
- Centrosomes are at the opposite poles.



- ANAPHASE : (sister chromatids pulled apart)
- Chromatids move toward opposite poles.
- Move as a result of motor proteins pushing microtubules.
- Centrosome remains attached while microtubules shorten.
- Now each pole of the cell has an identical set of chromosomes.
- Chromosomes take a V shape as they get shorter.



- TELOPHASE :A set of chromosomes is located at each pole.
- Nuclear membrane re-forms around each set of chromosomes.
- The chromosomes elongate.
- Nucleoli reappear.
- Spindle fibres disappears.
- The cell is ready for cytokinesis.



Meiosis As a Reduction Division

- kromozom sayısının indirgenmesi (mayoz yoksa çocuk 92 kromozom olur)

- Mother Cell → Has a diploid nucleus (two sets of chromosomes) (2n)
- Four new cells → Have haploid nuclei (one set of chromosomes) (n)

- DNA is replicated → chromosomes produced consisting two sister chromatids

- Interkinesis: Second growth phase between Meiosis I and II (NO DNA REPLICATION

- Meiosis I (Diploid → Haploid): Homologous chromosomes are separated
- P I (Prophase I): Chromosomes condense, Nuclear membrane dissolves, Homologous chromosomes form bivalents, Crossing over occurs

- M I (Metaphase I): Spindle fibres connect to bivalents (at centromeres)

- A I (Anaphase I): Spindle fibres split the bivalent, Homologous chromosomes move to opposite poles

- T I (Telophase I): Chromosomes condense, Nuclear membrane may reform, Cell divides (cytokinesis) to form two haploid daughter cells

People - Meet - And - Talk

Meiosis II (Separates sister chromatids): Not identical due to crossing over in prophase I

Same process as Meiosis I: P II / M II / A II / T II

★ Overall final outcome: Four haploid daughter cells (They may not be identical due to crossing over in prophase I)

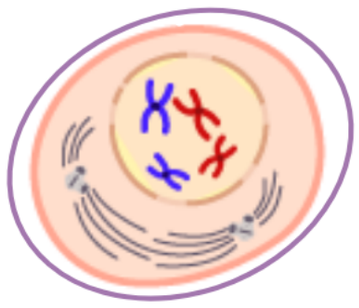
Meiosis I

Interkinesis
(no DNA replication)

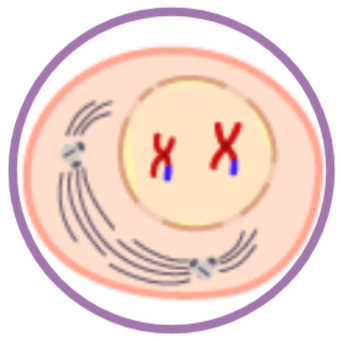
Meiosis II



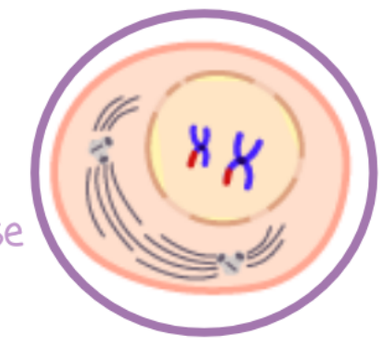
Interphase

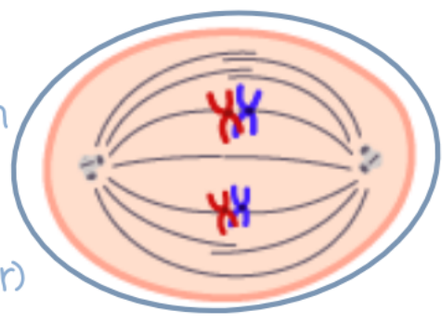


Prophase I
(Crossing Over)
2n

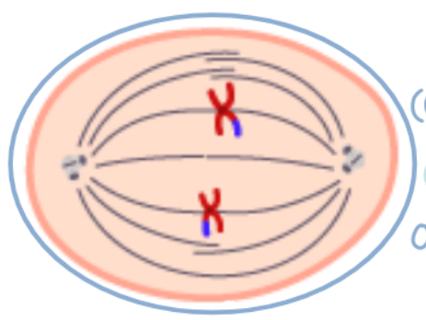


(Crossing over)
Prophase II
Chromosomes condense

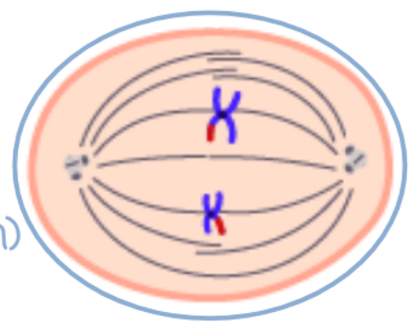


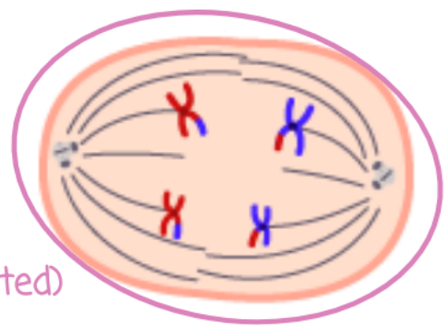


2n
Metaphase I
(homologous pairs
align on the equator)

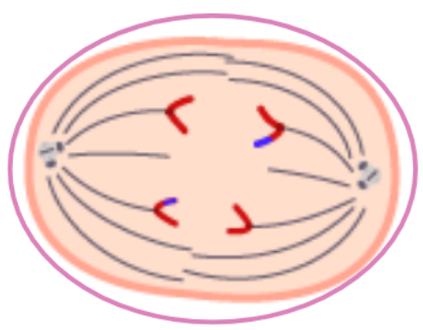


(Chromosomes align
Metaphase II
on the equator again)

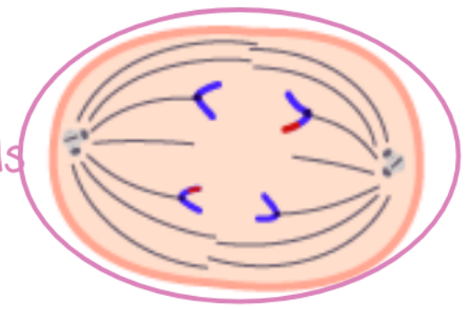


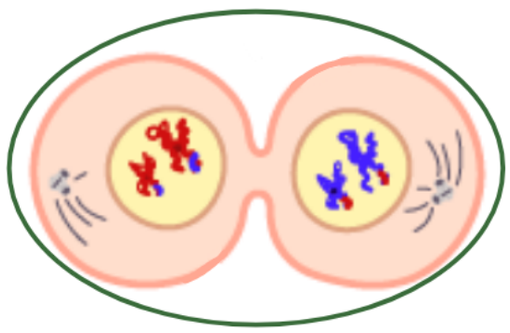


2n --> n
Anaphase I
(homologous
chromosomes seperated)

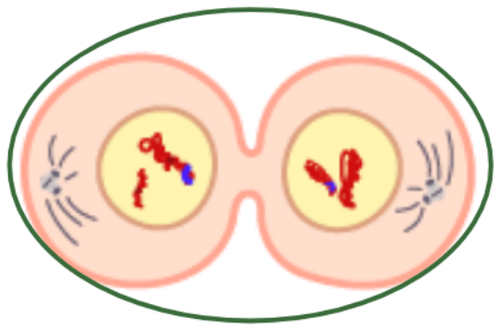


Anaphase II
(Sister chromotids
seperate)

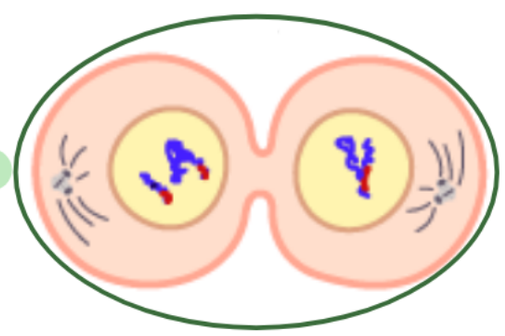


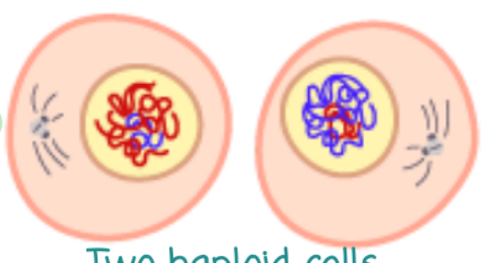


Telophase I



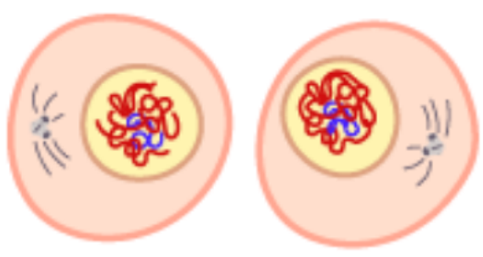
Telophase II





Cytokinesis I

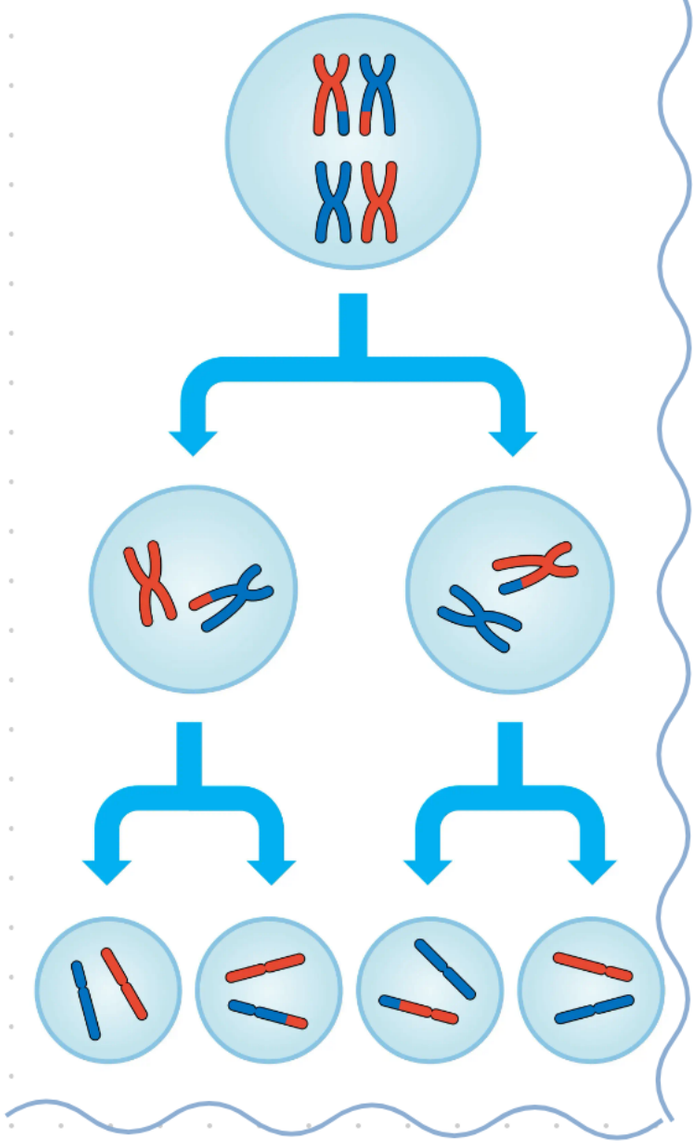
Two haploid cells



Cytokinesis II

Four haploid new cells (2 recombinant 2 parenter)

Meiosis:

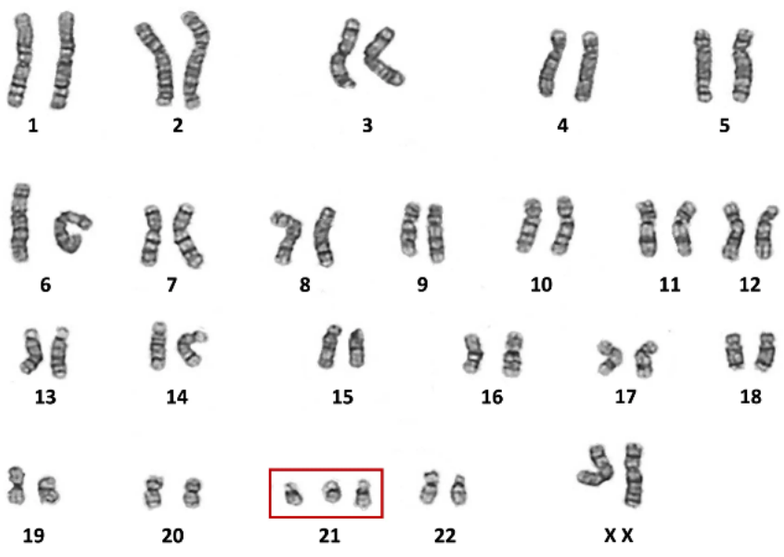


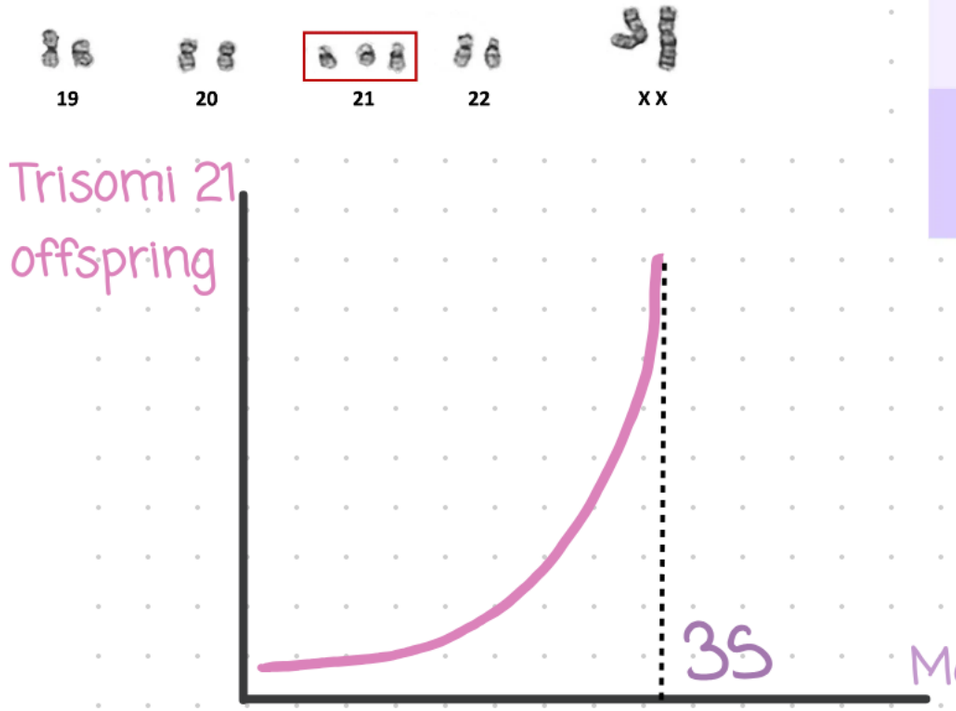
Down Syndrome and Non-Disjunctions

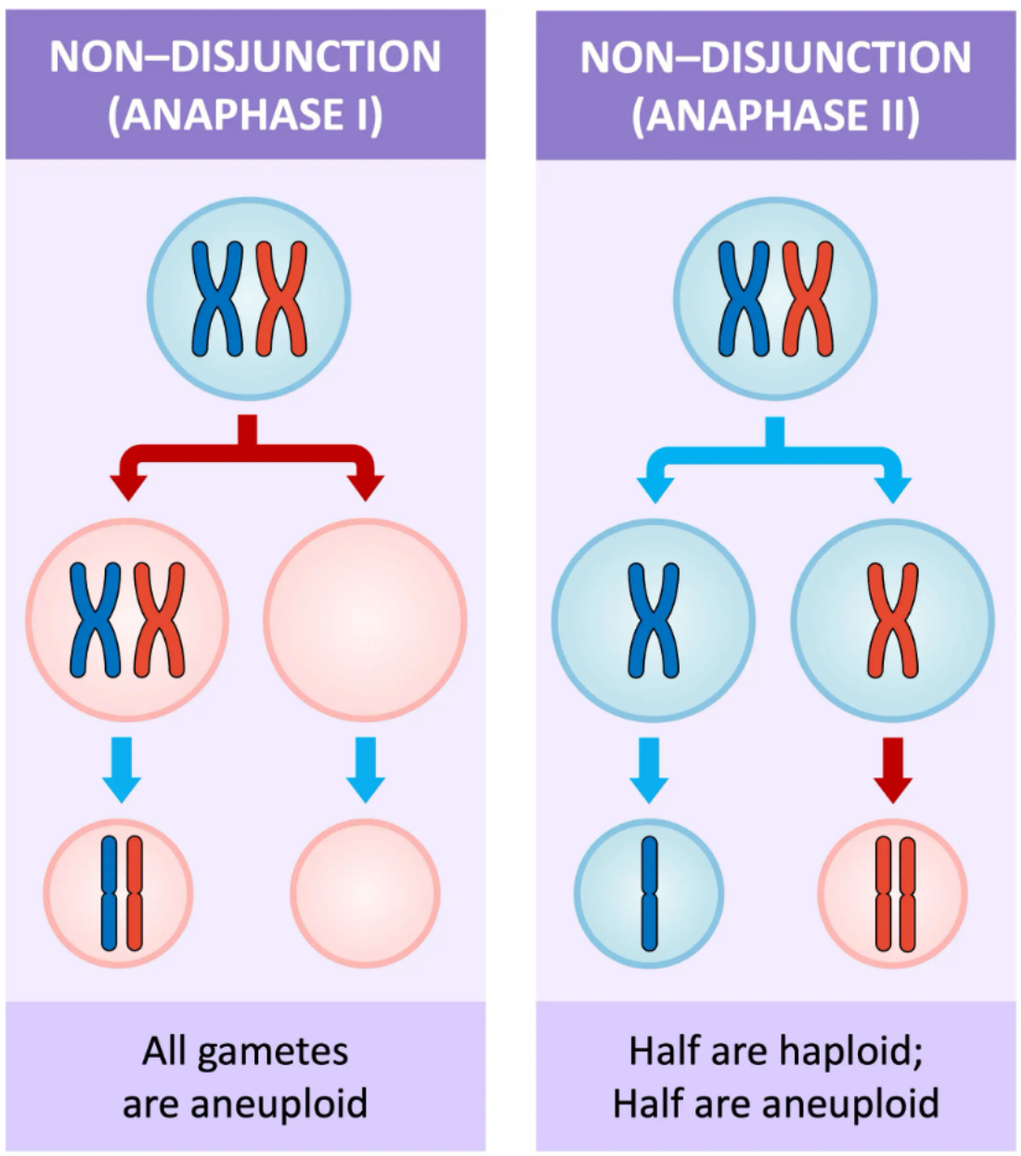
error in meiosis

- Trisomy: A pair of homologous chromosome (pair 21) fails to separate in anaphase I (non-disjunction) → A sperm or egg with two copies and a zygote with three copies.

- Three copies of chromosome is trisomy. (happens in Anaphase)







Meiosis as a source of variation

- Different combinations of alleles

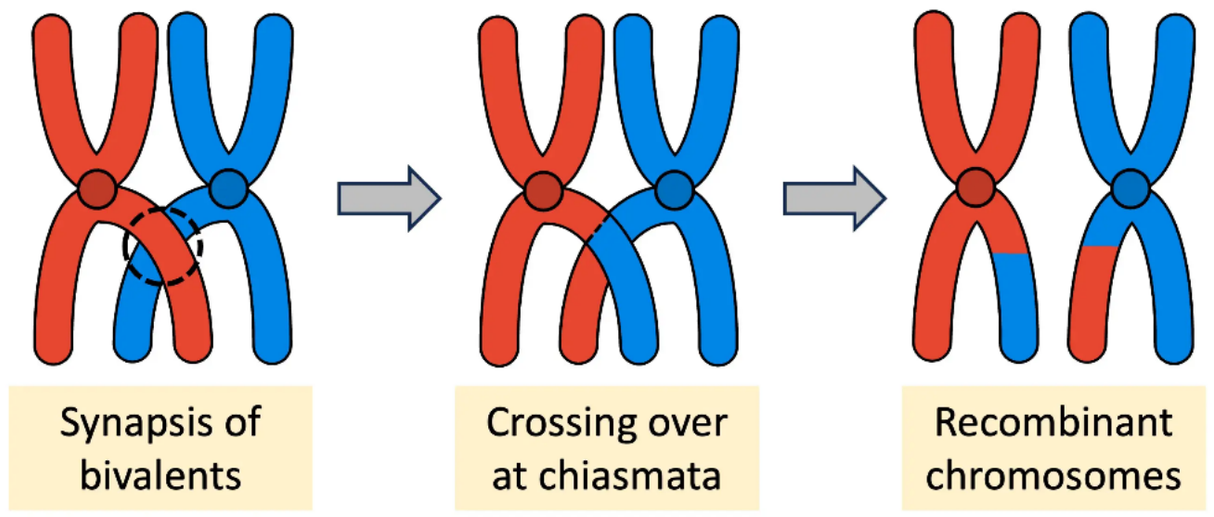
- 1.)Random orientation of bivalent: Orientation is random and doesn't influence other bivalents, many combinations can be produced when homologous chromosomes separate in anaphase I → different haploid cells

- 2.)Crossing over: Chromatids with different combinations produced. (prophase I)

- Mutation
- Meiosis
- Fertilization

} Ways of variatons

- Bivalent: a pair of homologous chromosomes
- Synapsis: formation of a bivalent (not sister chromatids)
- Chiasma: point of crossing over



Cell Proliferation for Growth, Cell Replacement and Tissue Repair

• Cell proliferation: repeated cell division → Multicellular organisms grow by adding more cells.

• Growth: to increase the size of the body. The entire embryo grows rapidly.
~ In plant cells: The root apical meristem lengthens the root. The shoot apical meristem lengthens the stem and produces cells for leaves or flowers.
→ Apical meristems = zones of cell division (at tips part).

• Cell replacement: Routine production of cells to replace those with a shorter lifespan (skin cells).

• Tissue repair: Healing after loss or damage (e.g. skin cells to heal cuts).

The Cell Cycle

Interphase

The cell grows and copies its DNA

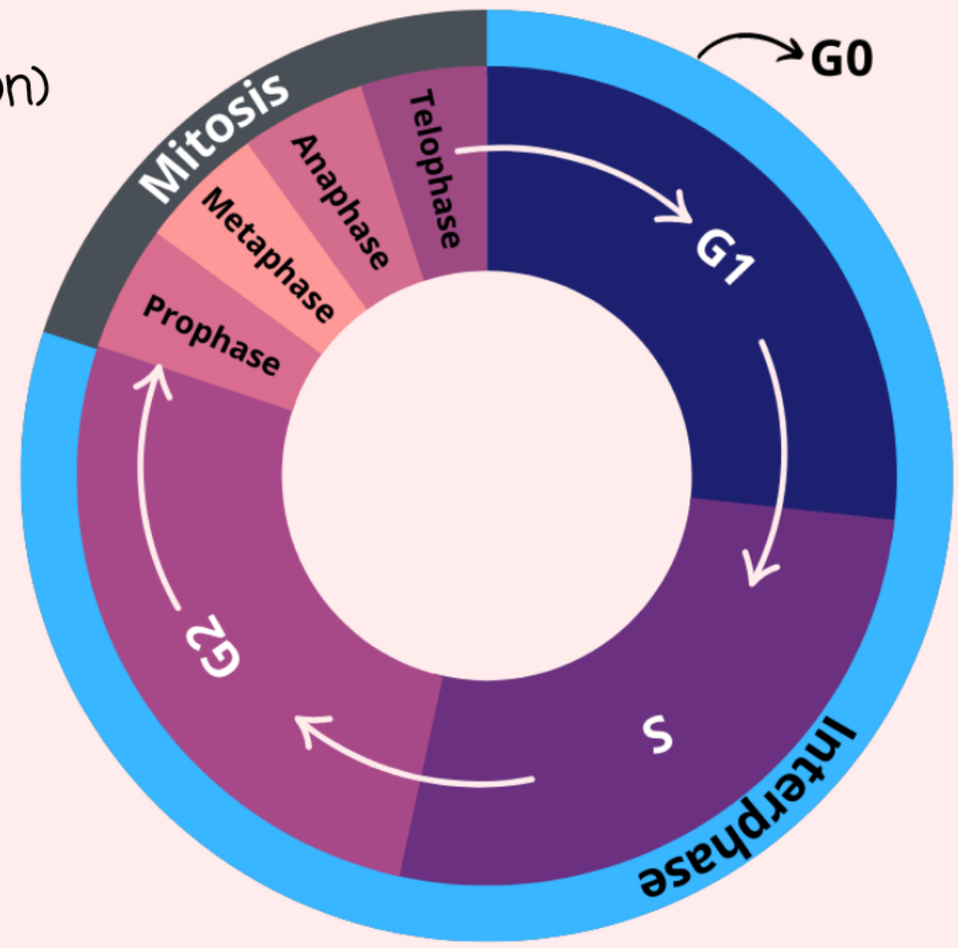
- **G1**: Cell growth
- **S** : DNA synthesis(replication)
- **G2:** More growth, preparation for mitosis

Mitosis

The cell divides its DNA and cytoplasm, forming two new cells

- **Prophase**
- **Metaphase**
- **Anaphase**
- **Telophase**

G0: Resting state where the cell performs its functions and is not preparing to divide



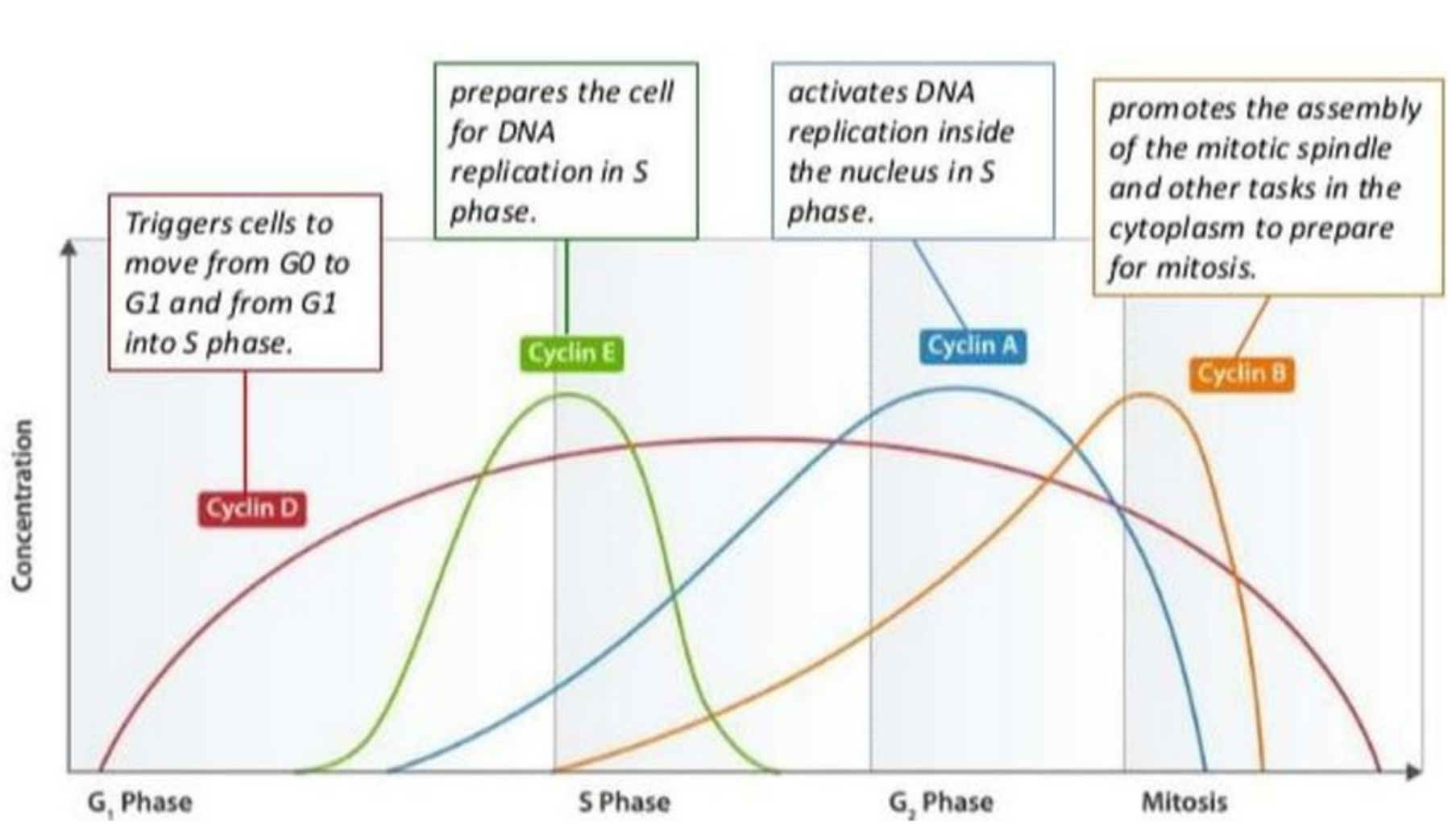
sciencenotes.org

Control of the Cell Cycle Using Cyclins

- There are checkpoints between one phase of the cell cycle and the next.

- Cyclins: Proteins used to control progression through these checkpoints. Their concentrations rise and fall throughout the cycle. Cyclins bind to kinase enzymes, activating them.

- These kinases phosphorylate other proteins → other enzymes perform tasks specific to each phase of the cell cycle.



- Progression through parts of the cell cycle is affected in various ways by specific cyclins. (DEAB)

Consequences of Mutations in Genes that Control the Cell Cycle

- Tumour cells that divide endlessly.
→ Cells have genes that ensure mitosis only happens when needed.

- Proto-oncogenes: Specific mutations change proto-oncogenes → oncogenes
→ Causes uncontrolled cell division.
→ Apoptosis: Cells have their death pre-programmed in their DNA.

- Tumour suppressor genes: Normally prevents uncontrolled division.
→ Multiple genes must have mutated in the same cell for control to be lost.

Differences Between Tumours in Rates of Cell Division and Growth and in the Capacity for Metastasis and Invasion of Neighbouring Tissue

- A tumour is a mass of proliferating cells in which normal control of the cell cycle has been lost.

- Benign Tumours: Grow slowly and are not life-threatening.
→ Cannot metastasise.

- Malignant Tumours: Grow aggressively, may spread to form secondary tumours.
→ Life-threatening.
→ (Only they can metastasise)

- Metastasis: Spreading of cells to form secondary tumours.

Application of Skills: Mitotic Index

$$\text{Mitotic index} = \frac{\text{(Number of cells in mitosis)}}{\text{(Total number of cells)}}$$

Phase	1	2	3
I (Interphase)	62	32	42
P (Prophase)	16	22	20
M (Metaphase)	13	16	15
A (Anaphase)	9	14	13
Total	100	100	100

Mitotic index calculation: $\frac{(P + M + A)}{\text{Total}}$

En yüksek oran → Most probably cancer

Stability and Change

Stability as a property of natural ecosystems

• Stability means an ecosystem can continue for a very long or unlimited time without collapsing. A sustainable system maintains its structure and function over time. Some ecosystems show long-term stability, such as the Daintree rainforest in Australia.

• The Daintree rainforest has existed for over 100 million years because the climate has remained warm and wet. Tectonic plate movement usually changes climate over geological time, but this area remained suitable by chance.

• Long-term stability has allowed very high biodiversity to develop.

• Many endemic species and ancient plant families are present. However, ecosystem stability is fragile. Even small disturbances (perturbations) can cause significant changes.

Requirements for stability in ecosystems

• A continuous energy supply is required because energy cannot be recycled. In most ecosystems, the main energy source is sunlight. Blocking sunlight (for example by volcanic dust) can cause ecosystem collapse and mass extinction.

• Nutrient cycles. Any loss of nutrients must be balanced by gains.

• Climatic variables, especially temperature and rainfall, must stay within the tolerance ranges of organisms. High genetic diversity within species increases stability.

• Keystone species are especially important for ecosystem stability.

• Genetic variation allows natural selection and adaptation to environmental change.

ECOSYSTEM STABILITY

An ecosystem is considered to be stable if it is capable of maintaining its ecological functions under changing conditions or during disturbances. There are four factors that must be present for an ecosystem to remain stable under changing conditions:

- **R**ecycling of nutrients (decomposers maintain a supply of chemical elements)
- **A**biotic conditions (key climatic variables must remain within tolerance levels)
- **G**enetic diversity (high levels of diversity allow populations to adapt to change)
- **E**nergy supply (constant energy supply must be made available for metabolism)



HINT: RAGE

Amazon rainforest and tipping points

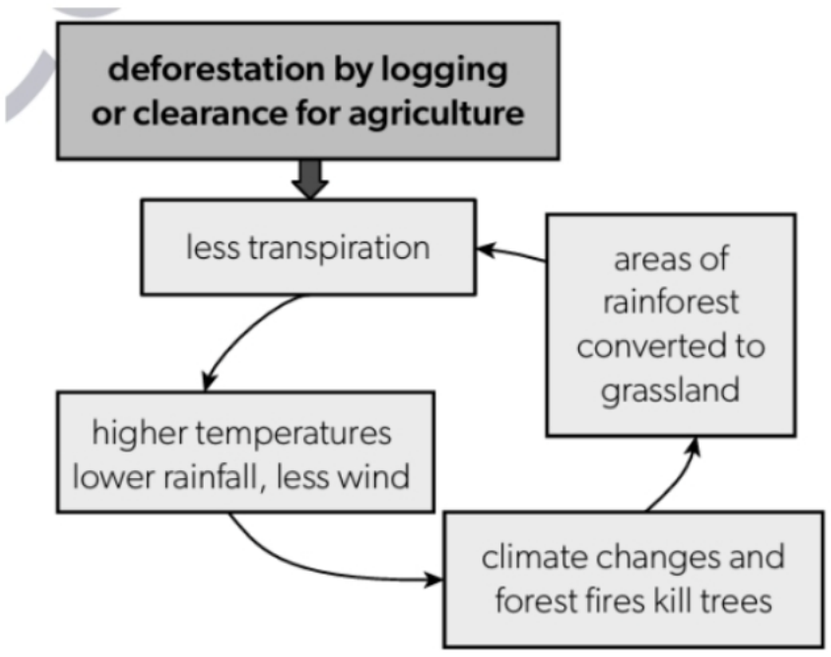
• The Amazon rainforest strongly affects regional and global climate. Transpiration from leaves releases water vapour and causes a cooling effect.

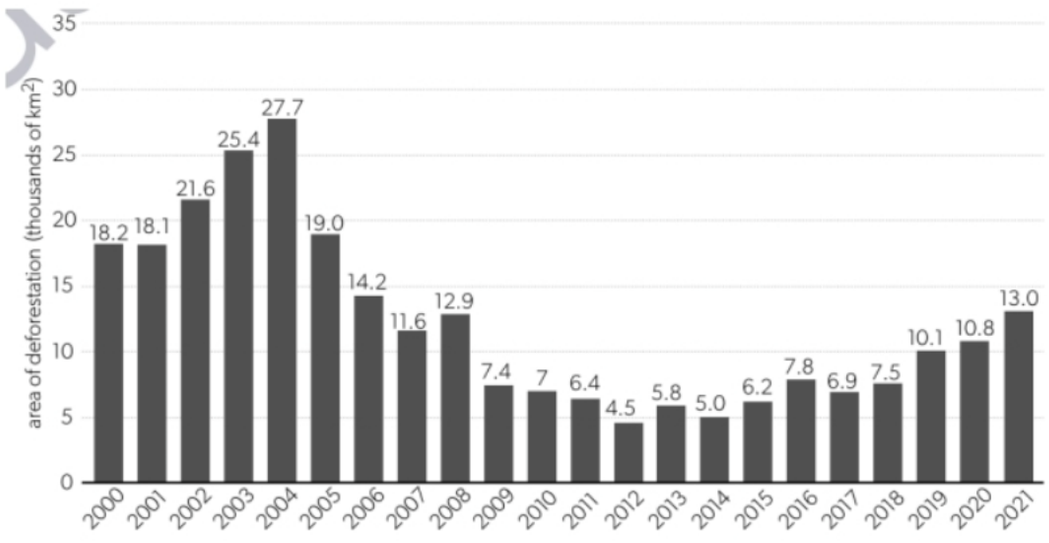
• Water vapour condenses, lowering air pressure and creating wind. Condensed water falls as rainfall, which is reused by the forest.

• Ecosystems can recover from disturbances. However, resilience is limited.

• A tipping point is reached when disturbance exceeds a critical level.

• Deforestation reduces transpiration and rainfall. After the tipping point, positive feedback causes rapid and irreversible change. Even if deforestation stops, the rainforest may turn into grassland. The exact area needed to avoid the tipping point is uncertain.





▲ The bar chart shows the area of deforestation in the Amazon rainforest for each year from 2000 to 2021.

Application of skills: calculating percentage change

To calculate percentage change, use this formula:

$$\frac{\text{final amount} - \text{initial amount}}{\text{initial amount}} \times 100\%$$

In 1970, there was an estimated 4,100,000 km² of Amazon rainforest in Brazil, with 3,268,000 km² remaining in 2022.

$$\text{percentage change} = \frac{3{,}268{,}000 - 4{,}100{,}000\ \text{km}^2}{4{,}100{,}000\ \text{km}^2} \times 100\%$$
$$= -20.3\%$$

Between 1970 and 2022, there was a 20.3% reduction in the area of Amazon rainforest in Brazil.

4,600 km² of Amazon rainforest in Brazil was lost in 2012; 11,600 km² was lost in 2022.

$$\text{percentage change} = \frac{11{,}600 - 4{,}600\ \text{km}^2}{4{,}600\ \text{km}^2} \times 100\%$$
$$= 152\%$$

In 2022, the loss of Amazon rainforest in Brazil was 152% higher than in 2012.

Mesocosms and ecosystem stability

• Ecosystems can be sustainable for very long periods if energy input (usually light) continues and nutrients are recycled. This can be studied using mesocosms, which are small experimental ecosystems.
• Terrestrial mesocosms include fenced grassland or forest areas.
• Aquatic mesocosms include open tanks or sealed glass vessels.
• In sealed mesocosms, matter exchange is controlled, but energy transfer occurs freely. For sustainability, autotrophs and saprotrophs are essential, while consumers and detritivores are not always essential. Large animals are not included because it is unethical if they cannot obtain enough food or oxygen.

Keystone species and ecosystem stability

• A keystone species has a disproportionately large effect on ecosystem structure. If it is removed, species diversity decreases and the ecosystem may collapse. An example is Pisaster ochraceus, a sea star on rocky shores. When Pisaster was removed, Mytilus californianus became dominant, algae disappeared, and many animals died or migrated. Pisaster maintains biodiversity by predation, preventing one species from excluding others.

Sustainability of resource harvesting

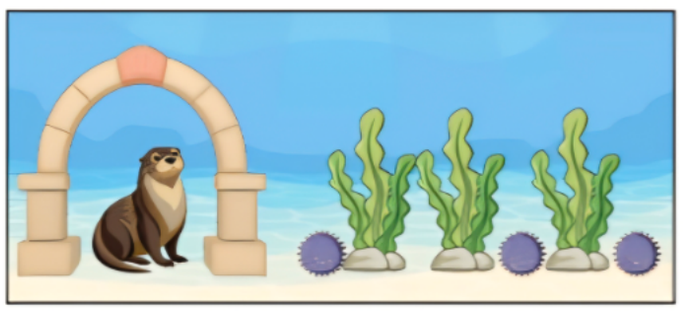
• Harvesting from natural ecosystems is sustainable only if the rate of harvesting is lower than the rate of replacement. Unsustainable harvesting has caused many extinctions, especially of megafauna. Today, pressure is higher due to a human population of over 8 billion.

KEYSTONE SPECIES

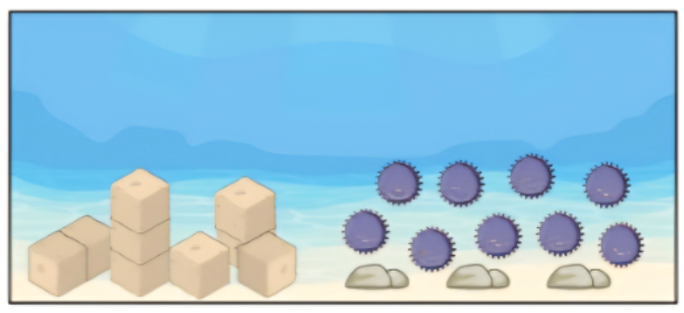
A keystone species is a species that has a disproportionately large impact on the environment relative to its abundance. They fundamentally support the ecosystem and prevent it from collapsing (like a keystone in an arch). These species don't have to occupy the highest trophic level and influence ecosystems in many ways:

- **Predators** – exert top-down pressure on lower trophic levels to prevent a monopolisation of resources
- **Mutualists** – exert bottom-up control by supporting the life-cycle of other organisms in the community
- **Engineers** – refashion the environment in a manner that promotes the survival of several other species

Examples of keystone species include sea otters (which prevent habitat destruction by feeding on the sea urchins that eat kelp), honey bees (pollinate flowering plants to ensure the continuation of these species) and beavers (who build dams that allow other species to thrive under the new environmental conditions).



Keystone species: Sea otters feed on sea urchins



Overpopulation of sea urchins destroys kelp numbers

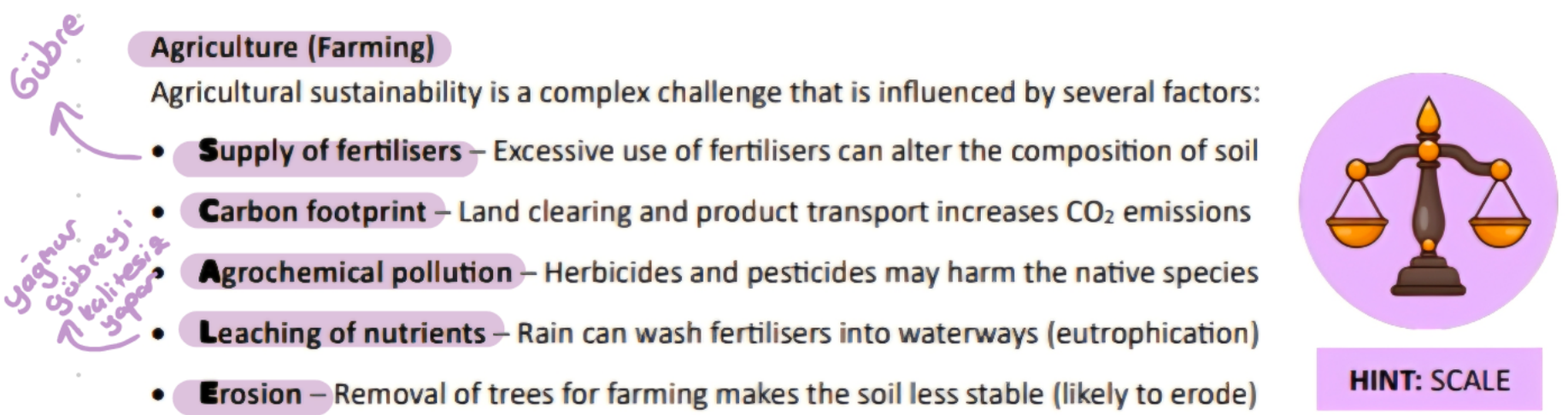
• Brazil nuts are harvested from Bertholletia excelsa trees in the Amazon. Sustainable harvesting depends on leaving some nuts to germinate. Agoutis help by burying nuts, aiding seed dispersal. In heavily harvested areas, few young trees grow, making harvesting unsustainable.

Atlantic cod fishing – harvesting an animal species

Atlantic cod (Gadus morhua) is heavily harvested from the North Atlantic. Overfishing caused the collapse of the Grand Banks population in the early 1990s, and it has not recovered, showing the importance of sustainable harvesting. Fish stocks outside national waters are open-access resources, so sustainability requires international cooperation. Harvesting must not exceed the maximum sustainable yield (MSY), which occurs at point M on a sigmoid growth curve, where population growth rate is highest.
In the North Sea, cod stocks fell by over 80%, but recovery measures included exclusion zones in nursery areas, larger net holes, reducing fishing fleets, and quotas based on population monitoring. Since 2005, adult cod biomass has tripled, showing that cod fishing there is now sustainable.

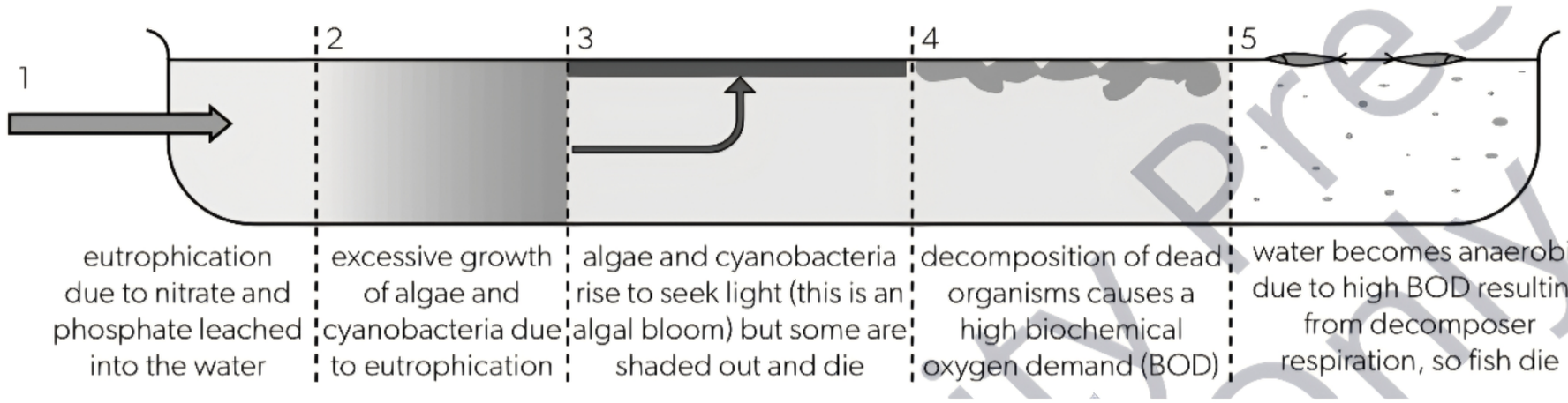
D4.2.7 – Factors affecting sustainability of agriculture

Agriculture must be sustainable because it feeds the human population. Intensive farming can increase yield but often reduces sustainability by damaging ecosystems or using finite resources.
Tillage can degrade soil structure and increase erosion, especially in cleared tropical forests.
Nutrient depletion occurs through harvesting and leaching, requiring fertilizers made from non-renewable minerals and fossil fuels.
Monoculture encourages pests and weeds, leading to pesticide and herbicide use, which causes pollution and resistance evolution. Agriculture has a high carbon footprint due to fuel use, fertilizer production, machinery, and heating, contributing to climate change.



Eutrophication due to leaching

Leaching occurs when rainwater dissolves soluble nutrients such as nitrates and phosphates and washes them out of soil into rivers, lakes and seas. Intensive agriculture increases leaching because of artificial fertilizers and poorly managed livestock waste. This causes nutrient enrichment of aquatic and marine ecosystems, called eutrophication. Although some ecosystems are naturally eutrophic, human activity has caused widespread eutrophication, leading to harmful effects such as algal blooms, oxygen depletion, and death of aquatic organisms.

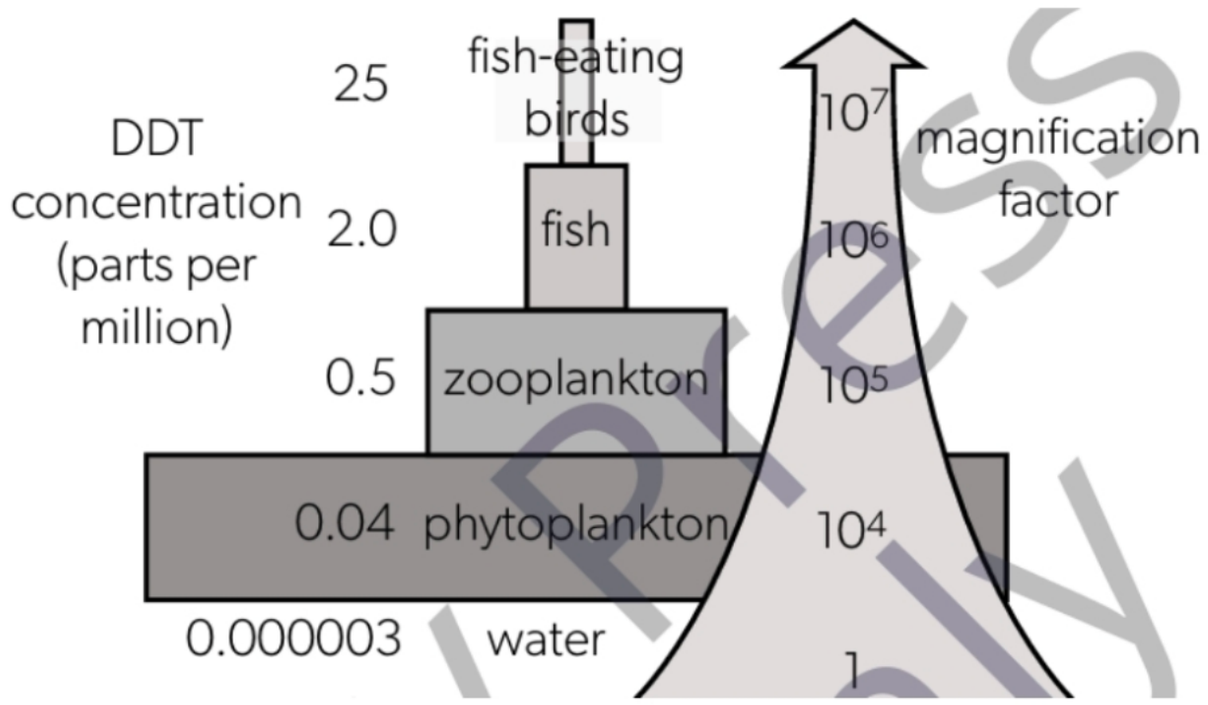


Biomagnification of pollutants

Human-made chemicals can be present in very low environmental concentrations but reach lethal levels in top predators due to bioaccumulation and biomagnification.

Bioaccumulation is the build-up of a toxin in an organism's tissues over its lifetime, especially with fat-soluble pollutants like DDT or methyl mercury, which are not easily excreted.

Biomagnification is the increase in toxin concentration at successive trophic levels of a food chain. Top predators accumulate the highest concentrations because they consume many contaminated prey. This caused population declines in species such as peregrine falcons, ospreys, and otters.



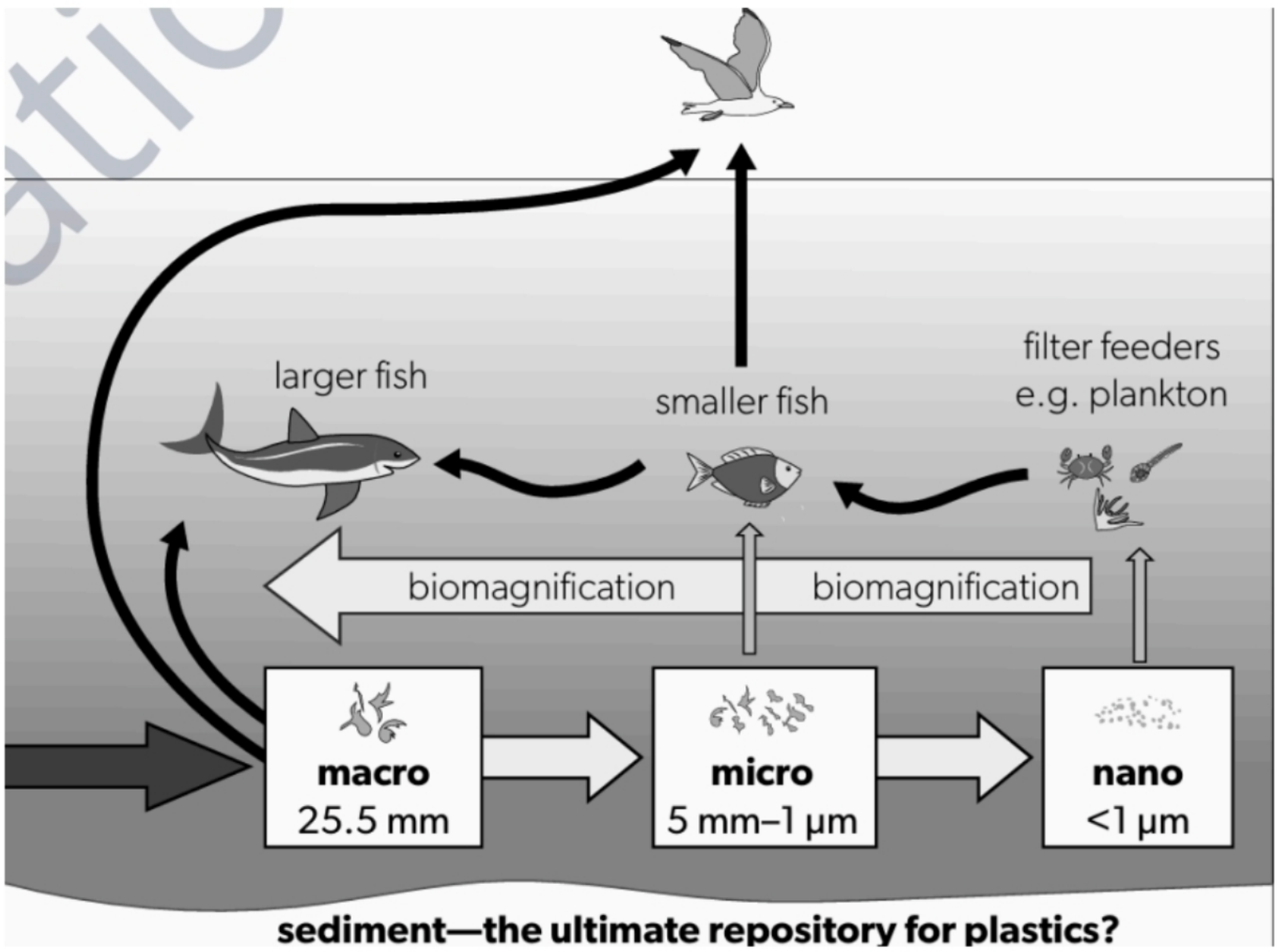
Effects of microplastic and macroplastic pollution

Plastics are synthetic polymers widely used in manufacturing. Large amounts are single-use, and although some are recycled, over 350 million tonnes were discarded in 2020. Plastics accumulate in oceans because they are non-biodegradable or degrade very slowly.

Macroplastics are large visible items such as fishing nets, ropes, bottles, and plastic bags. Marine animals like seabirds and turtles become entangled or ingest plastics after mistaking them for prey. Albatrosses confuse plastic bags with jellyfish or squid and feed them to chicks, causing gut blockage and high mortality.

Microplastics are plastic fragments between 5 mm and 1 µm. They come from microbeads, clothing fibres, tyre wear, and breakdown of macroplastics. They are found in all marine ecosystems. Filter feeders ingest microplastics together with toxic chemicals that adsorb onto their surface.

Nanoplastics are <1 µm and form from microplastics. They can pass through plasma membranes, enter cells, and accumulate in organs of animals, including humans. They are likely harmful, but their effects are not yet fully understood.



Rewilding and ecosystem restoration

Human activities have degraded ecosystems, causing biodiversity loss, high extinction rates, and loss of ecosystem services such as carbon sequestration, climate regulation, flood protection, and soil erosion prevention. Rewilding aims to restore ecosystems by allowing natural processes to operate with minimal human intervention. The first step is reducing activities like agriculture, logging, and harvesting. In some cases, stopping disturbance is enough, but often active interventions are needed, including seed spreading, reintroduction of keystone or apex predators, restoring habitat connectivity, and controlling invasive alien species.

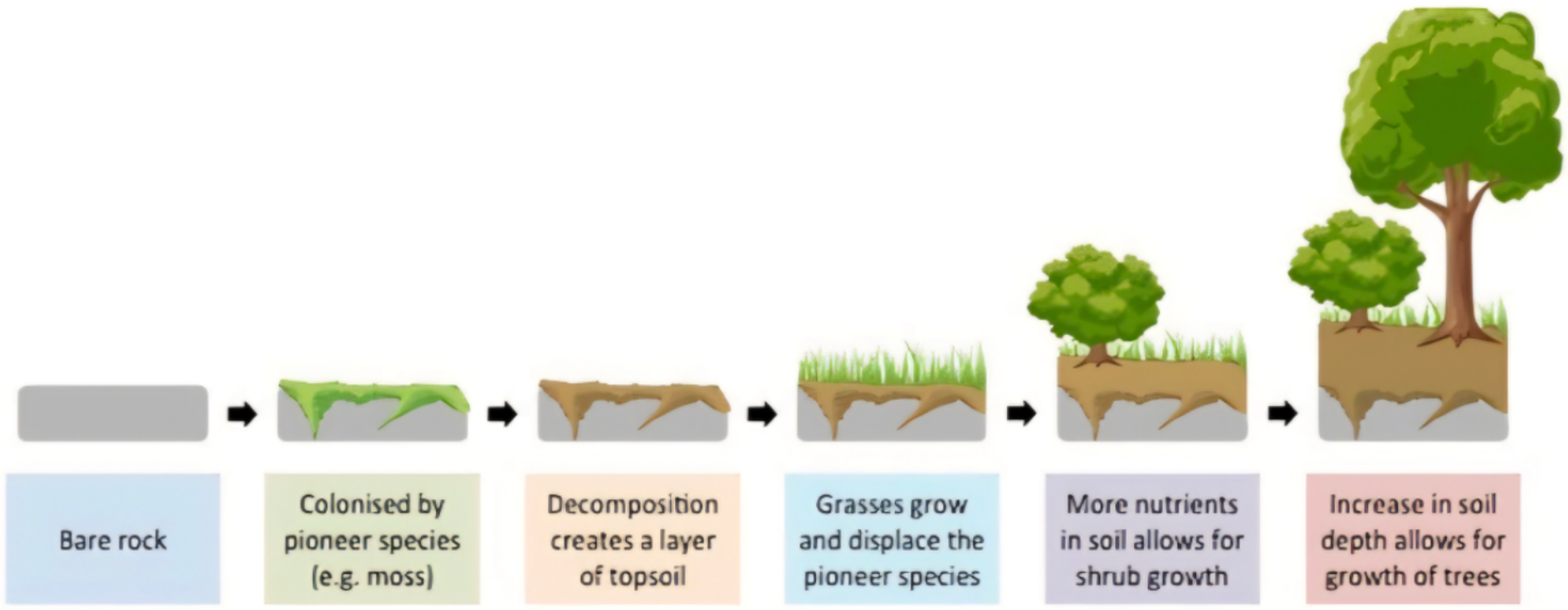
The Hinewai Reserve (New Zealand) shows successful rewilding, where farmland regenerated into native forest with minimal interference. However, climate change remains a major threat through increased droughts and floods.

D4.2.12 – Ecological succession and its causes

Ecological succession is a sequence of changes in species composition and abiotic factors over time, where one ecosystem replaces another. For example, grassland may change into forest as light decreases, humidity increases, and soil nutrients improve due to leaf litter. These changes cause some species to be lost and others to join. Succession may be triggered by abiotic factors (e.g. avalanches creating bare substratum) or biotic factors (e.g. beavers causing flooding). Succession may end in a climax community, which is stable and persistent.

Primary succession

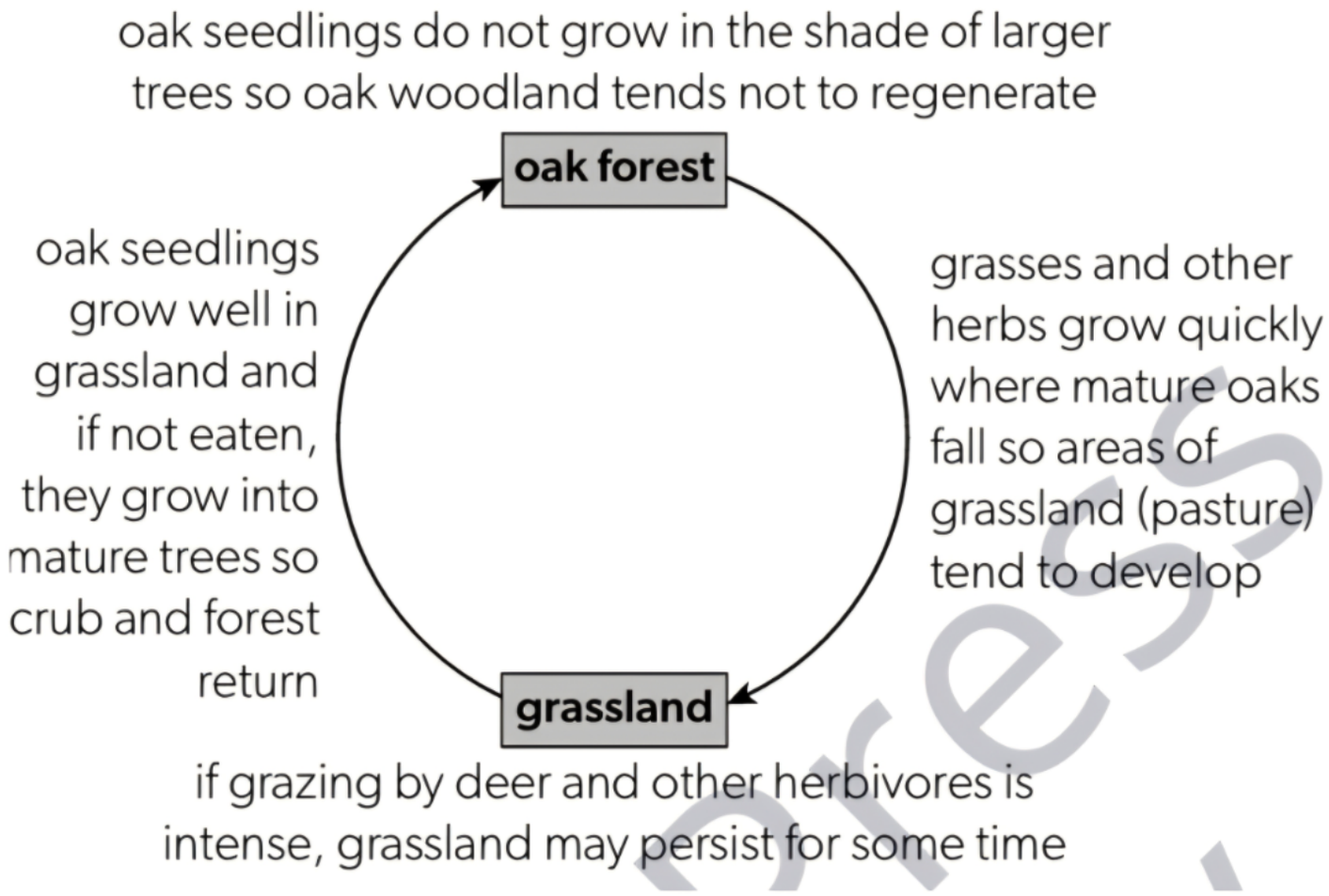
Primary succession occurs on new land with no soil, such as glaciers, sand dunes, river deltas, or exposed rock. Pioneer species like lichens and mosses colonize first. Their death and decomposition form organic soil. As plants establish, soil depth, mineral content, aeration, and water retention increase, while pH changes. Larger plants eventually grow, reduce erosion, and outcompete smaller shade–intolerant species, leading to increasingly complex communities and eventually a climax community.



Primary succession	Secondary succession
Begins with no life	Follows a disturbance of primary succession
No soil	Soil is present
New area, e.g. a volcanic island	Old area, e.g. following a forest fire
Lichen and mosses begin to grow on volcanic rocks	Seeds and roots are already present
Biomass low	Biomass higher
Low production*	Higher production*

Cyclical succession

Some ecosystems show cyclical succession instead of reaching a permanent climax community. In this type of succession, species repeatedly replace each other over time without a major disturbance. An example is wood-pasture in northwest Europe. Cyclical succession can also be driven by regular, recurring disturbances, such as fires in the California chaparral. Fires occur every 10–15 years and maintain a community dominated by deciduous shrubs and evergreen trees.



Climax communities and arrested succession

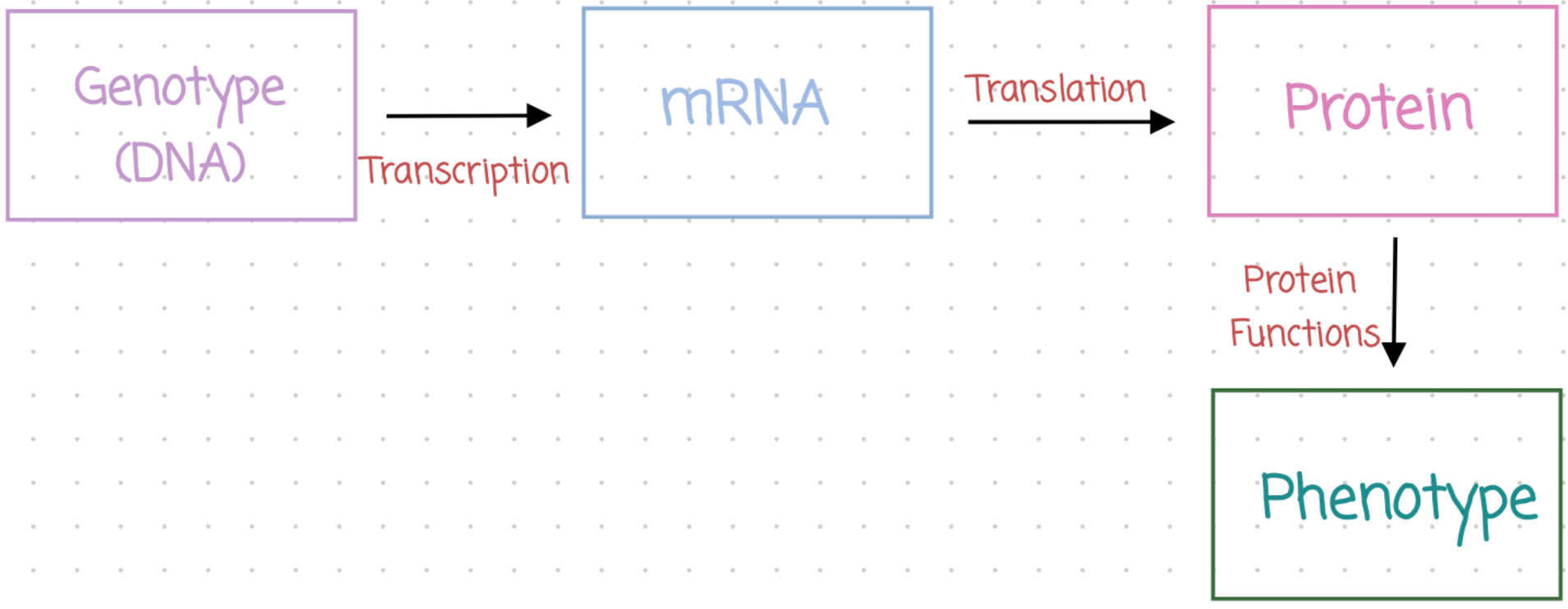
During succession, a stable climax community may develop, determined mainly by climate. Human activities can prevent succession from reaching this climatic climax, causing arrested or deflected succession, known as a plagioclimax.

Intensive grazing by livestock maintains grassland, as grasses tolerate grazing but tree and shrub seedlings are destroyed. Drainage of wetlands increases soil aeration, causing wetland species to die or migrate and allowing saprotrophic fungi to decompose peat. Shrubs and trees may then colonize, creating a plagioclimax instead of a wetland climax.

Gene expression

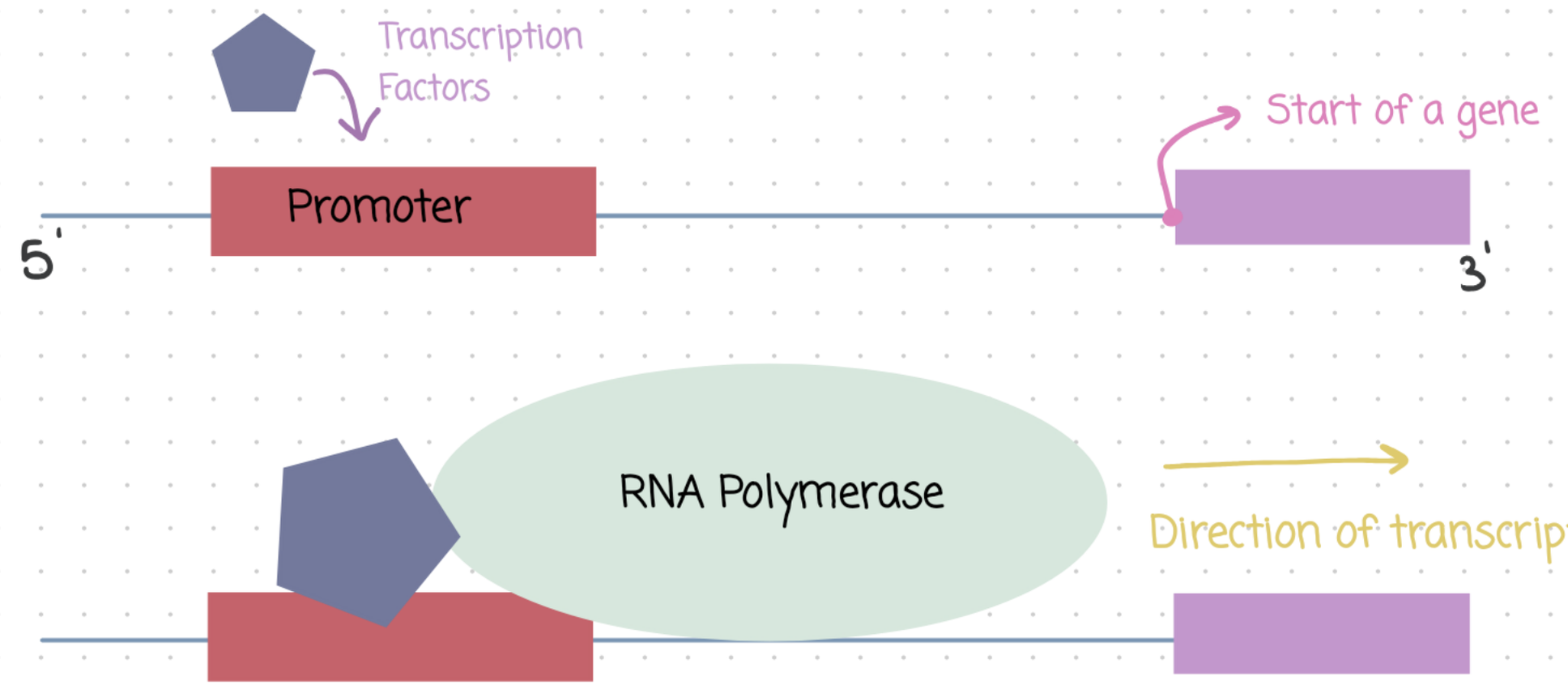
Gene Expression

- **Phenotype:** All the functional and structural characteristics of an organism.
- **Genotype:** All its genetic information.
- **Gene expression:** Process of turning genotype into phenotype.



Regulation of Transcription

- Gene expression requires selective transcription of mRNA. (Promoters, Transcription Factors, Enhancers)



Transcription Factors:

- Allow a cell to regulate gene transcription and be selective in which genes are transcribed at all times in the life of the cell.
(Example: Testosterone receptors)

- Enhancers: Vary the rate of transcription of genes.

- Transcription Factors + Enhancers = Increased rate of transcription

Control of the Degradation of mRNA

- Poly-A Tail: A long string of adenine bases at the end of the mRNA molecule. Controls the stability of mRNA. Over time, it gets shorter.

- The shorter → the more likely mRNA is to be destroyed and less likely to be reused.

Epigenesis:

- The process of how a cell changes from a simple state to a specialized one through gene activation/inactivation.

- Chemical tags (called epigenetic marks) turn genes on and off.

- These do not affect the DNA sequence but do affect how genes are used.

- Genome: All the DNA in a cell (includes both coding and non-coding regions).

- Transcriptome: All the mRNA currently made in a cell. It changes over time and between cells.

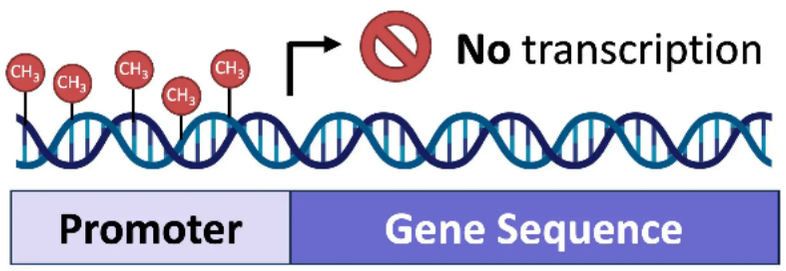
- Proteome: All the proteins made in a cell. Controls how the cell works and what type of cell it becomes.

Methylation:

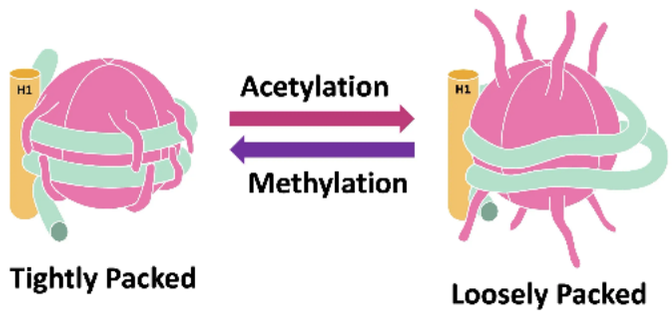
- When a small chemical group ($-CH_3$) is added to DNA or proteins. This is an epigenetic change and helps control gene expression. Often occurs near the promoter region.

- Methyl groups + DNA → Transcription might not start.

- Methyl group + Histone proteins → Affects how tightly DNA is packed. (The location of the methyl group affects gene's activeness.)



DNA.



Protein

Epigenetic Inheritance

- Epigenetic tags control gene expression and affect cell function. These tags can change due to environmental factors.

- When a cell divides → it can pass tags to new cells, keeping the same functions.

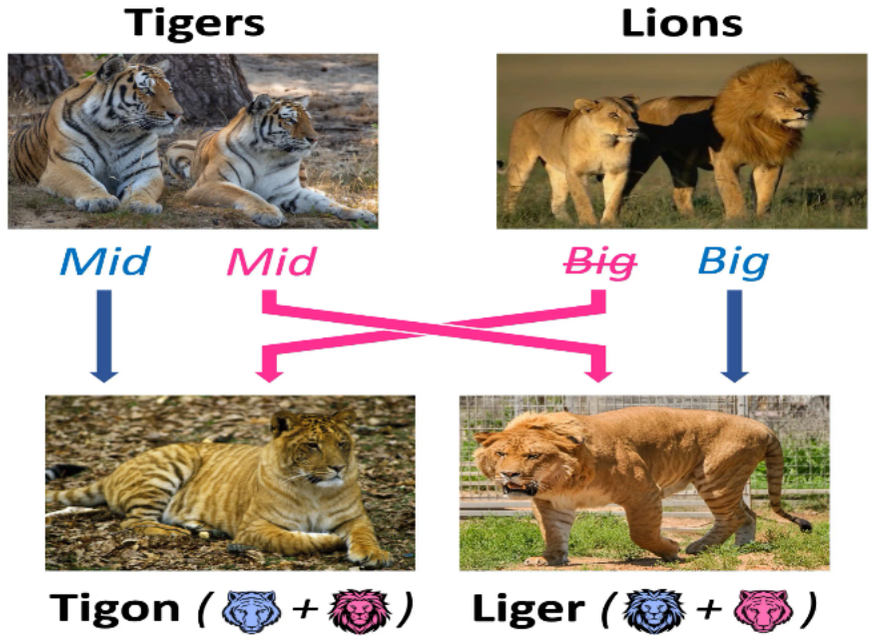
- Gamete formation: Most tags are removed, but some can stay and pass to the next generation. (Transgenerational epigenetic inheritance)

- Air pollution: Nitrous oxides and ozone can reduce DNA methylation.
→ Can cause asthma, inflammation, or heart problems. (Environmental effects)

Most Epigenetic Tags are Removed From Ovum and Sperm

- During sperm and egg formation, most epigenetic tags are removed.
→ But some might affect the next generation.
→ A dominant allele can be silenced, the recessive allele will be expressed.
→ These patterns can be passed on to all body cells.

- Sperm and eggs have different epigenetic patterns this explains behavioral differences between tigons and ligers.



Studying Twins

- Dizygotic (fraternal) twins → Come from 2 different eggs.
→ Share ~50% of their DNA.

- Monozygotic (identical) twins → One egg that splits.
→ Share 100% of their DNA.

- Studying how the environment affects traits and gene expression is best done on monozygotic twins.

External Factors That Impact Gene Expression

- Gene expression can be influenced by factors outside the cell.

Lactase Production in E. coli:

- E. coli has enzyme lactase, which digests lactose.
- No lactose present → A repressor protein binds to gene's promoter, blocking transcription.
- Lactose present → Lactose binds to repressor and removes it.
- This allows RNA polymerase to transcribe genes into Bacterium can use lactose for energy.

Testosterone and Gene Expression:

- Testosterone is a steroid hormone that controls gene expression in sperm production cells. It enters the cell and binds to androgen receptors.
- These complexes move and bind to specific DNA sequences.
- Either activates or blocks transcription of certain genes.