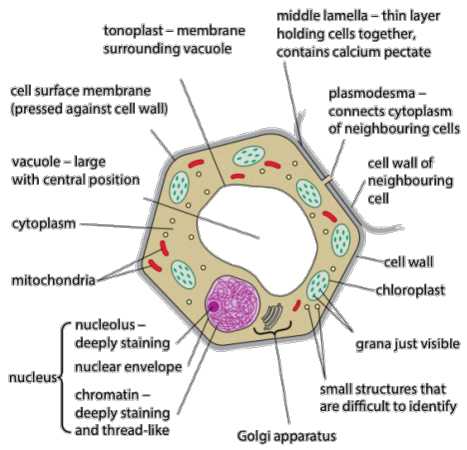
1 Cell structure

1.1 The microscope in cell studies

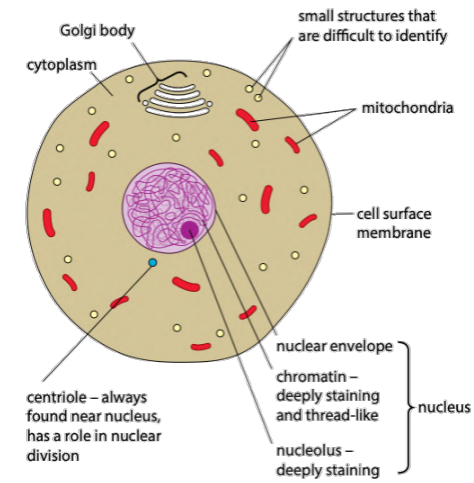
a) Differences between plant and animal cells

LIGHT MICROSCOPE

PLANT CELL

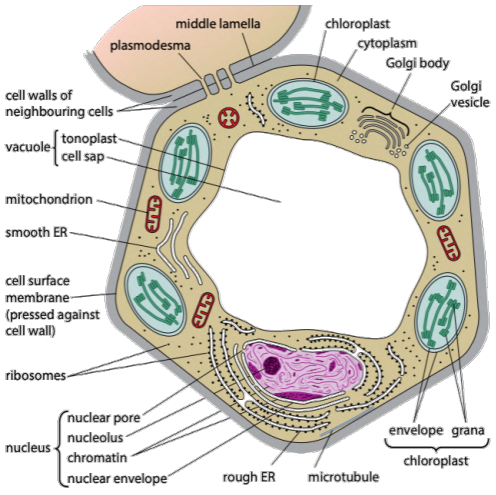


ANIMAL CELL



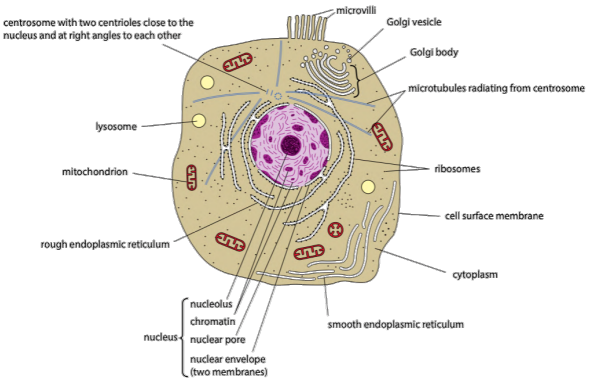
ELECTRON MICROSCOPE

PLANT CELL



ELECTRON MICROSCOPE

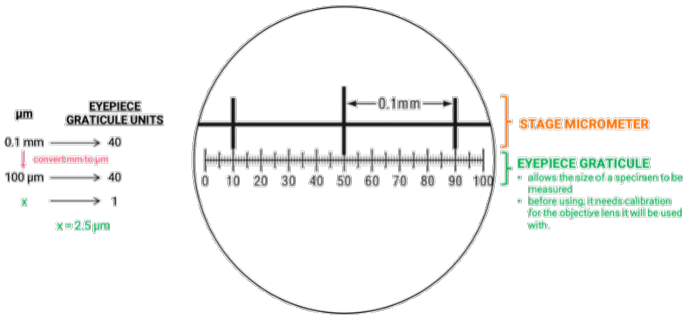
ANIMAL CELL



Images: Cambridge International AS & A Level Biology Coursebook

b, c, e) Magnification calculations

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}}$$



CONVERSIONS
1 mm = 1000 or 10^3 µm
1 µm = 1000 or 10^3 nm

d) Resolution and magnification

- **magnification** – how much bigger a sample appears to be under a microscope than it is in real life
- **resolution** – the ability to distinguish between 2 separate points.
  - as resolution increases, image clarity and detail also increase

Types of microscopes

	LIGHT	ELECTRON
RESOLUTION	200 nm	SEM – 3 nm TEM – 0.5 nm
MAGNIFICATION	x1500	x250,000 – x500,000

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a) Light microscopes

- limit of resolution: half the wavelength
- ribosomes (25nm) can't be seen with a light microscope as they don't interfere with the light waves

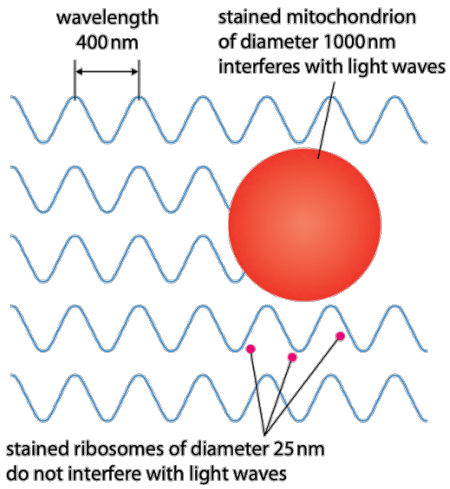


Image: Cambridge International AS & A Level Biology Coursebook

- different stains are absorbed by different cell organelles so they can be observed more clearly

b) Electron microscopes

- vacuum (electrons cannot be focused without a vacuum as they will collide with air molecules and scatter)
- water boils at room temperature in a vacuum, so the sample must be dehydrated (specimen has to be dead)

Advantages of a light microscope over an electron microscope

1) can observe living tissue
2) more portable
3) easier to use - no technical training required
4) possible to see real/natural colours and a live specimen
5) can stain particular types of tissue for better visibility

1.2 Cells as the basic units of living organisms

The cell is the basic unit of all living organisms.

The interrelationships between these cell structures show how cells function to transfer energy, produce biological molecules including proteins and exchange substances with their surroundings.

a) Electron micrographs of plant and animal cells

a) Plant cells

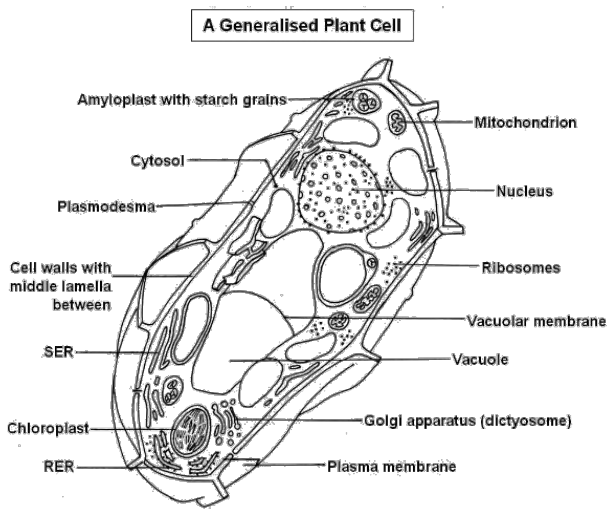


Image: https://cronodon.com/BioTech/Plant_Bodies_Cells.html



Image: https://www.tuttee.co/blog/gce-cie-biology-animal-and-plant-cell-structures-and-functions

b) Animal cells

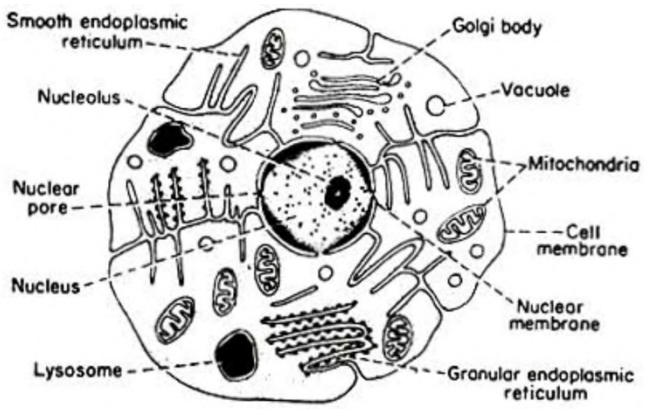


Fig. 168. Diagram of a typical animal cell under electron microscope

Image: https://brainly.in/question/1540878

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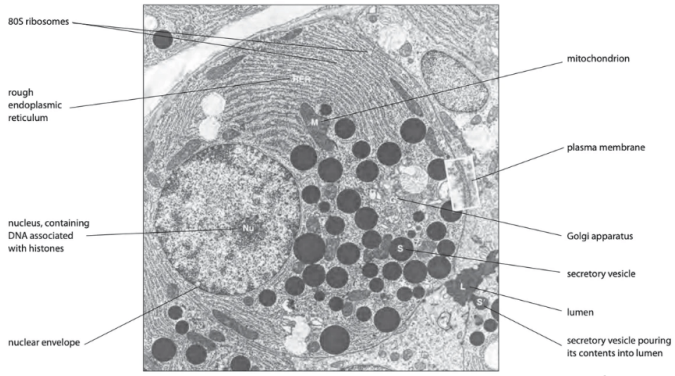


Image: https://www.tuttee.co/blog/gce-cie-biology-animal-and-plant-cell-structures-and-functions

b) Eukaryotic cell structures and their functions

1) Cell surface membrane *(phospholipid bilayer)* (7 nm)

- selectively permeable membrane that allows for the exchange of certain substances
- barrier between cytoplasm and external environment
- cell recognition (surface antigens)
- selection of substances that enter/leave cells

2) Nucleus (7 µm)

Controls cell's activities

- very dense, takes up colour the most when stained
- divides first during cell division
- surrounded by 2 membranes, known as the nuclear envelope which is continuous with the RER.

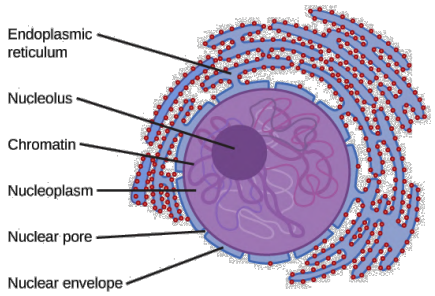


Image: https://courses.lumenlearning.com/boundless-ap/chapter/the-nucleus-and-ribosomes/

- contains:
  - a) **nuclear pores:** allow and control substances entering in *(protein to make ribosomes, ATP, some hormones, nucleotides)* and leaving *(mRNA, ribosomes for protein synthesis)* of nucleus
  - b) **nucleolus (2.5 µm):** contains loops DNA from several chromosomes and synthesises ribisomes

3) Ribosomes (25 nm)

- composed of 2 subunits

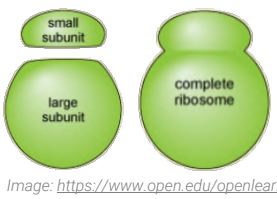


Image: https://www.open.edu/openlearn/

- carry out protein synthesis
- 80S – cytoplasm
- 70S – chloroplasts & mitochondria

4) Rough endoplasmic reticulum (RER)

- membranes that form an extended system of fluid-filled sacs (cisternae)
- single membraned organelle
- ribosomes are attached to the RER and are the site of protein synthesis
- proteins made by the ribosomes enter the sacs and are often modified as they go through them
- small sacs (vesicles) break off from the ER and join to form the golgi body

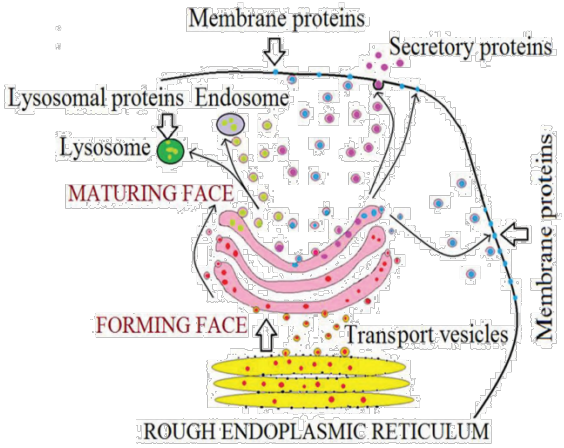


Image: Esrefoglu, Mukaddes. (2019). The Golgi Apparatus: Morphology and Function with Recent Facts. Bezmialem Science. 7. 331-338. 10.14235/bas.galenos.2019.2806.

5) Golgi body / apparatus / complex

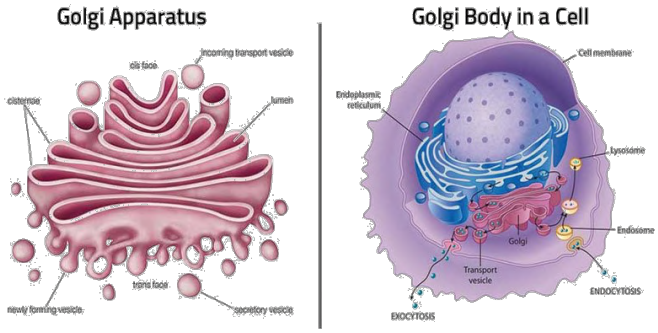


Image: https://microbenotes.com/golgi-apparatus-structure-and-functions/

- stack of flattened sacs (cisternae) formed by the vesicles which bud off from the RER
- Single membraned organelle
- Packages substances into vesicles for transport
- glycosylation
- phosphorylating proteins
- assembly of polypeptides into proteins (4º structure)
- folding proteins
- removing the 1st amino acid methionine to activate proteins

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6) Smooth endoplasmic reticulum (SER)

- synthesizes lipids and steroids such as cholesterol and the reproductive hormones estrogen and testosterone.

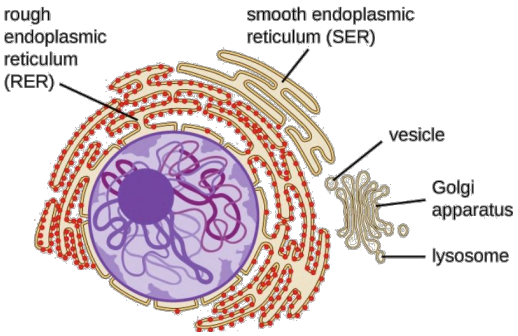


Image: https://studiousguy.com/

7) Lysosomes (0.1-1µm)

- spherical sacs surrounded by a single membrane
- not permanent structures
- no internal structure
- contain hydrolytic enzymes
- responsible for digestion/breakdown of unwanted structures e.g., old organelles
- can even digest whole cells e.g., in mammary glands after the period of lactation

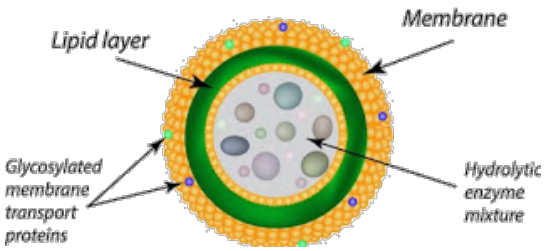


Image: https://www.ybstudy.com/2020/07/lysosomes-structure-functions.html?m=1

8) Mitochondria (0.5-10µm)

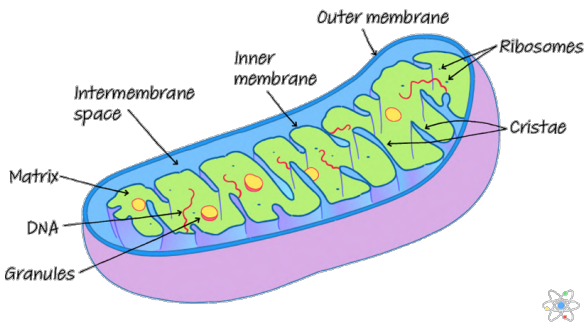


Image: https://brainly.in/question/21632838

- carries out aerobic respiration
- synthesizes ATP (adenosine triphosphate)
- more in cells that have a higher demand for energy e.g., muscle, liver, and root hair cells
- outer membrane contains a transport protein called porin
- energy released from energy-rich molecules e.g., sugars and fats during respiration is transferred to molecules of ATP
- ATP is the energy-carrying molecule in all living cells
- once made, ATP leaves the mitochondrion and can spread rapidly to all parts of the cell where energy is needed
- its energy is released by breaking ATP down to ADP (adenosine diphosphate) in a hydrolysis reaction
- *see Chapter 12.2(i) for more details*

9) Microtubules

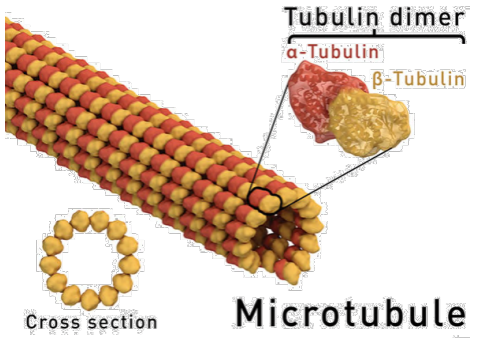


Image: https://www.microscopemaster.com/alpha-and-beta-tubulins.html

- long, rigid, hollow tubes found in the cytoplasm
- made of a protein called tubulin
- tubulin has 2 forms – α & β tubulin
- α & β tubulin molecules combine to form dimers
- many dimers are joined end to end to form protofilaments
- 13 protofilaments are in a ring to form a cylinder with a hollow center
- this cylinder is the microtubule

TUBULIN (α & β) → DIMERS → 13 PROTOFILAMENTS → MICROTUBULE

- supports and gives shapes to the cell
- the assembly of microtubules from tubulin molecules is controlled by special locations in cells called microtubule organizing centers (MTOCs)

9.5) Centrioles (and centrosomes)

9 TRIPLETS OF MICROTUBULES → CENTRIOLE

- outside the nucleus of animal cells, 2 centrioles are present close together at right angles in a region called the centrosome

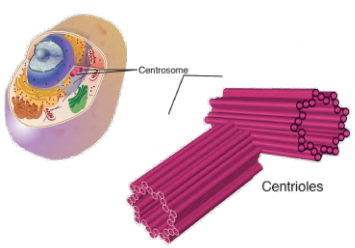


Image: https://www.microscopemaster.com/centriole.html

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- centrioles are hollow cylinders about 500 nm long
- produces spindle fibers
- organizes microtubules

10) Chloroplasts (3-10µm)

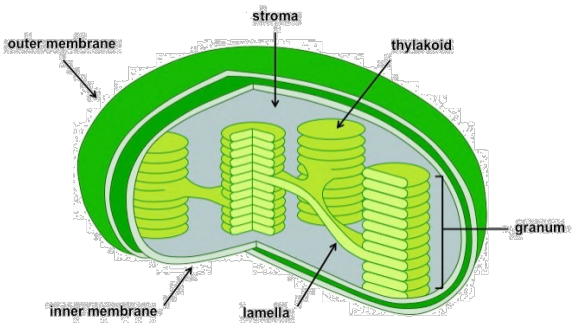


Image: https://askmicrobiology.com/do-bacteria-have-chloroplast/

- diameter 3-10 um
- carries out photosynthesis
- contains starch grains, circular DNA, and 70S ribosomes
- ATP is also produced here
- *see Chapter 13.3(a) for more details*

11) Cell wall

- gives cell definite shape
- rigid as made of cellulose
- freely permeable
- prevents cell from bursting

12) Plasmodesmata

- plant cells are linked to neighboring cells by means of fine strands of cytoplasm called plasmodesmata which pass through pore-like structures in their walls

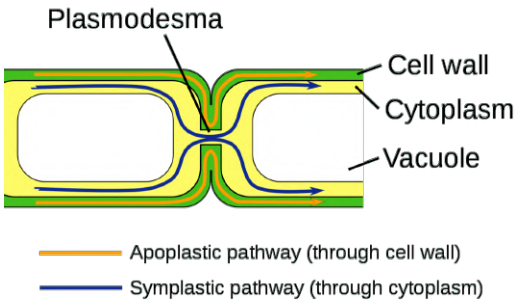


Image: https://mybody101.com/ap-bio-unit-4/

- allows the transport of water, sucrose, amino acids, ions, etc., between cells without crossing membranes
- this is called movement through the symplastic pathway
- allows communication/signaling between cells.

13) Vacuoles

- surrounded by a partially permeable tonoplast which controls exchange between the vacuole and cytoplasm

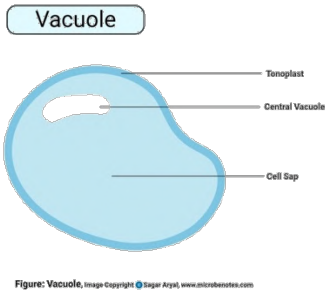


Figure: Vacuole, Image Copyright © Sagar Aryal, www.microbenotes.com

- helps regulate osmotic properties of cells
- fluid present in the vacuole consists of:

P igments
E nzymes
S tarch
O rganic molecules
M ineral salts
O xygen
C arbon dioxide

d) Structural features of prokaryotic cells

- organisms that lack nuclei or proper nuclear membranes are called prokaryotes
- unicellular
- 1-5um
- cell wall made of murein (peptidoglycan = protein + polysaccharides)
- no membranes around organelles
- 70S (smaller) ribosomes
- genetic material in the form of circular DNA
- have no ER

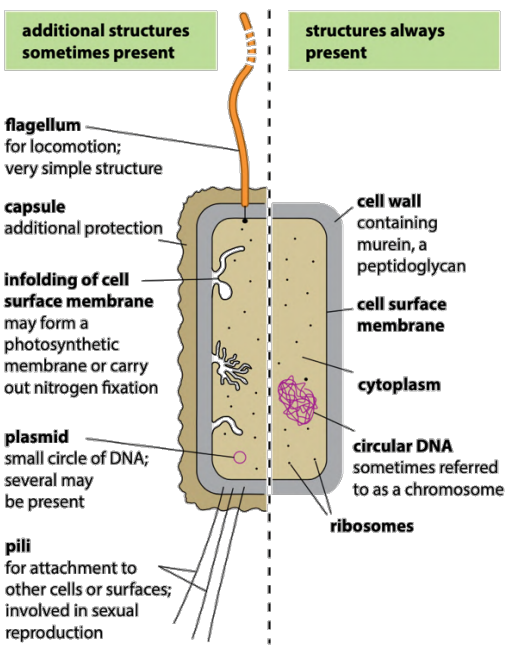


Image: Cambridge International AS & A Level Biology Coursebook

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e) Differences between typical eukaryotic and prokaryotic cells

Characteristic	Prokaryotic cell	Eukaryotic cell
Size of cell	Typically 0.2-2.0µm in diameter	Typically 10-100 µm in diameter
Example	Bacteria and Archaea	Animals and Plants
Nucleus	Absent	Present
Membrane-enclosed organelles	Absent	Present; examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria & chloroplasts
Flagella	Consist of two protein building blocks	Complex; consist of multiple microtubules
Cell wall	Usually present; chemically complex	Only in plant cells and fungi (chemically simpler)
Plasma membrane with steroid	Usually no	Yes
Cytoplasm	No cytosketeton or cytoplasmic streaming	Cytoskeleton; cytoplasmic streaming
Ribosomes	Smaller	Larger
Cell division	Binary fission	Mitosis
Number of chromosomes	One, but not true chromosome	More than one
Sexual reproduction	No meiosis; transfer of DNA fragments only (conjugation)	Involves meiosis

Prokaryotic cells, as well as eukaryotic cells, are covered with the plasma membrane, which is located on top of the cell membrane or mucous capsule. Despite of its relative simplicity, prokaryotes are typically independent cells. Table 4.1 presents the major differences between prokaryotic and eukaryotic cells.

Image: https://www.researchgate.net/fi

See Chapter 18.2 for more details

f) Viruses

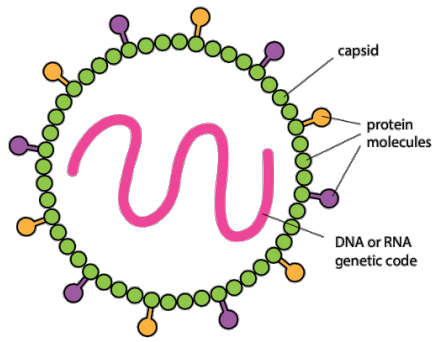


Image: Cambridge International AS & A Level Biology Coursebook

- noncellular/acellular
- protein coat
- nucleic acid core; DNA/RNA strand
- replicate inside host cells only
- show no characteristics of living organism
- symmetrical shape
- the virus DNA/RNA takes over the protein synthesizing machinery of the host cell which helps to make new virus particles
- *See Chapter 18.2(d) for more details*

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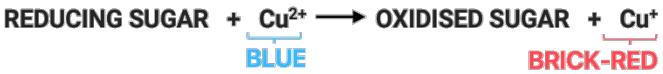
2 Biomolecules

2.1 Testing for biomolecules

Food tests

1) Reducing sugars

- reduce soluble blue copper sulphate containing copper (II) ions to insoluble brick-red copper oxide, containing copper (I)
- the copper oxide is seen as a brick-red ppt



- add equal volumes of Benedict's reagent and the food sample to a test tube
- heat in a water bath at 80°C
- if reducing sugars are present, the following colour changes are observed:



2) Non-reducing sugars

- e.g., sucrose
- disaccharide is first broken down into its 2 monosaccharide constituents in a hydrolysis reaction
- this is done by adding HCl, and then neutralising the acid with an alkali such as sodium bicarbonate
- constituent monosaccharides will be reducing sugars and their presence can be tested by Benedict's test

3) Starch

- add drops of iodine solution to the sample
- if blue-black colour is quickly produced, starch is present
- iodine solution is yellow brown

4) Lipids (emulsion test)

- sample is shaken with ethanol
- any lipids present will dissolve
- mixture of ethanol and sample is poured into a beaker containing water
- if lipids are present, a cloudy-white suspension is formed due to the lipids being unable to remain dissolved when mixed with water
- therefore, the lipid molecules form droplets throughout the liquid, this kind of mixture is called the emulsion

5) Proteins (Biuret test)

- all proteins have peptide bonds containing nitrogen atoms which form a purple complex with Cu^{2+} ions
- equal volumes of sample and Biuret reagent are mixed
- if proteins are present, the colour changes from blue to lilac
- instead of biuret reagent, KOH and dil. $CuSO_4$ can be used

For extra details on performing food tests, see paper 3 notes.

2.2 Carbohydrates and lipids

All living organisms are made of C, H, O + N molecules.

Carbohydrates

- composed of C, H, O
- divided into monosaccharides, disaccharides, polysaccharides

- **monomer** – one of many small molecules that combine to form a polymer, e.g. – monosaccharides, amino acids, nucleotides

- **polymer** – large molecule made from many similar repeating subunits, e.g. – polysaccharides, proteins, nucleic acids

- **macromolecule** – large molecule formed due to polymerisation of monomers, e.g. – polysaccharides, proteins (polypeptides), nucleic acids (polynucleotides)

Monosaccharides

Molecule consisting of a single sugar unit with the general formula $C(H_2O)_n$

- dissolves in water
- main types of monosaccharides – trioses (3C), pentoses (5C), hexoses (6C)
- glucose, fructose galactose, ribose, deoxyribose

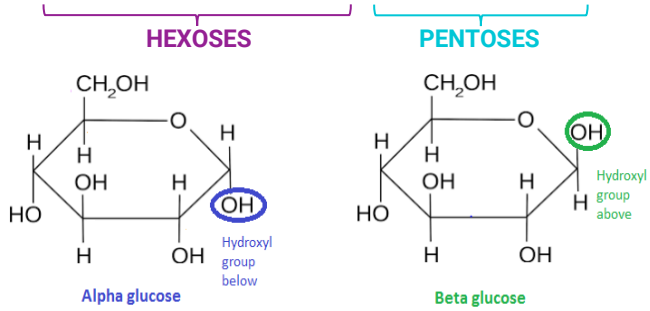


Image: https://tlamjs.com/2017/01/13/biological-molecules-carbohydrates/

Roles of monosaccharides

1) **source of energy in respiration** – C-H bonds can be broken to release a lot of energy which is transferred to help make ATP from ADP

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2) **building blocks for larger molecules** – glucose is uses to make the polysaccharides starch, glycogen, and cellulose; ribose is one of the molecules used to make RNA and ATP, deoxyribose is one of the molecules used to make DNA

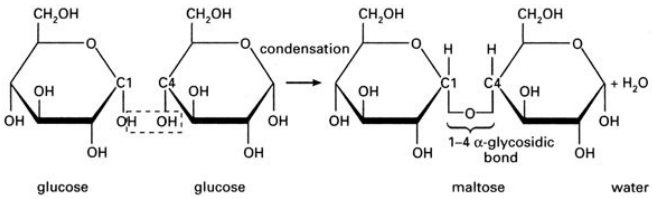
Disaccharides

Sugar molecule consisting of 2 monosaccharides joined by a glycosidic bond.

CONDENSATION

MONOSACCHARIDE + MONOSACCHARIDE → DISACCHARIDE

GLUCOSE + GLUCOSE → MALTOSE
α-GLUCOSE + β-FRUCTOSE → SUCROSE
GLUCOSE + GALACTOSE → LACTOSE



Glycosidic bond formation

Image: https://dopeahmeanbio.wordpress.com/tag/glycosidic-bonds/

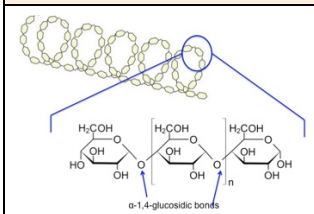
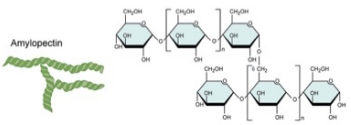
- H_2O molecule is removed; the bond formed by condensation is called a glycosidic bond

Polysaccharides

A polymer whose subunits are monosaccharides joined by glycosidic bonds

- e.g., starch, glycogen, cellulose (all polymers of glucose)
- not sugars
- if glucose itself accumulated in cells, it would dissolve and make the contents of the cell too concentrated which affects its osmotic properties
- storage polysaccharides – convenient, compact, inert, insoluble

1) Starch → amylose + amylopectin

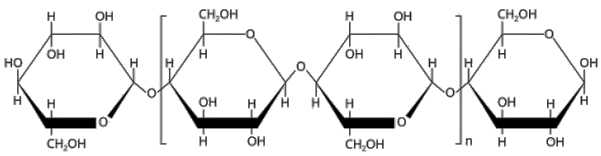
AMYLOSE	AMYLOPECTIN
 *Image: https://www.e-education.psu.edu/*	 *Image: http://futurefoodchemist.weebly.com/*
made by condensation reactions between 1,4 linked α-glucose molecules	also made of 1,4 linked α-glucose molecules
long, unbranching chain	chains are shorter than amylose and branch out to sides
chains are curved and coil into helical structures making the final molecule more compact	branches are formed by 1-6 linkages

2) Glycogen

- made of chains of 1-4 linked α-glucose molecules with 1-6 linkages forming branches
- tend to be more branched than amylopectin molecules
- many ends due to branching aids in easy addition and removal of glucose
- compact and insoluble, doesn't affect the water potential (Ψ)

3) Cellulose → polymer of β-glucose

- in order to form a glycosidic bond with the 4th carbon atom where the OH group is below the ring; every other glucose is rotated 180°
- so successive glucose molecules are linked 180° to each other
- one oxygen is up and the other is down
- the molecules are still linked 1-4



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- cellulose molecules become tightly cross-linked to form bundles called microfibrils
- microfibrils are held together in bundles called fibres by hydrogen bonding
- cellulose fibres have very high tensile strength – this makes it possible for a cell to withstand large pressures as a result of osmosis
- cellulose fibres, despite their strength, are freely permeable

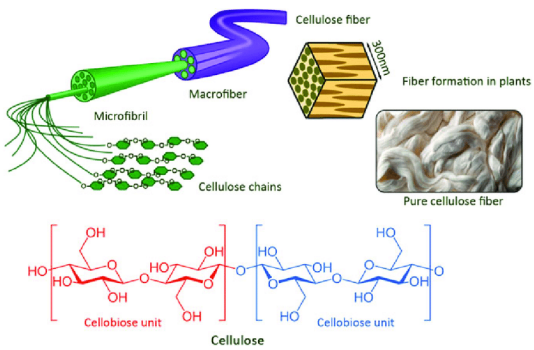


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Dipoles and hydrogen bonds

- unequal distribution of charges in a covalent bond is called a dipole
- molecules which have groups with dipoles are polar

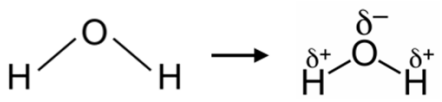


Image: https://alevelbiology.co.uk/notes/dipoles-of-water-molecules/

- in water, oxygen atom gets more electrons due to it being more electronegative and therefore gets a small negative charge denoted by delta (**δ**-)
- hydrogen atoms get less electrons and therefore get small positive charges (**δ**+)

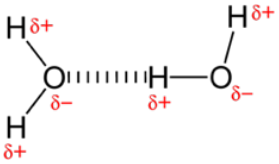


Image: https://courses.lumenlearning.com/cheminter/chapter/hydrogen-bonding/

- negatively charged oxygen of one molecule is attracted to a positively charged hydrogen of another, this attraction is called a hydrogen bond

Molecules which have groups with dipoles are polar

- they're attracted to H_2O molecules as they also have dipoles and are considered to be hydrophilic (water-loving)
- soluble in water
- e.g., glucose, amino acids, NaCl

Molecules which do not have dipoles are non-polar

- they're not attracted to water and hydrophobic (water-hating)
- insoluble in water
- e.g., oils, cholesterol

Lipids → 3 Fatty Acids + 1 Glycerol

Fatty acids

- contain the acidic group –COOH
- larger molecules in the series have long hydrocarbon tails attached to the acid which are 15-17 carbon atoms long
- of two types: saturated and unsaturated
- unsaturated fatty acids have C=C double bonds therefore don't have maximum amount of hydrogen atoms
- form unsaturated lipids
- mostly liquid

Alcohols & Esters

- alcohols contain hydroxyl group (–OH) attached to C atom
- reaction between (fatty) acid (–COOH) and alcohol (–OH) produces an ester
- the chemical link between acid and alcohol is called an ester linkage/bond and is formed by a condensation reaction

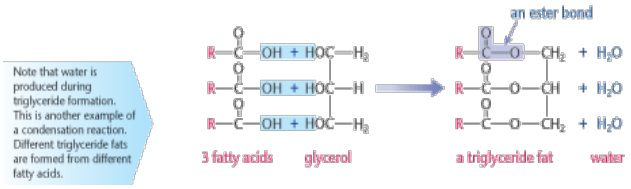


Image: https://revisionscience.com/

- glyceride is an ester formed by a fatty acid combining with the alcohol glycerol ($C_3H_8O_3$)
- glycerol has 3 hydroxyl groups; each one is able to undergo a condensation reaction with a fatty acid
- triglycerides are insoluble in water due to the non-polar nature of hydrocarbon tails – they don't have uneven distribution of charges and are hydrophobic

Roles of triglycerides

- energy reserves
- insulator
- protect vital organs

2.3 Proteins and water

Proteins

All proteins are made from the same monomer - amino acids.

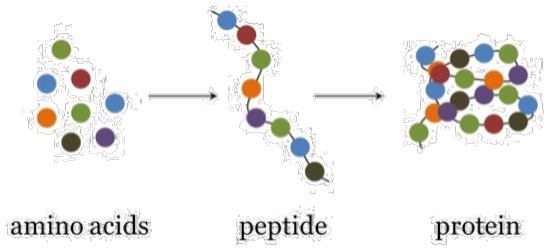


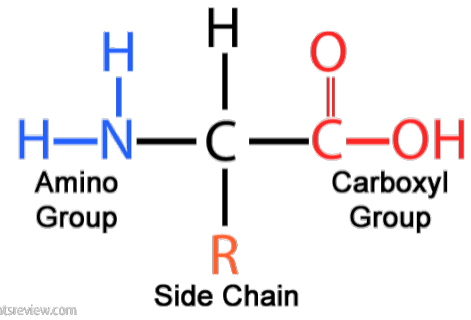
Image: https://beautiflworld.com/do-protein?print=print

Amino acids

All have a central carbon atom bonded to –

- an amine ($-NH_2$) group
- a carboxylic group (–COOH)
- a hydrogen
- a R-group that determines what type of amino acid it is

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The peptide bond

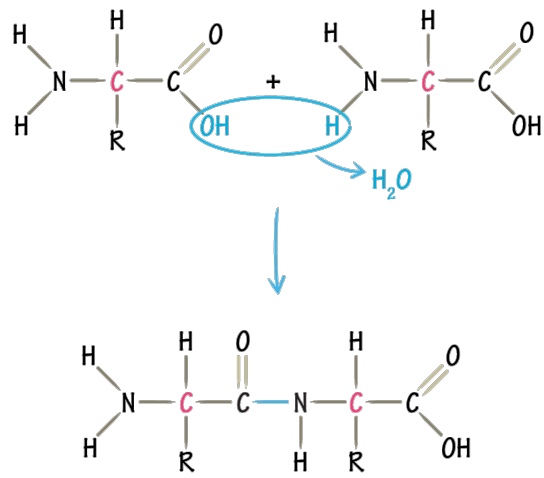
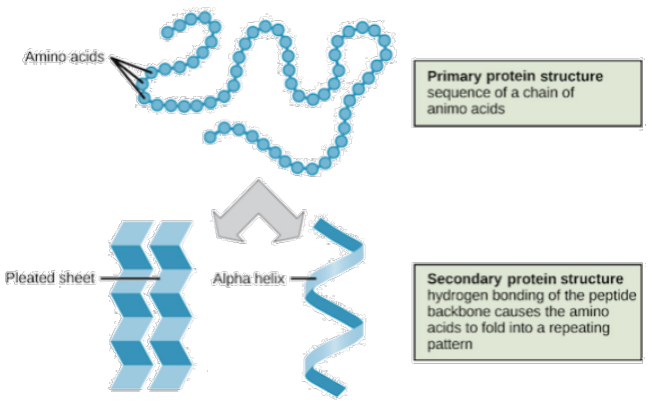


Image: https://www.drawittoknowit.com/

- a molecule made up of many amino acids linked together by peptide bonds is a polypeptide
- polypeptides can be broken down to amino acids by breaking the peptide bonds in a hydrolysis reaction
- this happens naturally in the stomach and small intestine during digestion

Structures of proteins



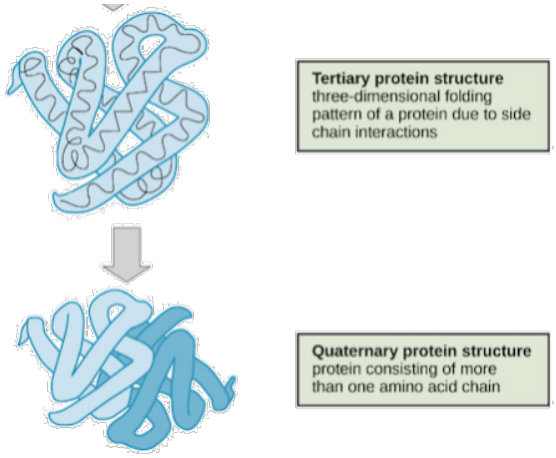


Image: https://www.khanacademy.org/

Bonds in the tertiary structure

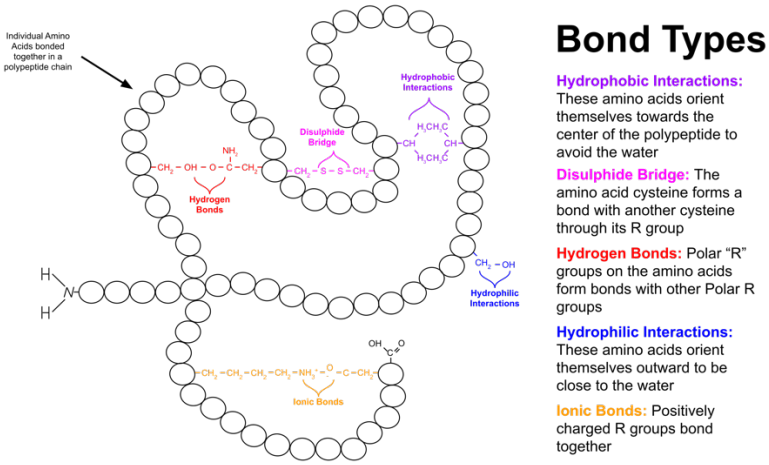


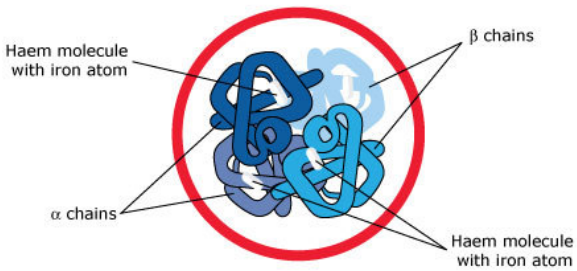
Image: By WikiComTD - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=79148318

PROTEINS	
GLOBULAR	**FIBROUS**
spherical/balled shaped • curl up so that their non-polar, hydrophilic R-groups point to the centre of the molecule away from watery surroundings • polar, hydrophilic R-groups are on the outside which makes mixing + dissociating in water easier	proteins that form long strands
usually soluble	usually not soluble in water
precise shape, have roles in metabolic activities and are specific in nature	have structural roles
e.g., enzymes, haemoglobin, myoglobin	e.g., keratin, actin, myosin, collagen

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Haemoglobin: a globular protein

- made of 4 polypeptide chains therefore they have a quaternary structure
- 2 of the haemoglobin chains, α-chains, are made of α-globin
- the other 2 chains, β-chains, are made of β-globin
- each polypeptide chain has a haem group attached (prosthetic group) to it
- haem contains charged particle of iron
- the haem group is also responsible for the colour of haemoglobin



Haemoglobin is made up of four chains (two α and two β), each one surrounding a haem molecule that holds a single iron atom.

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- each polypeptide chain can carry one molecule of oxygen
- therefore, in total, haemoglobin can carry 4 molecules of oxygen or 8 oxygen atoms

Collagen: a fibrous protein

- found in skin, tendons, cartilage, bone, teeth, etc.
- a structural protein
- collagen molecule consists of 3 polypeptide chains, each in a helical shape

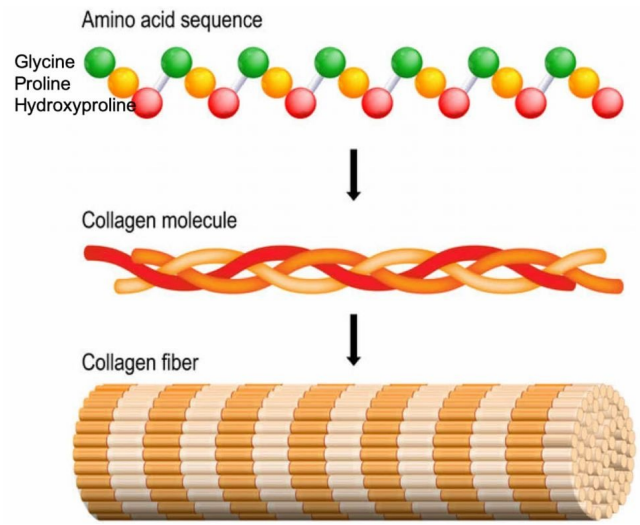


Image: https://rosemarycottageclinic.co.uk/

- helical polypeptides are wound together creating a triple helix
- strands are held together by hydrogen and some covalent bonds
- every 3rd amino acid in each polypeptide chain is glycine
- each 3 stranded molecule interacts with other collagen molecules running parallel to it
- covalent bonds form between R-groups of amino acids
- these cross-links hold many collagen molecules side by side forming fibrils
- many fibrils lie alongside each other forming strong bundles called fibres
- collagen is flexible but has tremendous tensile strength
- collagen fibres line up according to the forces they withstand

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3 Enzymes

3.1 Mode of action of enzymes

- enzymes are globular proteins that catalyse metabolic reactions
- function as biological catalysts
- specific in nature
- precise 3D shape with hydrophilic R-groups on the outside ensuring they're soluble
- possess active sites which are clefts/depressions to which a substrate can bind

ENZYMES	
INTRACELLULAR	**EXTRACELLULAR**
functions inside of cells	functions outside of cells
synthesised and retained in cell	synthesised in cell but secreted out

Lock and key

- idea that enzymes have particular shapes into which their substrate fits into exactly
- enzyme is said to be specific for a substrate

Induced fit hypothesis

- substrate is partially complementary to the active site
- the active site changes shape slightly to ensure a better fit and stronger binding of substrate
- this makes catalysis even more efficient

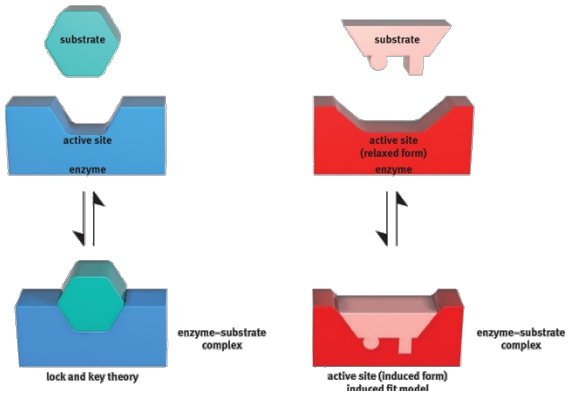


Image: https://schoolbag.info/chemistry/mcat_biochemistry/10.html

Enzymes reduce activation energy (E_a)

- in many chemical reactions, the substrate will not be converted to a product unless it's temporarily given extra energy
- this extra energy is activation energy (E_a)
- enzymes do this by holding their substrates in a way that bonds can be broken more easily hence reducing E_a
- or the shape is slightly changed, making it easier to change the substrate to a product (induced fit theory)

The course of a reaction

- when the enzyme and substrate are first mixed, there's a large number of substrate molecules therefore almost every enzyme has a substrate in its active site
- this makes the rate of enzyme-controlled reaction fastest at the beginning

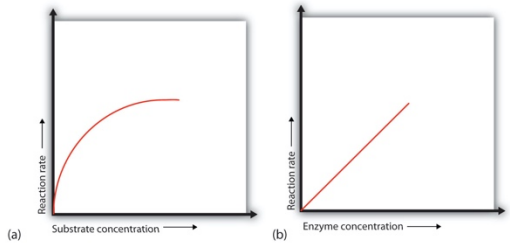


Image: https://2012books.lardbucket.org/

3.2 Factors that affect enzyme action

1) Temperature

- rate of reaction is slow at lower temperatures as molecules are moving slowly which makes collisions happen less frequently
- as temperature rises, enzymes and substrates move faster, and collisions happen more frequently
- when they collide, they do so with more energy which makes it easier for bonds to be formed and broken
- if temperature keeps increasing, bonds holding enzyme in shape (ionic, hydrogen bonds) break and the enzyme is said to be denatured
- the temperature at which enzymes catalyse a reaction at maximum rate is the 'optimum temperature'
- in humans, this is around 40°C

2) pH

- pH is a measure of the H^+ ions in a solution
- H^+ ions can affect the R-groups of amino acids which affects the ionic bonding between groups which in turn affects the 3D structure of the enzyme
- Active site may also be changed, reducing chances of a substrate fitting in

3) Enzyme concentration

- the more enzymes present, the more active sites are available for substrates to fit in
- as long as there's plenty of substrate available, initial rate of reaction increasing linearly with enzyme concentration

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4) Substrate concentration

- as substrate concentration increases, initial rate of reaction also increases
- the more substrate molecules there are around, the more often an enzyme's active site can bind with one
- saturation point – enzymes working at max (V_{max})
- all active sites are filled up
- enzyme moves to find substrates as it gets less, collision forces start to decrease

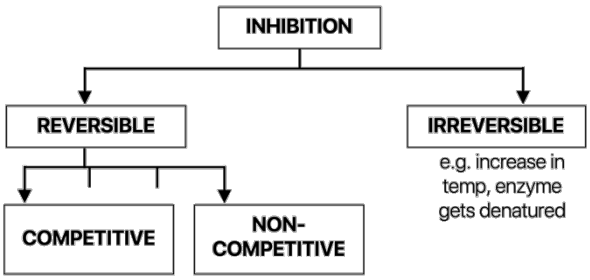
STARCH → MALTOSE → GLUCOSE

too much product so difficult to find substrate

acting as inhibiting agent

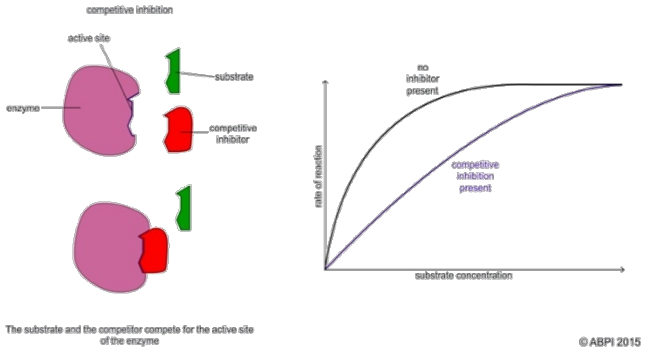
5) Inhibitor concentration

Decreases enzyme activity, slowing down the reaction.



a) Competitive inhibition

- compete with the substrate for the active site
- molecule similar in shape to the enzyme's substrate binds with the active site inhibiting the function



- if the concentration of inhibitor rises or substrate falls, it becomes less likely that the substrate will collide with an active site
- can be reversed by increasing the concentration of substrate

b) Non-competitive inhibitor

Molecule fits into the allosteric site of the enzyme rather than the active site.

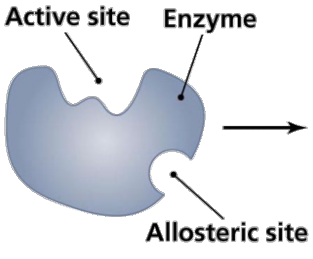
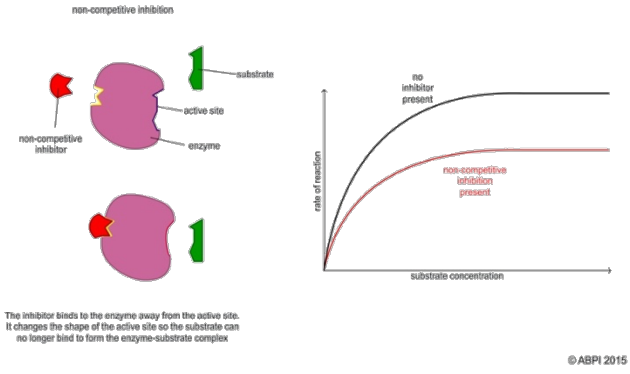


Image: https://aiimsrishikesh.edu.in/

- disrupts the three-dimensional shape of enzyme preventing the substrate from fitting into the active site as its distorted
- increasing the substrate concentration has no change on the rate of reaction here



- End product inhibition – as enzyme converts substrate into product, rate is slowed down at the end as the product binds to another part of the enzyme and prevents more substrate binding

Enzyme affinities

- affinity – enzyme willingness to bind to a substrate
- at V_{max}, all enzyme molecules are bound to substrate molecules; the enzyme is saturated with substrate

As substrate concentration is increased, reaction rate rises until the **max rate i.e., V_{max}**

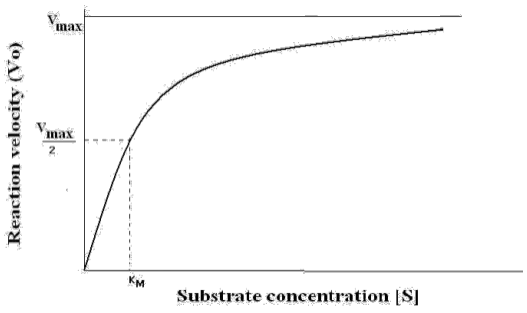


Image: https://commons.wikimedia.org/wiki/File:Michaelis-Memten.JPG

K_m (Michaelis-Menten constant)

- the substrate concentration at which enzyme works at half its maximum rate
- half the active sites of enzymes are occupied by substrate

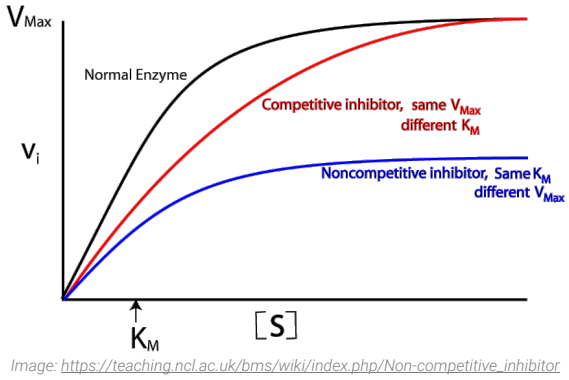


Image: https://teaching.ncl.ac.uk/bms/wiki/index.php/Non-competitive_inhibitor

- An enzyme with a lower value of K_m has a high affinity to its substrate

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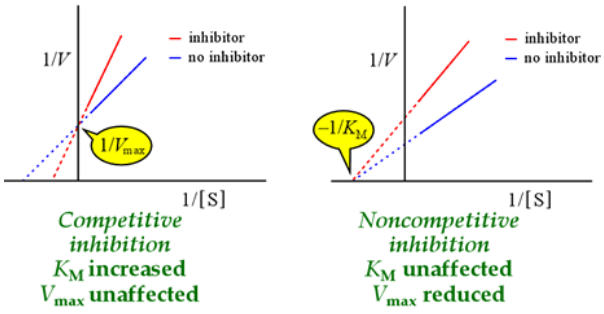


Image: https://epomedicine.com/medical-students/competitive-non-competitive-and-uncompetitive-inhibitors/

Immobilising enzymes

- enzyme is mixed with a solution of sodium alginate
- droplets of this mixture are added to calcium chloride solution
- a reaction occurs forming jelly/beads
- enzyme is immobilised in the bead

Advantages of immobilising enzymes

1) enzyme is reused
2) enzyme is easily recovered
3) product isn't contaminated with enzymes
4) reduces product inhibition
5) enzyme is more stable/less likely to denature
6) longer shelf-line of enzyme

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4 Cell Membranes and Transport

4.1 Fluid mosaic membranes

Fluid mosaic model

- 'fluid' refers to the movement of phospholipids while 'mosaic' refers to the scattered proteins (and glycoproteins) in the phospholipid bilayer

1) Phospholipids

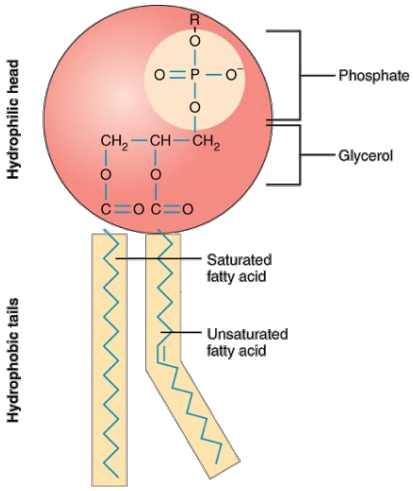


Image: https://courses.lumenlearning.com/

- phospholipids are arranged so that hydrophobic, non-polar tails do not face water. Water is on both the intracellular and extracellular sides
- therefore, tails point inwards, and hydrophilic heads face the aqueous medium

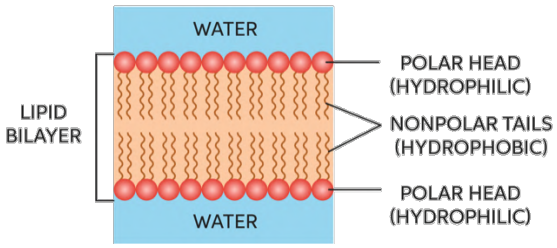


Image: https://www.chegg.com/

Membrane fluidity

Membrane fluidity refers to the viscosity of the lipid bilayer of a cell membrane.

Membrane fluidity is affected by:

1) **tail length** – longer the tail, the less fluid the membrane
2) **saturation of fatty acid** – the more unsaturated they are, the more fluid the membrane. This is as unsaturated fatty acid tails are bent and fit together more loosely

3) cholesterol

- regulates the fluidity of membrane
- at low temperatures, cholesterol increases the fluidity of the membrane preventing it from being too rigid, this is because it prevents close packing of phospholipid tails
- at high temperatures, cholesterol decreases the fluidity of membrane and stabilises the cell

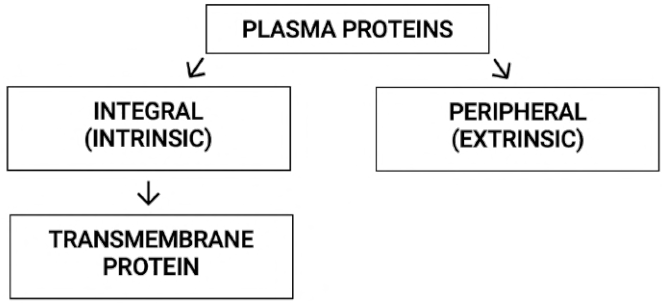
2, 3) Glycolipids and glycoproteins

Lipid and protein molecules on the outer surfaces of cell membrane have carbohydrate chains attached to them forming glycolipids and glycoproteins

These carbohydrate chains projecting out like antennae:

- stabilise the membrane structure by forming hydrogen bonds with water molecules surrounding the cell
- **glycocalyx** – sugary cell coating formed by carbohydrate chains
- act as receptor molecules:
  - ⇒ **signalling receptors** – recognise messenger molecules like hormones and neurotransmitters
  - ⇒ **endocytosis** – bind to molecule to be engulfed by membrane
- act as cell markers/antigens allowing cell-cell recognition

4) Proteins



- proteins that are found embedded within the membrane
- may be found in inner layer, outer layer or spanning the whole membrane (these are transmembrane proteins)
- helps in movement in and out of cell

- can be present inside or outside of the cell membrane i.e., intracellular, and extracellular
- extracellular peripheral proteins – communication, receptors, and recognition proteins
- intracellular peripheral proteins- structural support, attached to the cytoskeleton of the cell

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Function of transmembrane proteins

- act as gateways and can transform, helping in facilitated diffusion and active transport

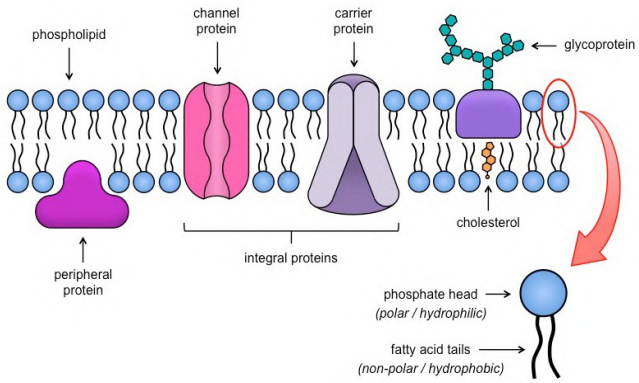


Image: https://o.quizlet.com/MZFY3U-L4j6xL86C4rWTOQ_b.jpg

Channel proteins

- do not require energy
- transport substances through membrane passively, along their concentration gradient
- used for both active transport and facilitated diffusion

Carrier proteins

- require energy
- go against the concentration gradient
- take substances from outside and pumps it inside or vice versa
- used for active transport

Cell surface receptors

- present in membranes and binds with particular substances
- used for signalling, endocytosis, cell adhesion, cell markers

Cell surface antigen

- acts as cell identifying markers
- each type of cell has its own antigen
- this enables cells to recognise other cells and behave in an organised way

Cell signalling

- cells detect signals with cell receptors, i.e., glycoproteins and glycolipids, present on their membrane
- the signalling molecule binds to the receptor as their shapes are complementary to each other
- this creates a chain of reactions in the cell, leading to a response

a) If the signalling molecules are hydrophobic (e.g., steroid hormones such as oestrogen)

- they can diffuse directly across the cell membrane and bind to receptors in the cytoplasm or nucleus.

b) If the signalling molecule is water-soluble

1) signal arrives at protein receptor in cell membrane
2) the receptor's shape is complementary to the ligand
3) the signal brings about a change in the receptor's shape
4) changing the shape of the receptor allows it to interact with the next component of the pathway so the message gets transmitted
5) binding triggers/stimulates reactions within the cell
6) cell signalling results in a response which may be intracellular or extracellular

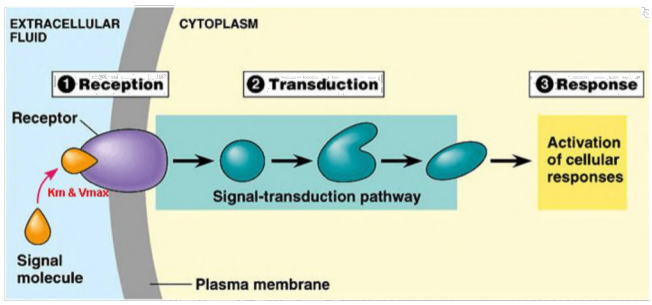


Image: https://croteaubio.wordpress.com/

4.2 Movement of substances into and out of cells

a) Diffusion

> Net movement of molecules or ions from a region of higher concentration to a region of lower concentration down a gradient, as the result of the random movement of particles.

- passive process
- molecules tend to reach an equilibrium situation

Factors affecting diffusion

- as steepness of gradient increases, diffusion increases
- as temperature increases, diffusion increases
- as surface area increases, diffusion increases
- as distance increases, diffusion decreases
- smaller and non-polar molecules like fats diffuse much easily across the cell surface membrane as they're soluble in phospholipid tails

b) Facilitated diffusion

> Diffusion of a substance through transport proteins in a cell surface membrane.

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- the proteins provide hydrophilic areas that allow the molecules or ions to pass through the membrane which would otherwise be less permeable to them

Channel proteins

- allow charged substances, usually ions to diffuse
- can move to open or close the pore, like a gate controlling ion exchange

Carrier proteins

- flip between 2 shapes, as a result, the binding site opens alternatively to each side

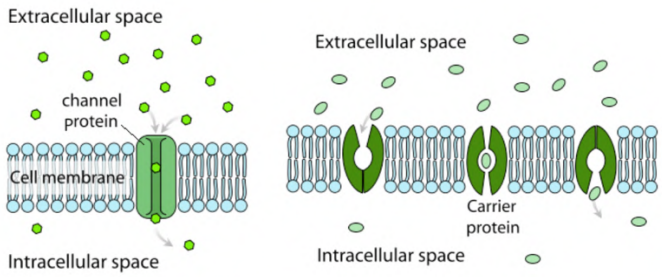


Image: https://www.khanacademy.org/

c) Osmosis

> Net movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane as a result of their random motion.

Water potential

> Tendency of water to move out of solution.

- water always moves down a water potential gradient, this happens until water potential is the same throughout the solution
- denoted by psi (Ψ)
- water potential becomes negative if the solute concentration is very high

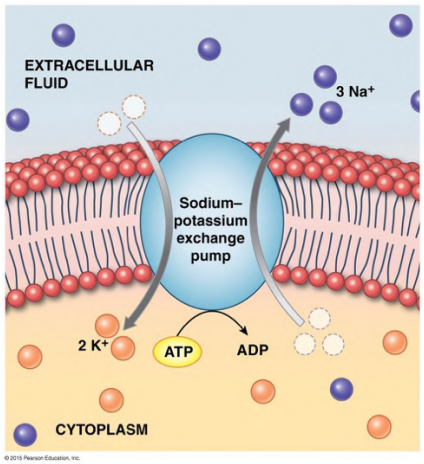
	RBC /ANIMAL CELLS	PLANT CELLS
WATER LOSS	crenated	plasmolysed, flaccid
WATER GAIN	haemolysed / lysed	turgid

d) Active transport

> Movement of molecules or ions through transport proteins, across a cell membrane, against their concentration gradient, using energy from ATP.

- achieved by carrier and channel proteins
- these are specific to the type of molecule they're transporting
- requires energy; supplied by ATP
- energy is used to make the channel/carrier proteins change shape, transferring molecules/ions across the membrane in the process

Sodium/Potassium pump



FOR EVERY ATP MOLECULE USED
$3Na^+$ - given out the cell
$2K^+$ taken in the cell

e) Bulk transport

> A type of active transport where large molecules are transported across the cell surface membrane, using energy from ATP.

ENDOCYTOSIS (INSIDE) | **EXOCYTOSIS (OUTSIDE)**

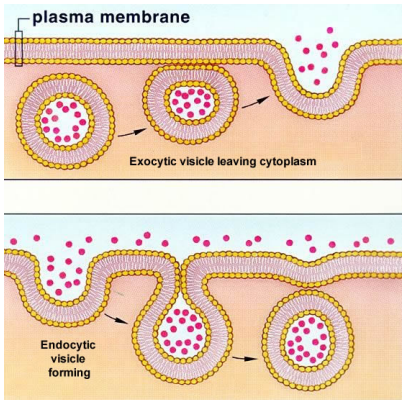


Image: http://lifeofplant.blogspot.com/

1) Endocytosis

> Bulk movement of liquids (pinocytosis) or solids (phagocytosis) into a cell by the infolding of the cell membrane to form vesicles containing the substance.

2) Exocytosis

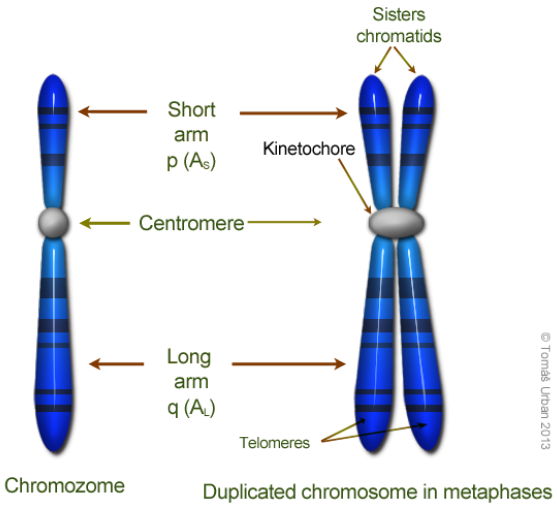
> Bulk movement of liquids or solids out of a cell by the fusion of vesicles containing the substance with the cell surface membrane.

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5 The mitotic cell cycle

Structure of a chromosome

Chromosomes are thread-like structures made of DNA.



- **Chromatid** – one half of two identical copies of a replicated chromosomes



- **Centromere** – the region of a chromosome to which the microtubules of the spindle attach, via the kinetochore, during cell division.
- **Telomeres** – protective sequence of nucleotides found at the ends of chromosomes

DNA (deoxyribonucleic acid)

DNA is the molecule of inheritance and is made up of a series of genes.

- a gene is a section of DNA that codes for one protein
- DNA molecules are in sister chromatids so that their genes are identical
- when cells divide, one chromatid goes into one daughter cell and the other to the other daughter cell, making the daughter cells genetically identical
- size of DNA molecule – 2nm

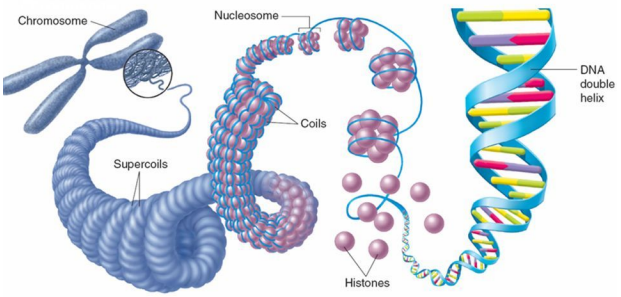
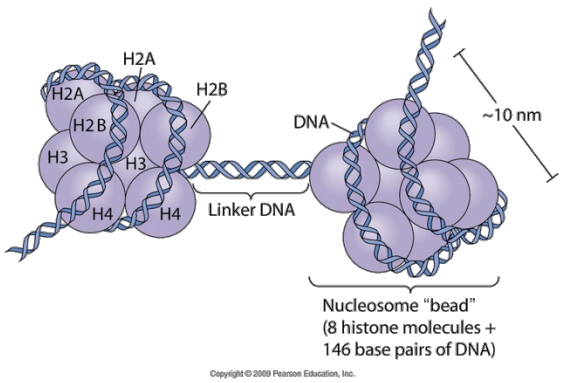


Image: https://mrleehamber119.wordpress.com/

- the total length of DNA of 46 chromosomes of an adult human is about 1.8m, this needs to be fit into a nucleus of 6µm
- therefore, the DNA is wound around the outside of proteins called **histones**
  - **histone proteins** – basic proteins which associate with DNA to form nucleosomes
- these histone proteins (and therefore, nucleosomes) condense DNA to **chromatin**
  - **chromatin** – a complex of nucleic acids (DNA and RNA) and other proteins whose primary function is to compress DNA into a compact unit which will fit inside the nucleus

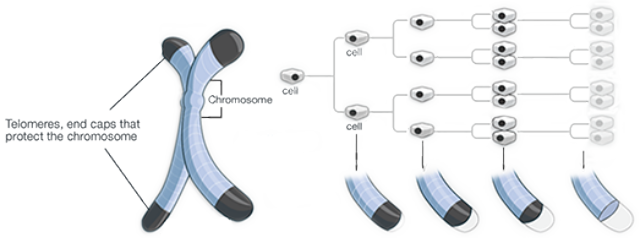
Nucleosomes



- 11 nm wide by 6 nm long
- made of 8 histone molecules

Telomeres

- cap the ends of chromosomes and are needed for successful cell division
- permit continued replication
- prevent the loss of genes



As cells divide over time...telomeres shorten, and eventually cell division stops.

Image: https://www.tasciences.com/what-is-a-telomere.html

- telomeres are made of DNA with short base sequences that are repeated multiple times
- the copying enzyme, telomerase, stops a little short of the end of DNA
- more bases are added, which don't have useful information, but allows telomerase to complete copying the meaningful DNA

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The cell cycle

Processes of growth, development, and reproduction.

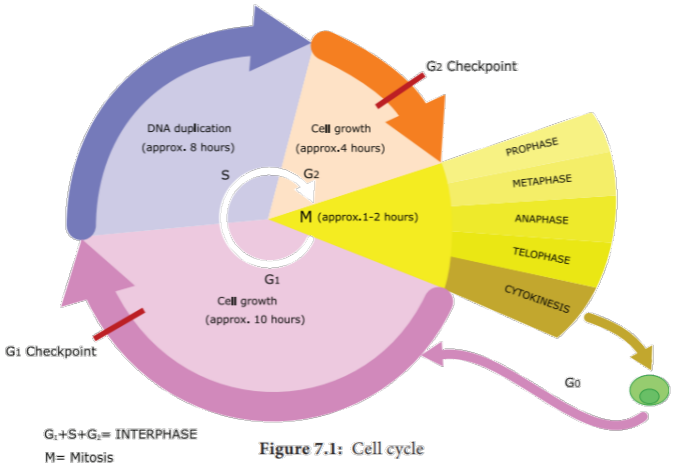


Figure 7.1: Cell cycle

Image: https://www.brainkart.com/article/Cell-Cycle_33013/

Interphase (G_1 + S + G_2)

- Longest phase
- Normal cell work/functions
- The cell grows to its normal size
- Time spent between cell divisions

1) G_1 phase

- cells make RNA, enzymes and other proteins needed for growth
- at the end of G_1 phase, the cell becomes committed to dividing or not

2) S phase

- synthesis of DNA
- the DNA in the nucleus replicates so that each chromosome consists of 2 identical chromatids: DNA replication

3) G_2 phase

- the cell continues to grow
- new DNA is checked, and any errors are repaired
- preparations are made to start cell division e.g., a sharp increase in production of the protein tubulin is observed which is needed to make microtubules for mitotic spindle

M phase (mitosis)

Nuclear division that produces 2 genetically identical daughter cells.

- Maintains genetic stability
- Ensures cells retain function
- Maintains chromosome number

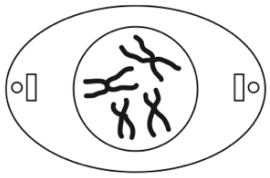
Functions of mitosis

- growth
- cell replacement
- repair of tissues
- asexual reproduction
- immune response (cloning B and T-lymphocytes)

The stages of mitosis

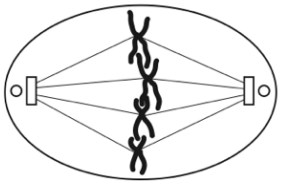


1) Prophase



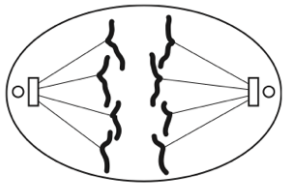
- centrosomes migrate to opposite poles of mitotic spindle
- chromatin starts to condense
- nuclear envelope and nucleolus begin to disappear
- centrosomes and migrate to opposite poles of the cell and form poles of mitotic spindle
- asters and spindle fibres form

2) Metaphase



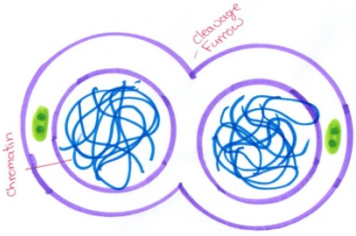
- centrosomes are at poles of the cell and organise the production of spindle microtubules
- chromosomes line up across equator of the spindle
- each chromosome splits at centromere
- chromosomes start to be pulled apart by microtubules

3) Anaphase



- chromatids move to opposite poles, centromeres are first pulled by microtubules
- spindle fibres contract and chromosomes are pulled to the opposite ends

4) Telophase



- nuclear envelope and nucleolus reforming
- nucleus divides
- chromosomes are at poles of cell

Image: https://www.tekportal.net/telophase/

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Cytokinesis

The division of cytoplasm.

Cytokinesis in plant cells

- cell plate forms across equator of cell; cellulose, cell wall laid down
- cytoplasm is hence divided into 2

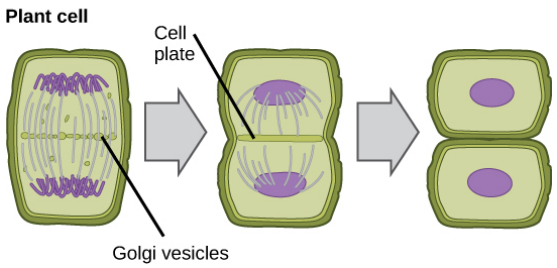


Image: https://courses.lumenlearning.com/

Cytokinesis in animal cells

- contractile ring forms, pushing the equator of cell inwards, forming a cleavage furrow
- this cleavage furrow deepens as active filaments in the ring contract
- eventually the cell splits into 2

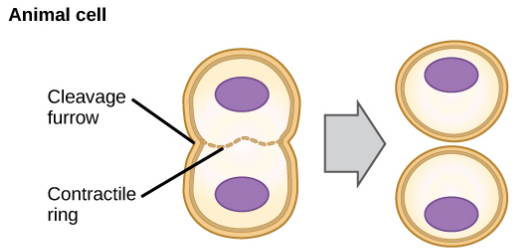


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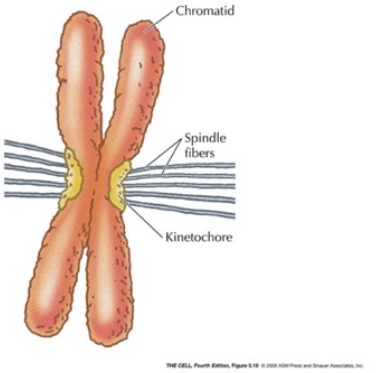
Differences in plant and animal cell mitosis

- plant cells don't have any visible centriole or aster
- in plant cells, daughter cells get separated by cell plate, there is no cleave furrow formation

Centromeres, centrosome, centrioles

1) Centromere

- needed for separation of chromatids during mitosis
- site of attachment of spindle microtubules
- each metaphase chromosome has 2 kinetochores at its centromere and microtubules
  - **kinetochore** – protein molecules which bind to DNA in centromere and microtubules
  - bundles of microtubules called spindle fibres extend from kinetochores to poles of spindle during mitosis



2) Centrosome

- an organelle found in animal cells that acts as the microtubule organising centre (MTOC) for construction of the spindle
- present at the poles of cell

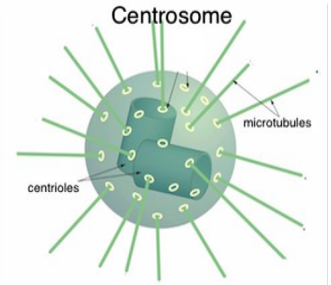


Image: https://www.qsstudy.com/biology/centrosome-definition-function

3) Centrioles

- act as MTOCs
- assemble/form spindle fibres during prophase
- contraction of spindle fibres during anaphase separates sister chromatids

Stem cells

Stem cells are cells that can divide an unlimited number of times by mitosis.

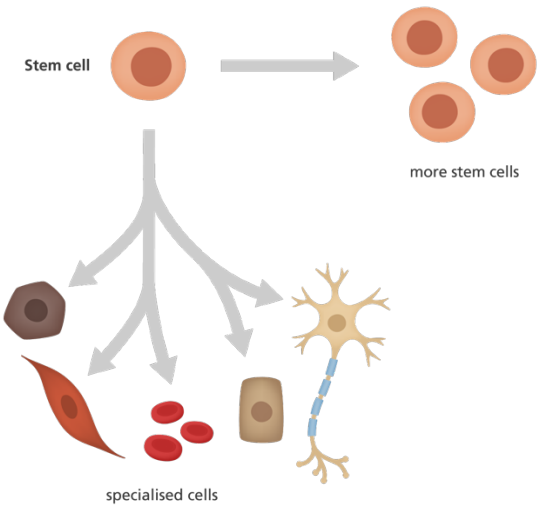


Image: https://www.yourgenome.org/facts/what-is-a-stem-cell

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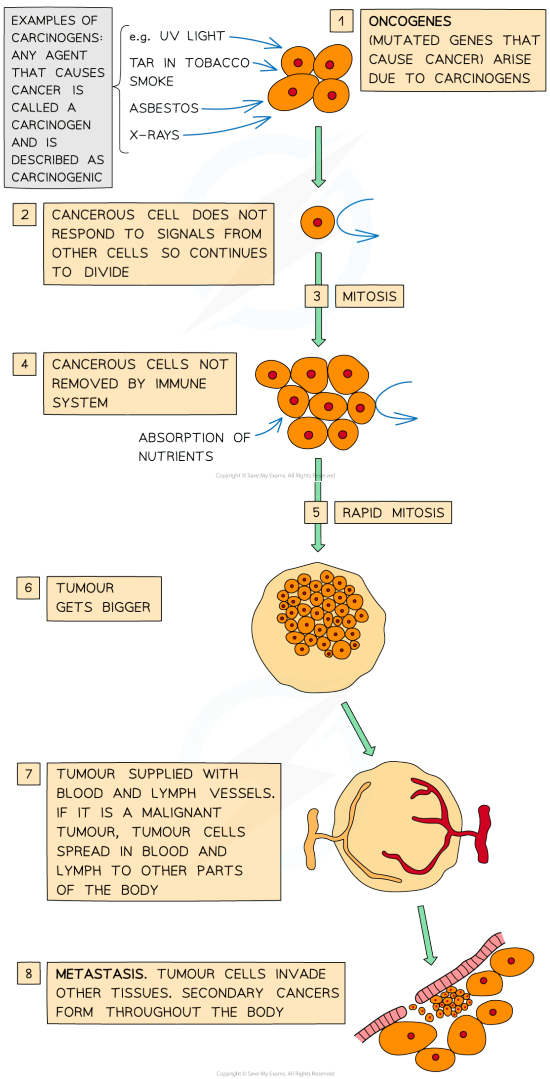
- extent of the power of a stem cell to produce different cell types is called its **potency**
- **stem cell therapy** – introduction of new adult stem cells into damaged tissue to treat a disease or injury

Cancer

- a result of uncontrolled mitosis; cancerous cells divide repeatedly and form a tumour
- **carcinogen** – agent that causes cancer e.g., radiations (UV, X-rays), tar, nuclear fallout

Cellular changes that occur in development of cancer

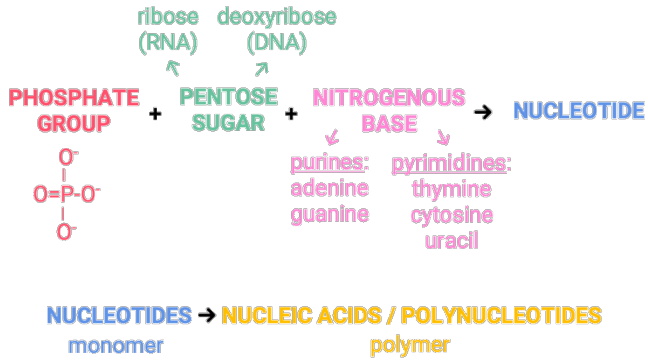
- mutation occurs in gene responsible for cell division leading to formation of an oncogene from a proto-oncogene
- this causes uncontrolled cell division
- coordination of cell cycle is lost (cell does not receive/respond to signals that tell it to stop dividing)
- loss of function and lack of specialisation occurs
- a tumour is formed, an irregular mass of cells showing an abnormal change in shape



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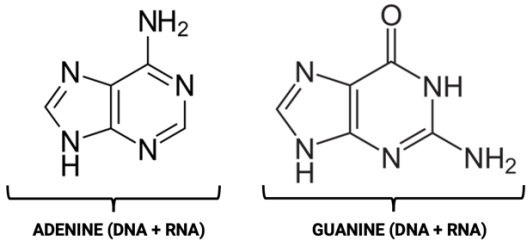
6 Nucleic acids and protein synthesis

6.1 Structure and replication of DNA



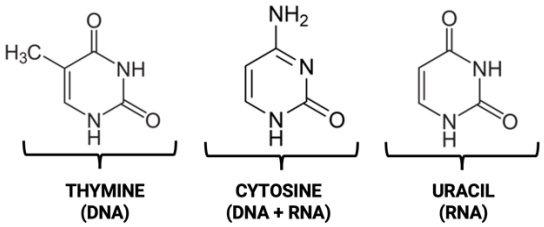
Purines

Larger, double-ringed molecules (adenine, guanine)

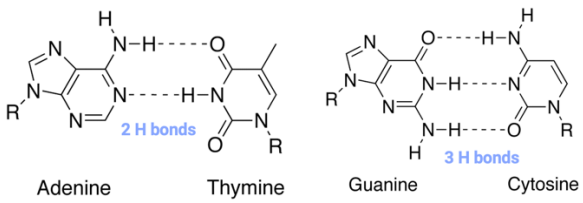


Pyrimidines

Smaller, single-ringed molecules (thymine, cytosine, uracil)



- to form the polynucleotides DNA and RNA, nucleotides are linked into a long chain
- nucleotides are linked together by covalent bonds called **phosphodiester bonds**
- this takes place inside the nucleus during interphase
- purines combine with pyrimidines



- in RNA, adenine pairs with uracil

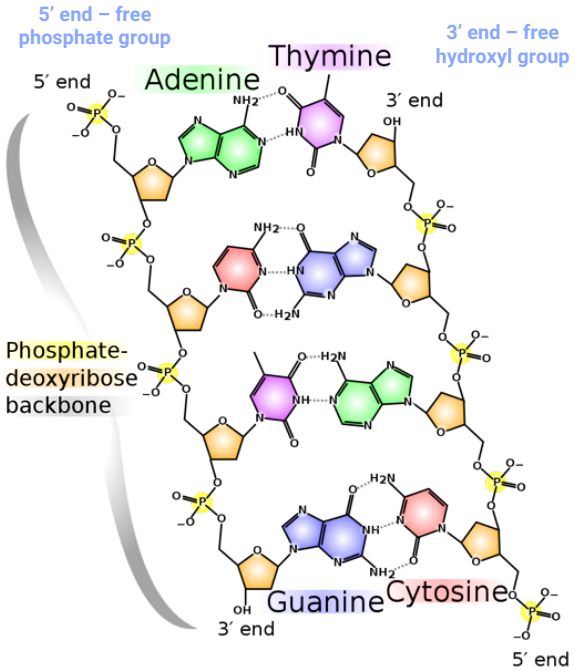


Image: By Madprime (talk · contribs), https://commons.wikimedia.org/w/index.php?curid=1848174

- sides of the ladder of DNA are made up of alternating molecules of phosphate and deoxyribose
- nitrogenous bases that make up rungs of ladder have hydrogen bonds between them
- they link bases and hold 2 strands together
- DNA molecules are made of 2 polynucleotide strands lying **anti-parallel** to each other held by hydrogen bonds between bases

Semi-conservative replication of DNA

DNA molecules replicate by semi-conservative replication – half of the original molecule is kept/conserved in each of the new molecules.

1) double helix of DNA is unwound by enzyme **helicase**
   - it does this by splitting hydrogen bonds between bases
   - the unwinding of DNA strands creates a 'replication fork' (a y-shaped structure)

2) enzyme **primase** synthesises a short piece of RNA called primer which marks the starting point for synthesis of new strand

3) **DNA polymerase** uses the primer and synthesises new strand
   - DNA strands are anti-parallel to each other, and DNA polymerase can only add bases in one direction which is 5' to 3'

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- one of the new strands, **the leading strand,** is made continuously
- DNA polymerase progresses down the strand adding bases in a 5′ to 3′ direction
- when using the lagging strand as a template, DNA polymerase adds nucleotides in short stretches called **okazaki fragments** to overcome directionality problem

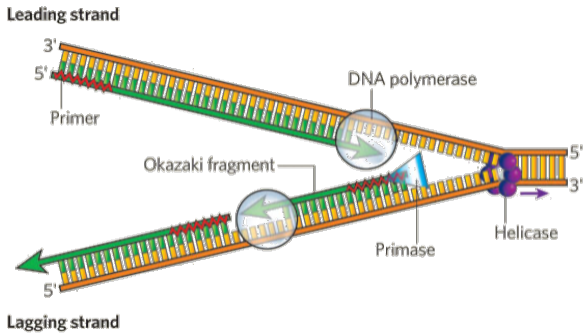


Image: https://www.nature.com/

4) DNA ligase seals up fragments of DNA in both to form a continuous double stranded helix

6.2 Protein synthesis

A polypeptide is coded for by a gene and that a gene is a sequence of nucleotides that forms part of a DNA molecule.

- DNA controls protein synthesis by determining the order of amino acids when proteins are synthesised in cells
- sequence of nucleotide bases in a DNA molecule is code for sequence of amino acids in a polypeptide
- each sequence of 3 bases (a codon) codes for 1 amino acid

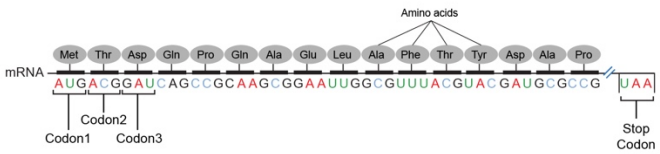


Image: https://www.genome.gov/

- **Gene** – part of a DNA molecule where the nucleotide sequence codes for just one polypeptide
- **Gene mutation** – a change in the sequence of nucleotides that may result in an altered polypeptide
  - types of gene mutations: substitution, deletion, insertion, inversion, frameshift
  - **alleles** – variants of genes (caused by mutations)

Sickle cell anaemia

- caused by a change in the base sequence of amino acids in the β-polypeptide chain
- adenine replaces thymine in CTT triplet forming CAT
- this type of mutation is called substitution
- during synthesis of sickle cell haemoglobin, the amino acid valine (GTG), which is non-polar, is incorporated instead of glutamic acid (GAG)
- having this non-polar R group on the outside of the molecule makes the cell less soluble
- individuals with 2 copies of Hb^S allele inherit the disease *(recessive)*

Protein synthesis

a) Transcription

Process by which enzymes use the sense strand of DNA as a template to produce a messenger RNA (mRNA) molecule.

1) **RNA polymerase binds to a region of gene called promoter**
   - this signals DNA to unwind so bases can be read from one strand
   - the strand that's read is the sense-strand

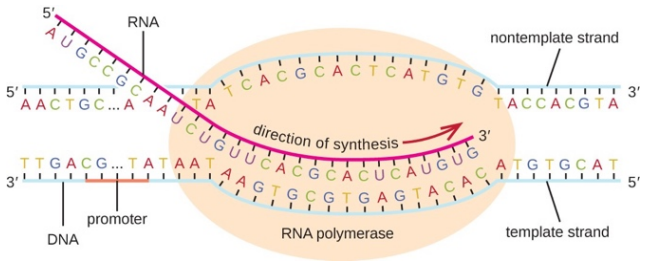


Image: https://courses.lumenlearning.com/

2) **RNA polymerase reads sense strand in a 3' to 5' direction and generates mRNA from 5' to 3'**
3) **when RNA polymerase has reached the terminator sequence at the end of the gene, transcription stops**
   - enzyme detaches from gene and DNA returns to original structure
4) **last triplet transcribed to mRNA is a DNA triplet coding for STOP e.g., ATT, ATC, ACT** *(in DNA the stop codons are UAA, UGA, UAG)*

STOP codons
- codons that terminate translation
- does not specify any amino acid
- has no complementary tRNA/anti-codon
- causes the release of a completed polypeptide chain

b) Translation

Process by which the genetic code in mRNA is read to make a protein.

1) **mRNA leaves the nucleus and binds to the smaller ribosomal unit**

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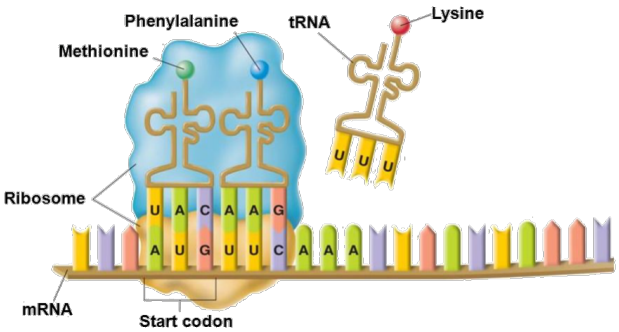


Image: https://slideplayer.com/slide/16525143/

2) every 3 bases (a codon) on mRNA codes for a specific anti-codon which is carried by a transfer RNA (tRNA) molecule

- each different tRNA is covalently linked to a particular amino acid

mRNA	**AUG**	**UGC**	**AAG**
tRNA	**UAC**	**ACG**	**UUC**
	Met	Cys	Lys

- since there are 4 bases (A, T, G, C) and each codon has 3 bases –

$$4^3 = 64$$

- there are 64 possible codons, more than enough to code for 20 amino acids
- some codons are 'special', e.g., AUG is a START codon and initiates translation by coding for methionine

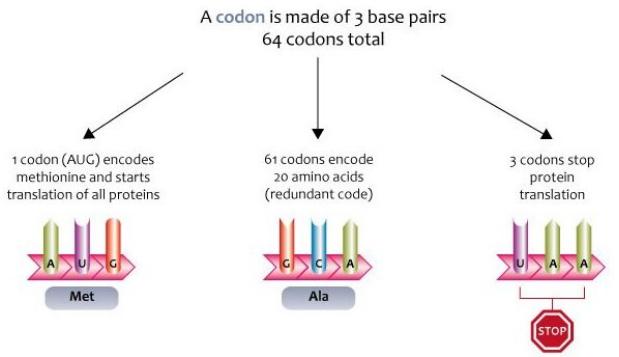


Image: https://www.differencebetween.com/difference-between-start-codon-and-stop-codon/

3) an initiator tRNA adheres to a START codon

4) the tRNA that corresponds to the next codon after the START codon enters the ribosome carrying an amino acid with it which becomes covalently bound to methionine from the initiator tRNA

5) the first tRNA detaches and leaves the ribosome which has shifted over making room for the next tRNA molecule

- new amino acid from new tRNA links the first two
- this process continues all the way down the mRNA strand
- this polypeptide chain continues to grow till a STOP codon is reached

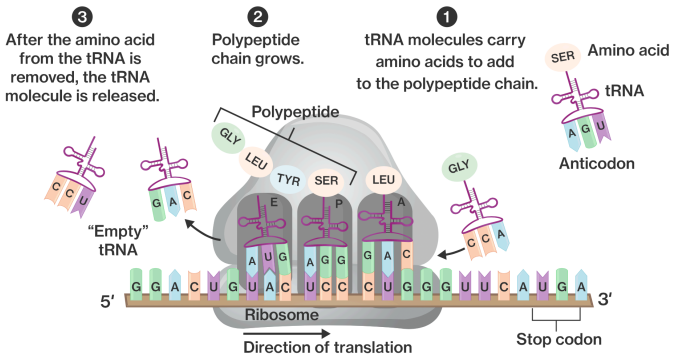


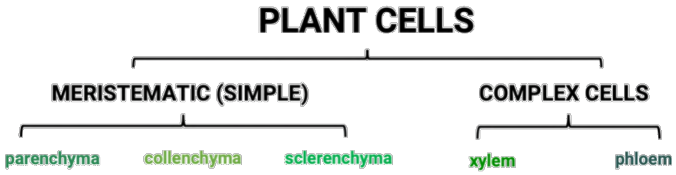
Image: https://www.coursehero.com/sg/cell-biology/translation/

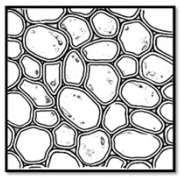
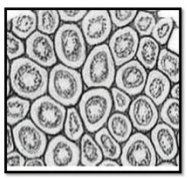
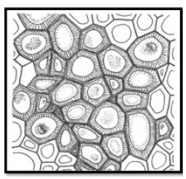
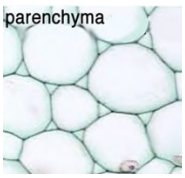
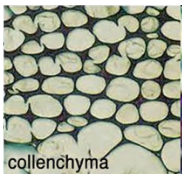
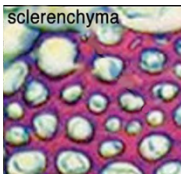
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7 Transport in plants

7.1 Structure of transport tissues

Types of plant cells



PARENCHYMA	COLLENCHYMA	SCLERENCHYMA
		
Image: https://www.vedantu.com/		
		
Image: http://www.bio.miami.edu/		
found in soft parts of the plant	found in the petiole, leaves, and young stems	found in mature parts of the plant
unspecialised cells	specialised cells	specialised cells
cell wall made of cellulose	cell wall made of cellulose and pectin	cell wall made of lignin
thin cell wall	unequally thin cell wall	thick and rigid cell wall
lots of intracellular spaces are present between cells	little intracellular space	no intracellular space
consists of living cells at maturity	consists of living cells at maturity	consists of dead cells at maturity
functions include photosynthesis, food storage, gas exchange	provides mechanical support to the plant	provides mechanical support, protection, and transports substances

Structure of roots (dicot)

Transverse section

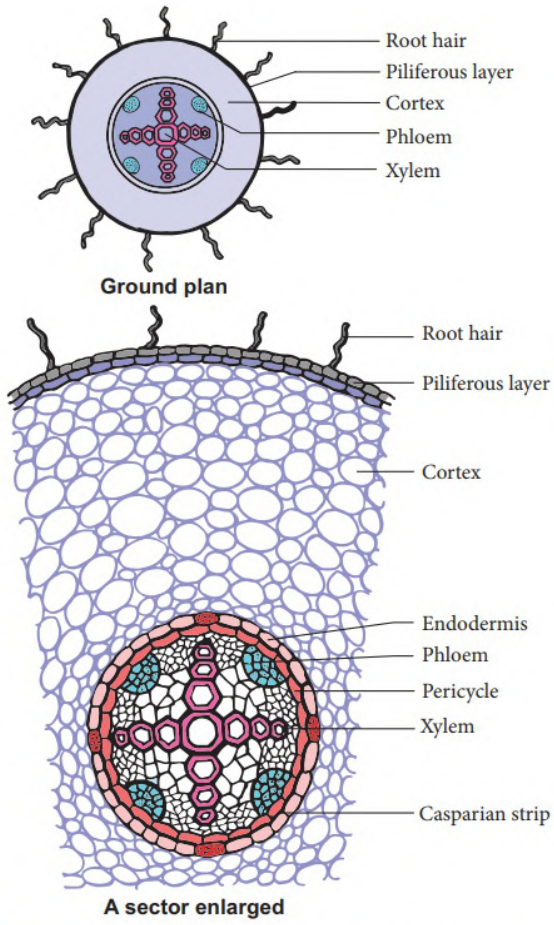


Figure 12.2 Transverse section of Dicot root

Image: https://www.brainkart.com/

- **piliferous layer (also called epiblema, rhizodermis)** – the outermost layer; unicellular root hairs present, cuticle and stomata absent
- **cortex** – it is a multi-layered large zone made of parenchymatous cells with intracellular spaces and stores food and water
- **endodermis** – the innermost layer of the cortex; the cells closely packed and have Casparian strips within their walls *(water-impermeable deposits of suberin)* which regulate water and mineral uptake by the roots
- **pericycle** – produces lateral roots when cells here divide
- **stele** – all tissues inner to endodermis constitute stele; here it includes pericycle and vascular bundle
- **vascular bundle** – xylem and phloem
- **conjunctive tissue** – the tissue present between xylem and phloem; in dicots, it's made up of parenchyma
- **pith** – absent in mature plants, present in young ones

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Longitudinal section (of roots)

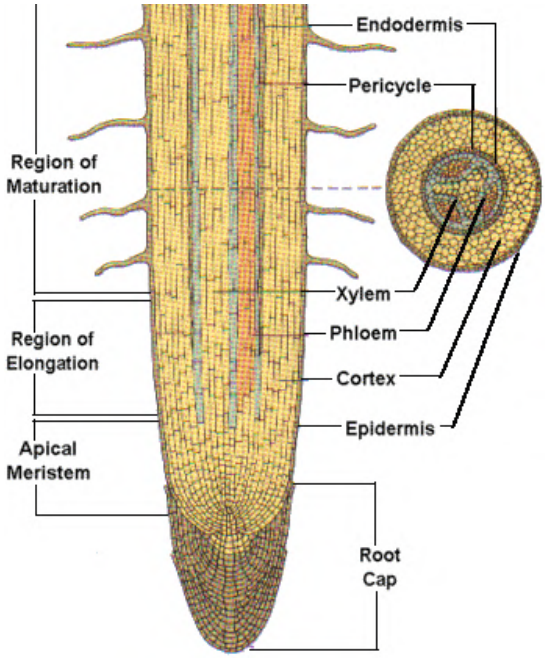


Image: https://www.anatomynote.com/

Structure of stems (dicot)

Transverse section

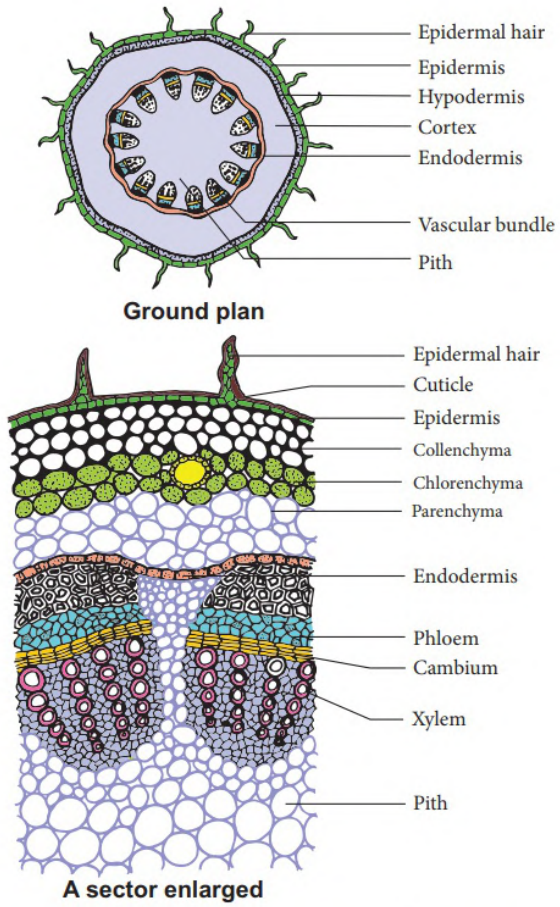


Figure 12.4 Transverse section of Dicot stem

Image: https://www.brainkart.com/

Longitudinal section

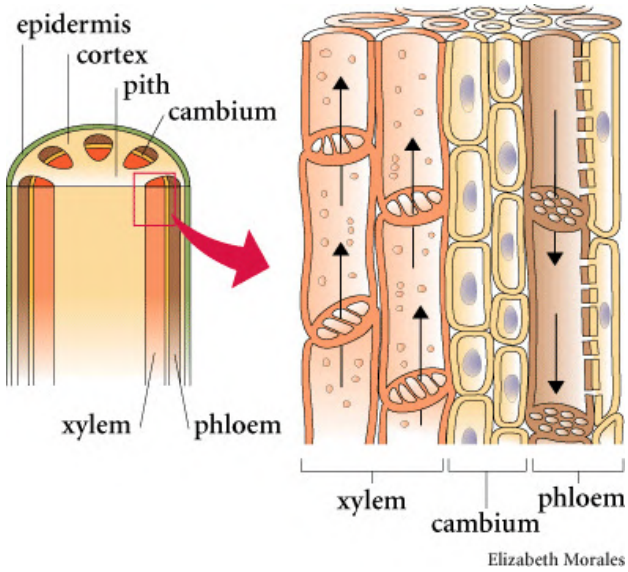


Image: http://mybiologypal.blogspot.com/

- **epidermis** – the outermost layer; made up of a single layer of parenchyma cells and its outer wall is covered with a cuticle
  - cuticle prevents infection of the plant by bacteria or fungi
  - also aids in reducing water loss
- **cortex** – divided into three regions:
  - hypodermis provides mechanical support
  - middle cortex is involved in photosynthesis
  - inner cortex helps in gaseous exchange and stores food materials
- **endodermis** – the innermost layer of the cortex, consists of a single layer of cells that contain starch grains
- **pith** – large, central, parenchymatous zone with intracellular spaces; helps in storage of food materials

Structure of leaves (dicot)

Transverse section

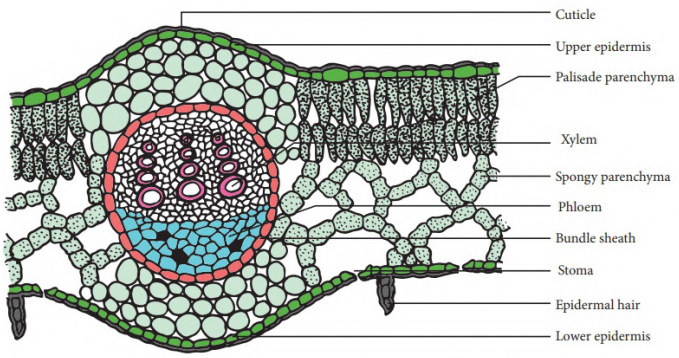


Figure 12.6 Transverse section of Dicot leaf

Image: https://www.brainkart.com/

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- **upper epidermis** – the outermost layer made up of a single layer of parenchyma cells without intracellular spaces; outer walls have cuticles, stomata are less in number
- **lower epidermis** – single layer of parenchymatous cells with a thin cuticle
  - contains numerous stomata
  - chloroplasts are only present in guard cells
  - helps in exchange of gases
  - loss of water vapour is facilitated through this chamber
- **mesophyll** – tissue present between the upper and lower epidermis, differentiated into palisade parenchyma and spongy parenchyma
  - **palisade parenchyma:** tightly packed, elongated cells with lots of chloroplasts *(for photosynthesis)* just below the upper epidermis.
  - **spongy parenchyma:** spherical/oval, irregularly arranged cells with lots of intracellular spaces; helps in gaseous exchange
- **vascular bundles**
  - vascular bundle of midrib is larger
  - each vascular bundle is surrounded by a sheath of parenchymatous cells called bundle sheath
  - each vascular bundle consists of xylem lying towards the upper epidermis and phloem towards the lower epidermis

For more information about the structure of plant tissues and how to draw them, see Biology Paper 3 Notes.

Structure of vascular system

Xylem

- transports water and mineral ions via mass flow (passive)
- unidirectional movement (from roots → rest of the plant)
- composed of tracheids, vessel elements, xylem fibres, and xylem parenchyma *(all dead except xylem parenchyma)*

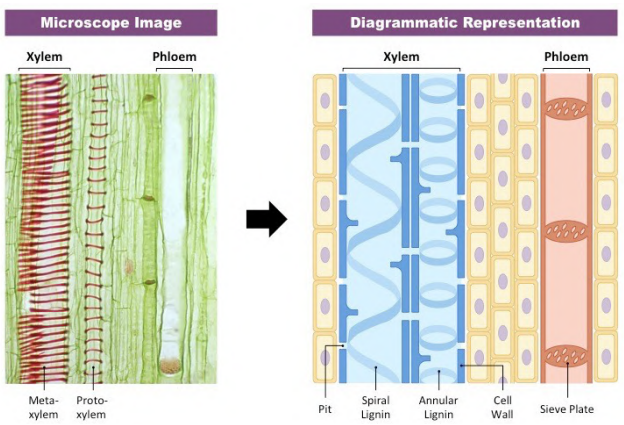


Image: https://ib.bioninja.com.au/

1) long hollow tubes with no end walls for uninterrupted transport of water and mineral ions
2) no cell contents (no protoplasm) to provide maximum space and minimum resistance
3) their walls are lignified to withstand negative pressure and provide mechanical support
4) cellulose lining is present for adhesion if water molecules which helps with their movement upwards
5) they have pitted walls (in non-lignified sections) for the lateral movement of water

Phloem

- transports sucrose and amino acids via mass flow *(active process)* from the source to the sink
- bidirectional movement *(translocation)*
- mainly composed of sieve tube elements + companion cells

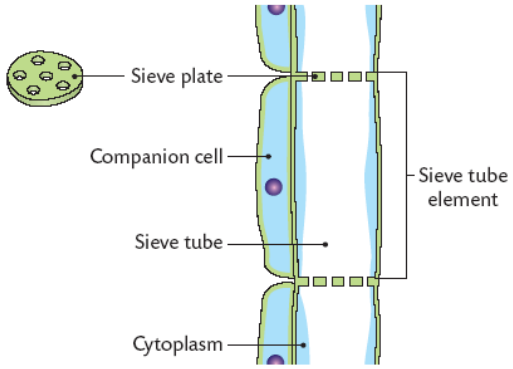


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Phloem sieve tube elements

1) contains ER, mitochondria, and cytoplasmic stands (cytoplasm reduces friction to facilitate the movement of the assimilates)
2) end-walls modified to sieve plates/perforated plates which allows for the continuous movement of the organic compounds
3) phloem tubes are present in a bundle
4) area where sucrose is loaded is source and where it's unloaded is sink

Companion cells

1) contains organelles such as nucleus, RER, mitochondria, and ribosomes which provides metabolic support to the sieve tube elements and helps with the loading and unloading of the assimilates
2) transport proteins are present in the plasma membrane which move assimilates in and out of the sieve tube elements
3) large numbers of mitochondria present which provide ATP for the active transport of assimilates into or out of the companion cells

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4) plasmodesmata are present which link the cell to the sieve tube elements

Comparing the structures of xylem and phloem tissues

	XYLEM	PHLOEM
made of	mainly dead cells (tracheids, vessel elements, xylem fibres) except for xylem parenchyma	living cells (only phloem fibres are dead)
cell wall material	lignin and cellulose	cellulose
presence of end walls	no	yes (sieve plates with sieve pores)
direction of flow	unidirectional and upwards (roots → leaves)	bidirectional (source → sink)
substance transported	water and mineral ions	sucrose, amino acids, and other organic compounds
mechanical support	provides mechanical support	does not provide mechanical support

7.2 Transport mechanisms

Plants must take in a constant supply of water and dissolved minerals to compensate for the continuous loss of water via transpiration in the leaves.

Transpiration

Transpiration is the loss of water vapour from the aerial parts of the plant. Around 99% of all water absorbed is lost via this process.

1) water evaporates from cell walls of mesophyll cells into air spaces
2) water vapour diffuses (out to atmosphere)
3) through open stomata (to atmosphere)
4) down a water potential gradient

When the following factors increase, transpiration (↑/↓)

1) humidity (↓)
2) wind speed (↑)
3) light intensity (↑)
4) temperature (↑)
5) water supply (↓)

Transpiration is considered as an inevitable consequence of gas exchange as –

1) stomata are open for gas exchange
2) this gas exchange is required to uptake CO_2 for photosynthesis
3) while stomata are open, water vapour diffuses out

Advantages of transpiration

1) helps in plants pulling up water from soil through roots (transpiration pull)
2) helps in sending out excessively absorbed water by plants
3) cools the plant (via evaporative cooling)
4) helps in the absorption and transport of mineral salts
5) helps in the absorption and distribution of water in plants

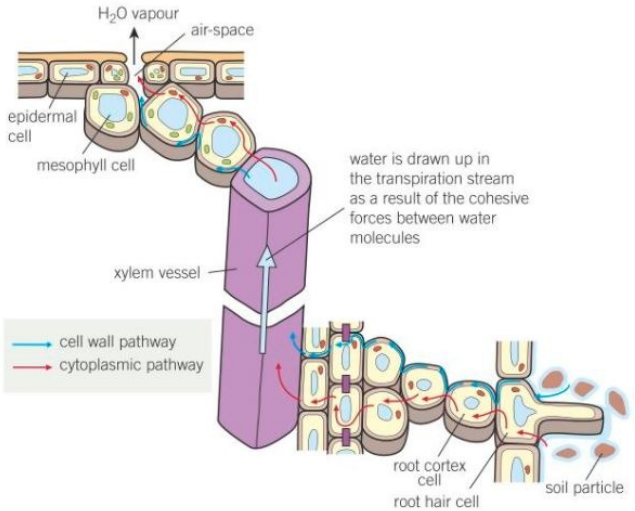


Image: https://alevelbiologystudent.weebly.com/

Transpiration pull

Transpiration pull is the force by which water ascends a plant.

- water molecules cling together by hydrogen bonds between molecules known as cohesive forces
- water molecules experience attraction towards the cellulose in the cell walls of the xylem (adhesion)

Cohesion-adhesion theory

- water molecules tend to cling to one another via hydrogen bonds (cohesion)
- when water evaporates from the surfaces of mesophyll cells, a tension is created in the xylem tissue which is transmitted all the way down the plant due to the cohesiveness of the water molecules
- the cohesive forces thus produce a continuous column of water (transpiration stream)
- the adhesive force stops the water column from pulling away from the walls of the xylem vessels, so water is pulled up the xylem tissue from the roots to replace what was lost in the leaves
- this is known as the cohesion-adhesion theory

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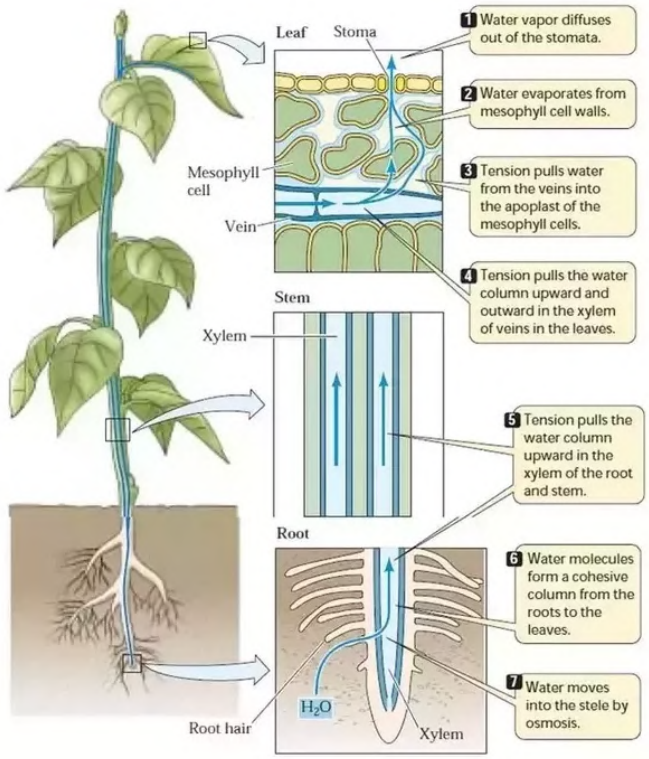


Image: https://www.quora.com/What-is-cohesion-tension-theory

Movement of water between plant cells

From soil to root hair

1) uptake of water – water moves into root hairs via osmosis down a water potential gradient (passive)
2) root hairs provide max surface area for the max absorption of water
3) the uptake of minerals can be passive or active and occurs by diffusion or active transport respectively

From root hair to xylem

1) water taken up by root hairs crosses the root cortex
   - **water moving thorough cells walls – apoplastic pathway**
   - **water moving through plasmodesmata – symplastic pathway**
2) water moves from one cell to another till it reaches xylem; movement is due to concentration gradient due to concentrated sap vacuole of cells
3) apoplastic pathway is stopped at endodermis due to cells in it having a band of suberin forming the Casparian strip (an impenetrable barrier to water)
   - suberin deposits increase with age of endodermal cells except for certain **passage cells**
   - water can pass freely through these passage cells

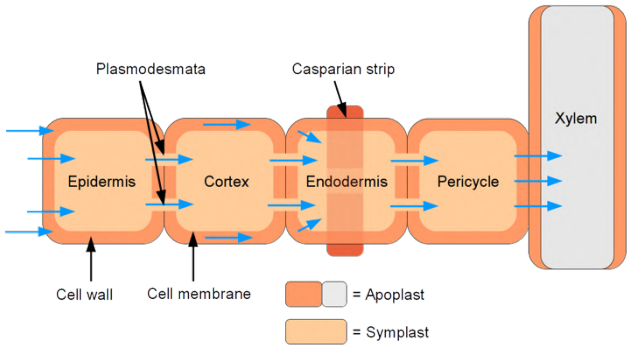
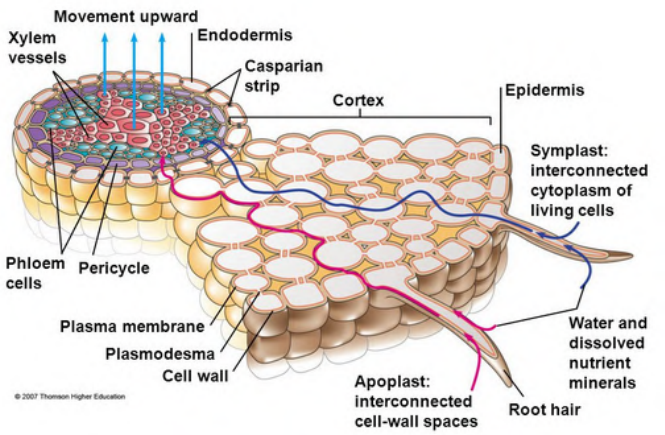


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   - this arrangement is *thought* to:
     - gives plants control over what mineral ions pass into xylem vessels (everything must cross cell membranes)
     - may help with generation of root pressure
4) once across endodermis, water moves into xylem through pits in their walls



From root → stem → leaf *via* xylem

1) removal of water from xylem vessels in leaf reduces hydrostatic pressure in xylem
2) hydrostatic pressure at top of xylem becomes less than bottom
3) pressure difference causes water to move up the xylem

Apoplastic pathway

- most water travels via the apoplastic pathway (when transpiration rates are high)
- these are the series of spaces running through the cellulose cell walls, dead cells, and the hollow tubes of the xylem
- the water moves by diffusion as it isn't crossing a partially permeable membrane
- the water can move from cell wall to cell wall directly or through the intracellular spaces
- movement of water via this pathway occurs more quickly than in the symplastic pathway

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- this movement is however stopped at the endodermis due to the presence of the Casparian strip

Symplastic pathway

- movement through the cytoplasm, plasmodesmata, or vacuole of cells (crossing membranes)
- the water moves by osmosis (across partially permeable membranes)

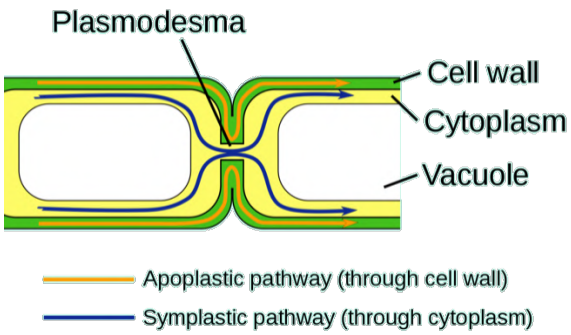


Image: Jackacon, vectorised by Smartse - Apoplast and symplast pathways.gif https://commons.wikimedia.org/w/index.php?curid=12063412

Movement in the phloem

Mass flow

Movement of fluids under a pressure gradient. Concentration gradient *does not* matter here.

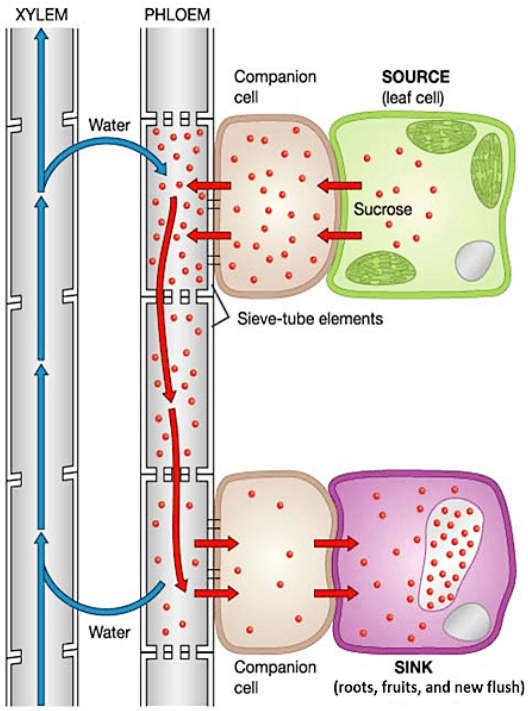


Image: https://www.researchgate.net/

Sucrose loading into phloem

This process is not fully understood yet. This is what is *thought* to happen.

1) H^+ ions are pumped out *(active process, ATP required)* of the cytoplasm of modified companion cells (called transfer cells)
2) this creates an excess of H^+ ions in the apoplastic pathway outside the cell
3) H^+ ions move back into the cell down their concentration gradient back into the cytoplasm of the companion cell via a cotransporter protein
4) this cotransporter protein acts as a carrier for both H^+ and sucrose (so sucrose moves into the companion cell too but *against* its concentration gradient)
5) sucrose then moves into the sieve tubes via the plasmodesmata from the companion cell
   - companion cells have infoldings in their cell surface membrane to increase the available surface area for the active transport of solutes
   - many mitochondria also present provide the energy for the proton pump

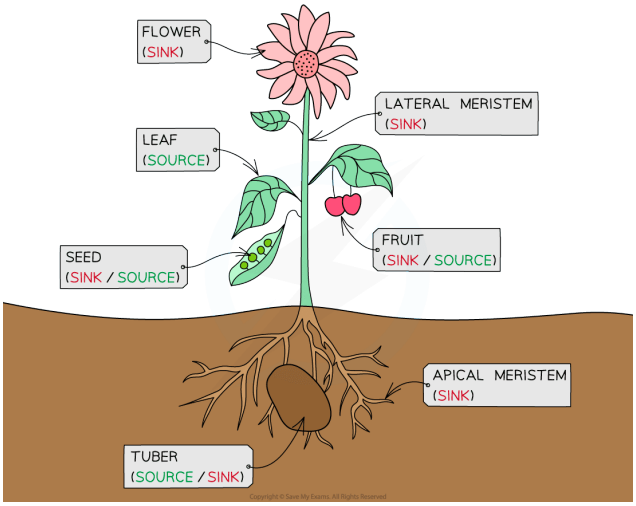
How assimilates that arrive in the phloem sieve tubes from mesophyll cells (source) can be translocated to other parts of the plant (sink)

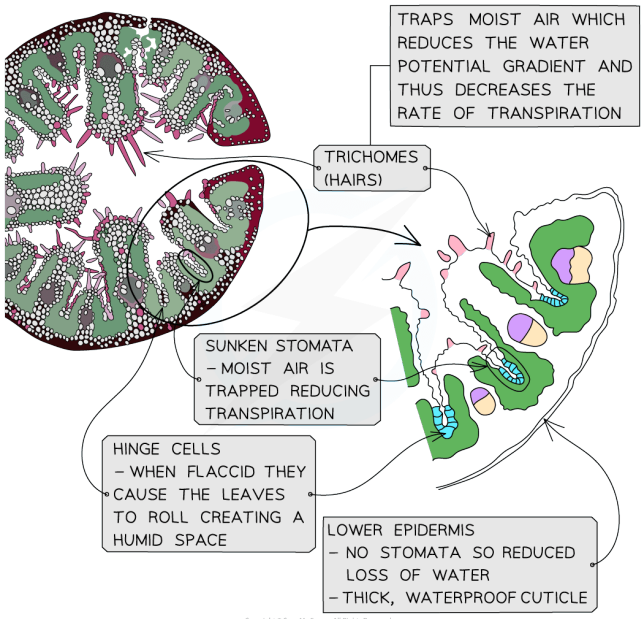
1) when sucrose is loaded into a sieve tube element, the water potential decreases
2) this causes water from surrounding tissue to enter by osmosis
3) this increased volume increases the hydrostatic pressure at the source compared to the sink
4) assimilates move down a hydrostatic pressure gradient to the sink

Sources and sinks

- the source of the assimilates could be:
  1) green leaves and green stem (photosynthesis produces glucose which is transported as sucrose, as sucrose has less of an osmotic effect than glucose)
  2) storage organs eg. tubers and tap roots (unloading their stored substances at the beginning of a growth period)
  3) food stores in seeds (which are germinating)
- the sinks (where the assimilates are required) could be:
  1) meristems (apical or lateral) that are actively dividing
  2) roots that are growing and / or actively absorbing mineral ions
  3) any part of the plant where the assimilates are being stored (eg. developing seeds, fruits or storage organs)

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Xerophytes

- xerophytes *(from the greek xero for 'dry')* are plants that are adapted to dry and arid conditions
- xerophytes have physiological and structural (xeromorphic) adaptations to maximise water conservation

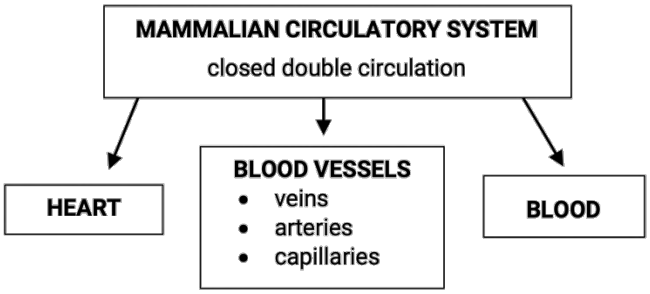
Xerophytic adaptation of leaves	Effect of adaptation	Example
Fleshy succulent leaves	Water stores for times of low availability	Fleshy leaves: Bryophyllum
'Hinge cells' shrink when flaccid	Causes leaves to roll exposing the thick, waterproof cuticle to the air and creates a humid space in the middle of the rolled leaf	Ammophila arenaria (Marram grass)
Leaves reduced to scales, spines or needles Leaves curled or rolled or folded when flaccid	Reduced transpiration due to reduced surface area available	Modified leaves: Opuntia (cactus) Rolled leaf:Ammophila arenaria (Marram grass)
Stomata closed during light Stomata open in the dark	CAM metabolism to minimise photorespiration; CO_2 fixed at night, day time water loss is minimised	CAM plants: Pineapple, American aloe, Yucca
Sunken stomata /presence of stomatal crypts Leaf surface covered in fine hairs	Water loss is minimised by trapping moist air close to the area of water loss reducing the diffusion gradient	Pinus sp, Phlomis italica, Nerium sp
Reduced numbers of stomata	Less water loss due to fewer pores	Opuntia, Nerium sp
Stomata only found in the upper epidermis	Open into the humid space created by the hairs and rolled shape	Ammophila arenaria (Marram grass)
Thick waxy cuticle on leaves	Water loss reduced via the cuticle	Pinus sp, Opuntia

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8 Transport in mammals

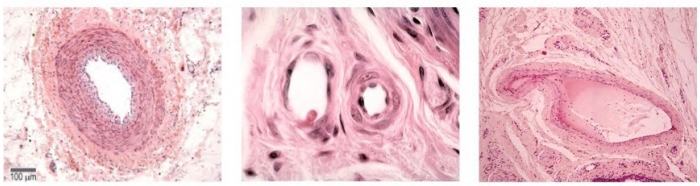
8.1 The circulatory system



It's called **closed** circulation as the blood remains within blood vessels.

DOUBLE CIRCULATION	
SYSTEMIC CIRCULATION	**PULMONARY CIRCULATION**
left ventricle → **AORTA** → body (except lungs) → **VENACAVA**	right ventricle → **PULMONARY ARTERIES** → lungs → **PULMONARY VEIN** → left atrium

Blood vessels



* The capillary is a significantly smaller structure and thus is shown at a substantially higher magnification than the artery and vein

Image: https://ib.bioninja.com.au/

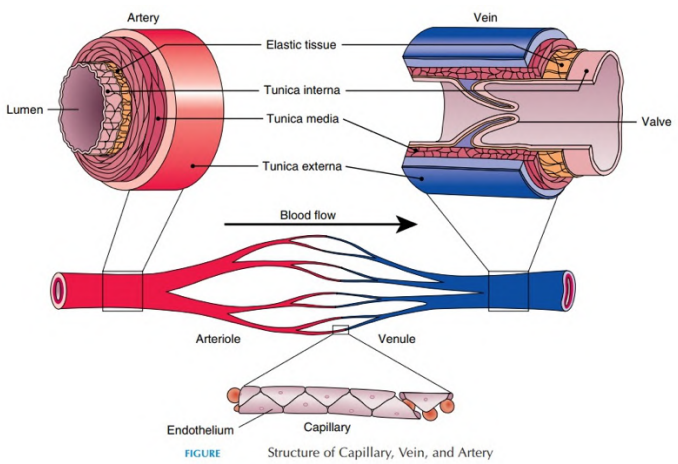


FIGURE Structure of Capillary, Vein, and Artery

Image: https://www.brainkart.com/

a) arteries

- transports oxygenated blood at high pressures to tissues
- pulmonary artery and aorta have semilunar valves in the beginning
- **tunica intima/interna** – very smooth, single layer of flat cells
- **tunica media** – smooth muscle, collagen fibres, elastic fibres
- **tunica externa** – collagen fibres, elastic fibres

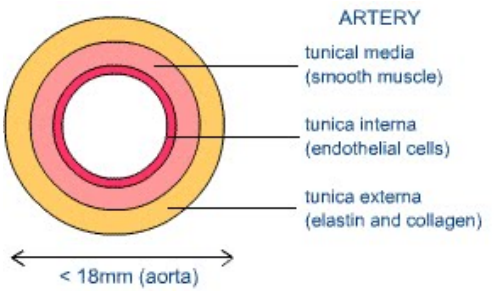


Image: http://www.hcc.ac.uk

- tunica media is the thickest in arteries
- depending on the pressure, thickness of arteries' walls differs
- tunica media contains large amounts of elastic fibres to allow the artery wall to stretch as blood surges through at high pressure
- artery wall can recoil inwards if the pressure drops
- as blood at high pressure enters, it can widen, reducing pressure slightly and vice versa
- arteries branch out into arterioles
- arteriole walls have more smooth muscle which can contract, narrowing the diameter and reducing blood flow

b) veins

- **tunica intima** – flat cells, smooth
- **tunica media** – smooth muscle, collagen, and elastic fibres
- **tunica externa** – elastic and collagen fibres

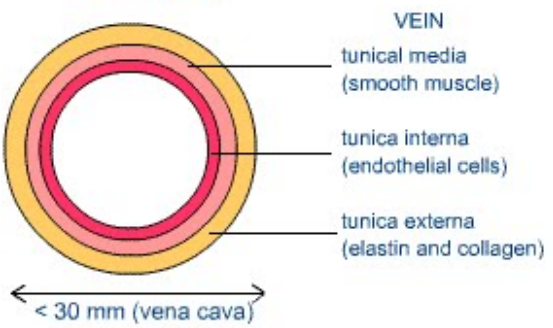


Image: http://www.hcc.ac.uk

- tunica externa is the thickest in veins
- thin tunica media
- tunica intima is smooth and not crinkly

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- blood is transported at low pressures, no need for thick walls
- contain semi-lunar valves (formed from their endothelium)
- large lumen
- irregular shape

c) capillaries

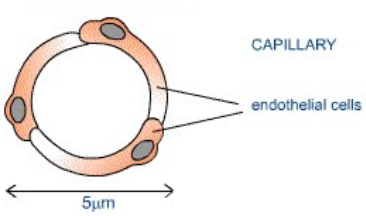


Image: http://www.hcc.ac.uk

- takes blood really close to cells allowing exchange of materials
- network of capillaries is called the capillary bed
- wall made of endothelial cells and is one cell thick
- gaps are present between individual cells that form the endothelium
- gaps allow some components of blood to seep through into spaces between cells (tissue fluid)

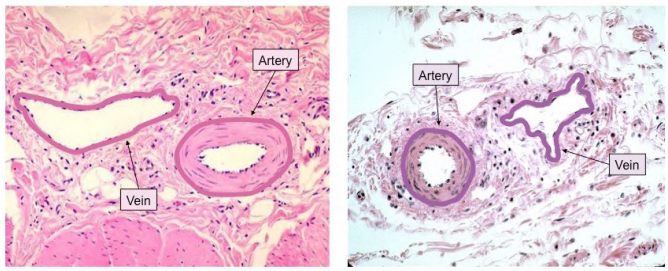


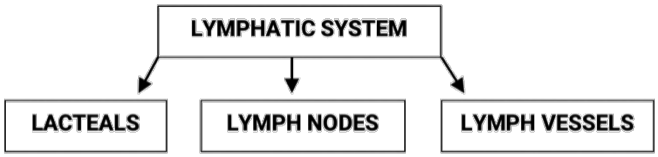
Image: https://ib.bioninja.com.au/

Blood plasma & tissue fluid

- as blood flows through capillaries within tissues, some plasma leaks out due to the pressure and seeps out into places between the cells of the tissues
- this plasma that leaks out is called tissue fluid
- if blood pressure is too high, too much fluid may be forced out of capillaries and the fluid may accumulate, this results in oedema
- it's through tissue fluid that the exchange between cells and blood occurs

Lymphatic system

- drainage system
- digestive (assimilation of fatty acids)
- immunity – produces lymphocytes



- lymphatics are tiny, blind-ended vessels
- they contain valves which allow to tissue fluid to flow in but not out
- walls are wide enough to allow larger protein molecules to pass through
- fluid inside lymphatics is called lymph
- lymph is transported to subclavian vein
- lymph vessels have smooth muscle in their walls which contract to push lymph along

Blood

a) red blood cells (erythrocytes)

- contain haemoglobin which gives red colour and transports oxygen
- produced in the bone marrow
- have a biconcave, disc shape – dent increases surface area in relation to volume
- spongy and flexible – have specialised cytoskeleton made of protein filaments that allow them to be squashed
- have no nucleus, endoplasmic reticulum, mitochondria – more space for haemoglobin, maximising amount of oxygen which can be carried
- broken down in spleen

b) white blood cells (leucocytes)

Refer to Chapter 11, Immunity.

c) platelets (thrombocytes)



8.2 The heart

- consists of 2 atria/auricles and 2 ventricles
- right and left side separated by septum
- made of cardiac muscle
- papillary muscles contract to pull on valve tendons to prevent inversion of valves during systole
- atria and ventricles have valves between them called atrioventricular valves:

RIGHT SIDE – TRICUSPID
LEFT SIDE – BICUSPID / MITRAL

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- 2 types of valves:

ATRIOVENTRICULAR – TENDONS
SEMI-LUNAR – POCKETS

The cardiac cycle

SYSTOLE – CONTRACTION, DIASTOLE – RELAXATION

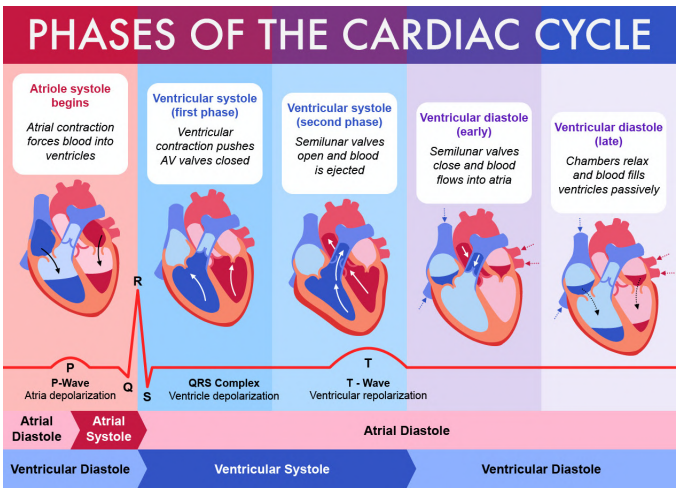


Image: https://www.artstation.com/

Atrial systole

- heart is filled with blood and the muscle in atrial wall contracts
- pressure is higher in atria than ventricles here so blood forces the atrioventricular valves open
- blood flows from atria to ventricles
- pressure developed isn't very high due to atrial walls being not very thick
- semi-lunar valves in pulmonary veins and venacavae prevent backflow from the atria

Ventricular systole

- occurs about 0.1s after atria contract
- ventricles contract increasing pressure and pushing blood out of the heart
- blood in ventricles is at higher pressure so atrioventricular valves are pushed shut, preventing blood from going back to atria
- blood rushes upwards into aorta and pulmonary artery as pressure forces aortic semi-lunar valves open

Ventricular diastole

- muscle relaxes, therefore pressure in the ventricles drops
- presence of semi-lunar valves prevents backflow of blood from aorta and pulmonary artery
- during diastole, whole of the heart muscle relaxes
- blood from the veins flow into atria
- some blood leaks down into ventricles
- the atrial muscle then contracts, forcing blood into ventricles
- atrioventricular valves close
- forced produced in the right ventricle must be relatively small as –
  1) blood goes only to the lungs which are at a shorter distance + less resistance to overcome
  2) if a too-high pressure was developed, tissue fluid would accumulate in lungs hampering gas exchange

Cardiac cycle

Cardiac muscles are myogenic which means it naturally contracts and relaxes without receiving impulses from a nerve.

1) SAN (sinoatrial node)/pacemaker sends out waves of excitation which stimulates atria to contract
2) non-conducting tissue between atria and ventricles prevents atria and ventricles from contracting at the same time
3) AVN (atrioventricular node) delaying the impulse allows atria to completely into ventricles
4) AVN sends impulse down to the bundle of his and along purkine fibres
5) this causes ventricles to contract from the base upwards

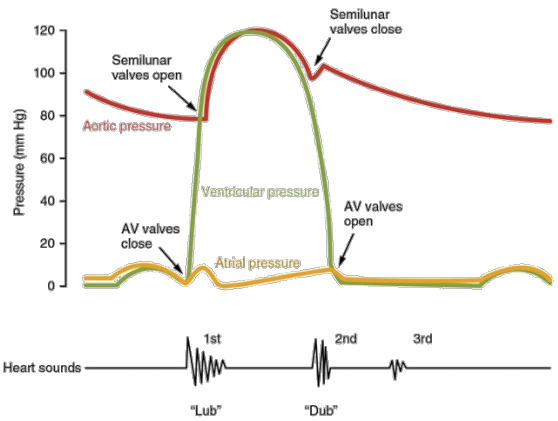


Image: https://teachmephysiology.com/

Oxygen dissociation curve

- once an O_2 molecule combines with haemoglobin, it becomes easier for more molecules to combine therefore, the curve rises very steeply
- a small change in the partial pressure O_2 causes a very large change in amount of O_2 carried by haemoglobin

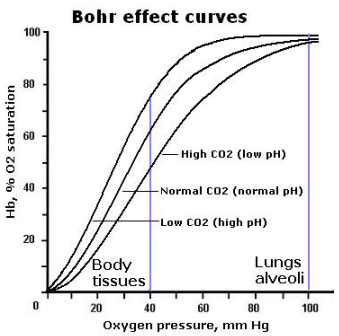


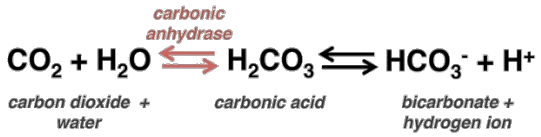
Image: https://www.onlinebiologynotes.com

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Bohr shift

- shift in the curve of oxyhaemoglobin due to concentration of CO_2 at a given partial pressure of O_2 is Bohr effect
- the amount of O_2 haemoglobin carries is affected by the partial pressures of both O_2 and CO_2
- the presence of high partial pressure of CO_2 causing Hb to release O_2 is the Bohr's effect

In the cytoplasm of red blood cells, CO_2 is catalysed by carbonic anhydrase enzyme when it reacts with water to form carbonic acid



- 2hen the carbonic acid dissociates; haemoglobin combines with H^+ ions forming haemoglobunic acid (HHb) and releases the O_2 it's carrying
- Haemoglobin combining with H^+ ions maintains blood pH as if the ions were left in solution, pH of the blood would've been less and turns acidic

- presence of high partial pressures of CO_2 causes haemoglobin to release O_2
- high concentration of O_2 is found in respiring tissues which need O_2
- high concentration of CO_2 causes Hb to release O_2, curve lies below and to the right

- **85% of CO_2** – diffuses out of RBC into blood plasma and are carried in solution
- **5% of CO_2** – CO_2 that hasn't dissociated and remains as CO2 dissolves in blood plasma
- **10% of CO_2** – CO_2 diffuses to RBC and combines directly with amine groups ($-NH_2$) of some haemoglobin molecules forming carbaminohaemoglobin

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9 Gas exchange

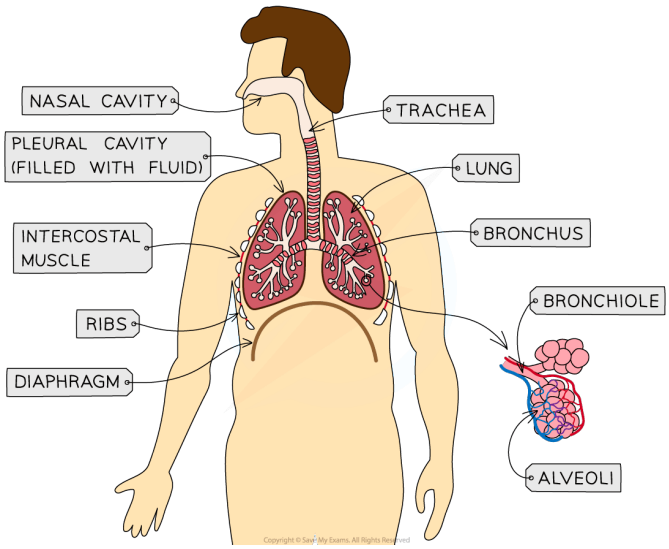
9.1 The gas exchange system

The gas exchange system is responsible for the uptake of oxygen into the blood and the excretion of carbon dioxide.

The gas exchange surface in the lungs is extensive, very thin, well supplied with blood and well ventilated.

The trachea and bronchi provide little resistance to the movement of air to and from the alveoli.

Gross structure of the human gas exchange system



- in single-celled organisms, oxygen can simply diffuse from fluid outside the cell through the cell surface membrane into the cytoplasm
- however, for multicellular organisms such as humans, most cells are at considerable distances from the external environment from which oxygen is obtained
- therefore, they need specialised gas exchange surfaces (alveoli) where oxygen can diffuse into the body, and carbon dioxide can diffuse out

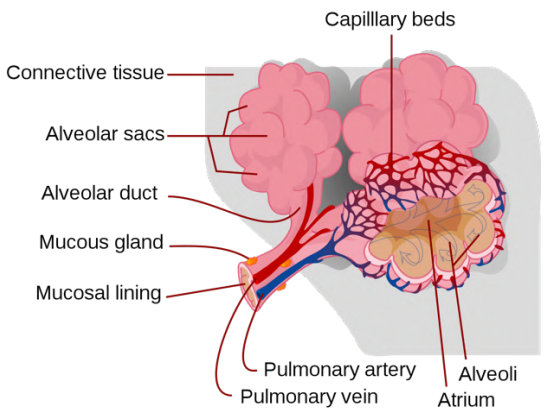


Image: https://commons.wikimedia.org/

STRUCTURE	SUMMARY
trachea	• airway that leads from the throat to the bronchi • lined with goblet cells and cilia
lungs	• present in the thoracic cavity surrounded by pleural membranes • contains pleural fluid to allow friction free movement between the lungs, and diaphragm and ribs
bronchi	• located at the base of the trachea and have a similar structure to it albeit narrower • each bronchus divides many times to forms smaller bronchioles • terminal bronchioles divide to form even narrower respiratory bronchioles that supply alveoli with air
bronchioles	• very narrow tubes (<1mm) that carry air from the bronchi to the alveoli • do not contain cartilage unlike the trachea and bronchi and so can collapse
alveoli	• main site of gas exchange in the lungs • essentially are tiny sacs with many structural adaptations to enable gas exchange
capillary network	• an extensive network of capillaries surrounds the alveoli • they are also an extensive exchange surface between the lungs and the blood

Trachea → bronchi → bronchioles

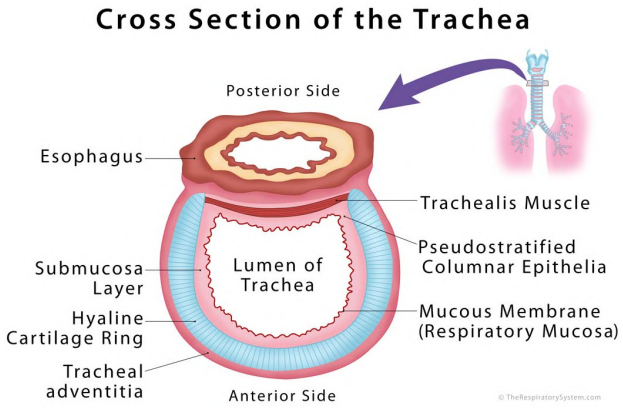
Cartilage

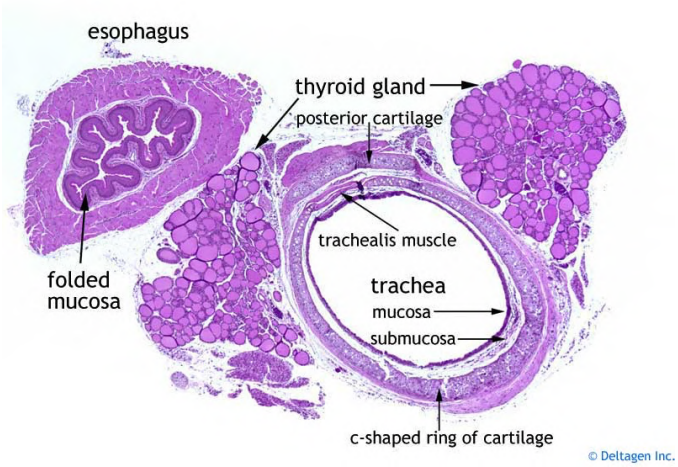
Cartilage is a flexible connective tissue of which the main cell type are chondrocytes.

- cartilage in the trachea and bronchi keep the airways open and air resistance low
- also prevents the airways from collapsing/bursting as air pressure changes during breathing
- the structure of the cartilage differs slightly in the bronchi and trachea

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a) Trachea





- cartilage here is present in a **regular arrangement of C-shaped rings**
- the trachea as a whole is supported by these rings of cartilage

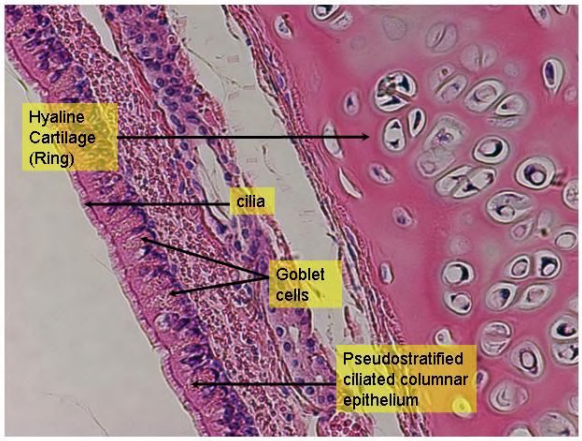


Image: https://o.quizlet.com/

- the lining is comprised of ciliated epithelium *(ciliated cells + goblet cells)* which rests on a basement membrane of protein fibres
- beneath the epithelium is an area of loose tissue with blood vessels and mucous glands

b) Bronchi *(singular 'bronchus')*

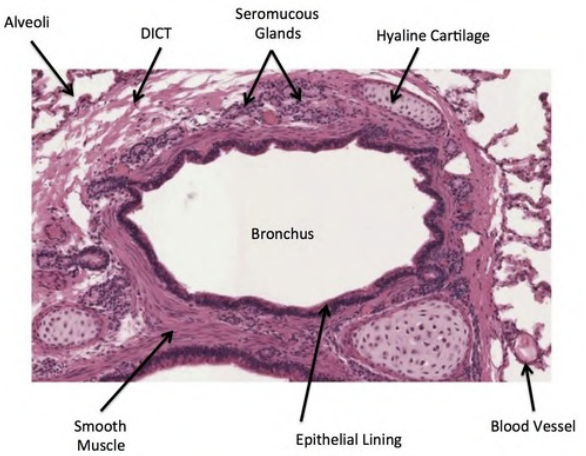


Image: https://o.quizlet.com/

- cartilage here is present in **irregular blocks**
- there are fewer goblet cells per cm^2 than in the trachea and the epithelial cells are not as tall
- beneath the epithelium, there are elastic fibres

c) Bronchioles



Image: https://i.pinimg.com/

- surrounding the epithelium is smooth muscle which can contract or relax to adjust diameter
- there is no cartilage (to make such adjustments to diameter possible
- around the bronchiole are some alveoli

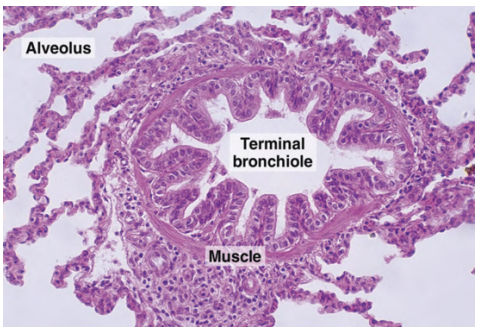


Image: http://ksumsc.com/

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Outline the function of cartilage in the human gas exchange system

1) keep airways open
2) provides support
3) allow flexibility
4) rings allow widening during inspiration

Outline the function of smooth muscle in the human gas exchange system

1) contraction and relaxation
2) changes diameter of trachea, bronchus, bronchioles
3) controls air flow in bronchioles

Warming and cleaning the air

- air is warmed to body temperature and moistened in the nose and trachea to prevent delicate areas in the lungs from desiccation (drying out)
- protection is also needed against the suspended matter carried in the air which may include dust, sand, pollen, fungal spores, bacteria, and viruses
- there are both mechanical and chemical barriers to protect against these particles which are all potential threats to the functioning of the lungs

MECHANICAL
hairs inside the nose
(catch particles >5-10μm)

CHEMICAL
mucus lining nasal passages + other airways

Mucus

- mucus is produced by goblet cells of the ciliated epithelium
- the upper part of each goblet cell is swollen with mucin droplets which have been secreted by the cell
- mucus is a slimy solution of mucin which is composed of glycoproteins with many carbohydrate chains that make them sticky and able to trap inhaled particles
- mucus is also made by mucous glands beneath the epithelium

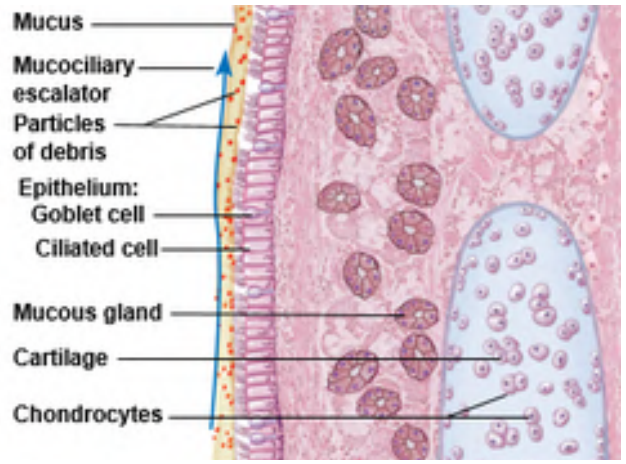


Image: https://o.quizlet.com/

- some chemical pollutants like SO_2 and NO_2 can dissolve in mucus to form an acidic solution that irritates the airway lining

Goblet cells and ciliated cells

- between goblet cells, there are ciliated cells
- ciliated cells have cytoplasmic extensions which beat rhythmically to move mucus up the throat
- when mucus is at the top of the trachea, it's swallowed – pathogens are destroyed by stomach acid

Alveoli *(singular 'alveolus')*

At the end of the pathway between the atmosphere and the bloodstream are the alveoli. They are the main site of gas exchange.

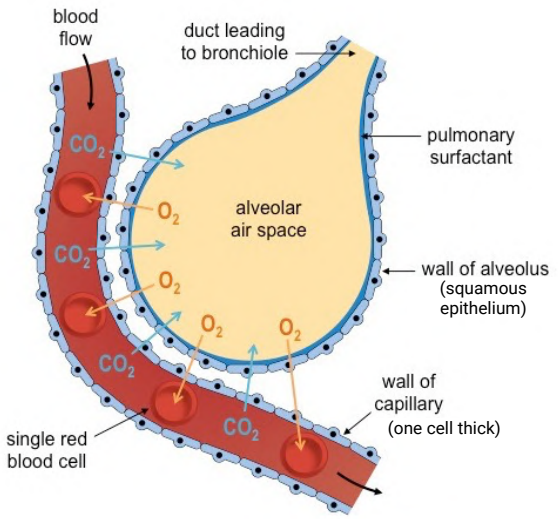


Image: https://ib.bioninja.com.au/

How alveoli are adapted for gas exchange

1) squamous epithelium is one cell thick

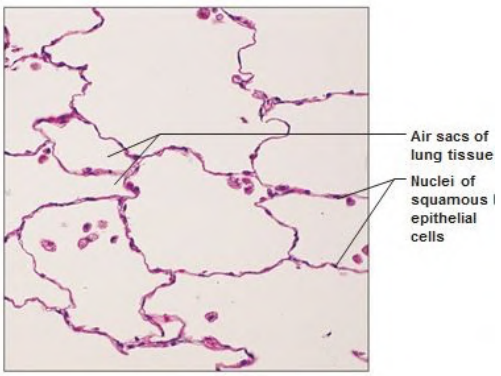


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2) for short diffusion distance
3) collectively many so large surface area for gas exchange
4) surrounded by a network of capillaries
5) so, RBC can come very close to air maintaining diffusion gradient

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Elastic fibres in alveoli walls

- stretch during inspiration
- recoil during expiration
- elasticity allows alveoli to expand according to volume of air breathed in
- it is the elastic abilities of alveoli which enable them to have such a large surface area

Process of gas exchange between air in the alveoli and blood

- oxygen and carbon dioxide are exchanged in a process of simple diffusion – passive movement from high to low concentration
- the air in the alveoli contains a high concentration of oxygen
- the blood in the capillaries has a relatively low concentration of oxygen and a high concentration of carbon dioxide
    - the oxygen diffuses from the alveoli into the blood capillaries, before being carried away to the rest of the body for aerobic respiration
    - the carbon dioxide diffuses from the blood into the alveoli and is then exhaled

Summary of structures in the gas exchange system

	CARTILAGE	GOBLET CELLS	SMOOTH MUSCLE	CILIA
TRACHEA	✓	✓	✓	✓
BRONCHUS	✓	✓	✓	✓
TERMINAL BRONCHIOLE	✗	✗	✓	✓
RESPIRATORY BRONCHIOLE	✗	✗	✗	✓
ALVEOLI	✗	✗	✗	✗

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10 Infectious diseases

10.1 Infectious diseases

> **Disease** – abnormal condition affecting an organism that reduces the effectiveness of the function of the organism

> **Infectious disease** – a disease caused by a pathogen, is transmissible and reduces the effectiveness of functions of the organism e.g., tuberculosis, cholera, etc.

> **Non-infectious disease** – long-term, degenerative diseases not caused by pathogens and not transmissible e.g., lung cancer, sickle cell anaemia, etc.

- ***Transmission cycle*** – *the way in which a pathogen transfers from one host to another*
- ***Endemic*** – *diseases that are always present in populations e.g., malaria is endemic in tropical and sub-tropical regions*
- ***Incidence*** – *the number of people who are diagnosed over a certain period of time*
- ***Prevalence*** – *the number of people who have that disease at any given time*
- ***Epidemic*** – *sudden increase in the number of people with a disease*
- ***Pandemic*** – *increase in the number of cases worldwide*
- ***Mortality*** – *death rate from different diseases*
- ***Incubation period*** – *time a disease takes to infect someone*

Summary of diseases and their causative agent

DISEASE	CAUSATIVE AGENT	TYPE OF ORGANISM
cholera	*Vibrio cholerae*	bacterium
malaria	*Plasmodium falciparum*, *P. malariae*, *P. vivax*, *P. ovale*	protocist
tuberculosis (TB)	*Mycobacterium tuberculosis* (airborne), *M. bovis* (infected milk/cattle)	bacterium
HIV/AIDS	human immunodeficiency virus (HIV)	virus
smallpox *(eradicated)*	*Variola* virus	virus
measles	a species of *Morbillivirus*	virus

How diseases are transmitted

a) Cholera

Transmission – via the faecal oral route or when raw human sewage of an infected person is used to irrigate vegetables

- infected people pass out the pathogen (Vibrio cholerae) in faeces which contaminates water supply and food whilst handling (due to lack of hygiene)
- the bacteria pass through the stomach acid to reach the small intestine – their site of action
- they multiply and secrete a toxin called **choleragen**
- it disrupts the functions of the epithelium lining in the small intestine
- salts and water leave the blood causing severe diarrhoea which may be referred to as 'rice water'

Prevention and control

- treatment is via oral rehydration therapy (a mixture of glucose and salts)
- drink bottled water or chlorinated water
- wash utensils and vegetables properly
- raise awareness
- improve sanitation services and sewage treatment plants

Global patterns of distribution

- prevalent in large cities in developing countries that don't have adequate sewage systems or clean water supply
- global distribution – Asia, Africa, Latin America

b) Malaria

> **Vector** – organism which carries a disease from one person to another or from an animal to a human e.g., female anopheles mosquito for plasmodium

Transmission

1) blood transfusion
2) when unsterilised needles are used
3) plasmodium can pass across placenta from mother to foetus

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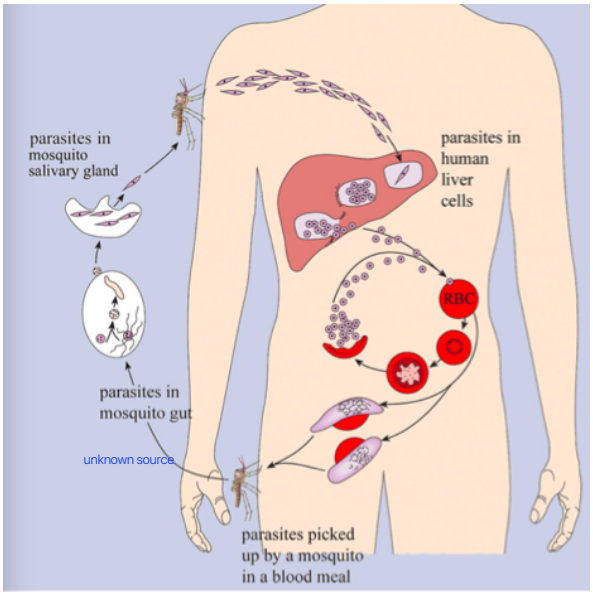


Image: unknown

How infection of malaria occurs

1) female anopheles mosquito feeds on human blood to obtain the protein they need to develop eggs
2) if an infected person is bitten, the mosquito takes up the pathogen's gametes with the blood meal
3) male and female gametes fuse in the mosquito's gut and develop into infective stages that move to the salivary glands
4) when the mosquito feeds again, an anticoagulant is injected from the salivary glands causing the infective stages to pass out as well
5) the anticoagulant is injected to prevent blood from clotting
6) parasites enter the blood stream, then enter liver cells and finally infect red blood cells

2. Prevention and control

1) control of breeding of mosquitoes *(e.g., drainage of stagnant water, aerial spraying of insecticide, oil on water, stocking ponds)*
2) reduction of contact between vector and humans *(e.g., bed nets impregnated with insecticide / insect repellents)*
3) earlier identification of cases *(introduction of dip stick tests ensuring diagnosis can be done quickly)*
4) use of new drugs to prevent transmission or using drugs in combination to reduce chances of drug resistance arising
5) better awareness
6) better screening of blood before transfusion

Why malaria is very difficult to control

1) no vaccine as plasmodium is eukaryotic and antigens differ in the different life stages
2) drug resistance in Plasmodium
3) insecticide resistance in Plasmodium
4) cost of drugs
5) problems with funding research
6) lack of knowledge
7) infected people not identified
8) inaccessibility of some regions to healthcare

Why is it difficult to create a vaccine for malaria?

1) plasmodium is eukaryotic
2) antigens differ in different life stages
3) intracellular parasite
4) antigenic concealment

c) HIV/AIDS (acquired immune deficiency syndrome)

Transmission

1) semen and vaginal fluids during intercourse
2) infected blood (via donation, etc)
3) sharing needles
4) mother to foetus across placenta
5) mother to infant in breast milk

Epidemic caused by:

1) anal intercourse *(mucous lining of rectum not as thick as a vagina's + less natural lubrication; rectal lining is easily damaged during intercourse and virus passes from semen to blood)*
2) many sexual partners
3) lack of awareness

How HIV affects the body

1) genetic material of HIV is RNA
2) viral RNA is converted to DNA inside host cells to be incorporated into human chromosomes
3) infects and destroys T_{helper} cells (cells that control the immune system's response to infection)
4) when the number of T_{helper} cells are low, the body is unable to defend against infection allowing pathogens to cause opportunistic infections
5) AIDS isn't a disease – it's a collection of opportunistic diseases associated with the immunodeficiency caused by HIV infection

Treatment

1) drug therapy (e.g., zidovudine)
2) it binds to viral enzyme reverse transcriptase and blocks its action
3) this stops the replication of viral genetic material and blocks its action and leads to an increase in the body's lymphocytes
4) combination therapies are however difficult to follow

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5) people are unable to keep up with the regimen are susceptible to strains of HIV that have developed resistance to drugs

> **reverse transcriptase** – an enzyme encoded by certain viruses (retroviruses) that uses RNA as a template for DNA synthesis

Prevention and control

1) spread awareness
2) use condoms, femidoms and dental dams
3) don't have many sexual partners
4) don't share needles
5) contact tracing
6) blood collected by donors screened and heat treated
7) reduce mother to child transmission by using formula milk

d) Tuberculosis (TB)

Transmission

1) infected person coughs
2) aerosol droplet carrying the pathogen
3) inhaled by uninfected person
4) *or* consumption of meat/milk of an organism carrying TB

Treatment

- when TB is confirmed, patients are isolated
- Several drugs such as the antibiotic streptomycin are used to ensure bacteria are killed

Prevention

- contact tracing
- cattle are routinely tested for TB

Global distribution

- TB is endemic however most common in poor and crowded living conditions
- also present where a large number of people have HIV/AIDs

10.2 Antibiotics

An antibiotic is a drug that kills or stops the growth of bacteria without harming the cells of the infected organism

Antibiotics may interfere with

- synthesis of bacterial cell walls
- activity of proteins in the cell surface membrane
- enzyme action
- DNA synthesis
- protein synthesis

How penicillin acts on bacteria

1) penicillin prevents the synthesis of cross links which hold together a bacterium's peptidoglycan walls (so penicillin is only effective when bacteria are growing)
2) enzymes autolysins secreted create small holes that allow the wall to stretch so new peptidoglycan chains can link
3) penicillin prevents linking but holes continue to appear making the cell wall weaker
4) when bacteria take up water via osmosis, it cannot withstand the pressure potential exerted due to the weakened cell wall and bursts

Why antibiotics do not affect viruses

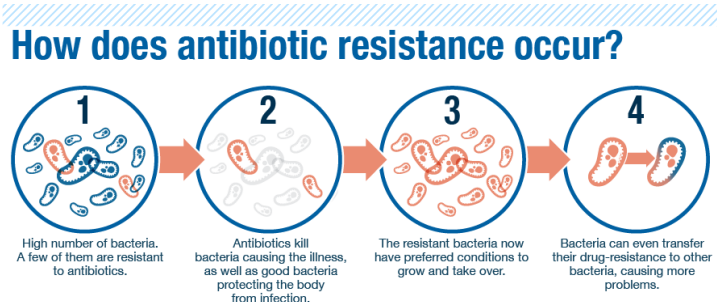
Antibiotics target areas of the bacterium such as its cell wall or other organelles. Viruses do not possess such organelles and therefore are immune to the effects of antibiotics.

How bacteria become resistant to antibiotics

1) people not completing course of antibiotics causing a reservoir of bacteria to remain
2) remaining bacteria mutate to become resistant bacteria with resistance survive
3) when they reproduce they pass on the allele for resistance to their offspring

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Image: Bioscience.com.pk



Bacteria transfer their drug-resistance by vertical or horizontal transmission. Some mutated bacteria may have plasmids carrying several resistance genes leading to multiple resistance.

Consequences of antibiotic resistance

1) decreased ability to treat infections
2) increased human illness and mortality
3) increased cost and length of treatments
4) adverse effects from alternate treatments
5) lack of availability of clinically effective antibiotics

Steps that can be taken to reduce the impact of antibiotic resistance

1) don't use antibiotics for trivial reasons or to treat viral infections
2) complete the course
3) use a combination of antibiotics
4) don't use as preventative medicine
5) only use wide-spectrum antibiotics when the pathogen is not known
6) rotate antibiotics so the same ones aren't used all the time
7) don't use the same antibiotics for animals and humans
8) don't cell antibiotics without a doctor's prescription

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11 Immunity

11.1 The immune system

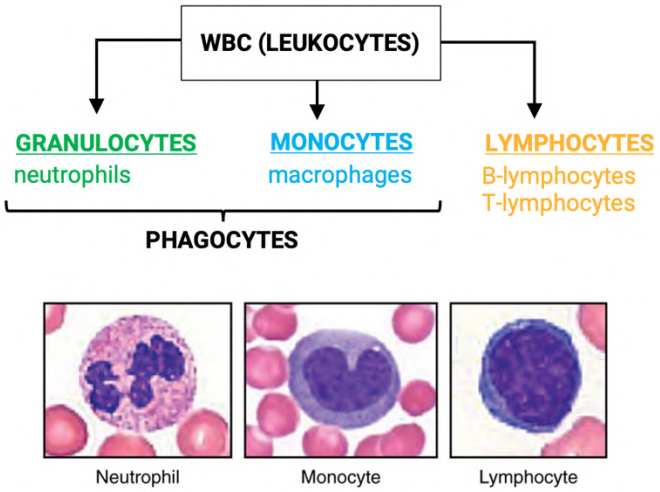


Image: Regents of University of Michigan Medical School © 2012

Phagocytes (neutrophils & macrophages)

- originate in bone marrow
- they're scavengers – removing any dead cells and invasive microorganisms

Neutrophils

- have a lobed nucleus and granular cytoplasm
- short-lived cells

Macrophages

- larger than neutrophils
- travel in blood as monocytes which develop into macrophages once they leave blood and settle in organs, removing foreign matter there
- long-lived cells
- do not destroy pathogens completely, they're cut up and their antigens are displayed, hence it becomes an antigen presenting cell (APC)

Phagocytosis

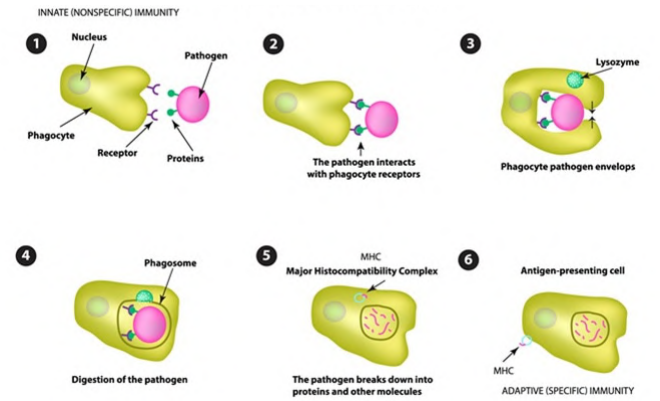


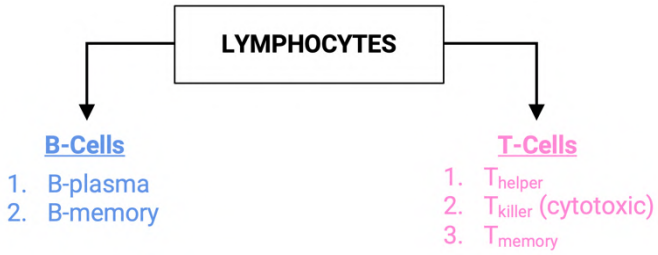
Image: Timonina / Shutterstock

- during an infection (caused by pathogens invading the body), cells under attack respond by releasing chemicals called histamines
- these attract neutrophils
- this movement towards chemical stimulus is called chemotaxis

General steps of phagocytosis

1) attraction (chemotaxis)
2) recognition and attachment
3) endocytosis
4) bacteria trapped within a phagocytotic vacuole
5) fusion of lysosomes and phagocytotic vacuole
6) killing and digestion

Lymphocytes



B-cells

- made and mature in the bone marrow
- travel to the spleen for final stages of maturation

1) B-plasma cells
- short-lived
- produce antibodies

2) B-memory cells
- form the immunological memory of the body
- responsible for 2° response

T-cells

Made in the bone marrow but mature in thymus.

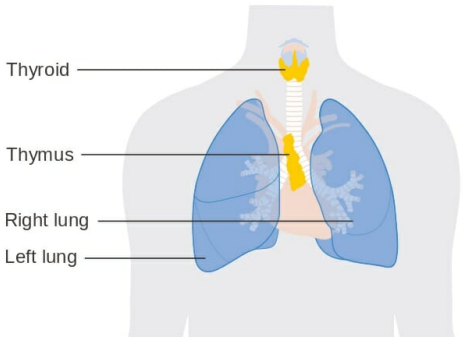


Image: https://biologydictionary.net/thymus-gland/

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T_{helper}

- produce interleukins
- interleukins stimulate:
  1) B-cells to make antibodies
  2) other T-cells to divide
  3) macrophages to enhance the effect of phagocytosis

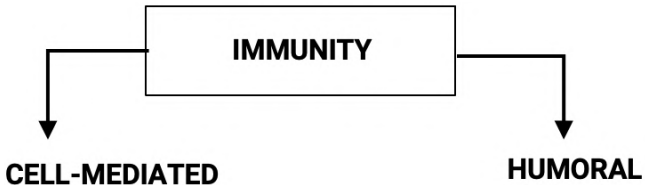
T_{killer} (cytotoxic)

- destroys cells by releasing perforin which makes holes in the cell surface membrane

T_{memory}

- leads to immunological memory of antigen
- responsible for 2° response

Immunity



a) Cell-mediated immunity

This is where T-lymphocytes respond to altered cells (APC, cancer cells, cells that've been infected by viruses)

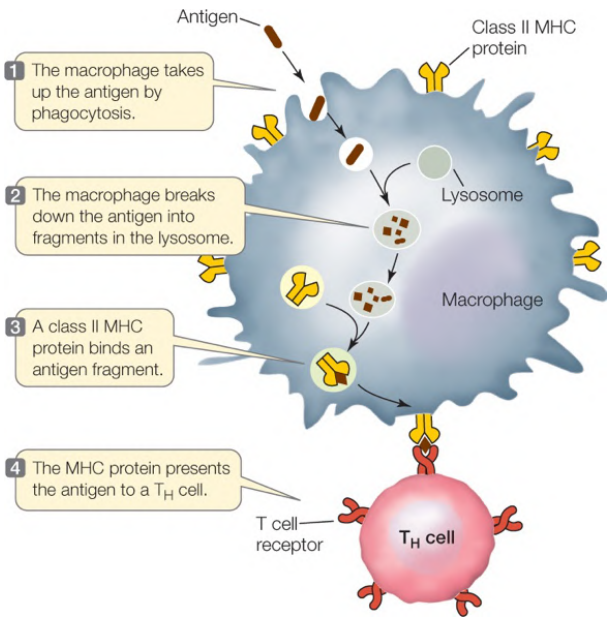


Image: www.macmillanhighered.com

1) macrophage engulfs pathogen and becomes an APC
2) T_{helper}'s cell receptor, which is complementary to the antigen, binds to antigen on APC
3) T_{helper} then releases interleukins
   - interleukins stimulate B-cells to divide into plasma cells and produce antibodies in the humoral response
   - they can also increase the effect of phagocytosis

⇒ **T-lymphocytes can only recognise antigens on an APC surface**

b) Humoral immunity

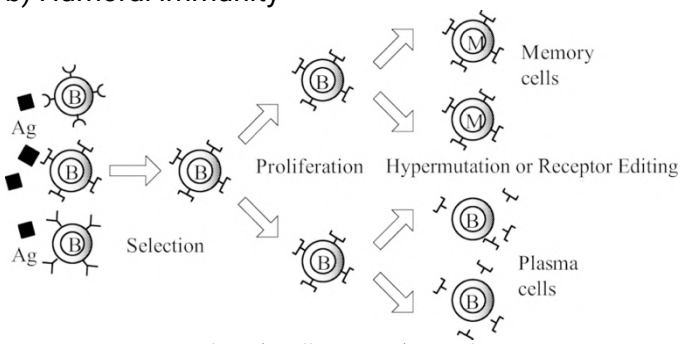


Image: https://www.researchgate.net/

a) Clonal selection

Process by which an antigen selectively binds to and activates only those lymphocytes bearing receptors for the antigen. In short, this is basically recognising and choosing which B-cells to use.

- T_{helper} cell recognises B-APC and becomes activated, releasing interleukins to signal further actions

b) Clonal expansion (proliferation)

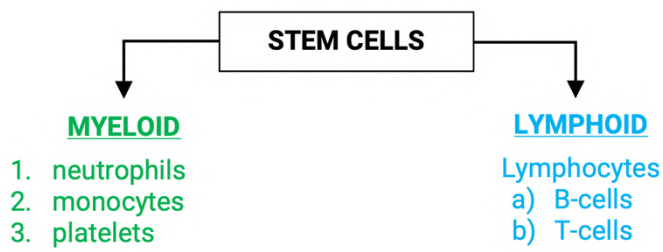
The rapid multiplication of B (or T) cell clones after activation by an antigen.

- B-APC divides and differentiates into –
  1) plasma cells to make specific antibodies
  2) memory cells to prepare for 2° response

⇒ **B-cells can respond to APC as well as pathogens directly**

Numbers of white blood cells

- Neutrophils in the blood increases during bacterial infections and whenever tissues become inflamed and die
- Lymphocyte numbers increase during viral infections and TB



- leukaemias are cancers of these stem cells
- cells divide uncontrollably to produce many cells that don't differentiate properly and disrupt production of normal blood cells

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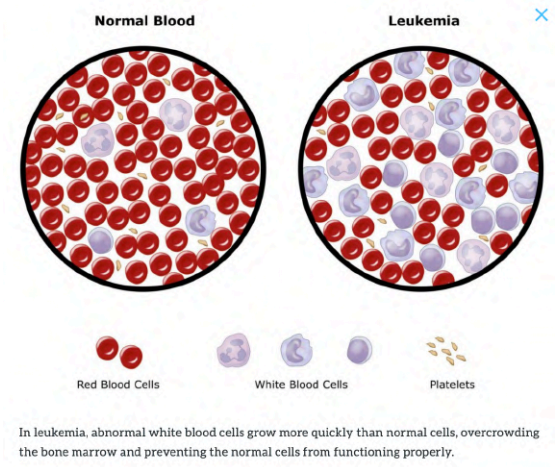


Image: https://orthoinfo.aaos.org/en/diseases--conditions/leukemia/

- immature white blood cells are produced quickly, disrupting balance of components in blood
- as a result, the body does not have enough red blood cells or platelets
- this causes anaemia and increases the risk of excessive bleeding
- the number of mature lymphocytes and neutrophils decrease, so susceptibility to infections increase
- the person is now said to be immunosuppressed

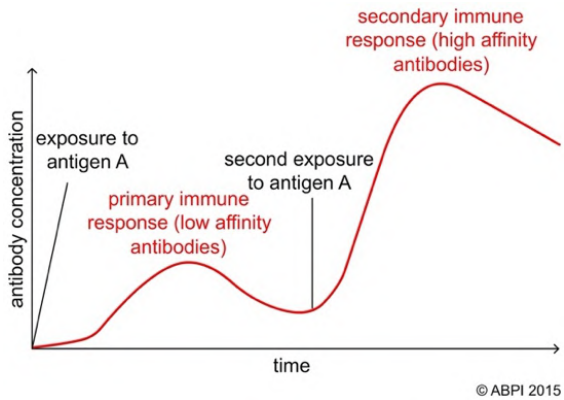
Immune response

> **immune response** – the complex series of responses of the body to the entry of a foreign antigen
  - involves the activity of lymphocytes and phagocytes

- **antigen** – substance that is foreign to the body and stimulates an immune response
- **self** – substance produced by the body that the immune system does not recognise as foreign and therefore does not stimulate an immune response
- **non-self** – any substance or cell recognised by the immune system as foreign and stimulates an immune response

Role of memory cells in long-term immunity

Remain in the blood for years and cause long-term protection.



Autoimmune diseases

Occurs when the immune system mistakenly identifies self-antigens as foreign (non-self) and mounts an immune response against them.

- during the maturation of T-cells in the thymus, millions of cells are destroyed as they have T-cell receptors complementary to self-antigens
- some of these cells evade destruction and are activated to stimulate an immune response against the body's own proteins
- starts as an attack involving antibodies and killer T-cells against certain parts of the body
- attack can be localised in one organ or directed against the whole body
- e.g., Myasthenia gravis, rheumatoid arthritis, type 1 diabetes, lupus, psoriasis, etc.

Myasthenia gravis (MG)

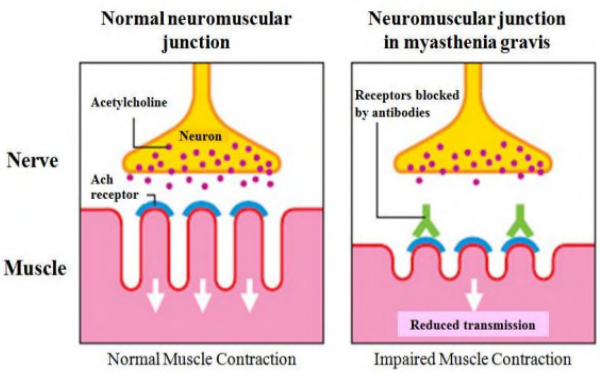


Image: https://healthjade.com/acetylcholine/

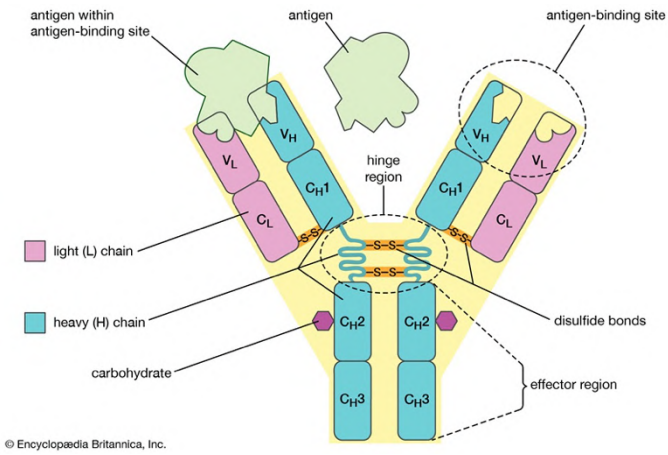
- antibodies are produced against receptors on muscle fibres for acetylcholine which is released by ends of motor neurones to stimulate muscle contraction
- people with MG have T_{helper} cells that are specific for cell surface receptors for acetylcholine
- T_{helper} cells stimulate a clone of B-cells to differentiate into plasma cells and secrete antibodies that bind to receptor blocking transmission from motor neurones
- muscle cells are not stimulated so muscle tissue starts to break down
- **symptoms** – muscle weakness
- **treatment** – drug that inhibits enzyme in synapses that breaks down acetylcholine increases its concentration so its action in stimulating muscle contraction lasts longer *or* surgical removal of the thymus gland

11.2 Antibodies and vaccination

Antibodies

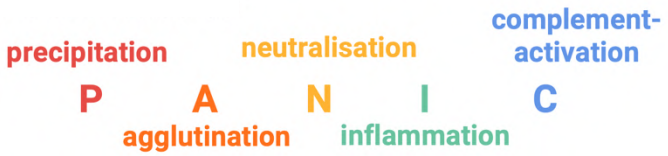
- globular glycoproteins
- have quaternary structure
- form group of plasma proteins called immunoglobulins

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- **Hinge region** – gives flexibility to bind around antigen
- **Antigen binding sites** – sequence of amino acids in these regions make a specific 3D shape which binds to one type of antigen

Functions of antibodies



- attach to flagella of bacteria making them less active and easier for phagocytes to engulf
- cause agglutination (clumping together) of bacteria, reducing chances of spread
- punch holes in bacteria cell walls, causing them to burst when they absorb water by osmosis
- antibodies coat bacteria, making phagocytosis easier as phagocytes have receptor proteins
- combine with toxins, neutralising them (antitoxins)
- combine with viruses and bacterial toxins, preventing them from entering or damaging cells

Hybridoma method for the production of monoclonal antibodies

- B-cells that divide by mitosis do not produce antibodies and plasma cells that secrete antibodies do not divide
- **monoclonal antibodies** – identical copies of one type of antibody

1) antigen is injected into a mouse
2) spleen cells which produce lymphocytes which produce antibodies are removed
3) plasma cells from spleen are fused with cancer cells or myeloma cells forming hybridoma cells that divide indefinitely
4) they divide by mitosis and produce antibodies

Using monoclonal antibodies in diagnosis and treatment of disease

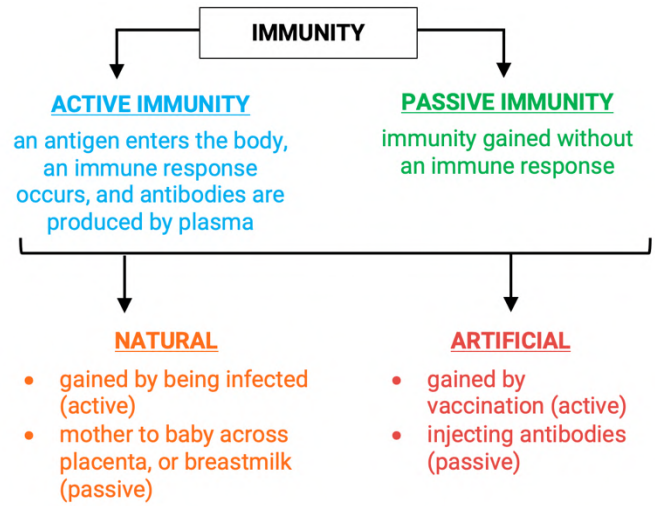
In diagnosis

- used to locate position of blood clots
- used to locate cancer cells which have different cell surface proteins and therefore can be detected by antibodies
- used to identify exact strain of virus or bacterium causing an infection, which speeds up treatment

In treatment

- treatment of breast cancer – antibody binds to cancerous cells and marks them for destruction by immune system
- treatment of rheumatoid arthritis (autoimmune) – antibody binds to proteins secreted by T-cells that causes damage to cartilage in joints and blocks its action

Types of immunity



Vaccination

Vaccines

- preparation containing antigens which is used to stimulate an immune response artificially
- it may contain antigens in the form of live or dead microorganisms, harmless (attenuated organism), toxoid (harmless toxin), surface antigens

How vaccines can provide long-term immunity

1) vaccine contains antigens that stimulate an immune response
2) macrophages take up virus by phagocytosis and act as antigen presenting cells (APC)
3) lymphocytes bind to these and under clonal selection
4) clonal expansion then occurs by mitosis
5) memory cells are formed
6) booster is used to further stimulate memory cell formation

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Poor response to vaccines due to –

- suffer from malnutrition and don't have enough proteins to make antibodies or clones of lymphocytes
- defective immune system and don't develop necessary B and T cell clones

Vaccination programmes

Eradication of smallpox

- *Variola* virus was stable, it didn't mutate and change cell surface antigens
- vaccine was made from a harmless strain of a similar virus – a 'live' vaccine is more effective
- infected people can be easily identified
- vaccine was freeze-dried and can be kept at high temperatures for as long as 6 months
- didn't affect animals – easier to break transmission cycle

Herd immunity

Herd immunity interrupts transmission in a population so that those who are susceptible never encounter the infectious agents concerned.

Why measles, cholera, malaria, and TB haven't been eradicated

Antigenic variation

a) Antigenic drift – minor changes in the viral antigen, memory cells are still able to recognise them and start a secondary response

b) Antigenic shift – major changes in antigen structure

- currently there are no effective vaccines for diseases caused by protocists as they're eukaryotes with many more genes.
- e.g., malaria; each stage has its own antigen

⇒ measles – poor response by some children, needs several booster shots

⇒ cholera – many strains

⇒ malaria – too many stages (antigenic variations)

⇒ TB – symptoms may not be shown

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