Biology is the branch of science concerned with the study of living organisms. There is no particular field of interest where living organisms are concerned, and you will come to realise how much of a broad subject biology is as you progress further through the course. When studying biology, it is best to read around each of the topics you cover, how much extra reading you do is up to you, but it is advised that to achieve a high 'A' grade extra reading is a must.

The notes contained within this book aim to provide you with a full understanding of the Edexcel A level biology syllabus. Please read through each of the pages carefully, a good A level candidate will read through the content and make notes from it, an excellent a level candidate will question the facts put forward and will try to not only learn the content but *understand* what is being said.

Molecules and cells

You and I are made up of millions of different molecules, in fact, this is true for all living organisms whatever their shape or size. There a five common atoms which can be found in living organisms. These atoms act as monomers, that is, they are the building blocks of much larger molecules or polymers. These are:

- Hydrogen
- Carbon
- Nitrogen
- Oxygen

Biological molecules can be either one of two types:

Organic – These are molecules which are found to contain carbon, in addition molecules of organic substances are often quite large.
Inorganic – These are molecules which do not contain carbon, in addition molecules of inorganic substances are often quite small or smaller than organic molecules

Water, carbohydrates, lipids, proteins and nucleic acids, are some of the important biological molecules which can be found inside living organisms, and are indeed polymers of the atoms mentioned above

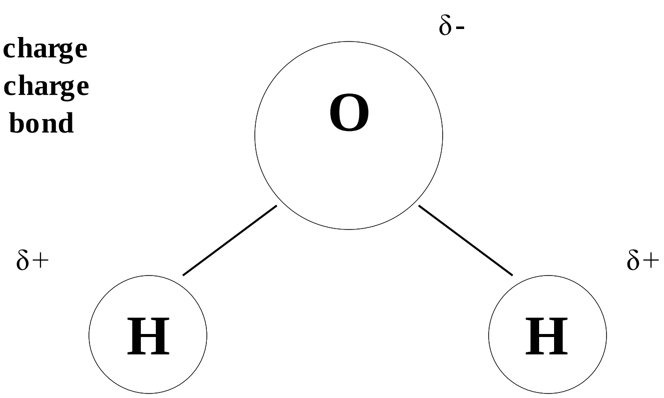
Water - Composed of two hydrogen atoms and one oxygen atom giving the molecular formula H_2O.
Carbohydrates with the general formula $(CH_2O)_n$ where $_n$ stands for any number of molecules.
Lipids made up of carbon, hydrogen and oxygen
Proteins - contain carbon, hydrogen, oxygen, nitrogen and sometimes even sulphur.
Nucleic acids - contain carbon, hydrogen, oxygen, nitrogen and phosphorus.

Water

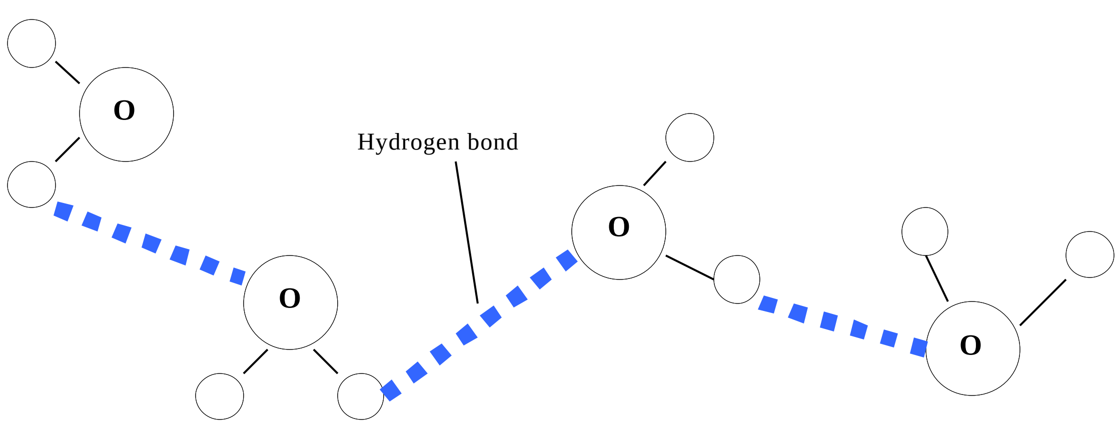
Water is the most important inorganic molecule found inside living organisms. Its role as a transport medium, a solvent, a habitat for aquatic life and its numerous other useful functions, stems from the unique properties which water molecules exhibit. Water molecules are described as ***polar***. A polar molecule is one which possesses regions of slightly positive and slightly negative charge, separated by a small distance. Each end of a polar molecule is called a ***dipole.*** Water molecules are in this state due to the difference in electronegativity of the hydrogen atoms and oxygen atom. Oxygen is more electronegative than hydrogen and therefore draws the shared electrons in the bond closer to itself, making the oxygen atoms slightly negative and the hydrogen atoms slightly positive.

Key

$\delta+$ **Slight positive charge**
$\delta-$ **Slight negative charge**
— **Single covalent bond**



Being a polar molecule, the positive ends of single water molecules (that is the hydrogen atoms) are attracted to the negative ends of other water molecules (that is the oxygen atoms). This creates a force of attraction known as a ***hydrogen bond.*** The hydrogen bond is what gives water molecules many of its unique properties which other liquids do not have, as water molecules are held more closely together as a result.



The properties which arise from water' sunique chemical nature include:

- Its ability to act as an excellent solvent
- A high latent heat of vaporisation.
- A high surface tension
- A High specific heat capacity
- High density

Solvent properties

Water' s ability to act as a solvent is due to the polar nature of its molecules. You are probably familiar with the ionic compound sodium chloride (NaCl) from GCSE. Substances that have dipoles as in NaCl or even potassium fluoride (KF) are able to easily dissolve in water. For it is the dipoles themselves, that are attracted to the charges on the water molecules. This results in the even distribution of the dipoles in amongst the water molecules.
You can imagine how this can be useful within living organisms. Materials can easily be transported in solution for example sap through the xylem and phloem of plants or the blood within animals, which contains hormones, glucose, amino acids and various other substances. Soluble substances are also free to move in water, enabling their particles to collide with others, resulting in metabolic reactions taking place.

* EXTRA SIDE NOTE AND DIAGRAM NEEDED

Specific heat capacity

This is defined as the amount of energy required to raise the temperature of 1g of substance by $1^{o}C$. The hydrogen bonding between water molecules draw them in close together causing water to have a very high specific heat capacity. This means that a great deal of heat must be applied to water molecules to make them move about by even a small amount. This can be extremely useful to the bodies of all organisms which contain large amounts of water; and are therefore able to tolerate large temperature changes in the external environment without affecting the temperature of their cells by very much. Organisms are therefore able to regulate their body temperature much more effectively than is the case. This is an example of homeostasis. This property of water can also be extended to aquatic organisms which live completely surrounded by water and hence have a fairly stable environment immune to rapid temperature changes.

Latent heat of vaporization

This is defined as the amount of heat energy required to turn a given quantity of liquid into a gas (i.e. a change of state is achieved). The attractions between water molecules make this property possible, allowing water to behave as an effective coolant. For example, transpiration from the mesophyll layers inside leaves allows them to cool, as water molecules are able to draw a great deal of heat away from the leaf before evaporating from the leaf as a gas. When we sweat, water evaporates from the surface of our skin, which in much the same way as in plant leaves, allows us to cool down.

Density

The density of water is often taken to be one gram per millilitre. This value can change with temperature which is why the word "often" was used in the preceding sentence. Thus a single body of liquid may layers of water molecules with different densities (which may be typically found in an aquatic environment for example). Water's density is higher than most other liquids, due to the hydrogen bonding between the water molecules. The differing densities of water in a single body of liquid, allows water molecules to circulate to different areas within the liquid body, carrying with them various nutrients and minerals (which are of course soluble in water). You can therefore begin to see how this can be useful to aquatic organisms in particular. The majority of living organisms also have a density which is similar to that of water, allowing them to float in water. Aside from an obvious example such as fish or ourselves, hydrophytes (plants adapted to survive in water – unit 2) are also able to float in water.

Surface tension

The attractions between water molecules enable their surfaces to be able to behave as a sort of membrane or skin. This can be useful to many aquatic invertebrates such as pond skaters which use the surface to literally walk on the surface of water. Some invertebrate may also choose to lay eggs on the surface of water. Mosquito larvae also use the surface tension of water to cling to the surface and breathe air, through siphons.

Carbohydrates

Carbohydrates are organic molecules that contain carbon, hydrogen and oxygen. They have a general formula $C_nH_{2n}O$, where n represents any number. This is shown when a molecule of water combines with a carbon atom to form CH_2O. This can be repeated many times to form a wide range of molecules.

There are three types of carbohydrates:

- Monosaccharides – single sugar units
- Disaccharides – two monosaccharides linked together
- Polysaccharides – many monosaccharides linked together

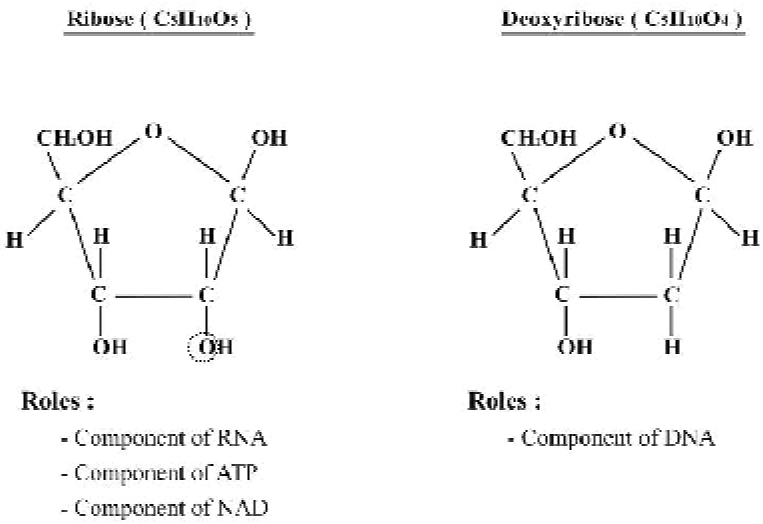
Monosaccharides

Monosaccharides are the simplest forms of carbohydrates i.e. **monomers**. They therefore act as building blocks for many larger molecules such as **starch** and **cellulose**. Monosaccharides are single sugar units and all sugars dissolve in water and taste sweet.

The names of monosaccharides are related to the number of carbon atoms in that molecule.

? Trioses have **three** carbon atoms – $C_3H_6O_3$
? Pentoses have **five** carbon atoms – $C_5H_{10}O_5$
? Hexoses have **six** carbon atoms – $C_6H_{12}O_6$

Two very important pentoses are shown in Fig 1

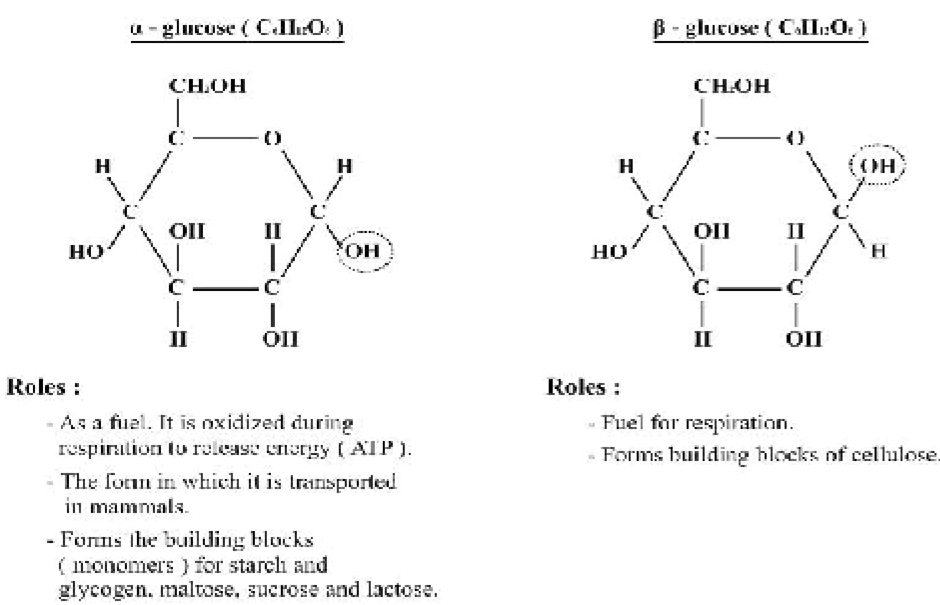


Ribose is a part of the **RNA** molecule
Deoxyribose is a part of the **DNA** molecule

Glucose

Glucose is the main substrate for respiration, it is also the form in which carbohydrate is transported in mammalian blood and it is the building block for other carbohydrates such as starch and cellulose.

Glucose can exist in either the α (alpha) or β (beta) form as shown in Fig 2:



α and β glucose can have the same molecular formula ($C_6H_{12}O_6$) but they have a different structural formula, they are said to be **structural isomers**.

Fructose

Fructose is a very sweet sugar which is found in nectar and many fruits, this property helps plants to attract insects during **pollination**. Fructose is also the sugar that is usually added to tea. With glucose it forms the disaccharide **sucrose**.

Galactose

Galactose is the sugar molecule found in milk, with glucose it forms the disaccharide **lactose**.

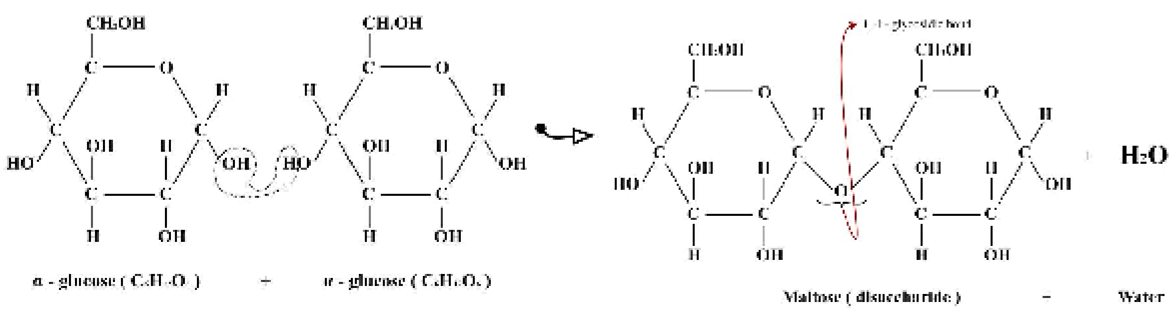
Isomers of a molecule e.g. glucose don’ t have an effect on its properties, but have a significant effect on the disaccharide or polymer made when the glucose molecules join together e.g. to form starch.

Disaccharides

Disaccharides are formed when **two** monosaccharides link together, releasing a molecule of **water**. A reaction in which a molecule of water is released is known as a **condensation reaction**. The link between the two monosaccharide molecules is known as a **glycosidic bond**.

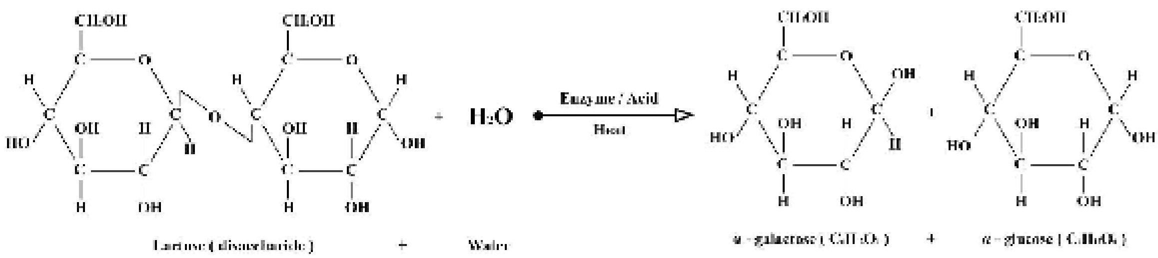
Disaccharides like monosaccharides are fairly small sugars in size and so are sweet to taste and soluble.

Fig 3 shows the formation of a disaccharide from two molecules of glucose.



Disaccharides can be formed by joining together two **similar** monosaccharides (**maltose**) or by **joining** two different monosaccharides (**sucrose** and **lactose**).

Splitting of a disaccharide in to its monosaccharide, by the addition of water molecules is known as a ***hydrolysis reaction***



Reducing sugars

Monosaccharides and disaccharides are known as reducing sugars. They have a carbonyl group (C=O) which can be oxidised to a carboxylic acid group (-COOH). If they themselves are oxidised, they must reduce other substances e.g. Benedict' s solution, producing a coloured precipitate. This is known as a redox reaction.

Benedict' s test is used as a method of estimating the concentration of a reducing sugar present in a solution. However, sucrose is an exception to this rule, it is actually a non-reducing sugar.

Testing for a reducing sugar

? Add Benedict' s solution to the substance under test
? A positive result (reducing sugar) will produce a yellow, orange or brick-red precipitate
? The solution will remain blue of a reducing sugar is not present

Testing for a non-reducing sugar

? First test for a reducing sugar (as above)
? If the result is negative, take a new sample of the sugar and boil it with hydrochloric acid (to hydrolyse the reducing sugar)
? Then add a weak alkali to neutralise the solution
? Test for a reducing sugar, a yellow, orange or brick-red precipitate is produced

The amount of a reducing present in a solution **increases** as the colour of the precipitate goes from green to yellow to brown and then to brick-red.

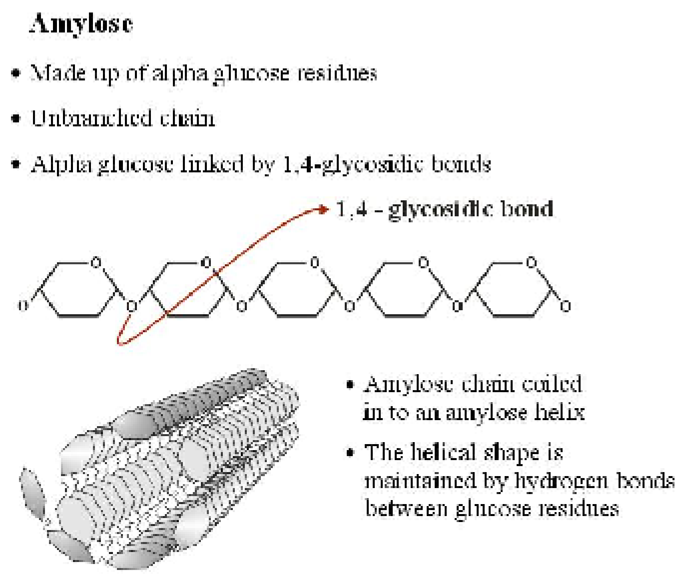
Polysaccharides

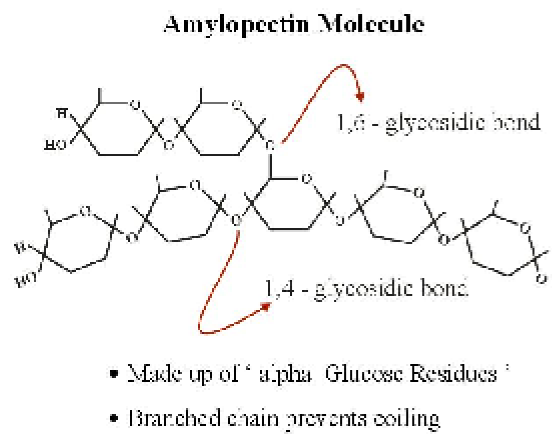
Polysaccharides are polymers, meaning that they are made up of hundreds of monosaccharide units linked together by glycosidic bonds. Polysaccharides are very large molecules and so are not soluble or sweet to taste. These long chains can be branched or un-branched, starch, glycogen and cellulose are all examples of polysaccharides.

Starch is a mixture of two polysaccharides, **amylose** and **amylopectin**. Amylose is a straight, un-branched polymer which accounts for **80%** of the starch molecule. It is made up of many α **glucose** units linked with **glycosidic bonds** on carbon **one** of one glucose unit and carbon **four** of another glucose unit. This can also be written as α(1,4) links. Amylopectin has α(1,4) links, but it also has α(1,6) links which result in its **branched** structure. Fig 5 shows the structure of amylose, amylopectin and starch.

Starch is an extremely effective **food store** in **plant** cells. It is **insoluble**, so it doesn’ t affect the solute concentration, hence has no affect on the water potential within the cell. It is **compact** which is ideal when taking into account the size of **chloroplasts** (in which they are found) and it is **readily** converted into sugars. **Amylase** (an enzyme) breaks down starch into **maltose** and then into **glucose** which acts as a **source** of **energy**.

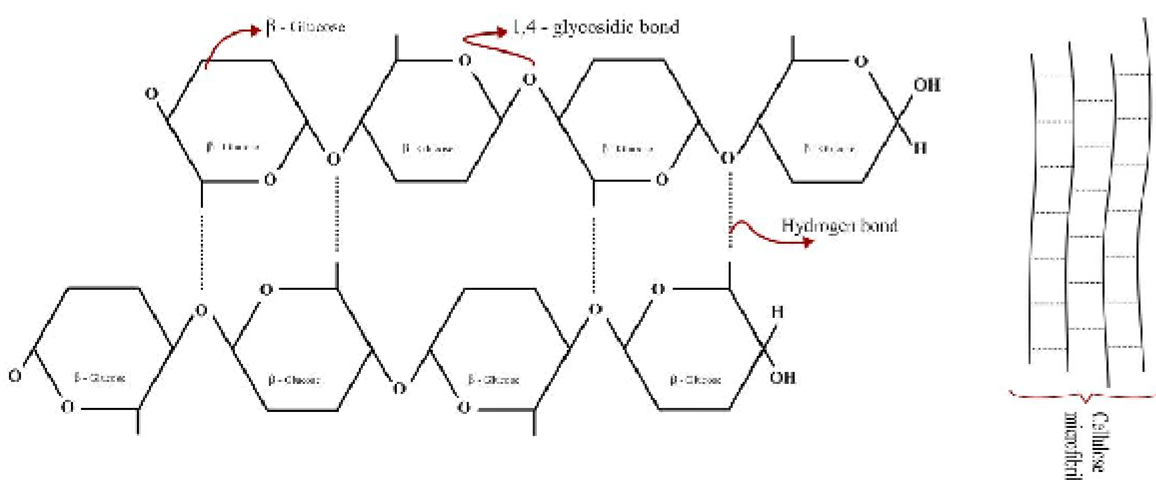
The starch molecules curl up into spirals forming grains inside chloroplasts. The spiral shape is maintained by strong hydrogen bonds between the –OH groups of glucose molecules.





Glycogen is chemically very similar to amylopectin. It is the only carbohydrate store in animals and is found in the liver and skeletal muscle cells.

Cellulose is a polysaccharide made up of **thousands** of β glucose units, linked together by β(1,4) links. Fig 6 shows the structure of cellulose.

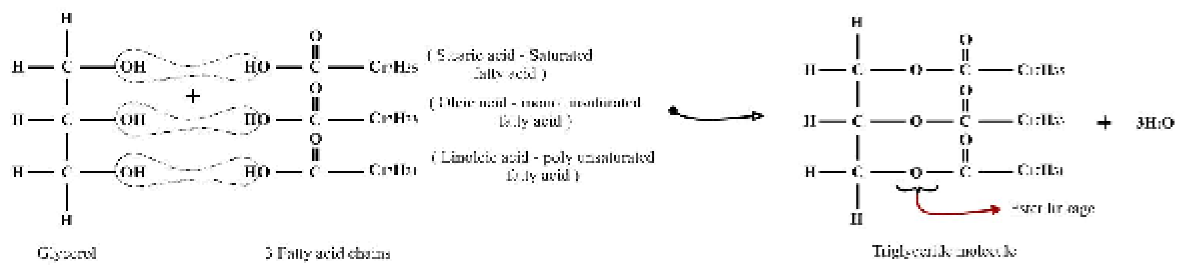


Cellulose is **not** branched or curled in any way, it consists of **straight**, **parallel** chains. These chains form a bundle of molecules known as **microfibrils**. The microfibrils are held together by **hydrogen bonds** between the **adjacent** chains, forming strong cellulose fibres. Cellulose is an important component of plant cell walls, making the plant cell wall difficult to digest, because very few organisms produce enzymes that break the β(1,4) links. Fig 6 shows the presence of hydrogen bonds between parallel chains.

<u>Lipids</u>

Lipids are large organic compounds which include **fats**, **oils** and **waxes**. They are made up of carbon, hydrogen and oxygen, just like carbohydrates, but the amount of oxygen is a lot **less**. Lipids are **insoluble** in water due to their **non-polar** nature.

Triglycerides are one of the most common types of lipids. They are formed from one molecule of glycerol and three fatty acids. The glycerol molecule is linked to the fatty acids by **ester bonds**. The structure of a triglyceride is shown in Fig. 8:



Fatty acids contain the **carboxyl** group (-COOH) at one end and a long **hydrocarbon tail** at the other. The length and structure of the hydrocarbon tail is dependent on the type of fatty acid. However the structure of the glycerol molecule always remains the same.

When triglycerides are oxidised during respiration they release **more** energy than an equal amount of carbohydrate and so they are useful **energy stores** in both animals and plants. Triglycerides have the added advantage of being insoluble in water and so have no effect on the water potential of a cell. The presence of triglycerides is extremely important to desert animals, because a lot of water is released when triglycerides are oxidised.

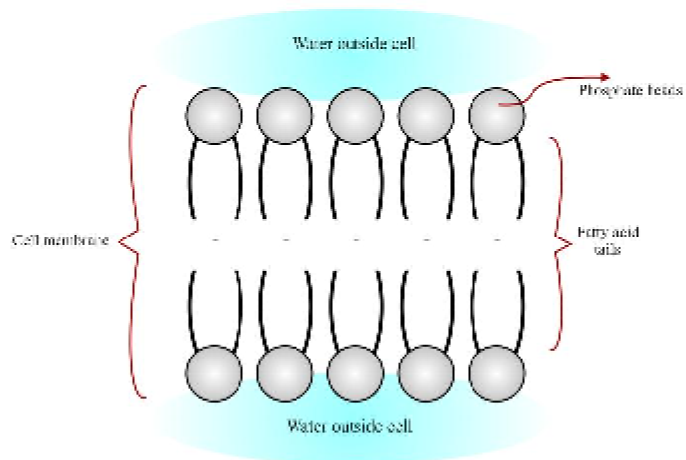
Tip: A camel’ s hump is made up of fat, which can also be an excellent source of (metabolic) water.

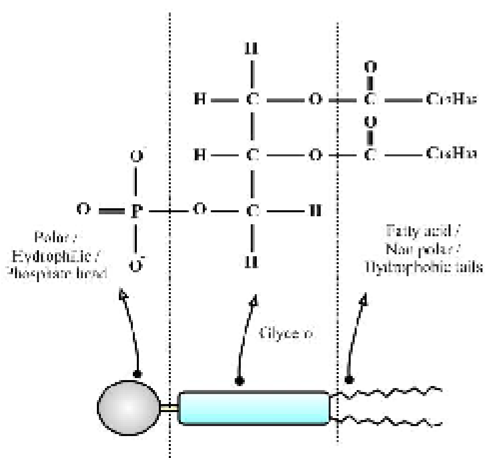
Triglycerides also play an important role in **buoyancy**. This is most obvious in aquatic mammals, such as whales, which have a large amount of fat beneath their skin known as adipose tissue. Its function is to not only serve as an energy store but to also provide buoyancy for the mammal as well as acting as a **thermal insulator** to prevent heat loss from the body.

Adipose tissue can be found beneath the skin of humans as well as around the internal organs, such as the kidneys, **protecting** them against damage. Another very important role of triglycerides is that they act as **waterproofing** layers (oils and waxes). A thin layer of waxy cuticle is found on the surface of leaves, where it prevents too much water loss.

Phospholipids are very similar to triglycerides, but one of the fatty acid molecules is replaced by a **phosphate group** as shown in Fig. 8:

The fatty acid molecule is **non-polar** and so is not attracted to water, it is said to be **hydrophobic**. The phosphate part is **polar** and is attracted to water, it is said to be **hydrophilic**.





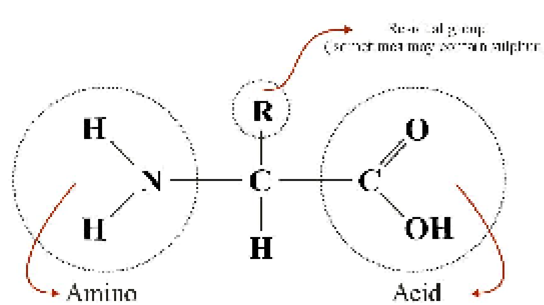
Structure of PHOSPHOLIPID

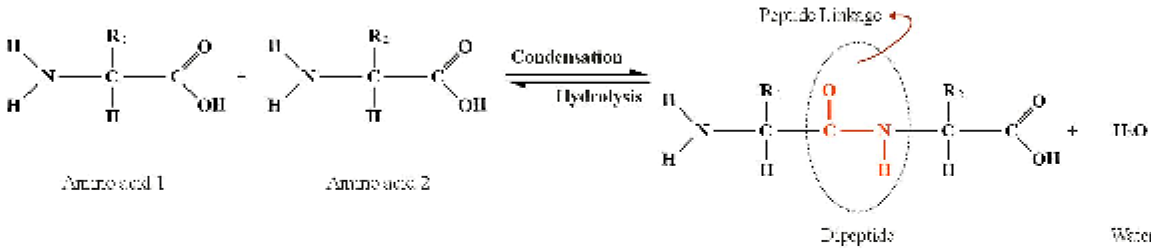
When placed in water phospholipids form a structure known as a **bilayer**. The non-polar hydrophobic tails point towards the centre and the polar hydrophilic phosphate groups come into contact with the water (as shown in Fig. 9). This is the structure of all phospholipid cell and organelle **membranes**.

Proteins

When numerous amino acid monomers are linked together, they form chains known as polypeptides. These polypeptides may also be referred to as proteins. Amino acids are able to join together by ***condensation*** reactions and can equally be broken down by ***hydrolysis*** reactions. The bond formed between adjacent amino acids is referred to as a peptide bond. The structure of an amino acid and a dipeptide (two amino acids joined together) are shown below respectively.

The molecular formula of an amino acid is written as $NH_2.RCH.COOH$





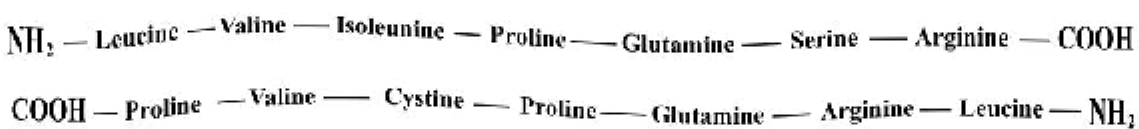
It is specifically the ***amino*** and ***carboxylic*** acid groups, which are involved in the formation of peptide bonds, whilst the R groups are involved in hydrogen, ionic and disulphide bond formation. Within organisms such as mammals proteins act as an important structural materials much the same as cellulose does in plants.
The order in which amino acids are linked together, is determined by the genes within a cell. This will be described in more detail under nucleic acids.

Protein structure

It is important to realise that there are four main structures, which amino acids can join to adopt. The greater the number of different structures a protein has, the more complex its structure. The four man structures are:

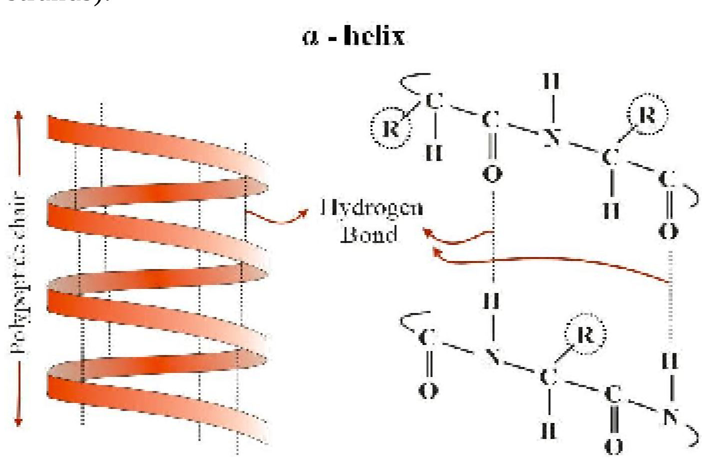
- ? Primary structure

This is referred to as the number, type or sequence of amino acids in a polypeptide chain. You should also note that the primary structure of a protein determines its secondary, tertiary, and quaternary structures and hence the eventual shape of a protein.

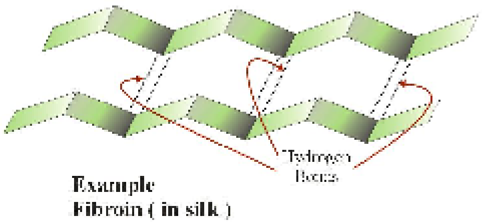


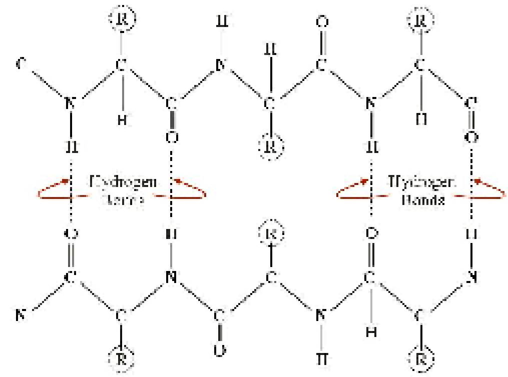
- ? Secondary structure

This is the curling or folding of the polypeptide chain into 3D ***regular*** shapes. The shapes may be either an alpha helix or beta-pleated sheets (also known as a beta strands).



B - pleated Sheet





? Tertiary structure

This is the folding of an alpha helix or beta-pleated sheet into a ***complex*** 3D Shape.

The tertiary structure of proteins if often maintained by a combination of hydrogen, ionic and disulphide bonds.

? Quaternary structure

This is the joining together of two or more polypeptide chains examples include insulin, collagen and haemoglobin.

1. **Hydrogen bonds:**

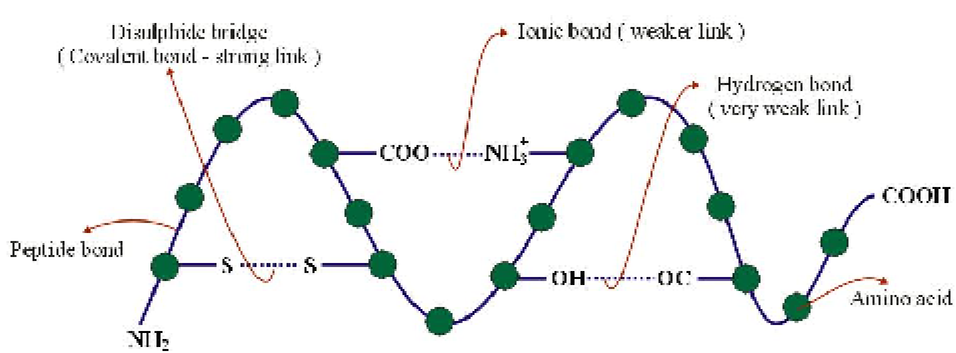
Occur between some H atoms (having a slight positive charge) an oxygen and nitrogen atoms (having a slight negative charge) i.e. molecules with dipoles. Although these bonds are weak, the large number of bonds maintains the three dimensional shape.

2. **Ionic bonds:**

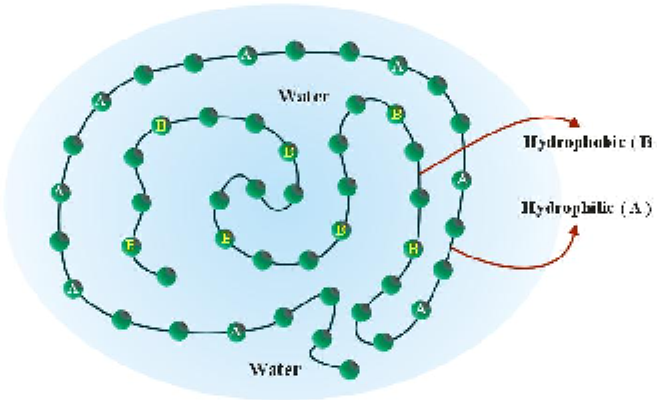
Occur between – COOH groups and – NH_2 groups found in the R groups. They are stronger than H bonds, but can be broken by changes in pH and temperature. This will become significant when you study the factors affecting enzyme activity.

3. **Disulphide bonds:**

Some amino acids, like cysteine and methionine contain sulphur atoms in the R-groups. Disulphide bonds can form between sulphur atoms of amino acids that are close together. These bonds are strong and contribute to the strength of structural proteins like collagen. They are also useful in linking the polypeptide chains of insulin together.



Note :
Hydrophilic and hydrophobic interactions also help to maintain the shape of globular proteins in water (solution). The hydrophobic (water hating) parts of the polypeptide chain face away from water by folding inwards. The hydrophilic parts of the chain remain on the surface of the globular structure.



Note: You are not expected to reproduce any of the diagrams needed for the primary, secondary, tertiary and quaternary structures.

Insulin is a globular protein. It is made up of two polypeptide chains linked by two disulphide bonds – Forming a quaternary structure.
The polypeptide chains are highly twisted and have sections where tertiary structures are present. The entire molecule is rolled up in to a globular shape or globule when dissolved in water (hydrophobic interactions). Insulin is a hormone (chemical messenger) whos functions include regulating blood glucose levels within mammals.

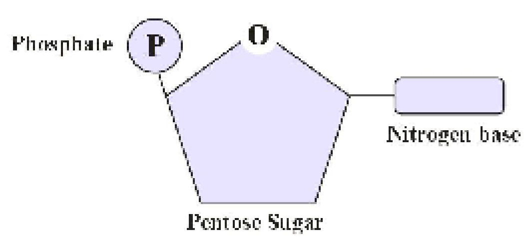
Collagen is a fibrous protein and hence is insoluble. This is an important different between globular and fibrous proteins. It is made up of three polypeptide chains (quaternary structure) each polypeptide chain is twisted to form a helix. The three polypeptide helixes wind around each other like a rope with three strands. Hydrogen bonds hold the three strands in place. This makes collagen very stable, insoluble, flexible, but inelastic. Collagen is found mainly in tendons and bones, teeth, and even the walls of blood vessels.

Test for proteins

RNA and DNA

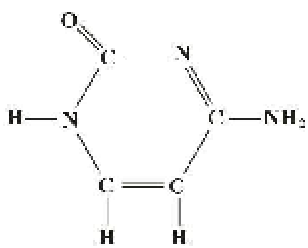
Ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) are made up by linking of many mononucleotides, by condensation reactions. A mononucleotides is made up of three parts

- ? An inorganic phosphate group;
- ? A pentose sugar (either ribose or deoxyribose);
- ? A base which contains nitrogen

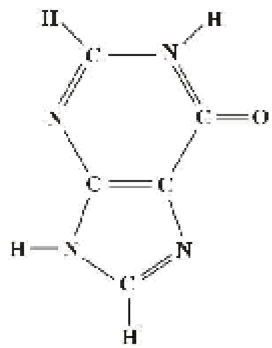


The nitrogenous bases are of two kinds:

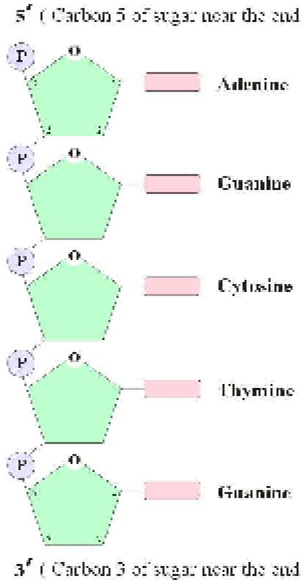
1. **Purines:** bases with a double ring structure.
   Eg: Adenine and Guanine
2. **Pyrimidines:** bases with a single ring structure.
   Eg: cytosine, uracil, thymine (PYCUT)



Cytosine (Pyrimidine)

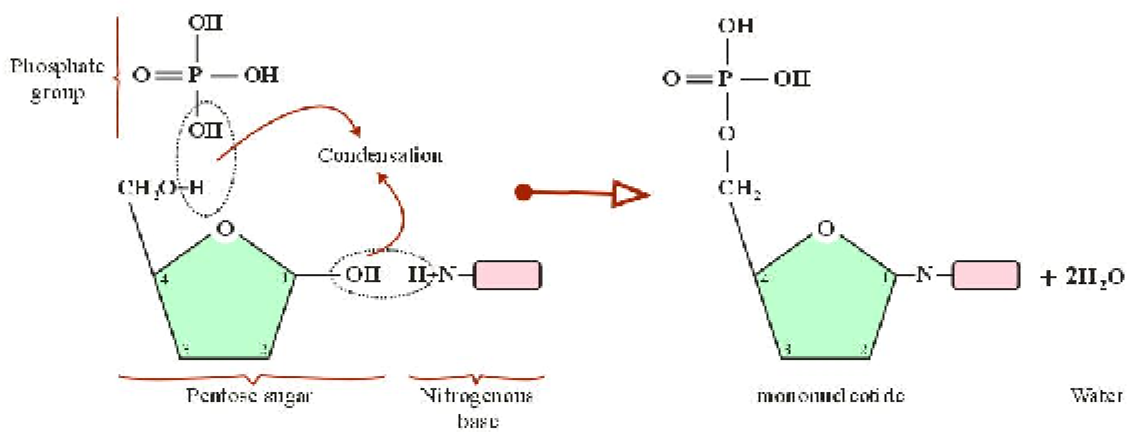


Guanine (Purine)



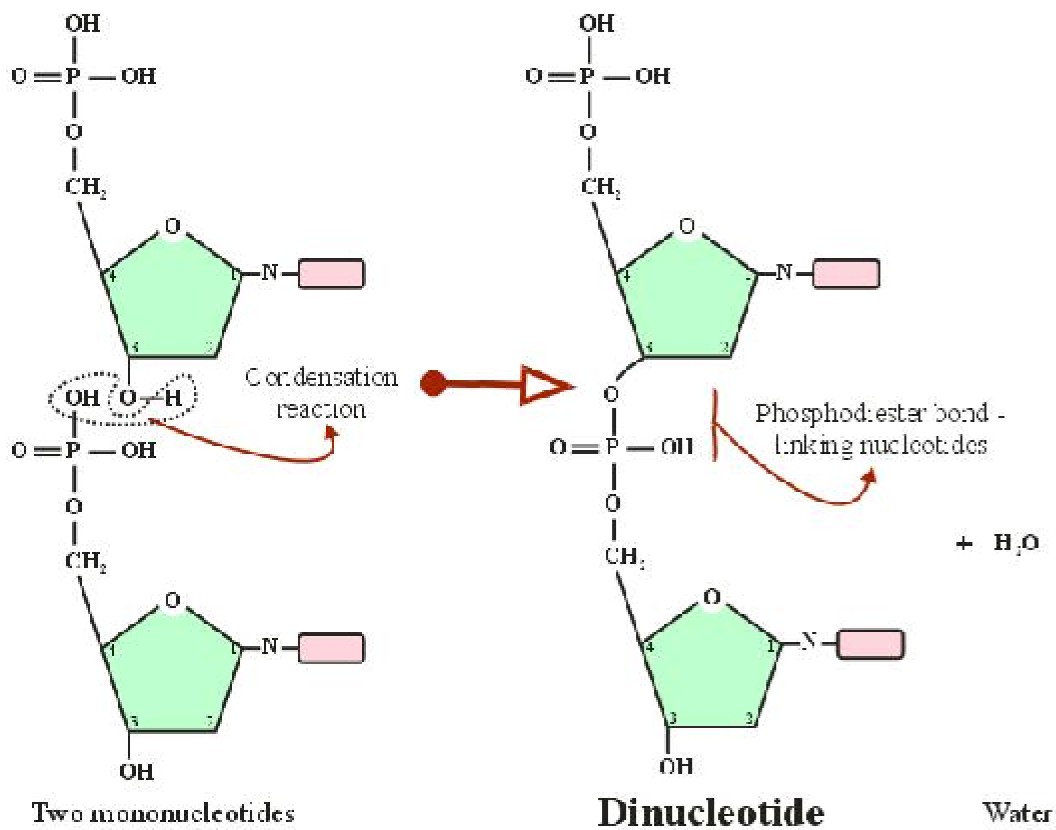
Polynucleotide chain

__Formation of a mononucleotide__.



Condensation reactions join up the phosphate and nitrogenous base to the sugar by removal of water molecules.

Formation of a polynucleotide by condensation.



- ? Many nucleotides can be linked by phosphodiester bonds to form a polynucleotide.
- ? Condensation reactions are involved in the formation of phosphodiester bonds.

- ? Carbon 5' of pentose binds with carbon 3' of pentose on another nucleotide by a phosphate group.

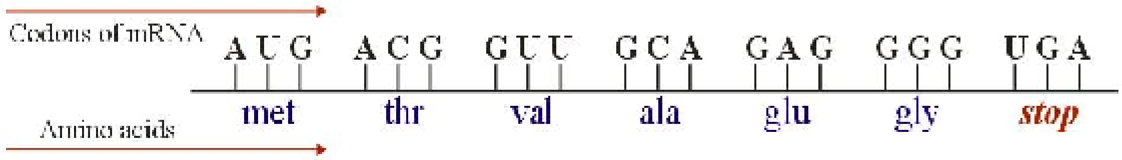
Role of mRNA and t RNA

mRNA is a single chain of poly nucleotides. It contains ribose sugar, phosphates and the nitrogenous base A, U, G, C (no thymine).

Function:
It is a complementary copy of a gene. Its function is to carry genetic information from DNA to ribosome for proteins synthesis. It is formed during transcription. (mRNA stands for *messenger* RNA)

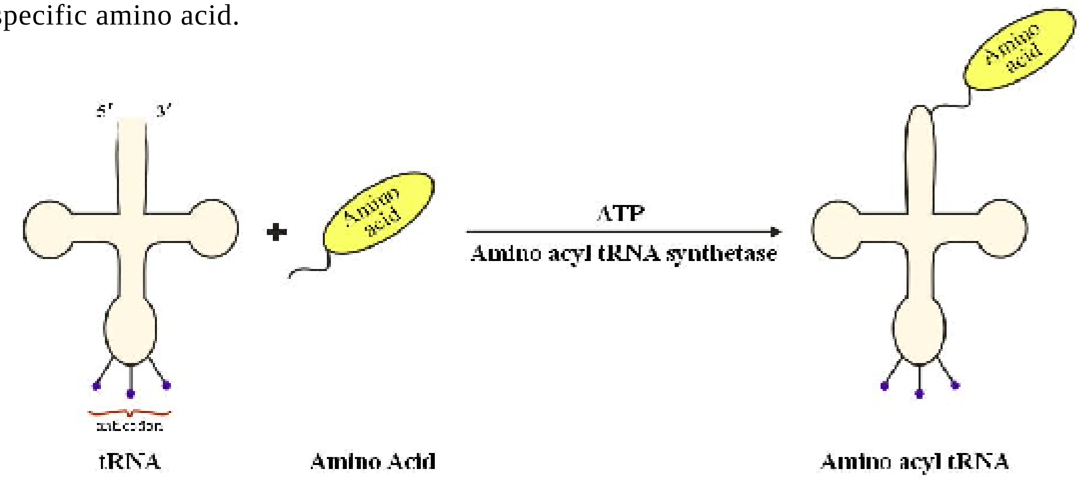
The genetic code can also be read from mRNA strand because it is complementary to DNA. A sequence of three nitrogenous bases on mRNA is called a **CODON**.

For example; here is the mRNA formed form the segment of DNA shown earlier



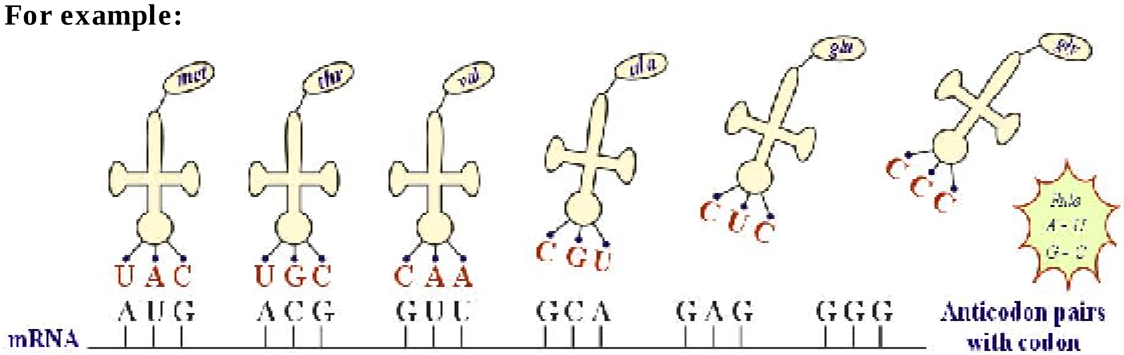
Structure and role of tRNA.

The main function of tRNA molecule is to transfer amino acids from the cytoplasm to the ribosome.
There are more than 20 different types of t RNA molecules in a cell, each carrying a specific amino acid.



The amino acid with which tRNA binds is determined by the anticodon of the tRNA. This enables the anticodon of tRNA to pair up with complimentary codons of mRNA and build up a specific sequence of amino acids in the polypeptide chain.

For example:



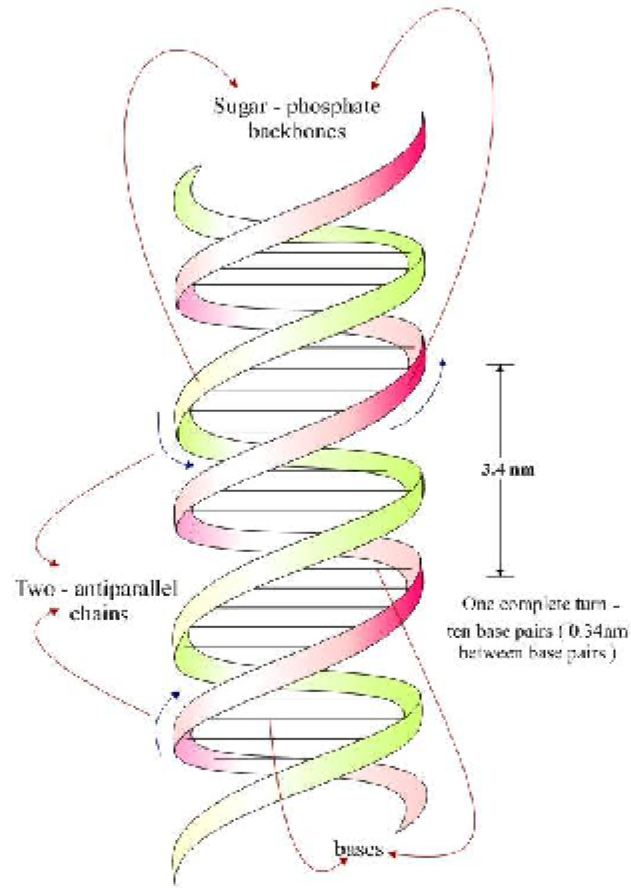
? tRNA is made up of a single chain of ribonucleotides – a ribose sugar, a phosphate group and a nitrogenous base (A, U, G or C). The chain is folded into a clover leaf structure due to H bonds between some base pairs.

? The anticodon is a sequence of a three bases that will pair up with complementary codons of mRNA.

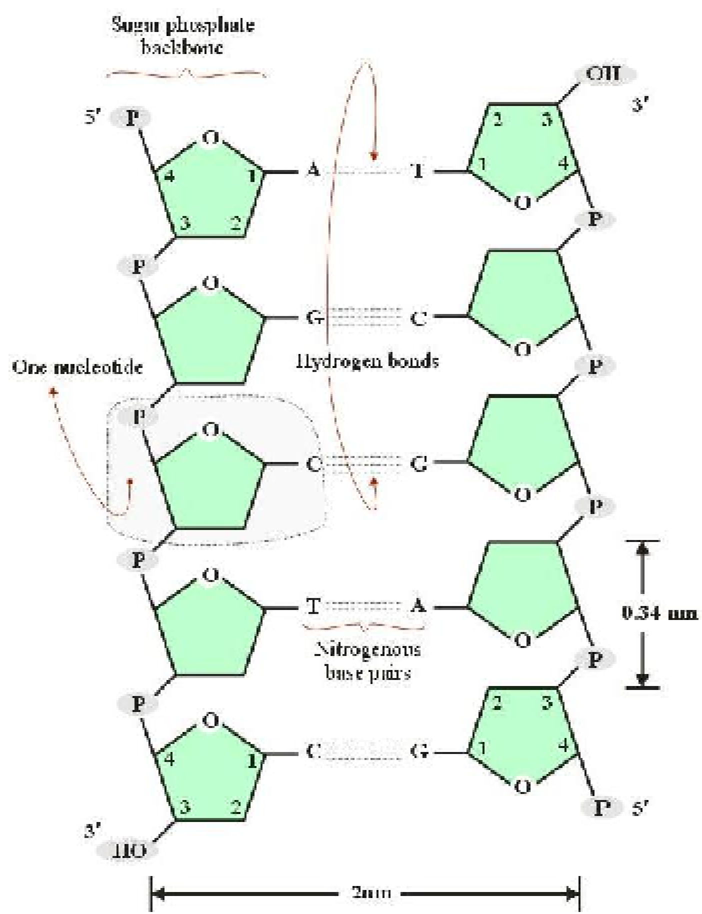
Structure of DNA

DNA is a polymer of deoxyribo-nucleotides (deoxyribose sugar , phosphate group and nitrogenous base).

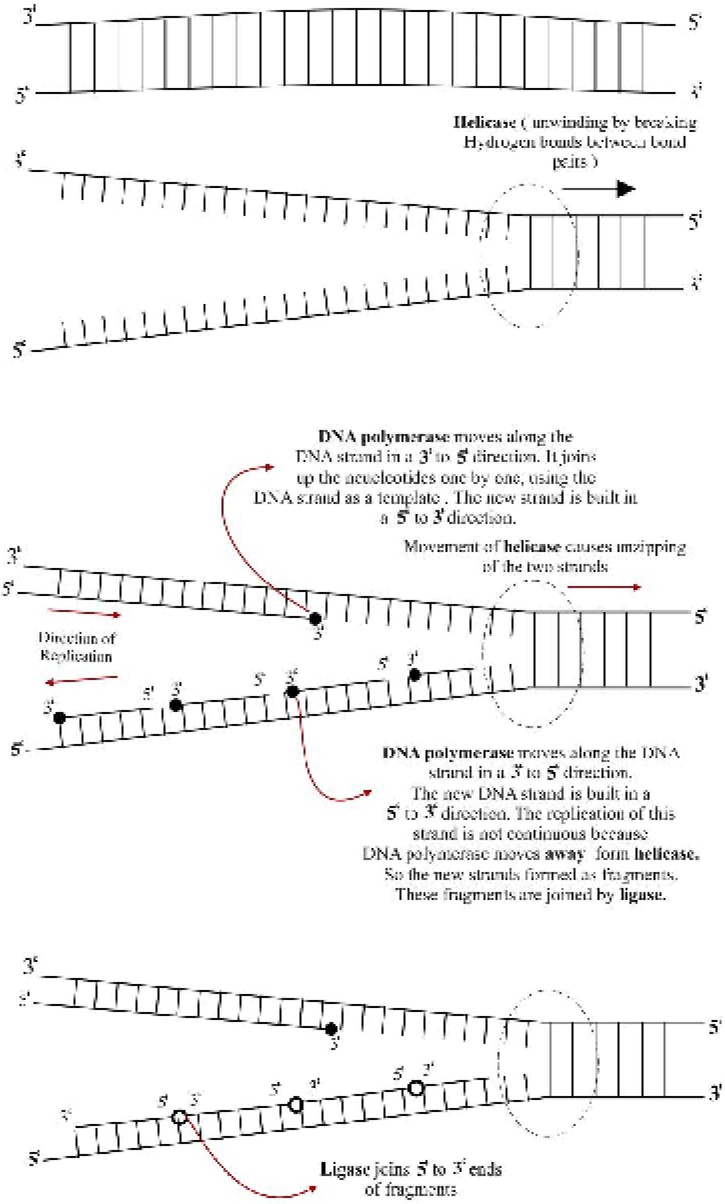
There are two polynucleotide strands which are anti parallel (one runs from 3' to 5' end and the other runs from 5' to 3' end), linked to each other by H bonds between nitrogenous base pairs (Adenine with Thymine A-T and Guanine with cytosine G-C) and wound in to a double helix (as shown in the diagram). The base pairs are 0.34 nm apart and there are 10 base pairs in one complete turn of the helix. Both strands are complementary to each other.

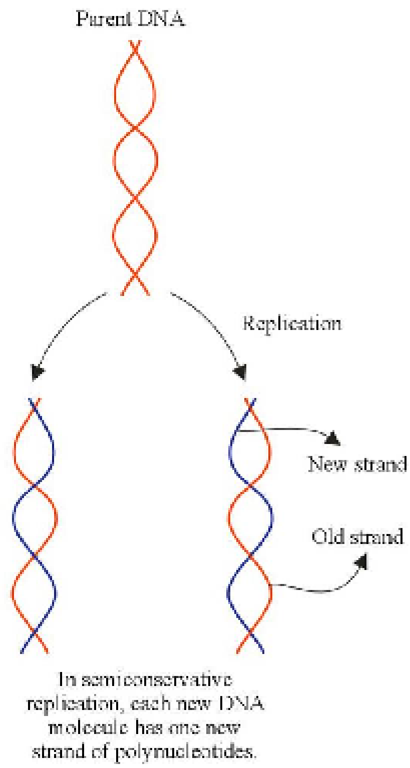


? The sequence of bases on DNA will determine the sequence of amino acids in a polypeptide chain.



? Replication is the formation of two identical molecules of DNA from the single parent molecule (DNA). It takes place during interphase.





The genetic code is the sequence of bases on DNA that determines the sequence of amino acids in a polypeptide chain (primary protein structure).

? **The genetic code is a triplet code** - this means that a sequence of three nitrogenous base (triplet) on DNA , codes for a single amino acid. eg;

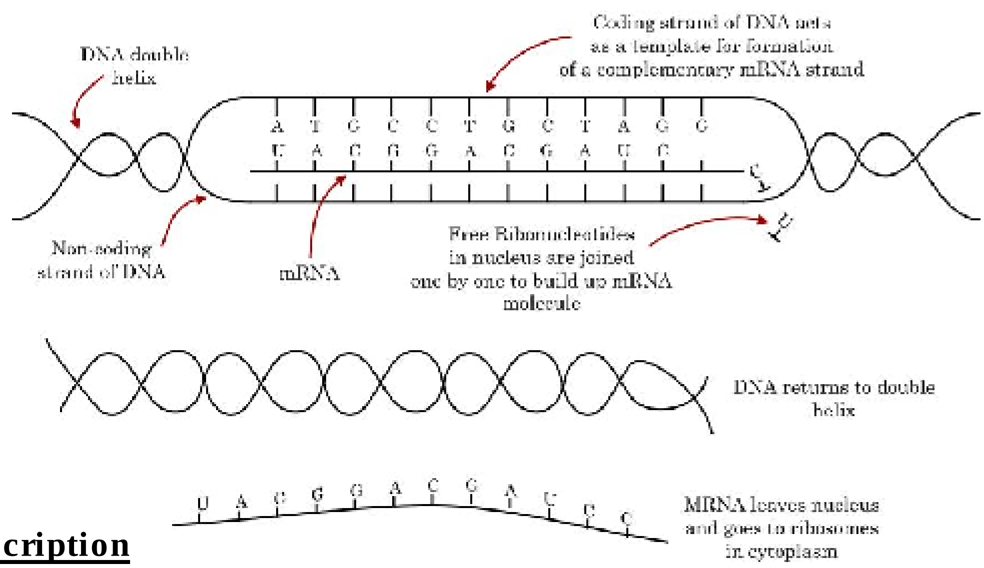
- **The genetic code is degenerate -** this means that a given amino acid can be coded for by more than one triplet code.
  Eg: GUC, GCC, GCA, GCG all code for the amino acid alanine.

- **The genetic code is universal -** The same triplets code for the same amino acids in all organisms (except for a few triplets in mitochondrial DNA and ancient bacteria).

What is a Gene?

A gene is a sequence of bases on DNA that codes for a sequence of amino acids in a polypeptide chain (primary protein structure).

<u>Protein synthesis (DNA makes mRNA; mRNA makes proteins)</u>



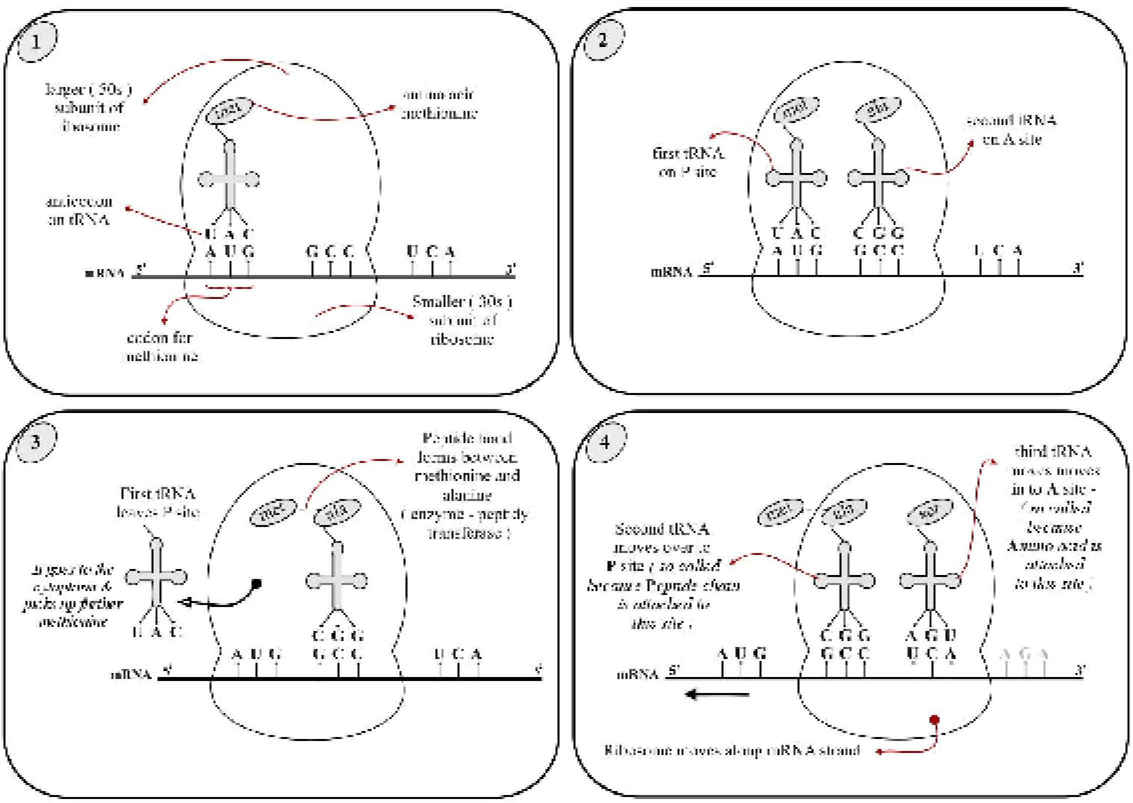
Transcription

This is the making of mRNA from DNA.
A length of DNA (a gene) is copied into an mRNA molecule.

- The unwinding of the double helix (by breaking H bonds) and the linking up of ribonucleotides to form mRNA is catalyzed by the enzyme RNA polymerase.
- Before leaving the nucleus, some parts of mRNA are cut of. These parts remain in the nucleus and are called introns. The remaining nucleotides rejoin and are called exons. The exons (mRNA) leaves the nucleus.

Translation

Using the genetic information (sequence of bases) on mRNA to form a polypeptide chain with a specific sequence of amino acids is called translation.
It occurs on the ribosomes in the cytoplasm.



The linking of amino acids (as shown above) to the polypeptide chain will continue until the stop codon is reached.
Note :
Main function of ribosome is to hold the mRNA molecule so that anticodons of tRNA can pair up with complementary codons of mRNA.
This brings amino acids to lie adjacent to each other so that peptide bonds can be formed.

Human Genome Project (HGP) - Goal: to identify the chromosomal location of every human gene and to determine the precise chemical structure (sequence of bases) and its application in health and diseases. It has revealed that the human genome has about 30,000 to 40,000 genes. The main role of these genes is to produce proteins.
Social, ethical, legal issues to be considered: the HGP has brought up many social, legal and ethical complications that have to be considered. Issues like who should be given access to an individuals' genome? Will there be discrimination on the basis of the type of genes that an individual possesses? Will parents abort children if their genome is undesirable? Will insurance companies refuse to insure people who have Huntington' s genes?Will employment opportunities be based on the genes of intelligence?

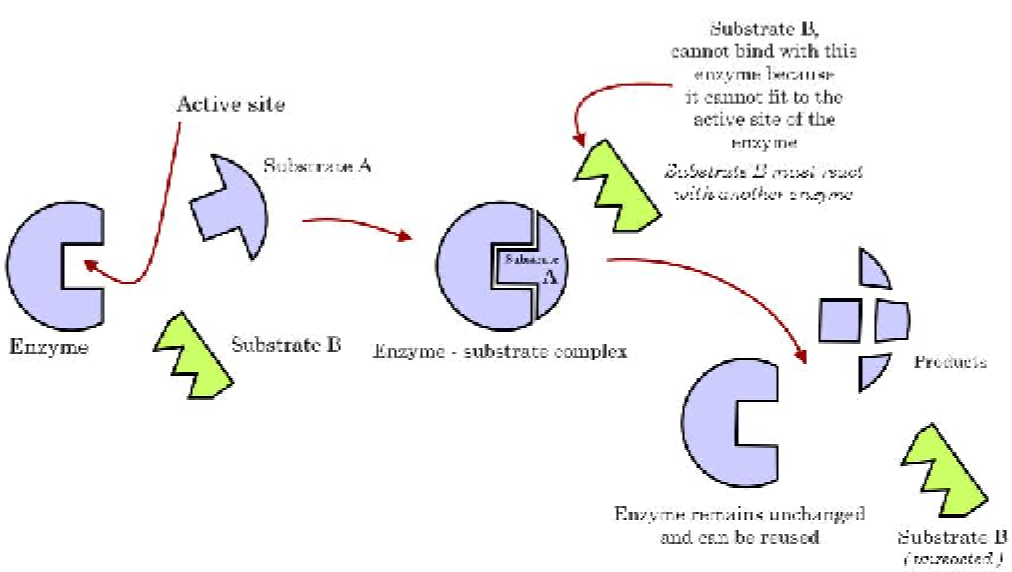
Enzymes

The bodies of living organisms undergo numerous changes throughout life. These changes are as a result of metabolic reactions. You will study such reactions as photosynthesis and respiration in more detail if you continue your studies into A2, for now however, its important to realise that these reaction are controlled by different ***enzymes.***

Enzymes are biological catalysts. They speed up the rate of a chemical reaction by lowering the activation energy required for that particular reaction, whilst being unaltered in the process. At the beginning of any reaction, a substance which an enzyme is attempting to hydrolyse is known as the ***substrate***. The new substance which is formed as a result of the enzyme catalysed reaction is known as the ***product***

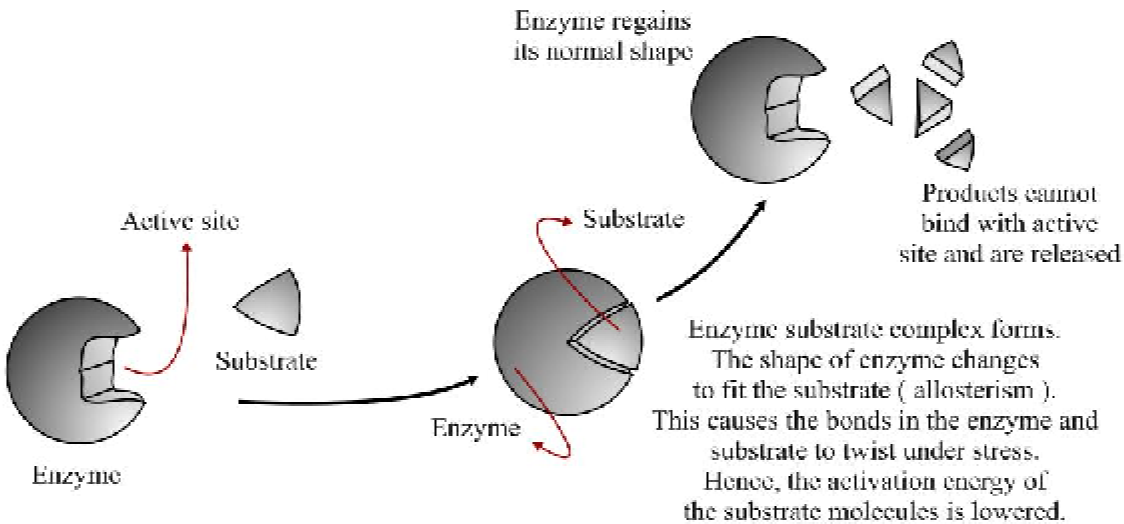
All enzymes are ***globular proteins*** **-** the secondary protein structure is folded into a spherical or globular shape. Hydrogen bonds, ionic bonds, disulphide bridges and hydrophobic interactions (between R groups of amino acids) maintain the specific three dimensional shape of the enzyme i.e. the tertiary structure. Different enzymes have different 3D shapes essential for their correct functioning in the reactions they catalyse. The part of the enzyme which reacts with the substrate is called the ***active site.*** The shape of the active site differs from one enzyme to another. This makes the enzyme react only with a specific substrate, which fits the active site. This property is known as ***enzyme specificity***. There is a hypothesis that enzymes react using a " " Lock and key" mechanism which suggests that a substrate specific to a particular enzyme will fit like a key into the enzyme' s active site. This can be summarised in the diagram below. You will not be expected to explain this theory in detail in examination answers, however it may be useful to know for any future essays you may choose to write about enzymes.

Lock and Key hypothesis - Explains specificity of enzymes



Activation energy is the minimum energy that the reactant molecules must posses in order to start a reaction.
Thus to start a reaction, energy must be supplied to the substrate molecules. This energy is called the activation energy.
Enzymes lower the activation energy and provide an alternate (lower energy) pathway for the reaction to proceed. Thus the rate of reaction speeds up (catalyst).

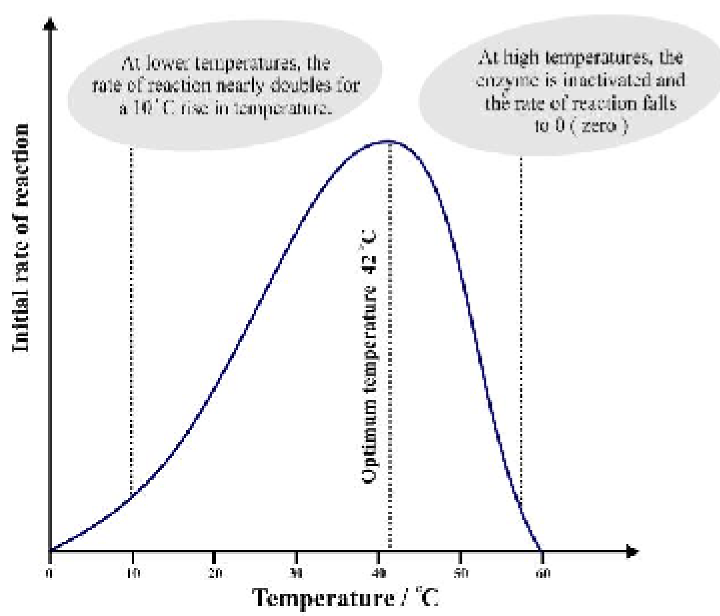
The induced fit model of enzyme activity explains how enzymes reduce activation energy (this could not be explained by lock and key model).



Note : Interestingly it is believed that the R groups in enzymes form temporary bonds with the substrate!

Factors affecting enzyme activity

As temperature increases up to the ***optimum*** (the temperature at which the enzyme works fastest, but not necessarily its best temperature), the rate of enzyme activity also increases.



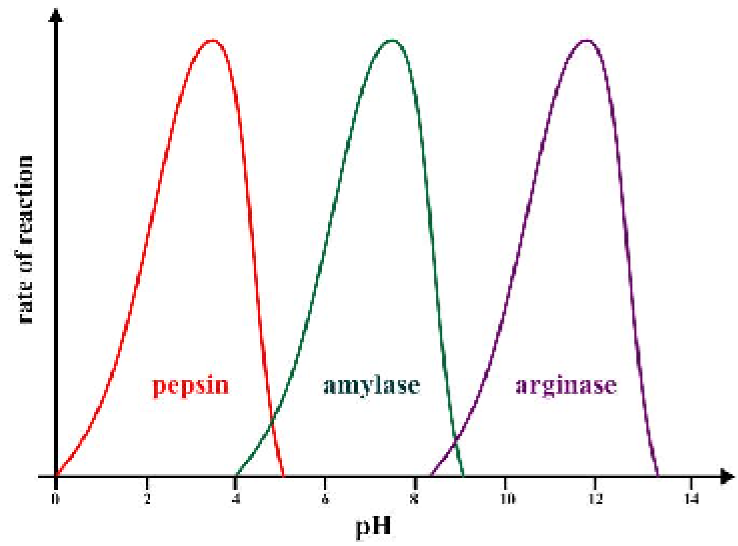
This is because enzyme and substrate molecules gain more kinetic energy and the collisions between active sites of enzymes and substrate molecule become ***more frequent.***

The *rate* of enzymes

substrate complex formation increases so enzymes activity speeds up.

Beyond the optimum temperature, the rate of enzyme activity decreases because the high temperature causes the enzyme molecule to lose its specific 3D shape (due to breaking of Hydrogen bonds and other bonds which help, maintain the tertiary structure). The active sites cannot therefore bind with substrate, so enzyme substrate complexes cannot form.

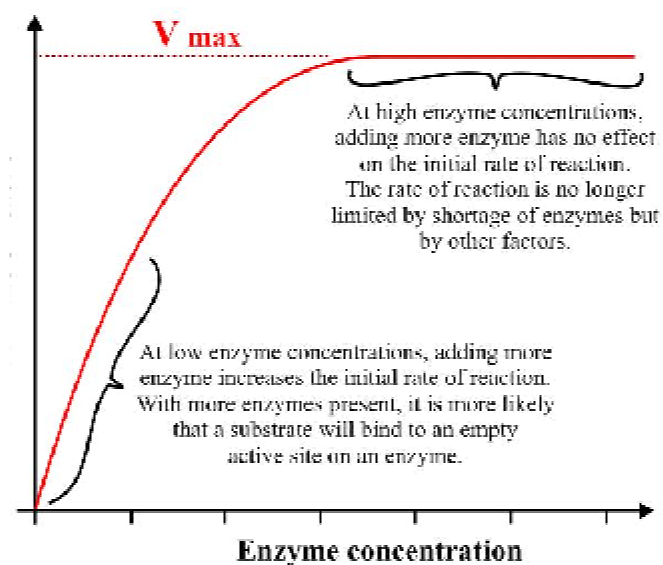
Effect of pH on enzyme activity:



Enzymes are very sensitive to changes in pH.
Every enzyme works best within a very narrow range of pH.
If the pH changes above or below the optimum then rate of reaction will decrease.

This is because at the optimum pH the H^+ ions / OH^- ionic balance (pH) of the solution is just right to maintain the specific 3D tertiary structure of the enzyme.
If pH changes then the change in H^+ ion concentration will disrupt the H bonds and the ionic bonds which maintain the tertiary structure of the enzyme.
This will cause the enzyme to change its shape so that the active site cannot bind with substrate molecules.
Enzyme substrate complexes will form at a slower rate, so rate of enzyme activity decreases / stops.

Enzyme concentration:

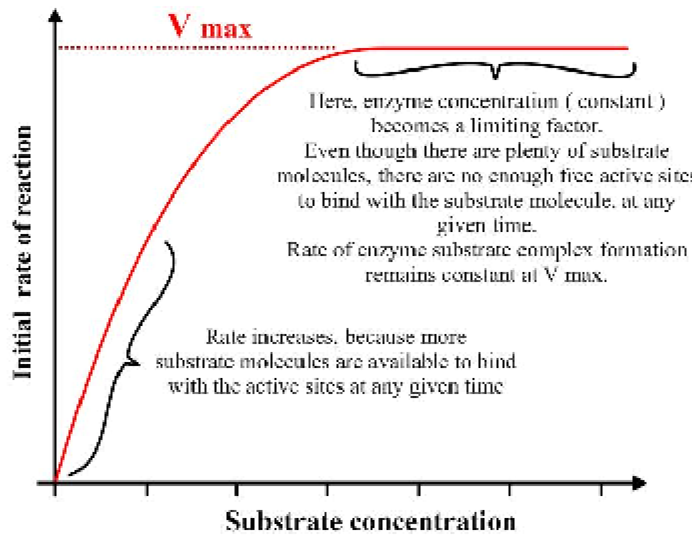


As the enzyme concentration increases (at constant substrate concentration) the rate of reaction increases until it reaches a maximum rate (V max).
This is because there will be more number of free active sites, at any given time.
So the rate of enzyme substrate complex formation increases.
Thus rate of reaction increases.

The rate doesn’ t increase beyond the V max because the substrate concentration becomes a limiting factor.

Even though there will be many free active sites, there will not be enough substrate molecules to bind with them. So, rate of enzyme substrate complex formation remains constant at V max.
But, increasing substrate concentration would further increase the rate of reaction.

Substrate concentration:



Rate will increase further if enzyme concentration is increased.

Note: when a graph begins to flatten out we often say that it begins to plateau or it plateaus. Also be aware that when an enzymes structure changes to such an extent where it cannot bind to its substrate any longer, its said to be ***denatured***

Inhibitors are substances that reduce the rate of enzyme activity. There may be two types of inhibitors:

Active site directed inhibitors.

These are also known as ***competitive*** inhibitors because they will compete with the substrate for the active site of enzyme.

They usually have a similar shape to the substrate and will bind with the active site, preventing the formation of enzyme-substrate complexes, thus decreasing rate of reaction.

However, at high substrate concentration, the inhibitors are less likely to bind with the active site (as substrate molecules outnumber the inhibitors), so the rate of enzyme-substrate complex formation and rate of reaction increases.

Non active site directed inhibitors.

These are **non- competitive** inhibitors which bind to the enzyme molecule and change the shape of the active site. This will prevent formation of enzyme substrate complex formation, reducing the rate of enzyme action.

Roll of pectinases in food modification

Pectin is a polysaccharide found in the cell wall and middle lamella of plant cells. They have a branching structure which readily traps water to form a gel. This property is used in jams, but if we want to make fruit juice or wine the pectin holds the juice in the gel and the juice appears very cloudy. This is called the ***pectin haze.***
Pectinase is added to crushed fruits to hydrolyzed the pectin molecules and make it easier to extract the juice. The breaking down of cell wall and addition of pectin gel to the juice increases the ***yield***.
Pectinase can also clear pectin haze by hydrolyzing pectin molecules into soluble sugars. Pectinase is also used in the production of olive oil, to soften the olives and make extraction of oil easier. It also can be used to clear pectin haze and make olive oil clear.

Proteases in biological detergents:

Proteases are used in ***biological detergents*** to remove stains like blood, grass stains, fruit juice, gravy, egg stains, etc. which contain ***insoluble*** proteins.

Protease hydrolyses large insoluble proteins into soluble amino acids by breaking of peptide bonds. This helps to remove protein stains easily (by dissolving them) at lower temperatures. Previously, proteins stains had to be removed by boiling the clothes.

Early biological washing powders caused allergies when inhaled or when it came in contact with the skin. This problem was over come by immobilization of the enzymes in capsules. The enzymes used are obtained from bacteria, which work best in alkaline medium and over a wide range of temperatures.

Immobilization of enzymes (holding enzymes in place):

Immobilization is a process by which enzymes are trapped in insoluble material such as beads of alginate or in cellulose fibres. The main advantages of using immobilized enzymes are**:**

The enzymes can be re used**:** this reduces the overall cost of production. Less money but must be spent to buy expensive enzymes.

Enzymes do not have to be separated from the products**:** this reduces the cost of purification of products and also saves valuable time.

Enzymes are more stable**:** less likely to be affected / denatured by changes in temperature or pH. They can be used at higher temperatures which will decrease reaction time. This makes the reactions faster. Temperature and pH regulation becomes easier.

***More than one enzyme can be fixed in order*:** this gives us greater control in industrial process. It allows industrial processes to use several enzymes, one after another, continuously, allowing the use of automated machines. This reduces cost and save time, making production more efficient and less labour intensive.

Immobilized lactase is used in modification of lactose in milk. It hydrolyses lactose into glucose and galactose.

This has many applications:

- Lactose in milk is hydrolysed so that it can be consumed by *lactose intolerant* people who cannot digest lactose (as they do not produce lactase).

- It sweetens the milk without adding additional sugars, because glucose and galactose are sweeter than lactose. This is useful in ice cream production.

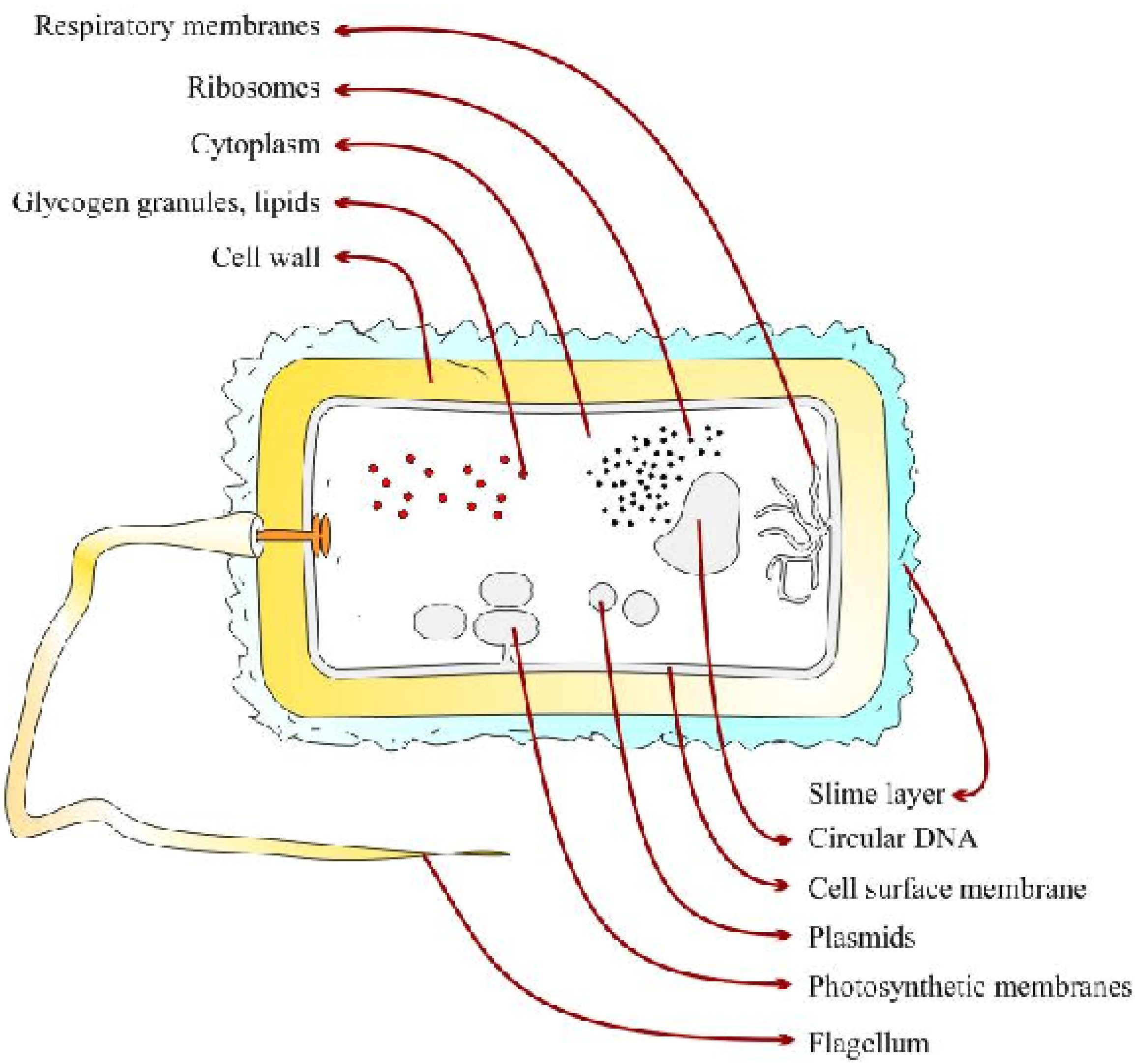
- Lactose crystallizes at low temperatures. This would give ice-cream a sandy texture.
  Use of lactase in ice cream production will remove lactose, so that no crystals form and the ice cream is creamy and smooth.

- Whey is the liquid obtained from milk during cheese production. This is usually discarded as a waste product.
  However; treatment of whey with lactase can yield sweet syrup, containing glucose and galactose.

Note: Common unit 1 questions ask for the advantages of immobilisation of enzymes. Make sure you LEARN IT!

Cellular organisation

Bacterial cells have a cell wall made up of murein or peptidoglycan.
There is no nuclear envelope surrounding the DNA/chromosome. Membrane bound organelles or vesicles are absent (mitochondria, endoplasmic reticulum, golgi appartus, chloroplast, lysosomes, vacuoles are absent).
Ribosomes are smaller (70S).
The generalized structure of bacterial cell and the roles of each structure is shown in the diagram below



? **Respiratory membranes (mesosomes):** Much folded intucking of cell surface membrane where respiratory enzymes are situated.

? **Ribosmoes (70S) :** Sites of protein synthesis (Translation).

? **Cytoplasm :** Site of all metabolic activities.

? **Glycogen granules, lipids :** Energy storage compounds.

? **Cell wall :** Provides shape and physical support to the cell.

? **Slime layer (capsule) :** Prevents desiccation, protects from enzymes of host.

? **Circular DNA :** Contains the bacterial genome, which codes for all structural proteins and enzymes.

? **Cell surface membrane :** Selective permeability of the membrane maintains appropriate composition of cytoplasm.

? **Plasmids (extra-chromosomal DNA) :** Produces proteins which help bacteria to survive in harsh environments.
Also helps to develop resistance to antibiotics.

? **Photosynthetic membranes (thylakoid):** Intucking of cell surface membrane where photosynthetic pigments are present.

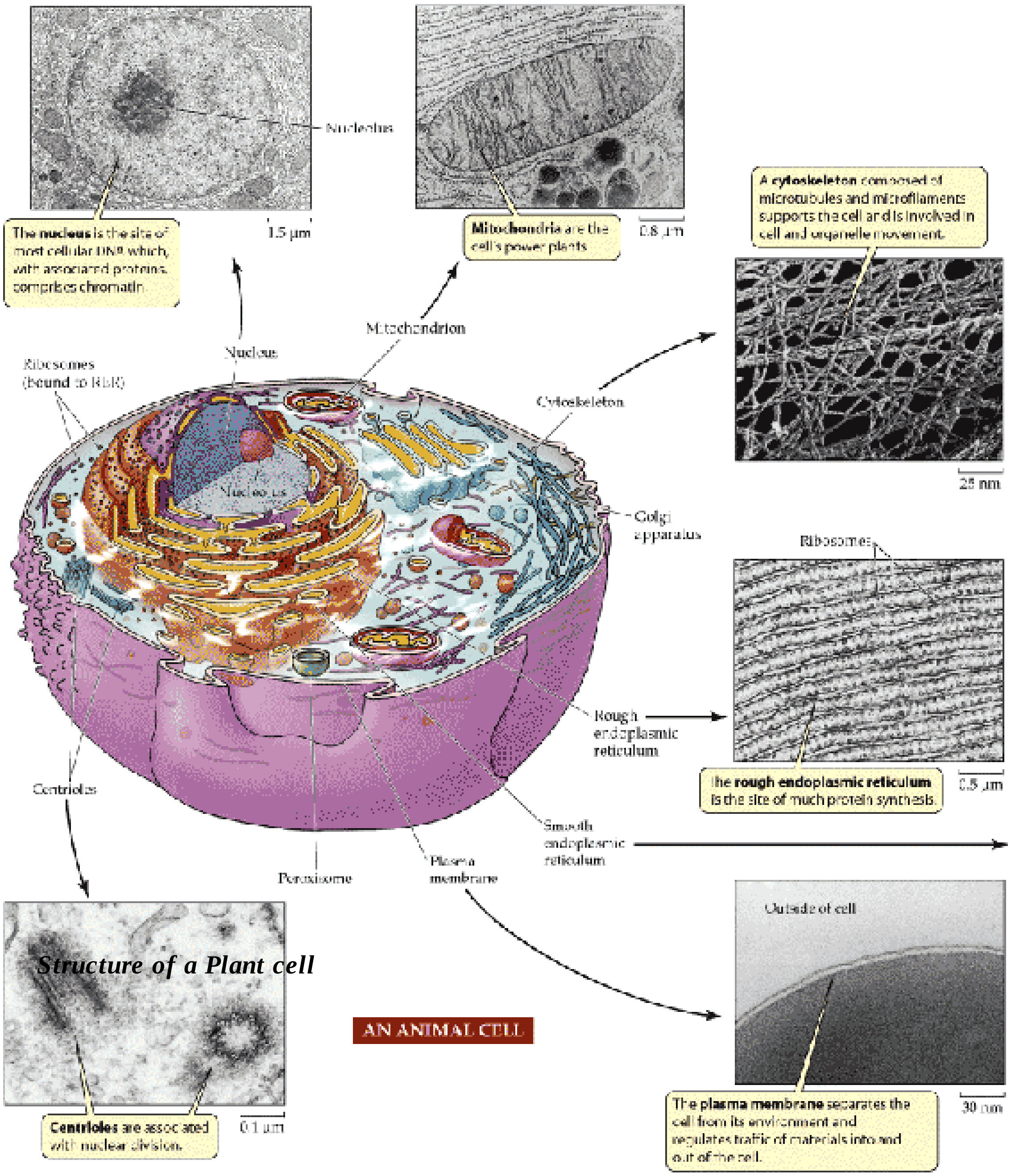
? **Flagellum ;** Helps in locomotion. Lacks 9 + 2 arrangement of microtubules.

E.coli is a rod shaped intestinal bacteria. It measures about 2.5 µm to 0.5µm. It can be seen using a light microscope. It is non – photosynthetic. Special cellular extension, called pili, can make direct contact with other bacterial cells and exchange genetic material. This is called conjugation.
E.coli is gram negative and appear pink when stained by the gram staining technique

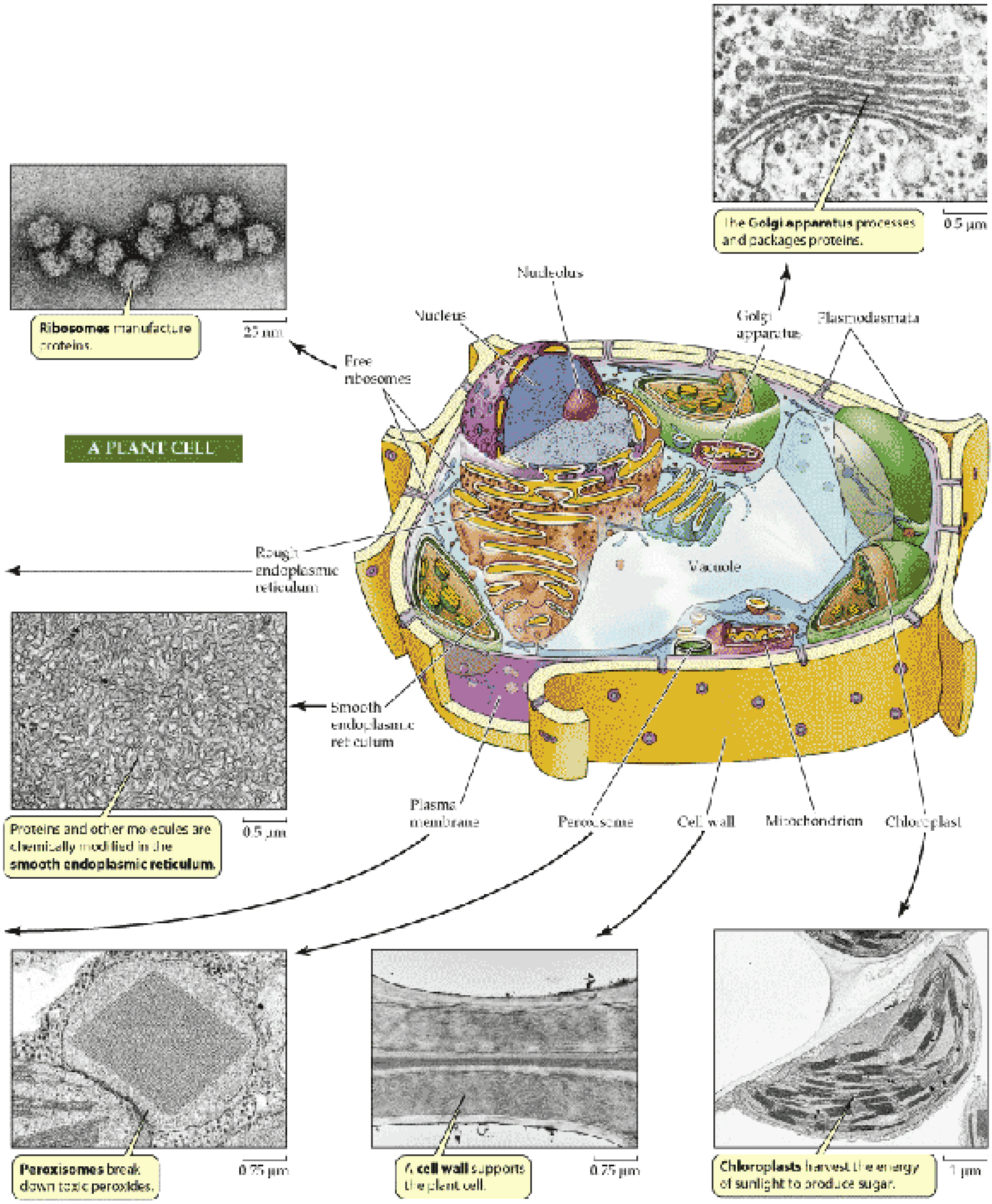
Eukaryotic cells have a true nucleus, i.e. the chromosomes are surrounded by a nuclear envelope. Membrane bound organelles, like mitochondria, chloroplasts, Golgi bodies, endoplasmic reticulum, lysosomes and vacuoles. Ribosomes are larger (80S) the structure of a generalized plant cell and an animal cell as revealed by the light microscope is shown in the diagram below.

__**Structure of eukaryotic cells revealed by an electron microscope.**__

Structure of an Animal cell



Structure of a Plant cell



The Golgi apparatus processes and packages proteins.
0.5 µm
Ribosomes manufacture proteins.
25 nm
A PLANT CELL
Nucleolus
Nucleus
Golgi apparatus
Plasmodesmata
Free ribosomes
Rough endoplasmic reticulum
Vacuole
Smooth endoplasmic reticulum
Proteins and other molecules are chemically modified in the smooth endoplasmic reticulum.
0.5 µm
Plasma membrane
Peroxisome
Cell wall
Mitochondrion
Chloroplast
Peroxisomes break down toxic peroxides.
0.25 µm
A cell wall supports the plant cell.
0.25 µm
Chloroplasts harvest the energy of sunlight to produce sugar.
1 µm

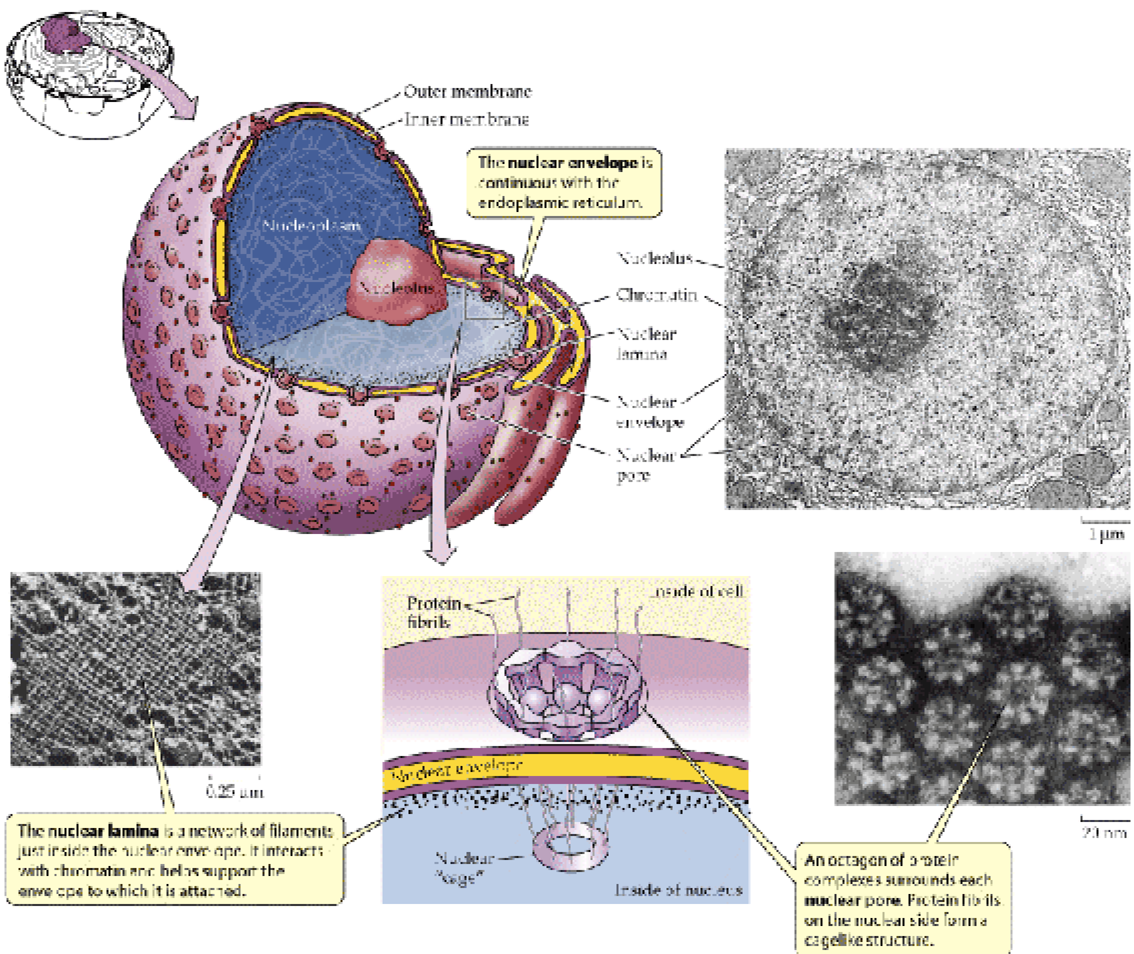
Nucleus:

The nucleus is the part of the cell that contains the DNA. It is surrounded by a nuclear envelope (double membrane with a space between them).

In an interphase cell, the DNA is not visible as chromosomes but appear as disorganized material called chromatin.
In some parts the chromatin appears to be densely packed and is called heterochromatin. In other parts it looks lighter in color. This is the euchromatin.

DNA in heterochromatin is not active (as it is coiled up around histones), but DNA in euchromatin is involved in transcription or replication.

The nucleus



Nucleolus:

This is a region of the nucleus which stains very dark.

Ribosomal RNA (rRNA) is made in this region by transcription from DNA.

The small and large subunits of ribosomes are assembled here.

They leave the nucleus through the nuclear pores and are assembled into complete ribosomes.

The nuclear envelope has pores, which allow RNA, ribosome subunits to move out of the nucleus and DNA polymerase, helicase, ligase, nucleotides, etc to enter the nucleus.

The inner membrane of the nucleus is usually continuous with the endoplasmic reticulum, which may contain ribosomes.

<u>Rough endoplasmic reticulum</u>:

Endoplasmic means “inside the cytoplasm” and reticulum means “network”. Thus the endoplasmic reticulum is a network of membranes running through the cytoplasm of every cell. These membranes enclose spaces called cisternae which forms an inter connecting channel throughout the cytoplasm.

Ribosomes are attached to the endoplasmic reticulum giving it a “rough” appearance.

Roles:

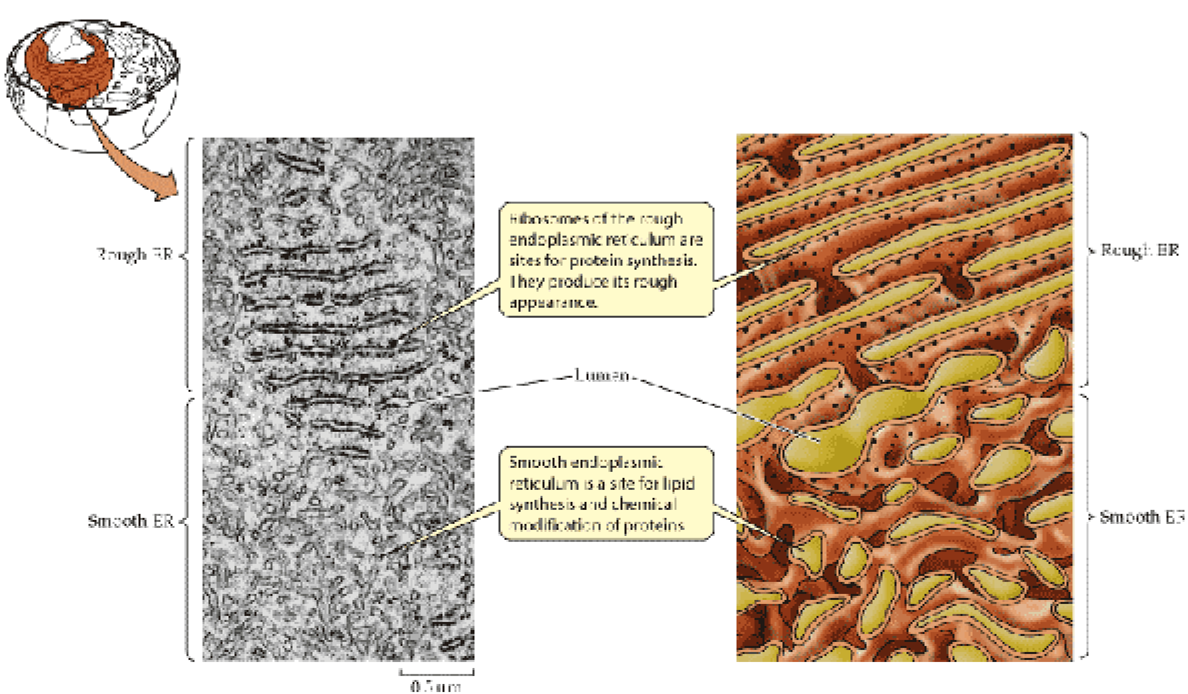
- ? Providing a pathway for transport of materials through the cell.
- ? Producing proteins, especially enzymes (for secretion) and structural proteins for cell repair.

<u>Smooth endoplasmic reticulum</u>:

When ribosomes are not found on the endoplasmic reticulum, then it is called smooth endoplasmic reticulum. However, here the lamellae (membranes) from tubular structures instead of flattened sacs.

Roles:

- ? Involved in lipid and steroid synthesis .
  eg. secretion of sebum.

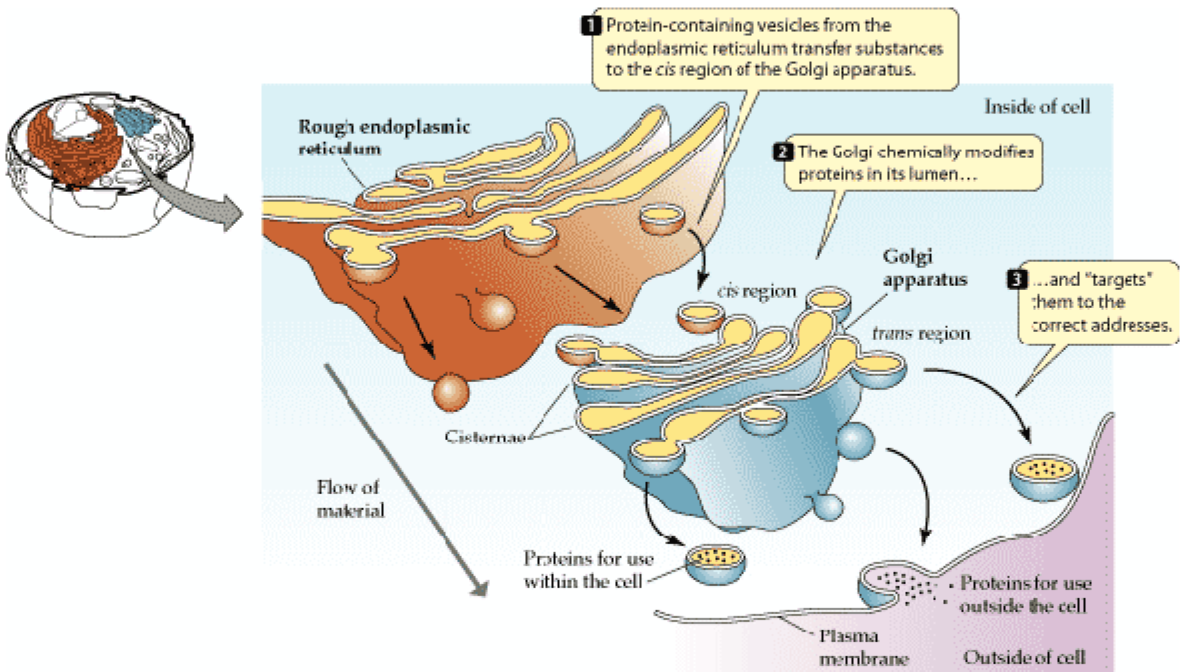


Golgi apparatus:

The golgi body / apparatus consists of a stack of flattened membrane bound sacs called cisternae. Small vesicles fuse with the cisternae at the *cis* region / forming face. These vesicles usually contain proteins from the RER. The proteins are modified as they pass through the cisternae and are finally released in vesicles from the *trans* region / maturing face.

Roles:

- Producing glycoproteins such as mucin, by adding carbohydrate to proteins.
- Producing secretory enzymes. e.g.: digestive enzymes of the pancreas
- Forming lysosomes.



Lysosomes:

These are spherical bodies (about 0.5 nm in diameter) they are filled with about fifty different hydrolytic enzymes, in acidic solutions. These are found only in animal cells.

Roles:

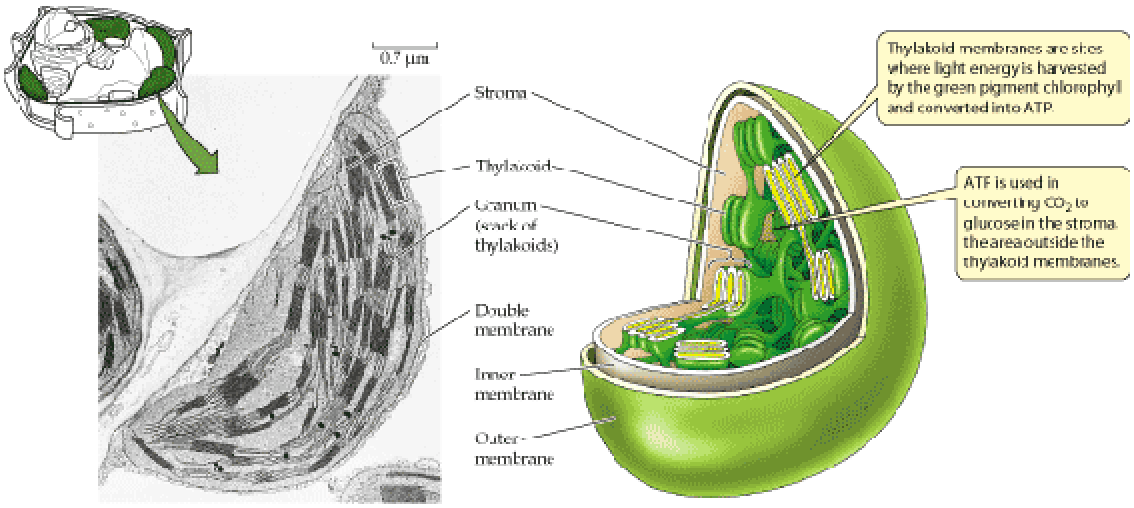
- To digest materials that the cells consume from the environment. Eg: bacteria engulfed by white blood cells. The bacteria are hydrolyzed by the hydrolytic enzymes from lysosomes. The useful substances are absorbed into the cytoplasm of the WBCs and undigested components are removed by exocytosis.
- To digest parts of the cell or worn out organelles, in a similar way as above, this is called autophagy. (Scavanger of the cell).
- To release their enzymes by exocytosis and break down other cells. e.g.: during metamorphosis of tadpoles. (Suicide bag of the cell).

Chloroplasts:

Found only in plant cells.
Each chloroplast is surrounded by a double membrane (envelope).
The inside is filled with a gelatinous matrix called stroma.
In the stroma, there are stacks of thylakoid membranes called grana.
Some thylakoid membranes connect one grana to another. These are intergranal thylakoids or lamella.
Chlorophyll is embedded into the thylakoid membranes.
Starch grains, circular DNA and 70S ribosomes are also found in the stroma.

Role:

? sites for photosynthesis

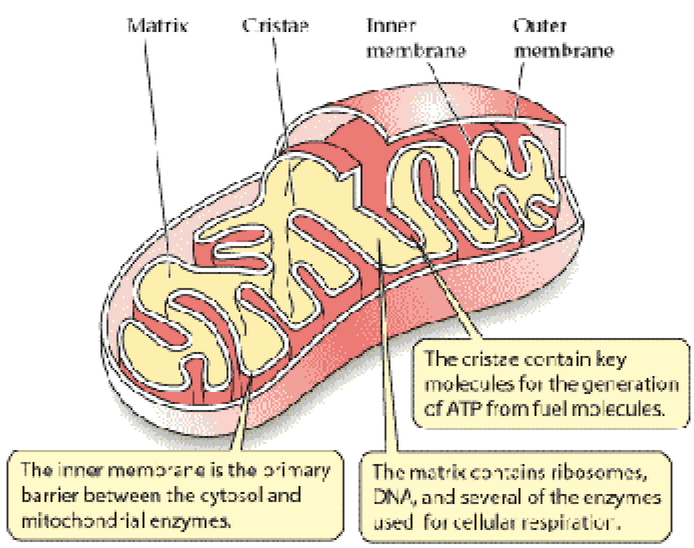


Mitochondria:

These are rod shaped organelles bound by a double membrane, separated by an intermembranal space.
The inner membrane has many infoldings called cristae. The inner membrane encloses a semi rigid substance called matrix.
Circular DNA and 70S ribosomes are present.

Role:

? Site of aerobic respiration in eukaryotic cells.



Ribosomes:

Ribosomes appear as small black dots in electron micrographs. Some are found free in the cytoplasm, while others are attached to the outer surface of membranes of the rough endoplasmic reticulum (RER). Each ribosome is made up of a small sub unit (30S) and a larger subunit (50S). The larger sub unit is made up of two molecules of rRNA and proteins, the smaller subunit is made up of one rRNA molecule and proteins.

Role:

- Sites of protein synthesis (translation).

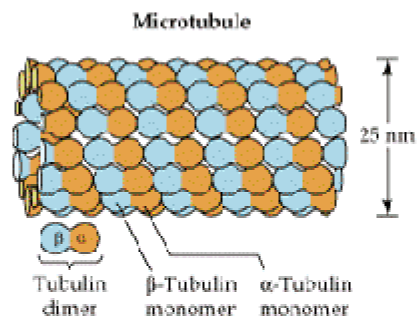
Centrioles

Centrioles are hollow cylinders of microtubules. Each centriole is made up of 9 triplets of microtubules. They are found in the cytoplasm. There are two centrioles arranged at right angles to each other, to form the centrosome.

Role:

- During cell division they replicate and move towards the poles of the cells and help in organizing the spindle fibers during cell division in animal cells.

Microtubules



These very fine, tubular organelles made up of repeating units of proteins called tubulin.
They are straight unbranched hollow structures which vary in length but have an external diameter of about 20 to 25 nm

Role:

- To provide an internal skeleton (cytoskeleton) for cells and so help to determine its shape.
- To aid transport within cells by providing routes along which materials move.
- As a major component of Cilia and flagella.
- In the formation of spindle during cell division, it helps to pull chromosomes / chromatids apart (to opposite poles).

Cellulose cell wall:

The cell wall is a characteristic feature of a plant cell. It consists of cellulose microfibrils embedded in an amorphous polysaccharide matrix of pectins, hemicelluloses and lignin. The arrangement of microfibrils may be regular or irregular.

Role

- To provide mechanical strength and support to the cell.
- To resist expansion of the cell when water enters (turgidity).

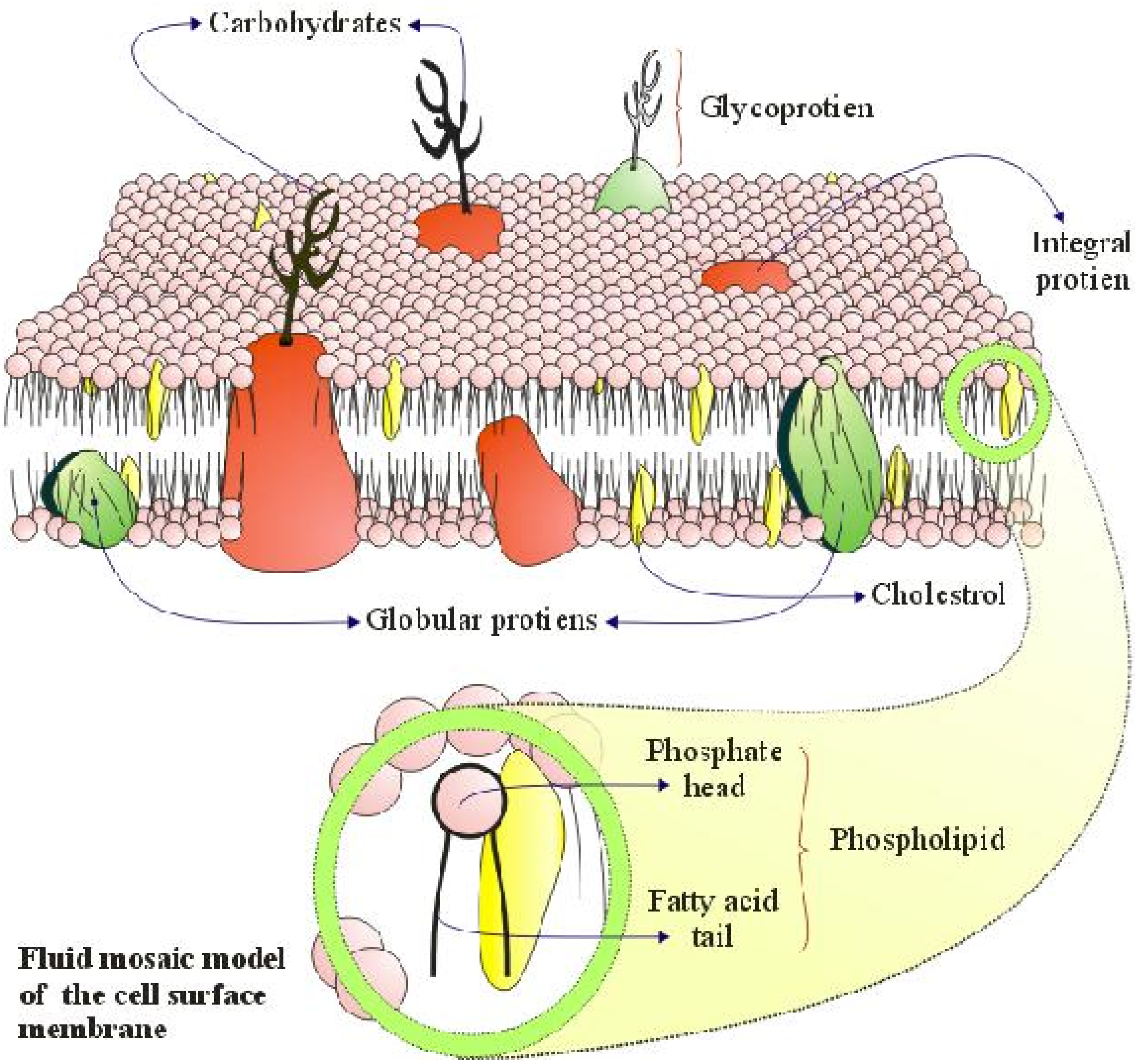
Cell surface membrane.

Structure/ properties and roles:

The **Cell surface membrane** is made up of a phospholipid bilayer, with hydrophilic phosphate heads facing towards water molecules on the membrane surface.

The hydrophobic fatty acid tails face away from water molecules on the membrane surface.

This hydrophobic region forms a barrier to polar molecules like Na^+, K^+, Ca^{2+}, Cl^-, etc…



However , lipid soluble, non polar molecules like CO_2, O_2, cholesterol, fatty acids etc… can pass across the phospholipid bilayer. Water can pass through the phospholipid bilayer because of its small size and relatively low polarity.

Proteins are embedded into the phospholipid bilayer. These proteins allow certain polar molecules and ions to pass across the membrane. Hence they are often referred to as channel proteins, carrier proteins or transporter proteins. They are specific and will allow only certain substances to pass across.

Some of the proteins (extrinsic proteins) act as enzymes, recognition sites and electron carriers. The proteins also provide structural support for the membrane. Branched chains of carbohydrates maybe attached to some phospholipid molecules (glycolipids) or to proteins (glycoproteins).

The carbohydrates act as recognition sites for neurotransmitters, hormones or for cell to cell recognition.

Cholesterol makes the membranes less fluid and more stable. This model of cell surface membrane is called the ‘ fluid mosaic’ model.
Fluid means that molecules can change places within the membrane.
Mosaic means that proteins are embedded randomly in to the phospholipid bilayer.

Role:

? Selectively permeable membrane helps to prevent passage of some substances and allow passage of other substances. This helps to maintain the appropriate composition of the cytoplasm.

Magnification and resolution:

Magnification is how many times larger an image is when compared to the object.

Magnification = size of image / size of object.

The magnification produced by a light microscope depends on the strength of the objective lens and the eye piece lens.
For example if you are using a 40x objective lens and a 10x eye piece lens then the specimen is being magnified 400 times.

There is no limit to the magnification of a light microscope. However, at higher magnification the image becomes blurred and you would not be able to see any more details than before. To see more details a microscope of higher resolution must be used (a electron microscope).

Resolution is the degree of detail which can be seen.
The limit of resolution is the minimum distance between two points which can be seen clearly.
The limit of resolution of a light microscope is 200 nm. This means that object smaller than 200nm will be invisible, or, two points which are less than 200nm apart (150 nm) will be seen as a single point. This is because the distance between the points is too small to be seen. The limit of resolution of an electron microscope is 0.5 nm.

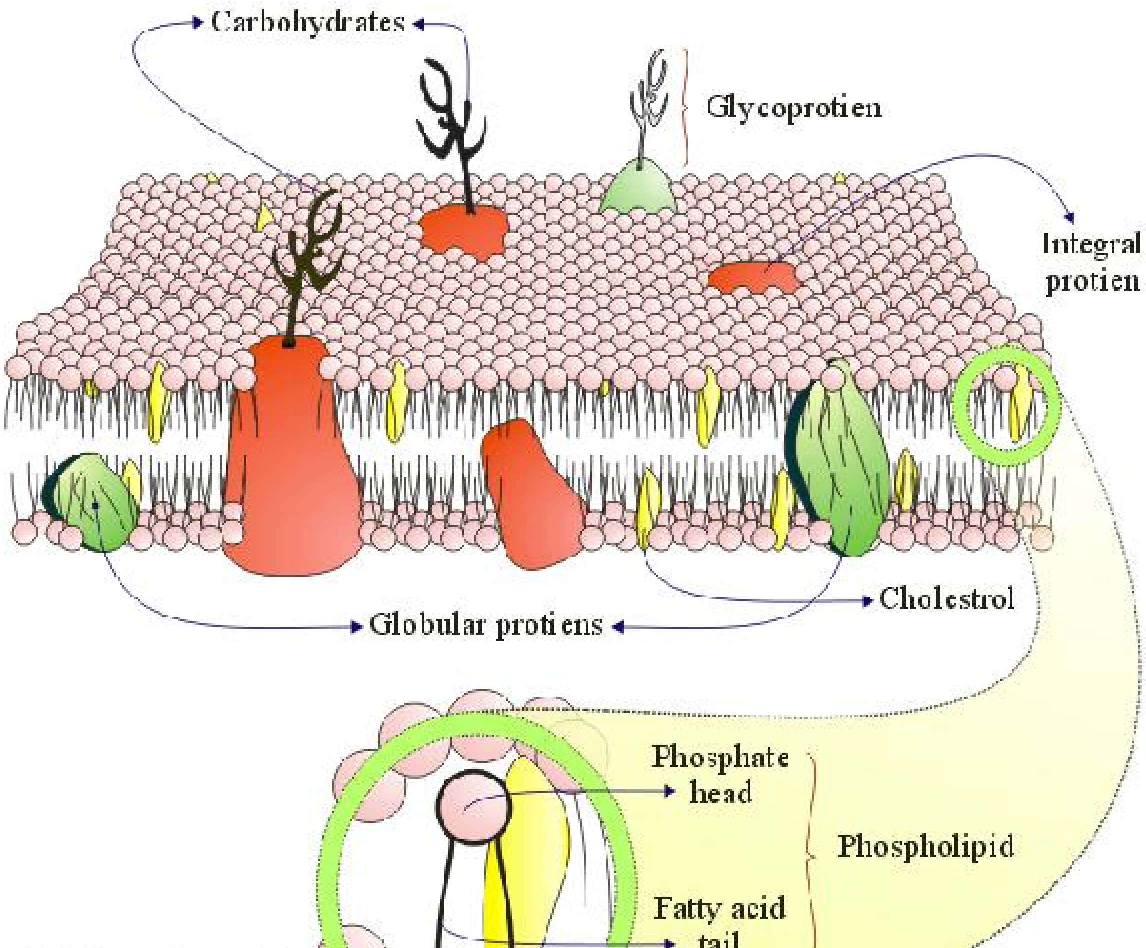
Cell surface membrane.

Structure/ properties and roles:

The **Cell surface membrane** is made up of a phospholipid bilayer, with hydrophilic phosphate heads facing towards water molecules on the membrane surface.

The hydrophobic fatty acid tails face away from water molecules on the membrane surface.

This hydrophobic region forms a barrier to polar molecules like Na^+, K^+, Ca^{2+}, Cl^-, etc…



Fluid mosaic model of the cell surface membrane

However , lipid soluble, non polar molecules like CO_2, O_2, cholesterol, fatty acids etc… can pass across the phospholipid bilayer. Water can pass through the phospholipid bilayer because of its small size and relatively low polarity.

Proteins are embedded into the phospholipid bilayer. These proteins allow certain polar molecules and ions to pass across the membrane. Hence they are often referred to as channel proteins, carrier proteins or transporter proteins. They are specific and will allow only certain substances to pass across.

Some of the proteins (extrinsic proteins) act as enzymes, recognition sites and electron carriers. The proteins also provide structural support for the membrane.

Branched chains of carbohydrates maybe attached to some phospholipid molecules (glycolipids) or to proteins (glycoproteins).

The carbohydrates act as recognition sites for neurotransmitters, hormones or for cell to cell recognition.

Cholesterol makes the membranes less fluid and more stable. This model of cell surface membrane is called the ‘ fluid mosaic’ model.
Fluid means that molecules can change places within the membrane.
Mosaic means that proteins are embedded randomly in to the phospholipid bilayer.

Role:

? Selectively permeable membrane helps to prevent passage of some substances and allow passage of other substances. This helps to maintain the appropriate composition of the cytoplasm.

Molecules move in and out of cell across the selectively permeable cell membrane. There are four basic processes, namely, diffusion, osmosis, active transport and bulk transport (exocytosis and endocytosis). Diffusion and osmosis are passive processes which use kinetic energy of molecules (not ATP), but active transport and bulk transport are active processes, which use metabolic energy (ATP) from the cell.

Diffusion is the ***net*** movement of particles from a region of their high concentration to a region of their lower concentration down a concentration gradient.

It is a passive process, which means that it does not require ATP. It occurs due to the random movement of particles across the membrane. The particles ***move in both directions*** across the membrane, but the rate of movement of particles from higher to lower concentration is greater than the movement in the opposite direction.
Each type of molecule / ion moves down its own diffusion gradient, independent of other molecules.
For Example: O_2 and CO_2 diffuse in different directions in the lungs.

Factors affecting diffusion: The rate of diffusion across membranes depends on the following factors.
a) - Surface area of membrane: rate of diffusion is directly proportional to surface area.
b) - Difference in concentration across the membrane: rate of diffusion is directly proportional to the concentration gradient.
c) – Thickness of membrane: rate of diffusion is *inversely* proportional to the thickness of the membrane or the diffusion distance.
d) – Temperature: rate of diffusion is directly proportional to the temperature as the kinetic energy of particles increase with temperature.
e) - Size of particles: Smaller / lighter particles diffuse faster.

Substances that can be exchanged by diffusion

? O_2 and CO_2 are non polar, small molecules which can diffuse rapidly across the phospholipid bilayer.

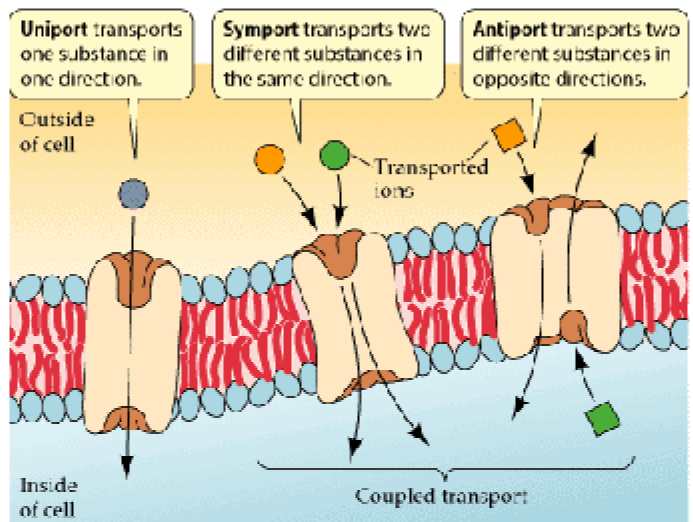
? Ions and large polar molecules, like glucose , amino acids ,Na^+, Cl^- are repelled by the hydrophobic region (fatty acid tails) of the phospholipids and diffuse across extremely slowly, if at all.

? Steroid hormones are lipid soluble and can diffuse across the membrane easily.

<u>Facilitated Diffusion:</u>

Some ions (Na^+, Ca^{2+}, K^+, Cl^-, HCO_3) and polar molecules (Glucose, amino acids) can diffuse through special transport proteins called channel proteins or carrier proteins. Diffusion can occur through the channel in either direction. Since diffusion would not be possible without these proteins the process is called facilitated diffusion. The proteins that allow facilitated diffusion may be of two kinds:

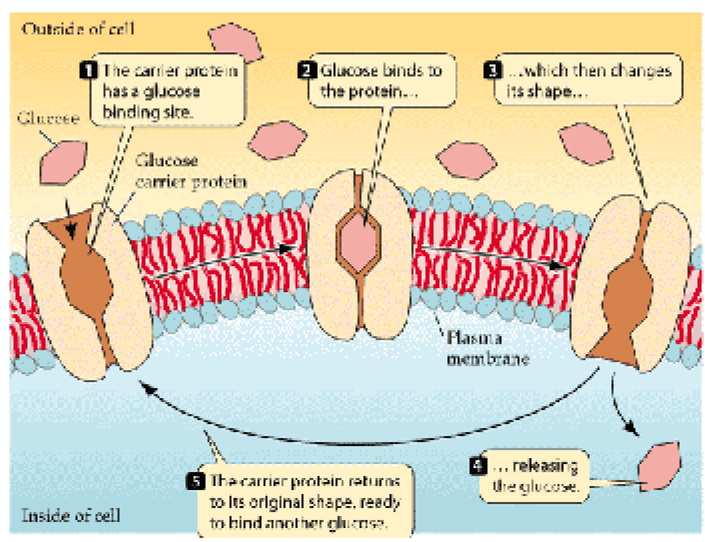
Channel Proteins:
These have a fixed shape and allow a specific ion to pass across the membrane. These channels act as water filled passages for specific substances to diffuse across the membrane. They allow substances to flow in both directions across the membrane. However some of these channels may be gated, allowing substances to pass in a specific direction.



(a)

Carrier Proteins:

They undergo rapid changes in shape (about 100 times/sec).
These are useful to allow larger polar molecules like sugars and amino acids to cross the membrane. When a specific molecule binds with the carrier protein at its binding site, the protein changes shape and delivers the molecule across the membrane.



<u>Osmosis:</u>

Is the net movement of water molecules form a region of higher water potential to a region of lower water potential across a selectively permeable membrane.

Water potential is defined as the tendency of water molecules to move from one place to another. It is represented by the symbol ¥ (psi). The unit of measurement is KPa.

There are two factors which affect the water potential.

a). Solute concentration:

Pure water has a water potential of 0 KPa.
Adding solute into pure water will decrease its water potential.
For example, a solution containing 17g of sucrose in $1dm^3$ of water has a water potential of -130KPa. A solution containing 35g of sucrose in $1dm^3$ of water would have a water potential of -260 KPa.
This simply means that the water molecules will have a lesser tendency to move away from a more concentrated solution (with a low ¥).

b). Pressure on both side of the membrane:

Consider a plant cell placed in pure water. Water enters the cell by osmosis down a water potential gradient. However, this does not go on forever. The inward movement of water will stop when the cell becomes turgid, even though a water potential gradient still exists. This is because the cell wall exerts a pressure on the water molecules and decreases its tendency (water potential) to enter the cells.

Active Transport:

It is the uptake of molecules or ions against a concentration gradient using energy from respiration (ATP).

How does it work?

? The molecule or ion combines with a specific carrier protein in the cell surface membrane.
? ATP transfers a phosphate group to the carrier protein on the inside of the membrane. This causes the carrier protein to undergo a change of shape which causes the molecule or ion to move across the membrane.
? The molecule or ion is then released and the protein changes back to its original shape.

Due to energy needed for this process, the cells involved tend to contain more mitochondria and a high rate of respiration.
Their ability to carry out active uptake is affected by temperature, oxygen concentration and the presence of respiratory poisons like Cyanide. (All factors which affect respiration).

Some processes involving active transport are:

Nerve impulse transmission, muscle contraction, absorption of amino acids in ileum, absorption of ions by root hair cells of plants, protein synthesis, selective re-absorption in kidney.

Diffusion, osmosis and active transport move molecules and ions individually through the cell surface membrane. However endocytosis and exocytosis transport large amounts of molecules in one go into and out of the cell through the cell surface membrane i.e. in bulk.

In endocytosis, the cell surface membrane wraps around the material forming a vesicle,.

There are two main types of endocytosis:

? Phagocytosis – involves solid material being taken into the cell within a vesicle. As the vesicle moves through the cell, lysosomes fuse with the vesicle releasing hydrolytic enzymes into it. The enzymes break the solid substance into smaller soluble molecules. This is an important part of the immune response, involving white blood cells.

? Pinocytosis – involves the transport of liquid material into a cell. This however usually involves a number of small vesicles transporting the liquid material, rather than one large vesicle.

TIP: Human egg cells use pinocytosis to obtain nutrients from surrounding cells.

Exocytosis is the opposite of endocytosis, in this case certain substances are expelled by a cell.

A vesicle with the substance to be removed moves towards the cell surface membrane and fuses with it.

TIP: These vesicles usually originate from the Golgi body.

This process is known as secretion – only if the substance being released has a useful function outside the cell e.g. digestive enzymes, mucus or hormones.

Tissues are a group of cells of common origin, structure and function. The different tissues found in a mesophytic leaf are:

a). Parenchyma:

These cells are roughly spherical or elongated. They have a thin primary cell wall of cellulose and have an active cytoplasm. They are living tissues and are found in modified forms in the epidermis, palisade and spongy mesophyll layers and between xylem and phloem of leaves.

Functions: protection, storage, photosynthesis.

b). Collenchyma:

These are elongated cells, usually polygonal in shape with tapering ends. They have less cytoplasm. They contain a nucleus and are living. They are found in the midrib of leaves.

Function: Provide mechanical support.

c). Sclerenchyma:

These are elongated cells. They are Polygonal in shape with tapering and interlocking ends. They have highly lignified cell walls. They are dead cells with no cytoplasm.

Function: Provide mechanical support. Found in xylem and phloem (referred to as fibres).

d). Xylem and Phloem:

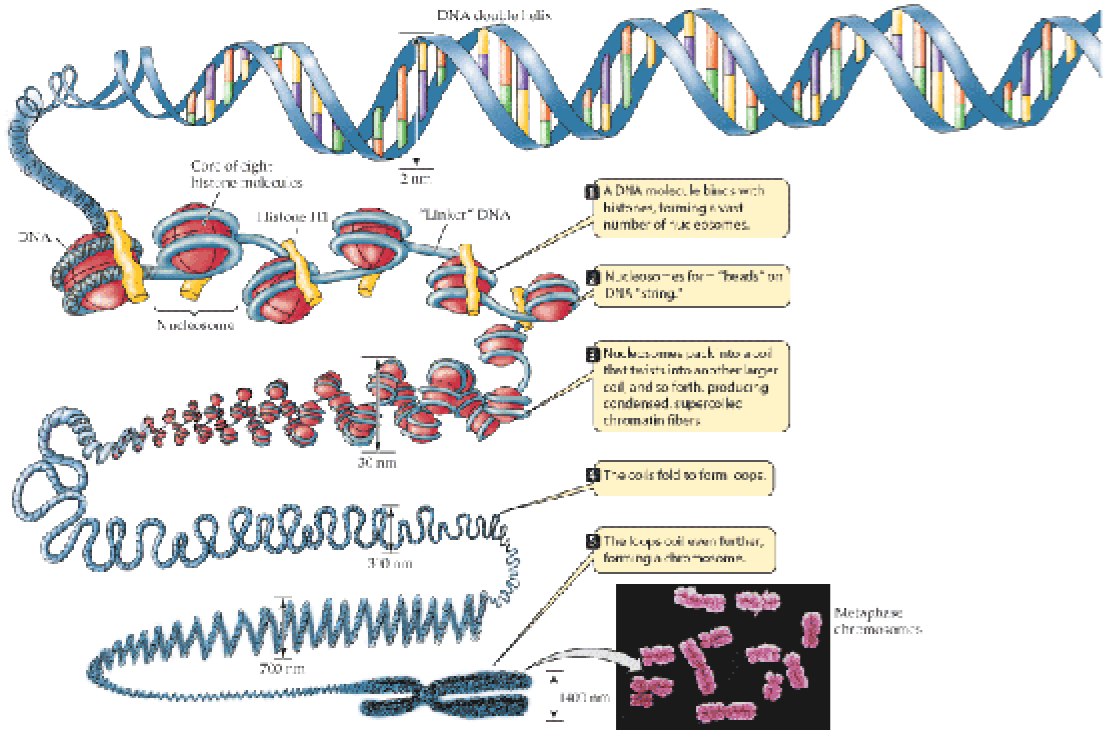
These are tissues which are composed of more than one type of cells. Found in veins/midrib of leaves. They are referred to as vascular tissues. (Refer to structure of xylem and phloem in unit 2 notes).

Organs

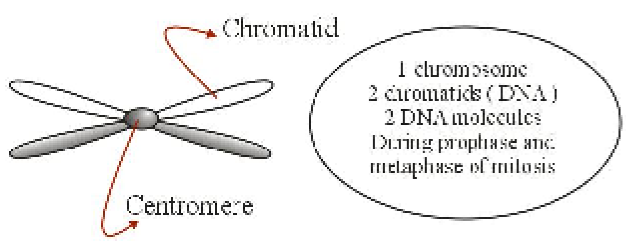
These are groups of tissues performing a similar function.
Eg: leaf is an organ. All the tissues of the leaf work to perform photosynthesis.
The liver is an organ. It is composed of cells called Hepatocytes. These cells perform all the functions of the liver. However, blood cells, nervous tissues and connective tissues are all necessary to enable the hepatocytes to function normally. Thus, all these tissues function together as an organ.

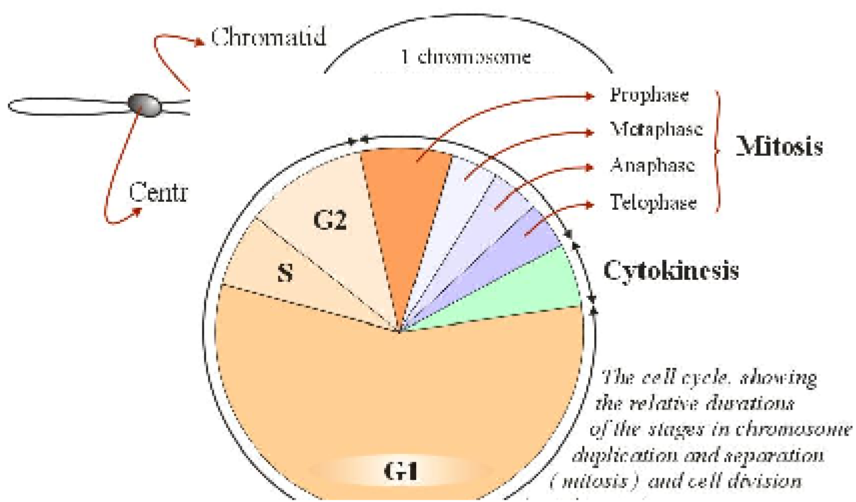
Chromosomes of eukaryotic cells are composed of DNA and proteins called **histones**. DNA has negative charges along its length and positively charged (basic) protein molecules called histones are bonded to it.
This DNA-protein complex is called **chromatin**.

The DNA Helix combines with groups of eight histone molecules to form structures known as **nucleosomes** (having the appearance of beads on a string).
Strings of nucleosomes are further coiled into a **solenoid**, which are further coiled to form a super coiled structure called a **chromosome.**



A Leaf palisade cell and a liver cell have been formed by mitosis.
This ensures that their diploid number of chromosomes is maintained.
However, both the palisade cell and the liver cell have developed from an undifferentiated cell, called the **zygote**.
During development, cells begin to specialize and become adapted, in shape and structure to perform specific functions.
This is called **differentiation**. This enables division of labour which is a common feature of higher organisms.





Mitosis

The stages of the cell cycle are explained below.

a). G1 - phase

During this stage there is rapid synthesis of mitochondria, chloroplasts (in plants), Endoplasmic reticulum, lysosomes, Golgi bodies, vacuoles and vesicles.

mRNA, tRNA, rRNA and ribosomes are also produced. The cell produces structural and functional proteins (enzymes, carriers), cell growth occurs.

b). S - phase

DNA replication occurs.
Histones are synthesized and combine with each DNA strand.
Each chromosome has become two chromatids.

c). G2 - phase

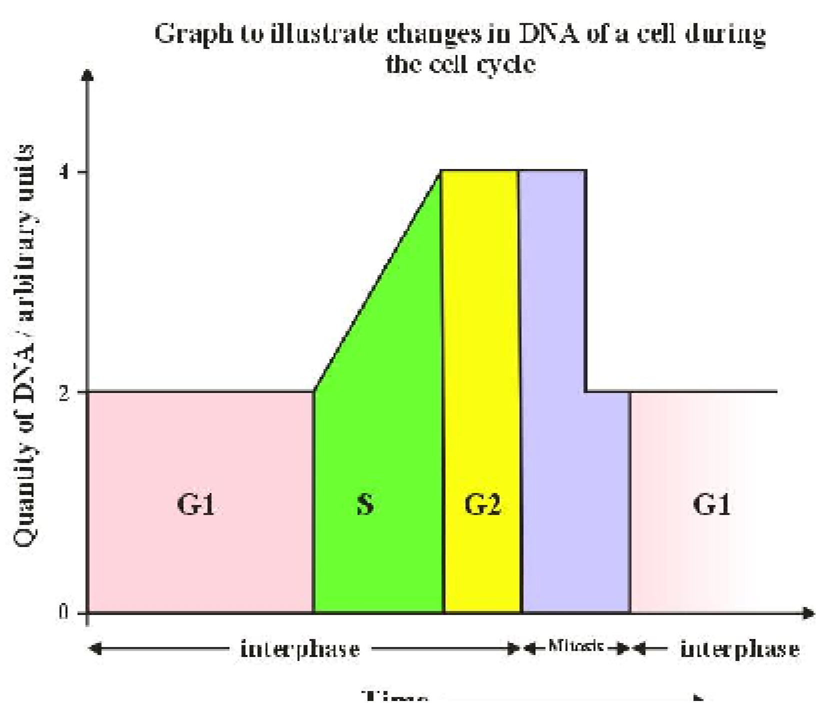
Mitochondria and chloroplasts divide.
Energy stores increase and mitotic spindle begins to form.

d). M - phase

Nuclear division occurs in four stages (prophase, metaphase, anaphase and telophase)

e). C - phase

Cytokinesis: Equal distribution of organelles and cytoplasm into each daughter cell.



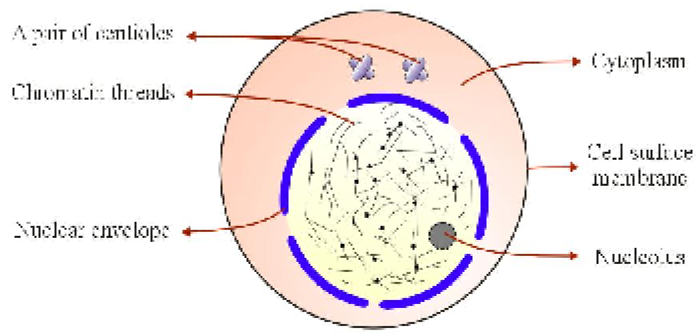
Interphase

Interphase consists of G1, S and G2 phases.

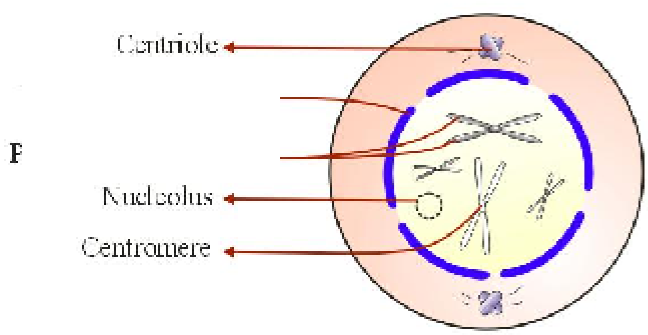
DNA replication occurs during this stage.

The DNA is not highly coiled and not visible as chromosomes. The DNA appears as a network of fine threads called chromatin.

Interphase



Prophase



Usually the longest phase of division.

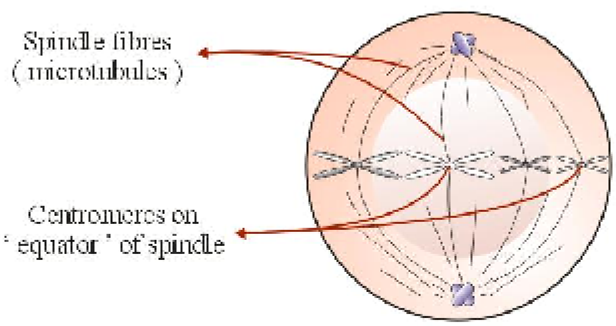
Spiralisation and condensation of DNA with histones causes chromatids to shorten and thicken (upto 4% of their original length).

Chromatids satin clearly ,but centromere does not stain.

Nucleoli and nuclear envelope begin to disappear

Spindle begins to form.

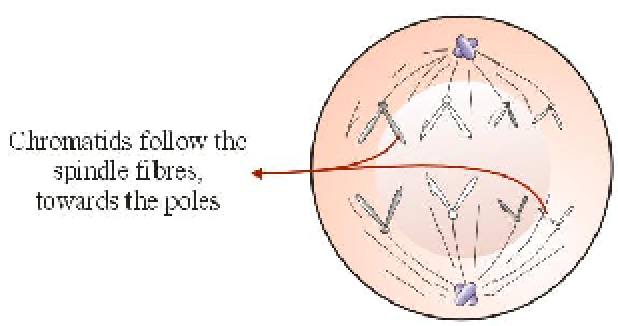
Metaphase



Chromosomes lined up on the equator of the cell (perpendicular to the axis of the spindle).

Centromeres attached to spindle fibres.

Anaphase

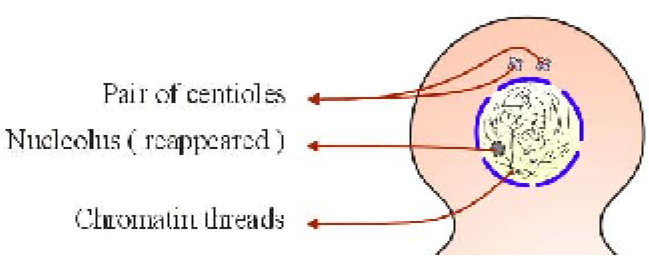


The centromeres split and sister chromatids are pulled apart, towards the poles.

Each chromosome now consists of one chromatid.

The chromatids follow the centromere towards the poles.

Telophase



The chromosomes reach the poles of the cell, uncoil, lengthen and lose their ability to be seen clearly.

The spindle fibres disintegrate and the centrioles replicate.

Significance of mitosis

? **Genetic stability** - Mitosis produces two nuclei which have the same (identical) number of chromosomes as the parent cell. Moreover, each chromosome is genetically identical to parent DNA as it is formed by replication. These genetically identical cells are called clones.

? **Growth** - Growth is achieved by an increase in the number of cells in an organism. Mitosis helps to increase cell numbers, thus causing growth.

? **Asexual reproduction, regeneration and cell replacement** - Binary fission in amoeba, budding in hydra, growth of plants from stem cuttings, bulbs and tubers form new individuals from parents, by mitosis (Meiosis is not involved). Regeneration of missing parts (such as legs in crustaceans, arms of starfish) and healing of wounds also involves mitosis.

As state above, mitosis maintains genetic stability during growth and development.

Reproduction is the ability to produce a new generation of individuals of the same species.
This involves the transfer of genetic information from parental generation to the next, there by ensuring that the characteristics, not only of the species, but also of the parental organisms, are perpetuated.
A new individual has to go through a period of growth and development before it reaches a stage where it can reproduce itself.
Mitosis maintains genetic stability during this period. It also helps to preserve genetic characters from generation to generation during asexual reproduction.

Cloning is the production of a genetically identical offspring (genetically identical to the parent) by asexual reproduction.
Asexual reproduction in plants, yeasts, bacteria are examples of natural cloning.
However, artificial cloning is possible in both plants and animals.
An outline of the process is given below;

Advantages of cloning

? A large number of genetically identical offspring with favourable characters can be produced in a short time.

? It also helps to preserve desired characters.