GCE A Level Cambridge Biology Study Notes

The Cell and Biomolecular of Life

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Learning Outcomes

Candidates should be able to:

(a) outline the cell theory with the understanding that cells are the smallest unit of life, all cells come from pre-existing cells, and living organisms are composed of cells

(b) interpret and recognise drawings, photomicrographs and electronmicrographs of the following membrane systems and organelles: rough and smooth endoplasmic reticulum, Golgi body, mitochondria, ribosomes, lysosomes, chloroplasts, cell surface membrane, nuclear envelope, centrioles, nucleus and nucleolus (for practical assessment, candidates may be required to operate a light microscope, mount slides and use an eyepiece graticule and a stage micrometer)

(c) outline the functions of the membrane systems and organelles listed in (b)

(d) describe the structure of a typical bacterial cell (small and unicellular, peptidoglycan cell wall, circular DNA, 70S ribosomes and lack of membrane-bound organelles)

(e) describe the structural components of viruses, including enveloped viruses and bacteriophages, and interpret drawings and photographs of them

(f) discuss how viruses challenge the cell theory and concepts of what is considered living

(g) describe the structure and properties of the following monomers:

i. α-glucose and β-glucose (in carbohydrates)

ii. glycerol and fatty acids (in lipids)

iii. amino acids (in proteins) (knowledge of chemical formulae of specific R-groups of different amino acids is not required)

(h) describe the formation and breakage of the following bonds:

i. glycosidic bond

ii. ester bond

iii. peptide bond

(i) describe the structures and properties of the following biomolecules and explain how these are related to their roles in living organisms:

i. starch (including amylose and amylopectin)

ii. cellulose

iii. glycogen

iv. triglyceride

v. phospholipid

(j) explain the fluid mosaic model and the roles of the constituent biomolecules (including phospholipids, proteins, glycolipids, glycoproteins and cholesterol) in cell membranes

(k) outline the functions of membranes at the surface of cells and membranes within the cell

(l) explain how and why different substances move across membranes through simple diffusion, osmosis, facilitated diffusion, active transport, endocytosis and exocytosis

(m) explain primary structure, secondary structure, tertiary structure and quaternary structure of proteins, and describe the types of bonds that hold the molecule in shape (hydrogen, ionic and disulfide bonds, and hydrophobic interactions)

(n) explain the effects of temperature and pH on protein structure

(o) describe the molecular structure of the following proteins and explain how the structure of each protein relates to the function it plays:

i. haemoglobin (transport)

ii. collagen (structural)

iii. G-protein linked receptor (signalling)

(knowledge of details of the number of amino acids and types of secondary structures present is not required)

(p) explain the mode of action of enzymes in terms of an active site, enzyme–substrate complex, lowering of activation energy and enzyme specificity using the lock-and-key and induced-fit hypotheses

(q) investigate and explain the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of an enzyme-catalysed reaction by measuring rates of formation of products (e.g. measuring gas produced using catalase) or rate of disappearance of substrate (e.g. using amylase, starch and iodine)

(r) describe the structure of competitive and non-competitive inhibitors with reference to the binding sites of the inhibitor

(s) explain the effects of competitive and non-competitive inhibitors (including allosteric inhibitors) on the rate of enzyme activity

(t) describe the unique features of stem cells, including zygotic stem cells, embryonic stem cells and blood stem cells (lymphoid and myeloid), correctly using the terms:

i. totipotency (e.g. zygotic stem cells)

ii. pluripotency (e.g. embryonic stem cells)

iii. multipotency (e.g. lymphoid and myeloid stem cells)

(u) explain the normal functions of stem cells in a living organism, including embryonic stem cells and blood stem cells (lymphoid and myeloid)

(v) discuss the ethical implications of the application of stem cells in research and medical applications and how human induced pluripotent stem cells (iPSCs) overcome some of these issues (procedural details of how iPSCs are formed are not required).

Use the knowledge gained in this section in new situations or to solve related problems.

The cell theory

The cell theory states that:

All living things are composed of one or more cells. The cell is the basic unit of life and new cells arise form existing cells.

1. The cell is the fundamental unit of structure and function in living things.
2. All organisms are made up of one or more cells.
3. Cells arise from other cells through cellular division

Watch the Cell Theory on YouTube here.

Functions of membrane systems and organelles in cells

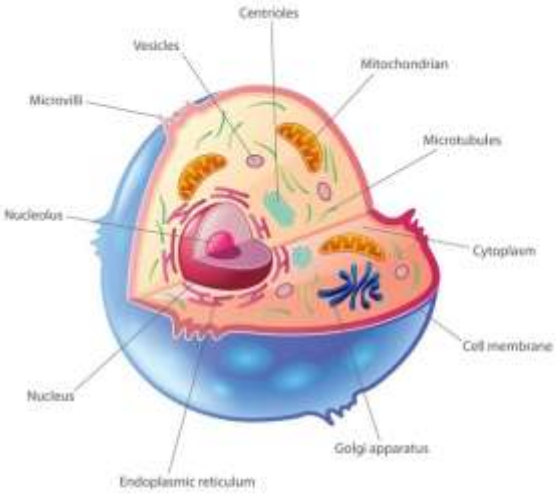
Membrane systems

The membrane systems of a cell performs many important functions. It controls the entrance and exit of substances into and out of the cell.

Biological membranes have three primary functions

1. They keep toxic substances out of the cell
2. They contain receptors and channels that allow specific molecules such as ions, nutrients, wastes and metabolic products that mediate cellular and extracellular activities to pass between organelles and between the cell and the outside environment
3. It separates vital but incompatible metabolic processes conducted within organelles.

An organelle (you can think of it as a cell’s internal organ) is a membrane bound structure found within a cell. These mini organs are bound in double layer of phospholipids to insulate their little compartment within the larger cells.



Structure of a typical bacterial cell

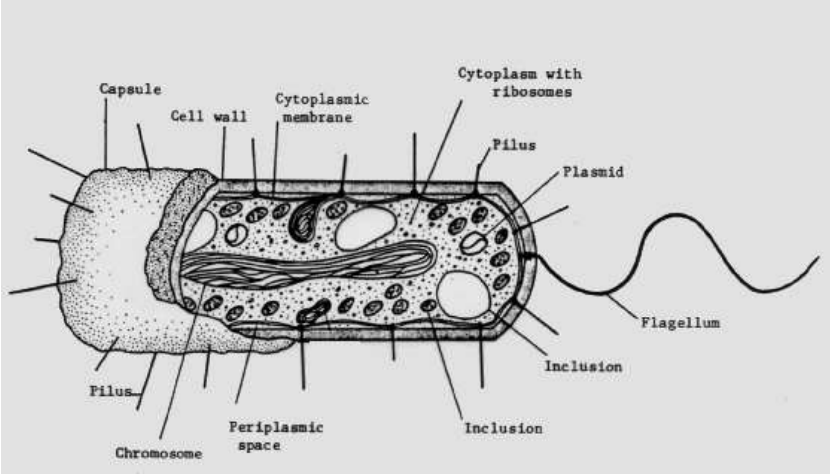


Table 2. Summary of characteristics of typical bacterial cell structures

Structure	Function(s)	Predominant chemical composition
Flagella	Swimming movement	Protein
Pili		
Sex pilus	Stabilizes mating bacteria during DNA transfer by conjugation	Protein
Common pili or fimbriae	Attachment to surfaces; protection against phagotrophic engulfment	Protein
Capsules (includes "slime layers" and glycocalyx)	Attachment to surfaces; protection against phagocytic engulfment, occasionally killing or digestion; reserve of nutrients or protection against desiccation	Usually polysaccharide; occasionally polypeptide
Cell wall		
Gram-positive bacteria	Prevents osmotic lysis of cell protoplast and confers rigidity and shape on cells	Peptidoglycan (murein) complexed with teichoic acids
Gram-negative bacteria	Peptidoglycan prevents osmotic lysis and confers rigidity and shape; outer membrane is permeability barrier; associated LPS and proteins have various functions	Peptidoglycan (murein) surrounded by phospholipid protein-lipopolysaccharide "outer membrane"
Plasma membrane	Permeability barrier; transport of solutes; energy generation; location of numerous enzyme systems	Phospholipid and protein
Ribosomes	Sites of translation (protein synthesis)	RNA and protein
Inclusions	Often reserves of nutrients; additional specialized functions	Highly variable; carbohydrate, lipid, protein or inorganic
Chromosome	Genetic material of cell	DNA
Plasmid	Extrachromosomal genetic material	DNA

(Source: http://textbookofbacteriology.net/structure.html)

Structures of biomolecules and their functions

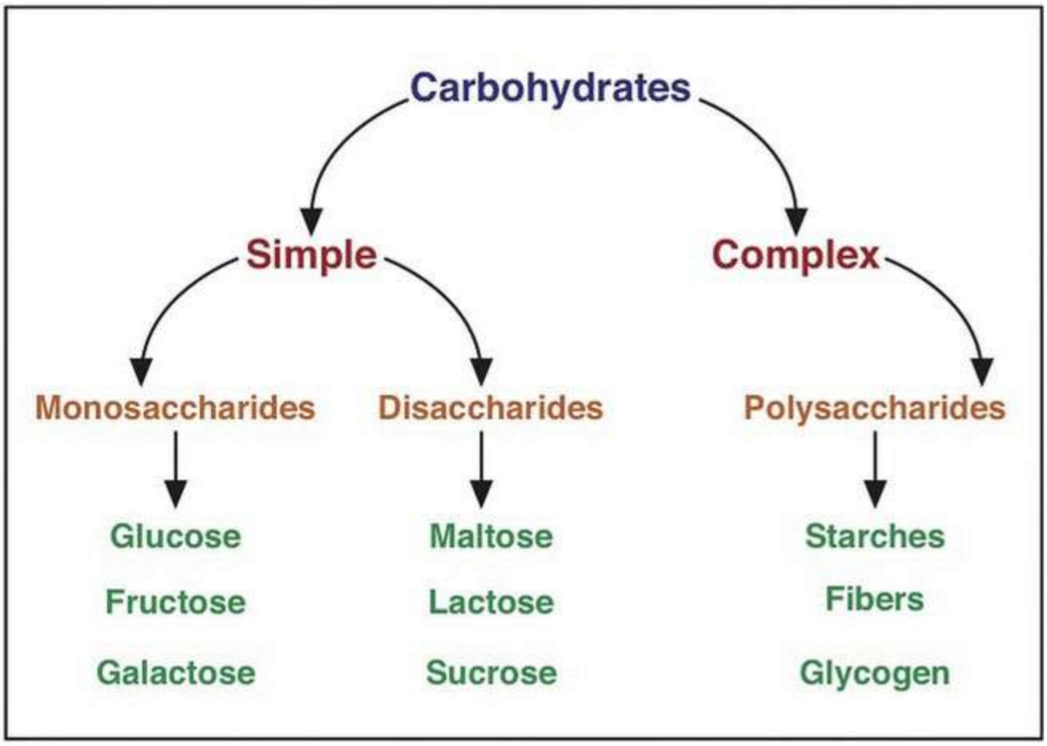
There are 4 major types of biomolecules

1. **Carbohydrates**

Carbohydrates are molecules which consist only of carbon, hydrogen and oxygen and they are long chains of sugar units called saccharides.

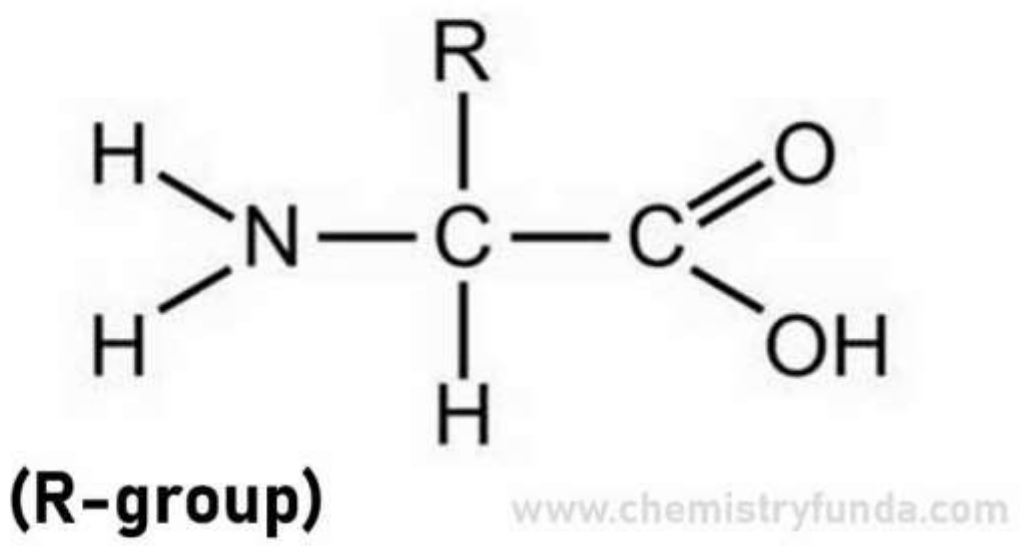
There are three types of saccharides -monosaccharides, disaccharides, and polysaccharides.

Monosaccharides are single units that can join to form disaccharides and polysaccharides by glycosidic bonds which are formed in condensation reactions.



(Source: https://socratic.org/questions/5848ae62b72cff7fcfd41ae3)

2. Proteins



(Source: https://chemistryfunda.com/protein-and-structure-of-protein-amino-acids-chemistry-funda/)

Amino acids are the monomers from which proteins are made.

Amino acids contain an amino group – NH2, carboxylic acid group and a variable R group which is a carbon-containing chain.

There are 20 different amino acids with different R groups

Amino acids are joined by peptide bonds formed in condensation reactions.

A dipeptide contains two amino acids and polypeptides contain three or more amino acids.

The structure of proteins is determined by the order and number of amino acids, bonding present and the shape of the protein:

Primary structure of a protein is the order and number of amino acids in a protein.

The secondary structure is the shape that the chain of amino acids chains – either alpha helix or beta pleated sheet.

The shape is determined by the type of bonding present such as hydrogen bonding, ionic bonds and disulphide bridges.

Tertiary structure of proteins is the 3D shape of the protein, it can be globular or fibrous. Globular proteins such as enzymes are compact whereas fibrous proteins such as keratin are long and thus can be used to form fibres.

For instance, collagen is a fibrous protein of great strength due to presence of both hydrogen and covalent bonds in the structure.

Collagen molecules wrap around each other and form fibrils which form strong collagen fibres.

Collagen forms the structure of bones, cartilage and connective tissue and is a main component of tendons which connect muscles to bones.

Haemoglobin is a water-soluble globular protein which consists of two beta polypeptide chains and a haem group. It carries oxygen in the blood as oxygen can bind to the haem (Fe^{2+}) group and oxygen is then released when required.

Peptide bonds can by hydrolysed (broken) with the addition of water in a hydrolysis reaction.

Water is a very important molecule which is a major component of cells, for instance:

Water is a polar molecule due to uneven distribution of charge within the molecule – the hydrogen atoms are more positive than the oxygen atom causing one end of the molecule to be more positive than the other.

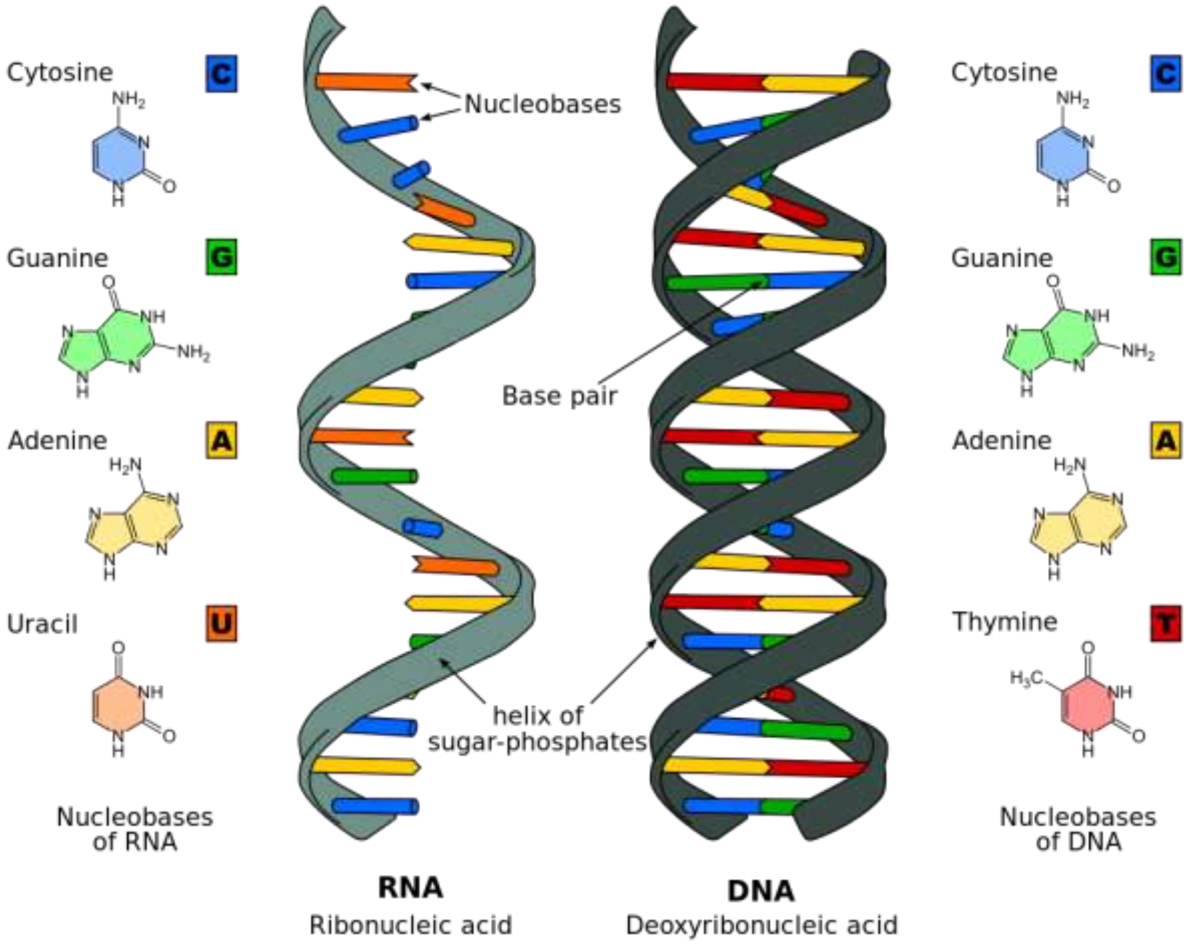
It is a metabolite in metabolic reactions such as condensation and hydrolysis which are used in forming and breaking of chemical bonds. It is a solvent in which many metabolic reactions occur .

It has a high specific heat capacity meaning that a lot of energy is required to warm water up therefore minimising temperature fluctuations in living things therefore it acts as a buffer.

It has a relatively large latent heat of vaporisation, meaning evaporation of water provides a cooling effect with little water loss.

There is strong cohesion between molecules enables effective transport of water in tube like transport cells as the strong cohesion supports columns of water (capillary action), because of strong cohesion the surface tension at the water-air boundary is high.

3. Nucleic acids



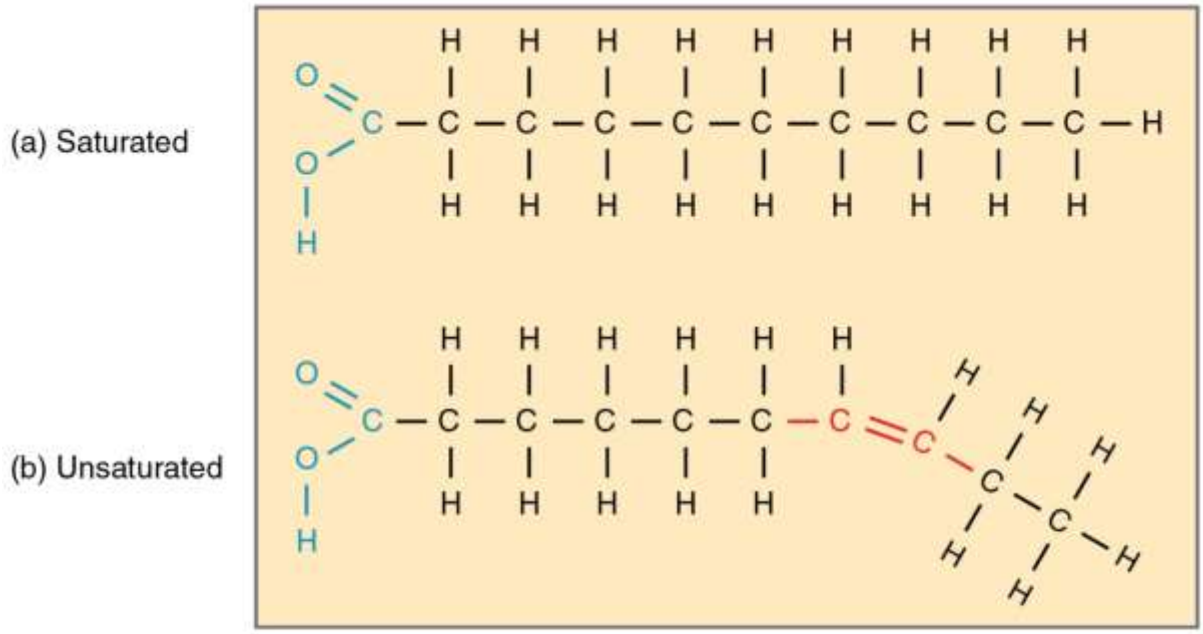
(Source: https://en.wikipedia.org/wiki/Nucleic_acid#/media/File:Difference_DNA_RNA-EN.svg)

Nucleic acids are macromolecules present in cells and viruses, and they are involved in the storage and transfer of genetic information. It is a mixture of basic proteins and phosphorus-containing organic acid.

Structurally, nucleic acids are polymers of nucleotides (or polynucleotides) which are phosphate esters of nucleosides. The nucleotides are comprised of three components.

4. Lipids

Lipids are biological molecules which are only soluble in organic solvents such as alcohols.



(Source: https://commons.wikimedia.org/wiki/File:221_Fatty_Acids_Shapes-01.jpg)

There are two types of lipids:

- **Saturated**

Saturated lipids such as those found in animal fats – saturated lipids don't contain any carbon carbon double bonds.

Too much saturated fat can increase the cholesterol levels in blood thus increasing the risk of coronary heart disease.

- **Unsaturated**

Unsaturated lipids which can be found in plants – unsaturated lipids contain carbon-carbon double bonds and melt at lower temperatures than saturated fats.

Unsaturated fats are healthy as they provide essential fatty acids.

The greater the number of unsaturated bonds, the weaker the intermolecular bonds resulting in lower melting point, and because of those saturated fats which don't contain any double bonds are solid at liquid temperature and unsaturated lipids are liquid at room temperature.

Triglycerides are lipids made of one molecule of glycerol and three fatty acids joined by ester bonds formed in condensation reactions.

There are many different types of fatty acids, they vary in chain length, presence, and number of double bonds.

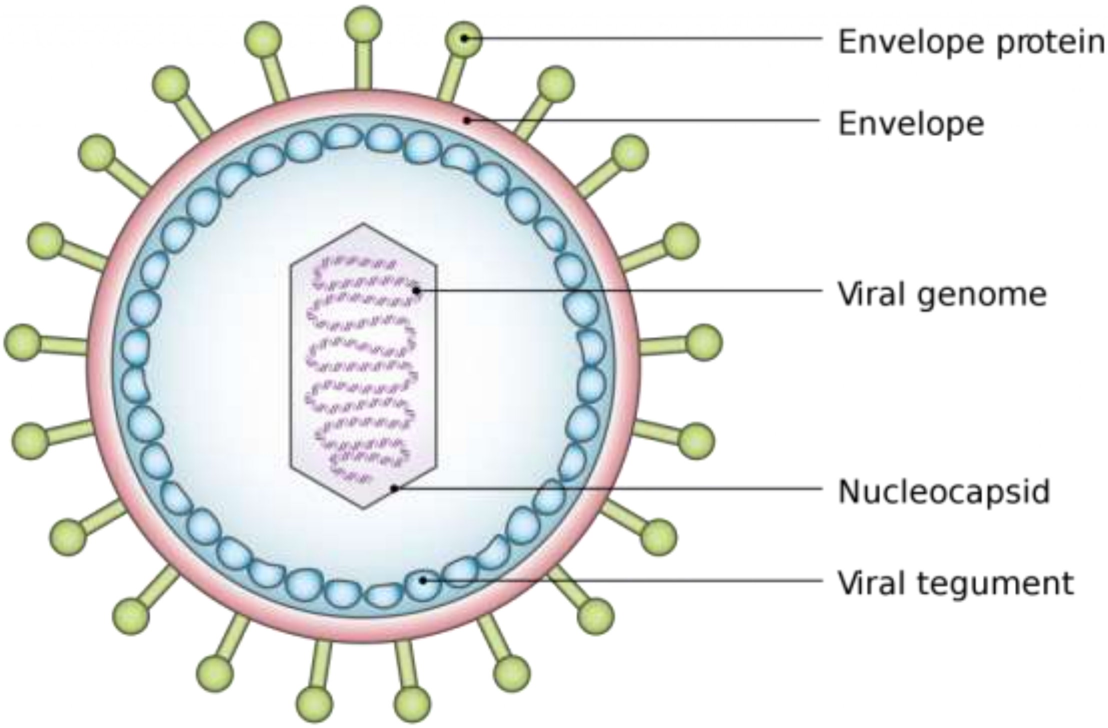
Also, some triglycerides contain a mix of different fatty acids.

Triglycerides are used as energy reserves in plant and animal cells.

In phospholipids, one of the fatty acids of a triglyceride is substituted by a phosphate containing group.

Phosphate heads are hydrophilic, and the tails are hydrophobic and as a result phospholipids form micelles when they are in contact with water as heads are on the outside as they are attracted to water and tails are on the inside as they move away from water.

The structural components of viruses



(Source:
https://bio.libretexts.org/Bookshelves/Microbiology/Book%3A_Microbiology_(Bruslind)/08%3A_Introduction_to_Viruses)

The fluid mosaic model of membrane structure

The fluid mosaic model describes the cell membrane as a tapestry of several types of molecules (phospholipids, cholesterol, and proteins.) that are constantly moving.

This movement helps the cell membrane maintain its role as a barrier between the inside and outside of the cell environments.

This model is used to explain the structure of the plasma membrane.

Components of the Plasma Membrane	
Component	**Location**
Phospholipid	Main fabric of the membrane
Cholesterol	Attached between phospholipids and between the two phospholipid layers
Integral proteins (for example, integrins)	Embedded within the phospholipid layer(s). May or may not penetrate through both layers.
Peripheral proteins	On the inner or outer surface of the phospholipid bilayer; not embedded within the phospholipids
Carbohydrates (components of glycoproteins and glycolipids)	Generally attached to outside of membrane layer

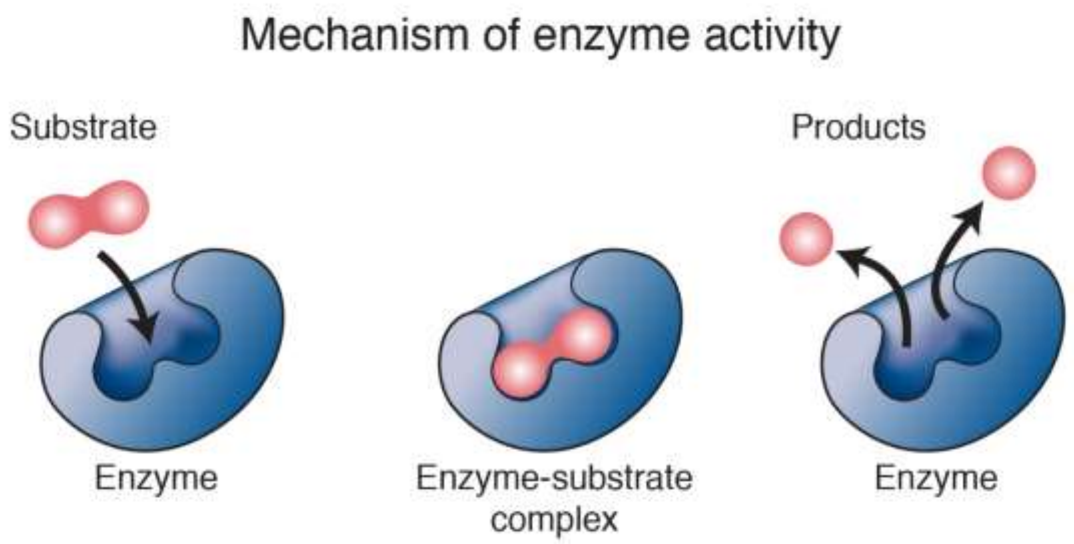
(Source: https://courses.lumenlearning.com/boundless-ap/chapter/cell-membranes-and-the-fluid-mosaic-model/)

Mode of action of enzymes

Enzyme, a substance that acts as a catalyst in living organisms, regulating the rate at which chemical reactions proceed without itself being altered in the process.

The mode of action of enzymes

An enzyme attracts substrates to its active site, catalyses the chemical reaction by which products are formed and then allows the products to separate from the enzyme surface.

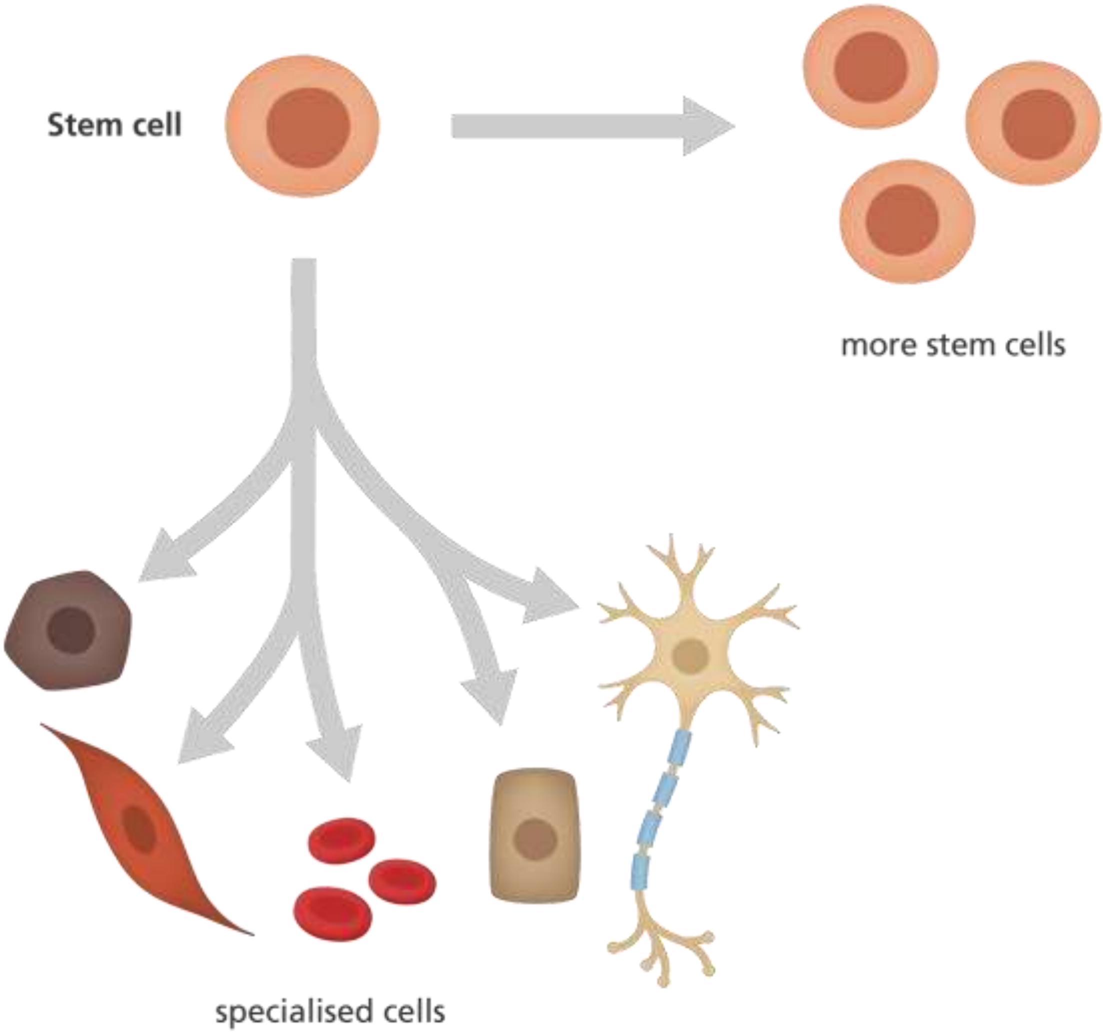


(Source: https://www.genome.gov/genetics-glossary/Enzyme)

Watch a YouTube explanation of the mode of actions of enzymes here.

Stem Cells

Stem cells are the body's raw materials — cells from which all other cells with specialized functions are generated. Under the right conditions in the body or a laboratory, stem cells divide to form more cells called daughter cells.



(Source: https://www.yourgenome.org/facts/what-is-a-stem-cell)

Stem cells provide new cells for the body as it grows and replace specialised cells that are damaged or lost. They have two unique properties that enable them to do this:

They can divide repeatedly to produce new cells.

As they divide, they can change into the other types of cells that make up the body.

Different types of stem cell

There are three main types of stem cell:

- **embryonic stem cells**

  Embryonic stem cells supply new cells for an embryo? as it grows and develops into a baby.

  These stem cells are said to be pluripotent, which means they can change into any cell in the body.

- **adult stem cells**

Adult stem cells supply new cells as an organism grows and to replace cells that get damaged.

Adult stem cells are said to be multipotent, which means they can only change into some cells in the body, not any cell, for example:

Blood (or 'haematopoietic') stem cells can only replace the various types of cells in the blood.

Skin (or 'epithelial') stem cells provide the different types of cells that make up our skin and hair.

- **induced pluripotent stem cells**

Induced pluripotent stem cells, or ‘iPS cells’, are stem cells that scientists make in the laboratory.

‘Induced’ means that they are made in the lab by taking normal adult cells, like skin or blood cells, and reprogramming them to become stem cells.

Just like embryonic stem cells, they are pluripotent so they can develop into any cell type.

Benefits of using stem cells	Risks / issues of using stem cells	Social issues	Ethical issues
Great potential to treat a wide-variety of diseases from diabetes and paralysis. Organs developed from a patient's own stem cells reduces the risk of organ rejection and the need to wait for an organ donation. Adult stem cells are already used successfully in a variety of treatments acting as proof of benefits.	Stem cells cultured in the lab could become infected with a virus which could be transmitted to the patient. There is a risk of cultured stem cells accumulating mutations that can lead to them developing into cancer cells. Low numbers of stem cell donors.	It is possible for embryonic stem cells to be collected before birth (from amniotic fluid) or after birth (umbilical cord blood) and stored by a clinic – but this can be expensive and isn't an option for everyone. A lack of peer-reviewed clinical evidence of the success of stem cell treatments. Educating the public sufficiently about what stem cells can and cannot be used for.	Stem cells may be sourced from unused embryos produced in IVF treatment – is it right to use them? Who gives permission? Is it right to create embryos through therapeutic cloning and then destroy them? Who owns the embryo? Should an embryo be treated as a person with human rights? Or as a commodity?

(Source: https://www.savemyexams.co.uk/notes/gcse-biology-aqa-new/cell-biology/cell-division/stem-cells/)