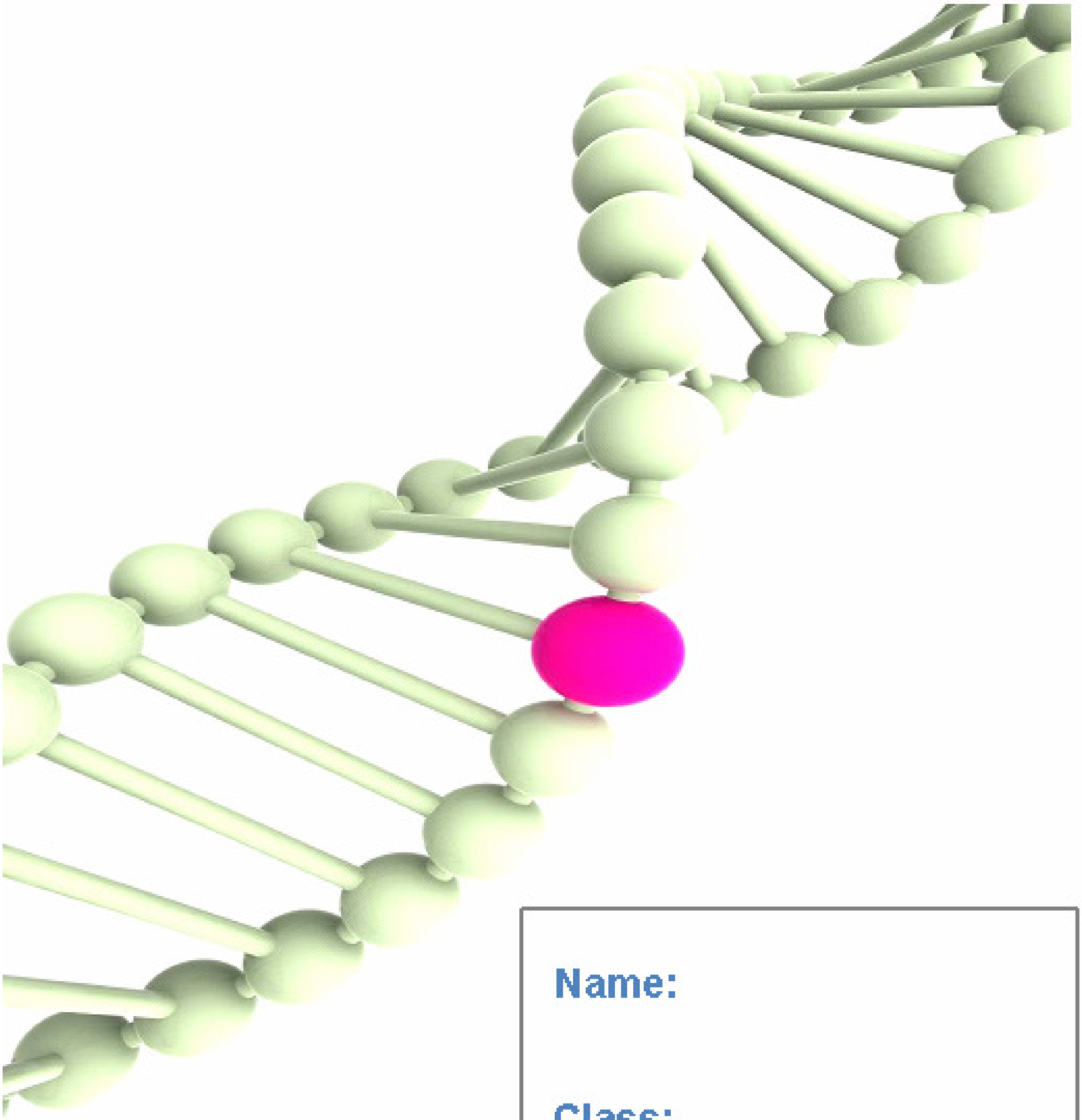
NAT 5 Biology

Cell Biology



Name:

Class:

Learning Outcomes/ Mandatory Course Key Content	Learned notes	Completed Practice Quests	Got help from my teacher
1 Cell structure Cell ultrastructure and functions to include: cell walls, mitochondria, chloroplasts, cell membrane, vacuole, nucleus, ribosomes and plasmids using examples from typical plant, animal, fungi and bacteria cells.			
2 Transport across cell membranes a. The cell membrane consists of lipids and proteins and is selectively permeable. b. Passive transport is with the concentration gradient and does not require energy. c. The importance of diffusion in cells as the movement of molecules along a concentration gradient. d. Osmosis as the movement of water molecules across a membrane in terms of water concentration. e. Animal cells can burst or shrink and plant cells can become turgid or plasmolysed in different solutions. f. Active transport requires energy for membrane proteins to move molecules against the concentration gradient.			
3 Producing new cells a. Maintenance of diploid chromosome complement by mitosis. Sequence of events of mitosis, including equator and spindle fibres. b. Cell production by cell culture requires aseptic techniques, an appropriate medium and the control of other factors.			

4 DNA and the production of proteins a. Structure of DNA: double-stranded helix held by complementary base pairs. DNA carries the genetic information for making proteins. The four bases A, T, C and G make up the genetic code. The base sequence determines amino acid sequence in protein. b. Messenger RNA (mRNA) is a molecule which carries a copy of the code from the DNA, in the nucleus, to a ribosome, where the protein is assembled from amino acids.			
5 Proteins and enzymes a. The variety of protein shapes and functions arises from the sequence of amino acids. b. Functions of proteins to include structural, enzymes, hormones, antibodies. c. Enzymes function as biological catalysts and are made by all living cells. They speed up cellular reactions and are unchanged in the process. The shape of the active site of enzyme molecules is complementary to a specific substrate. d. Each enzyme works best in its optimum conditions. Enzymes and other proteins can be affected by temperature and pH, which result in changes in their shape. A change in shape will affect the rate of reaction and may result in denaturation.			
6 Genetic engineering Genetic information can be transferred from one cell to another naturally or by genetic engineering. Stages of genetic engineering to include: identify section of DNA that contains required gene from source chromosome, extract required gene, insert required gene into vector/bacterial plasmid, insert plasmid into host cell and grow transformed cells to produce a GM organism.			
Contoversial biological procedure Pros and cons of using GM organisms			

7 Photosynthesis a. Chemistry of photosynthesis, as a series of enzyme-controlled reactions, in a two-stage process Light reactions: the light energy from the sun is trapped by chlorophyll in the chloroplasts and is converted into chemical energy in the form of ATP. Water is split to produce hydrogen and oxygen. Excess oxygen diffuses from the cell. Carbon fixation: hydrogen and ATP produced by the light reaction is used with carbon dioxide to produce sugar. b. The chemical energy in sugar is available for respiration or can be converted into plant products such as starch and cellulose. c. Limiting factors: carbon dioxide concentration, light intensity and temperature and their impact on photosynthesis and cell growth.			
8 Respiration a. The chemical energy stored in glucose must be released by all cells through a series of enzyme-controlled reactions called respiration. b. The energy released from the breakdown of glucose is used to generate ATP from ADP and phosphate. The chemical energy stored in ATP can be released by breaking it down to ADP and phosphate. This energy can be used for cellular activities including muscle cell contraction, cell division, protein synthesis and transmission of nerve impulses. ATP can be regenerated during respiration. The breakdown of each glucose molecule via pyruvate to carbon dioxide and water in the presence of oxygen yields 38 molecules of ATP. The breakdown of each glucose molecule via the fermentation pathway yields 2 molecules of ATP when oxygen is not present. Breakdown of glucose to lactic acid via pyruvate in animal cells. Breakdown of glucose to alcohol/ethanol and carbon dioxide via pyruvate in plant and yeast cells. c. Fermentation occurs in the cytoplasm. Aerobic respiration starts in the cytoplasm and is completed in the mitochondria.			

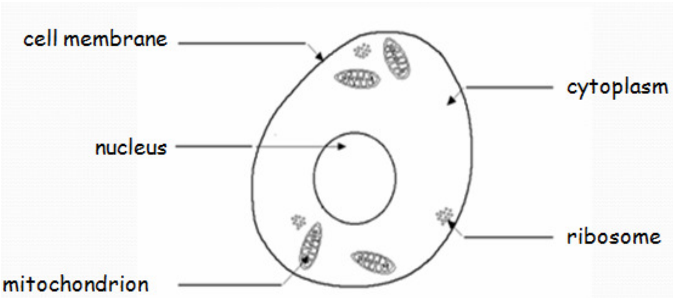
Cell Structure

What you need to know already:

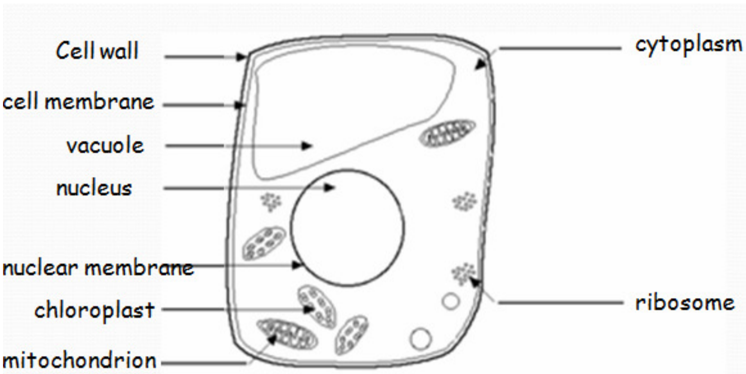
- Structure of a plant and animal cells from S2 / S3 Cells topics

Structure	Function
nucleus	Controls all cell activities, including cell division. Contains genetic information that is passed on from one generation to another.
cell membrane (plasma membrane)	Controls the entry and exit of substances to/ from the cell. Composed of a phospholipid bilayer with a patchy mosaic of proteins that make it selectively permeable (to smaller molecules).
cytoplasm	The jelly-like substance where chemical reactions take place.
mitochondria	The site of aerobic respiration (release of energy from glucose in the presence of oxygen)
ribosome	The site of protein synthesis in cells

Animal Cells (cheek cell)



Plant Cells (green leaf cell)



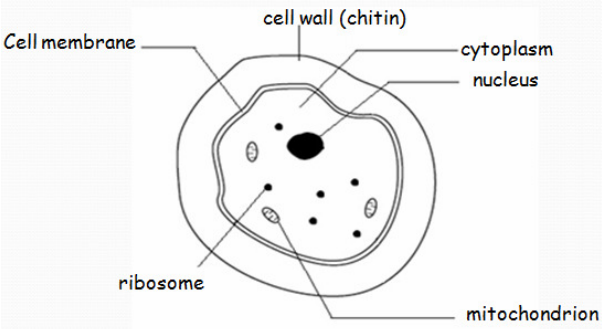
In addition to the structures in the table above, **plant** cells may also **have** the following:

Structure	Function
cell wall	The outer boundary of the plant cell made of cellulose (structural carbohydrate). Gives the cell support and helps it keep its shape as well as preventing it from bursting when water enters by osmosis.
large central vacuole	Contains cell sap made of a solution of salts and sugars. Regulates water content of cell and when vacuole is swollen, it gives the cell a degree of support.
chloroplast	Discus shaped structures that contain chlorophyll to trap light energy for photosynthesis

Fungal Cells (yeast)

Fungal cell structure may be quite similar to plant cells, but fungi are not plants.

- Fungal cells have many structures which carry out the same functions as those in plant and animal cells e.g. ribosomes, mitochondria, nucleus, cell membrane, *etc.*

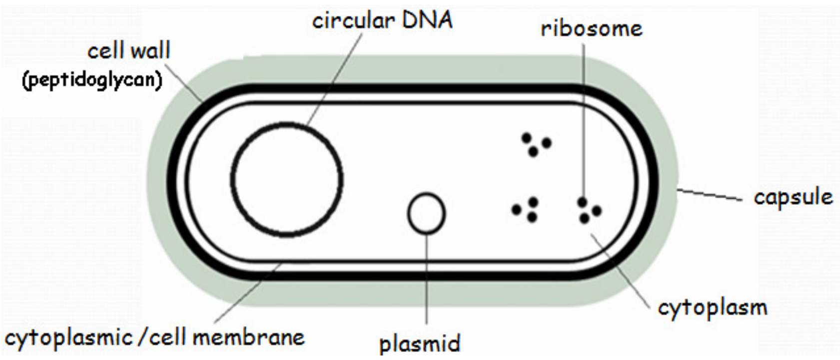


- Fungal cells do not have chloroplasts and therefore **cannot carry out photosynthesis**.

Fungal cells get their energy by breaking down or decomposing dead or decaying matter as their food source. They are nature's recyclers (**decomposers**) as they break down waste material and release the nutrients into the soil.

Bacterial Cells (*E.coli*)

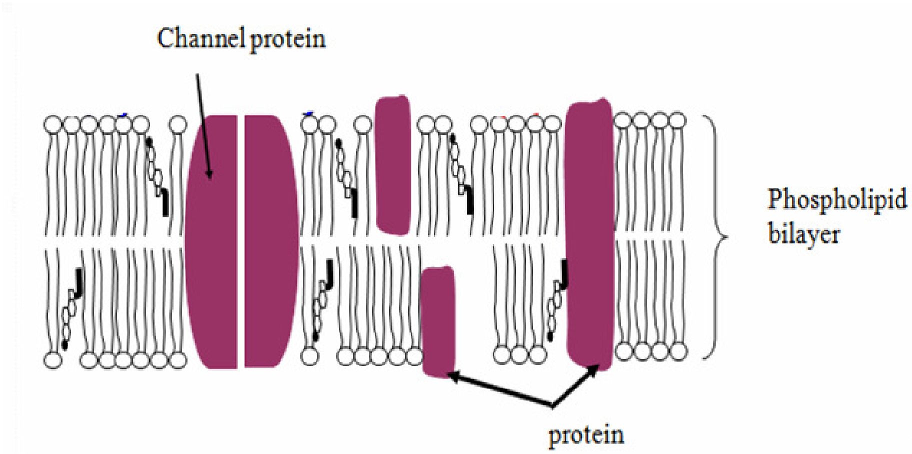
Bacteria are some of the smallest and simplest organisms on earth. They also act as **decomposers**.



- Bacteria have some structures in common with other cells: cytoplasm, ribosomes.
- Bacteria do not have a true nucleus, but instead have a **circular chromosome** made of DNA.
- Bacteria may also have smaller rings of DNA called **plasmids**. These are useful as they may contain extra genes for drug resistance and are useful to Scientists for Genetic Engineering.
- They **do not possess mitochondria**, so respiration is carried out in the cytoplasm.

Transport Across Cell Membranes

Structure of a Cell Membrane (Plasma membrane)



The cell membrane is also known as the plasma membrane.
The arrangement of phospholipids and proteins is described as a **'Fluid Mosaic'** model since there is a fluid bilayer of phospholipds with a patchy mosiac of proteins.

The **phospholipid bilayer** is freely permeable to small molecules such as water, oxygen and carbon dioxide, which diffuse through it rapidly.

Larger molecules such as proteins and starch cannot pass through the membrane and the so the plasma membrane is described as being **selectively permeable**.

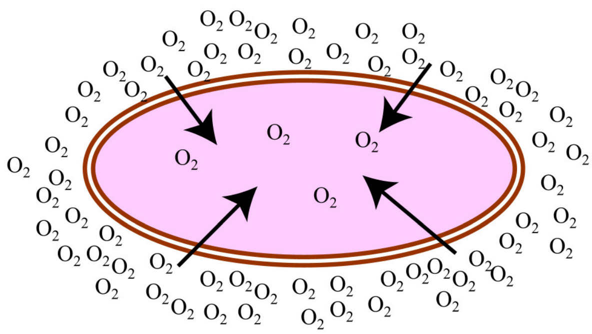
Diffusion

- Diffusion is the movement of molecules **from** an area of **high** concentration **to** an area of **low**er **concentration** until the molecules are evenly spaced out and the concentration becomes equal

- Diffusion **does not require energy** (it is a passive process)

- The difference in concentration between the 2 regions before diffusion occurs is called the **concentration gradient**. Molecules always move **down** a concentraion gradient by diffusion from high to low concentration.

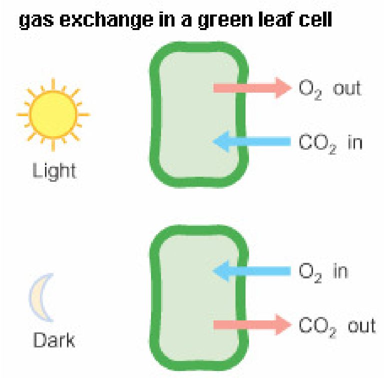
Importance of diffusion

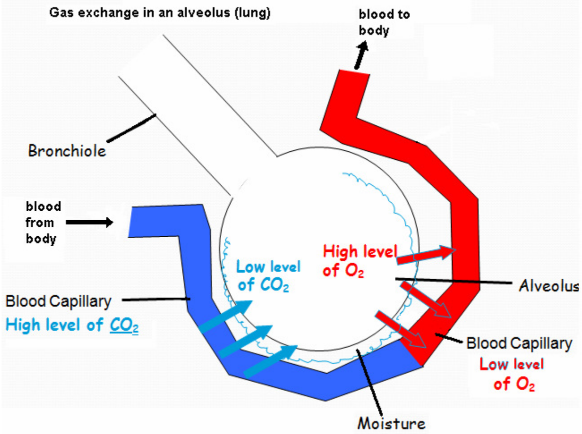


Diffusion is important in both unicellular (Amoeba, Paramaecium, yeast) and multicellular organisms (plants and animals).

In **single-celled organisms** diffusion allows small, soluble food molecules (glucose / amino acids) and oxygen to move into the cell and wastes such as carbon dioxide can diffuse out.

Cells are constantly using up oxygen and producing carbon dioxide. These gases pass into and out of the cell through the cell membrane (plasma membrane). The direction of movement of molecules depends on the concentration gradient.





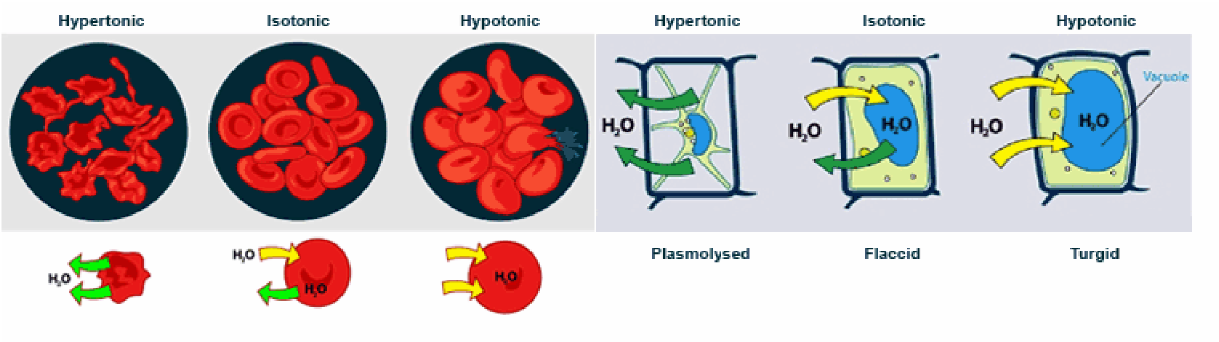
In multi-cellular organisms diffusion allows small, soluble food molecules to move from the gut into the bloodstream so they can be carried to the body cells.

Osmosis

- Osmosis is the movement of **water** molecules **from** a region of **high** water concentration **to** a region of **low**er water concentration, **through a selectively permeable membrane.**

- Osmosis occurs between neighbouring cells and their environment. When a cell is in contact with a solution or another cell, osmosis will occur.

- Osmosis is a passive process and **does not require energy**.



Effect of different solutions on blood cells

Plant Cell Under Different Environments

- When 2 solutions have different water concentrations the one with the higher water concentration (more water) is said to be **hypotonic**.
  The solution with the lower water concentration (less water) is described as being **hypertonic**.

- Distilled water is pure (100%) water and is therefore hypotonic to all other solutions.

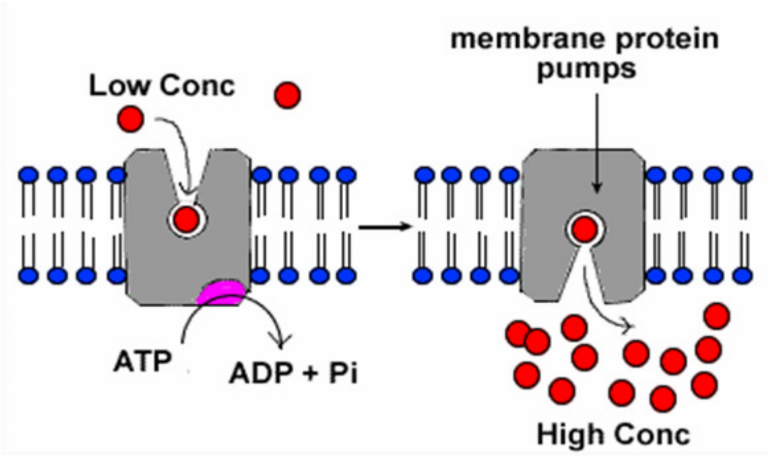
- When 2 solutions have the same water concentrations they are **isotonic**.

Active Transport

Active transport of molecules or ions occurs **AGAINST** a concentration gradient (from low to high concentration) and therefore **requires energy**. This energy is provided by the ATP produced during aerobic respiration in cells. (We will cover this in more detail later in the Cells unit.)

Protein molecules in the cell membrane (plasma membrane) act as carrier molecules (or pumps) as they 'recognise' specific ions and transfer them across the membrane.

The diagram below shows the carrier protein molecule **actively** pumping potassium ions **into** the cell, **against** a concentration gradient:



Conditions Required for Active Transport

Any factor that affects the rate of aerobic respiration also affects the rate of active transport.

glucose + oxygen ⟶ ENERGY (ATP) + carbon dioxide + water

- **Temperature** (aerobic respiration is a series of enzyme controlled reactions, so an increase in temperature will increase the rate of ion uptake by active transport, but at high temperatures the enzymes are denatured and the cell will die if can't make energy /ATP)

- Availability of **oxygen**

- **Concentration** of respiratory substrate (**glucose**)

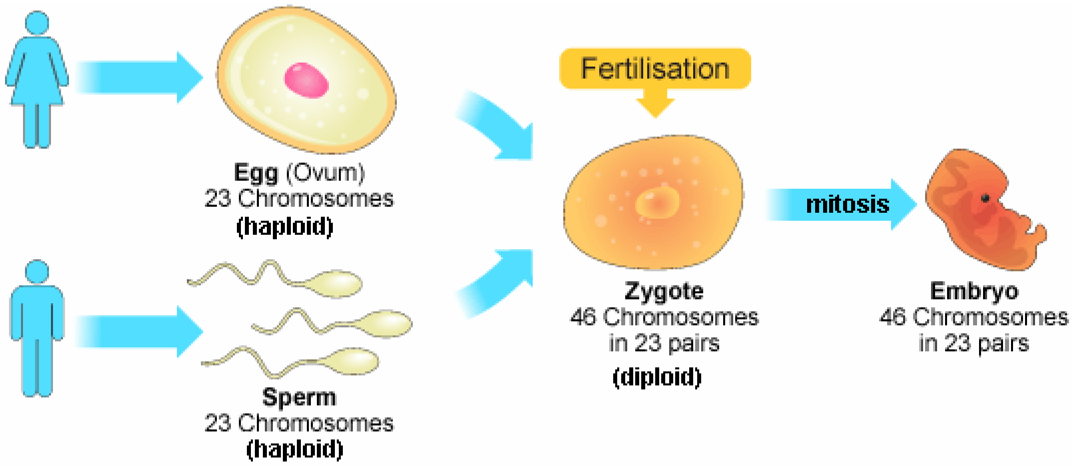
Producing New Cells

Chromosome Complement

Every species of plant and animal has characteristic number of chromosomes present in the nucleus of each of its cells, known as the **chromosome complement**. During mitosis, the chromosome complement is **maintained** *i.e.* each new cell produced has the same number of chromosomes as the original cell.

In **humans**, the chromosome complement in a normal **diploid body cell** is 46 chromosomes:

- **One set** of 23 single chromosomes from the egg (**haploid gamete** cell) and
- **One set** of 23 single chromosomes from the sperm (**haploid gamete** cell)
- fuse during fertilisation to produce one **diploid** cell with 46 chromosomes (or **2 sets** of chromosomes)



- Most human cells have 23 **pairs** of chromosomes, a double set (diploid)
- Human body cells have 22 **pairs** of 'normal' chromosomes + one pair of sex chromosomes (XX or XY)
- A **female** has 22 'normal' pairs + **XX** in each body cell
- A male has 22 'normal' pairs + **XY** in each body cell
- Gamete cells are haploid, so contain a single set of chromosomes
- An egg contains 22 single 'normal' chromosomes + X
- A sperm contains 22 single 'normal' chromosomes + X **OR** 22 single 'normal' chromosomes + Y
- The sex of a baby is determined by the sex chromosome carried in the sperm cell

Mitosis

You **MUST** know all the stages of mitosis and the description of stage.

During mitosis the chromosomes replicate, so each new cells is **GENTICALLY** identical.

Cell culture

Scientists take advantage of cell division by **growing cells in the lab**. The process of growing cells in the lab in either solid or liquid media is called **cell culture**.

Cells are grown in culture to

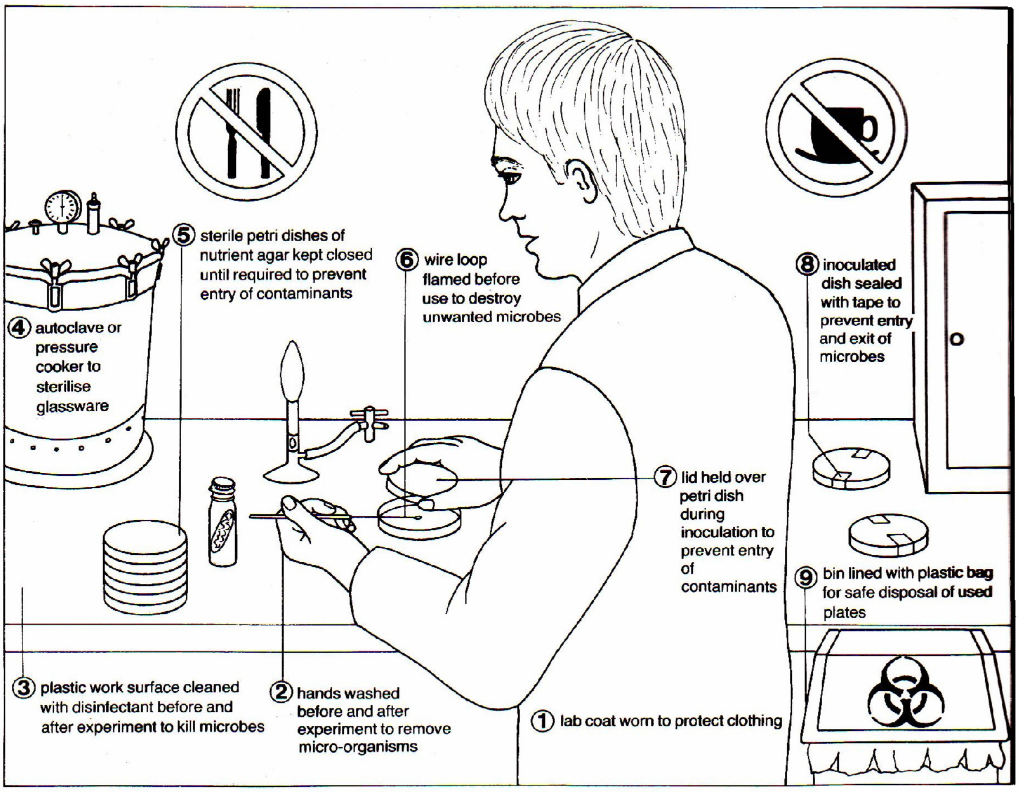
- make food and drink such as mycoprotein (Quorn), beer and wine,
- to test antibiotics, vaccine and medicines
- to learn about cell division

It is possible to grow a layer of cells in dishes/bottles which can then be used for a variety of purposes.

Current research is being done to use cells grown in the lab as skin grafts for burn victims and even to grown whole entire organs.

Aseptic Techniques

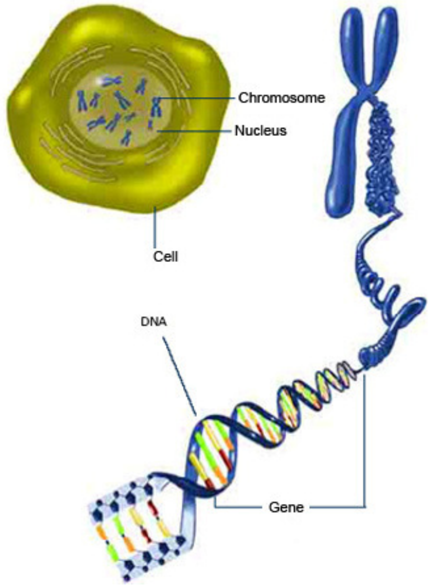
When growing cells in the lab it is very important to limit any chance of contamination. There are certain procedures that must be followed to make sure only the cells of interest are grown and microbes from the surrounding environment don't interfere with their growth.
This safe working procedure is called 'aseptic technique'.



Cell culture also requires:

- an appropriate medium with all the necessary nutrients and growth factors (e.g. nutrient broth or solid nutrient agar)
- careful control of growing conditions: temperature, pH, oxygen availability, etc.

DNA and the Production of Proteins

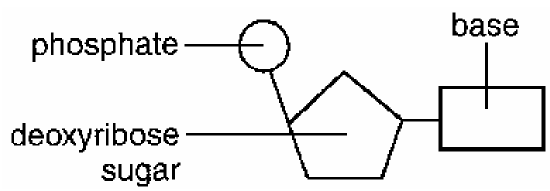


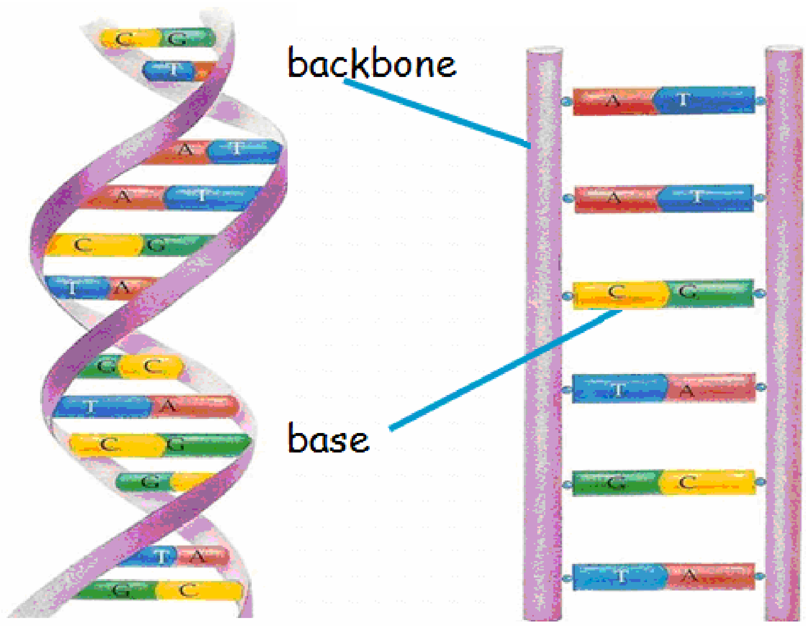
DNA Structure

Chromosomes are thread-like structures found in the nucleus of a cell and they are composed of DNA (deoxyribonucleic acid). This is the genetic information for making proteins and it is passed on from one generation to the next.

DNA is a **double** stranded molecule twisted to form a **helix**.

DNA is made up of basic building blocks called **nucleotides**. A nucleotide has the following structure:





The 'backbone' of the DNA molecule is sugar and phosphate molecules.

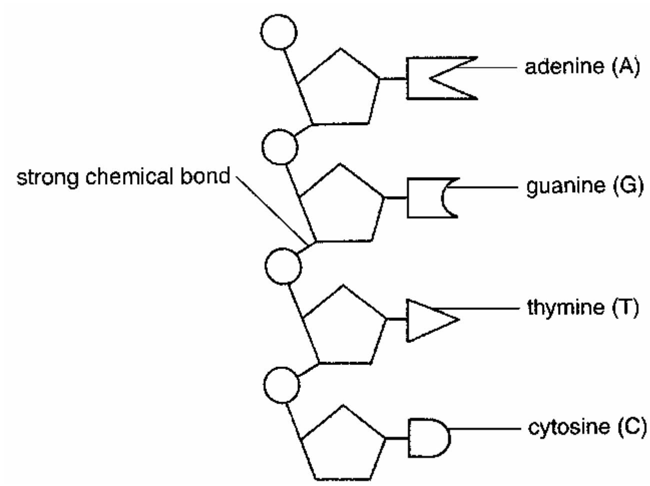
The 'rungs' are made of **pairs** of bases. There are four types of base

- Adenine (A)
- Thymine (T)
- Guanine (G)and
- Cytosine (C)

In DNA, adenine always pairs with thymine and guanine always pairs with cytosine.

A-T and C-G

(**A**ll **T**rains **G**o **C**hoo choo!)

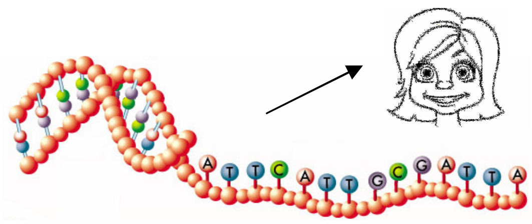


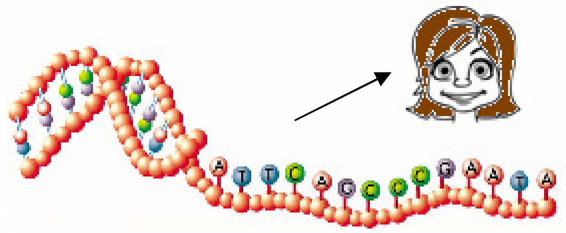
The base pairs are held together by weak hydrogen bonds.

The nucleotides are joined by strong chemical bonds between the sugar and phosphate to create the backbone of the DNA molecule.

The **sequence of bases** carried on the DNA makes up the **genetic code** and determines the amino acid sequence in a protein. The order of amino acids gives each individual protein its characteristic properties.

The **variation** that exists in the members of a species is mainly **due to** the **differences in** their **DNA** and the proteins they produce. For example your hair colour may be different to another person as your DNA carries a different sequence of bases, so the protein that makes your hair is also different. The production of these proteins is controlled by a variety of enzymes.

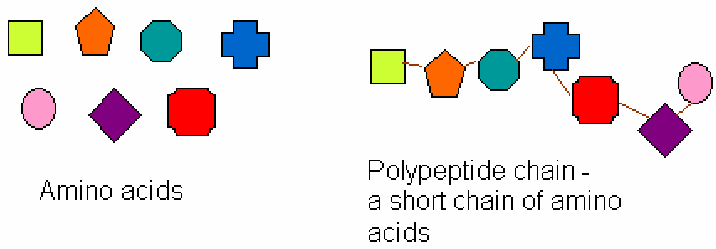


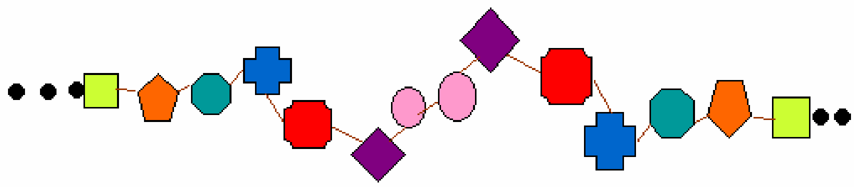


Proteins

Proteins are made up of basic building blocks called amino acids. There are about 20 different types of amino acids, so the variety of proteins that can be made is extensive.

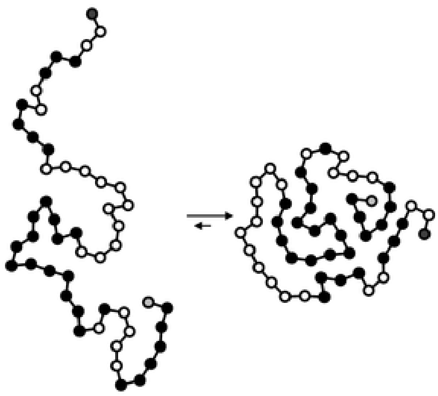
The hundreds of amino acids in a protein are joined by peptide bonds to make polypeptide chains.





A protein - a long chain of amino acids. The sequence of amino acids will determine the proteins shape & therefore function.

Other bonds between certain amino acids from, making the chain coil up and become folded in a characteristic way. The exact nature of the coiling and folding determines the final structure of the protein and the function it carries out.

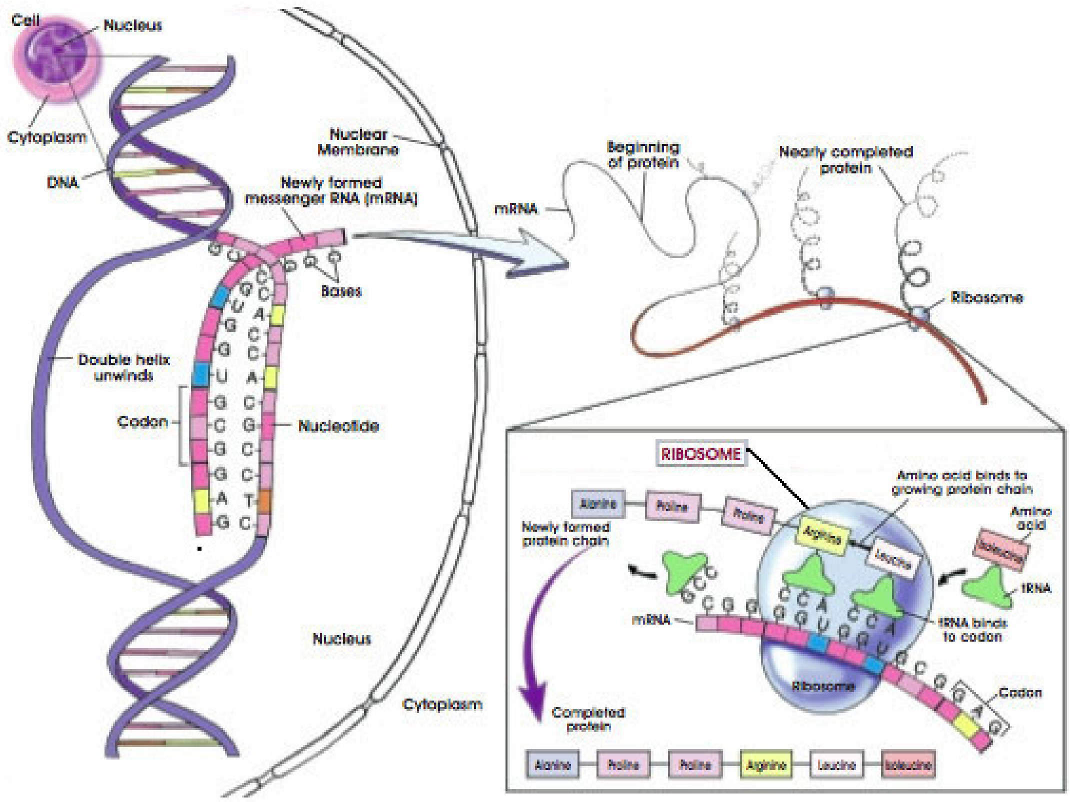


Making Protein (Protein Synthesis)

The **DNA** template for making proteins is held on the chromosomes, in the **nucleus** of a cell. **Proteins** are very large molecules and cannot be built in the nucleus of the cell, so must be **made in the cytoplasm**. (It would be like using a reference book in the library to build a car – you could take all the parts into the library to make the car using the instructions in the book, but the car couldn't get out of the library. It would be too large to fit through the door!)

The information from the DNA is copied as a **single strand of messenger RNA (mRNA)**, which takes the message from the nucleus to the ribosome, so that the protein can be built.

- **RNA** (ribonucleic acid) is a messenger molecule made by copying the code from the DNA in the nucleus
- The mRNA strand leaves the nucleus through a **nuclear pore** and travels to a ribosome in the cytoplasm
- The **ribosomes** in the cytoplasm (or bound to the rough endoplasmic reticulum) are the site of protein synthesis in cells.
- At the ribosome, the **code on the mRNA** is read in groups of 3 bases (**codon**), to allow the correct amino acids to be joined together in the correct order to make the required protein.
- The **amino acids** are **joined by** strong chemical bonds called **peptide bonds**



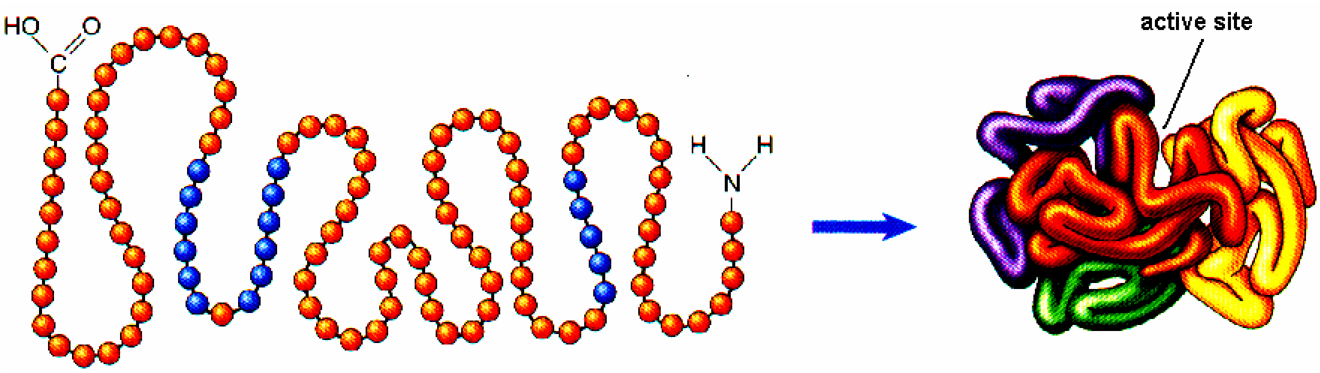
- It is the order of bases on the DNA that determines the order of amino acids in the protein.

Proteins and Enzymes

More About Proteins

The sequence of bases carried on DNA determines the order of amino acids and so the shape and function of the protein.

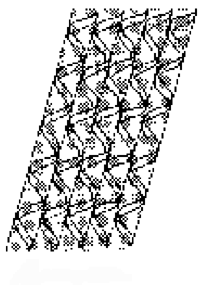
Enzymes are made of protein and all enzymes are ‘specific’ to a substrate because the way they fold determines the shape of the active site. Since the active site is complementary in shape to the substrate, each enzyme can catalyse only one reaction.



Variety and Function of Proteins

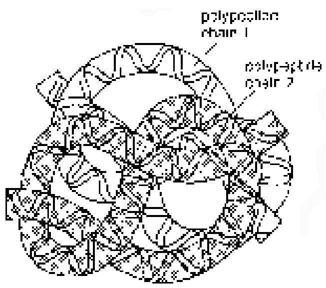
An enormous number of different proteins are found in living things. A human being possesses over 10,000 different proteins.

Fibrous and Globular Proteins



Fibrous Protein

A fibrous protein is made up of several spiral shaped polypeptide molecules, joined together to make a rope-like structure.



Globular Protein

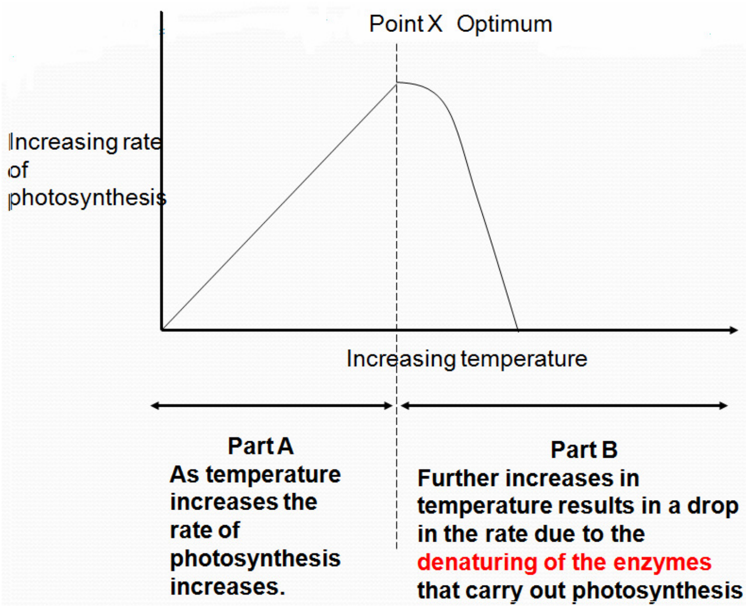
A globular protein consists of several polypeptide chains folded into a roughly spherical shape.

Name of Protein	Type of Protein	Function
antibodies	globular	Made by white blood cells (lymphocytes) and defend the body by attaching to antigens
enzymes	globular	Speed up chemical reactions. They are vital in biological processes such as photosynthesis and respiration. Also required for digestion of food.
growth hormone	globular	Promotes growth of long bones -in general terms hormones are chemical messengers
insulin hormone	globular	Helps to control sugar balance by converting excess glucose to glycogen for storage in the liver
structural protein in membrane	globular	Support in cell membranes; transport proteins for active transport; channel-forming proteins
collagen	Structural fibrous	Rigid support in bones; strength and attachment in tendons and ligaments
actin and myosin	Structural fibrous	These fibres have properties that allow muscles to contract, allowing movement

Enzymes

Optimum conditions for enzymes

- The conditions in which an enzyme is most active, e.g. temperature, concentration of substrate or pH, are called the **optimum conditions**
- As the temperature increases, enzyme activity increases up to an optimum
- **Above this optimum temperature** (usually above 40 ºC the enzyme's active site will become **denatured** (changing shape so the substrate will no longer fit).
- The optimum temperature for human enzymes is **37ºC**, body temperature



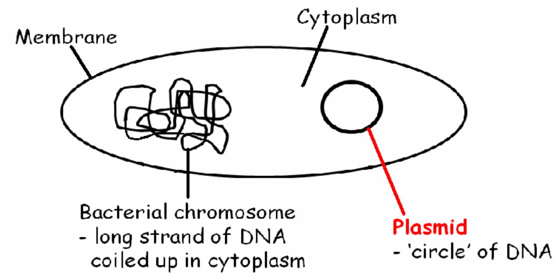
- The shape of an enzyme is partly due to the hydrogen bonds that hold the globular protein together. If the protein is exposed to **extremes in pH**, some of these bonds will break and the **protein** will be **denatured**.

- Most **enzymes work within a range of pH** e.g. pepsin works best at a pH of 2.5 in the stomach acid. Other digestive enzymes work best at pH 8-9

Genetic Engineering

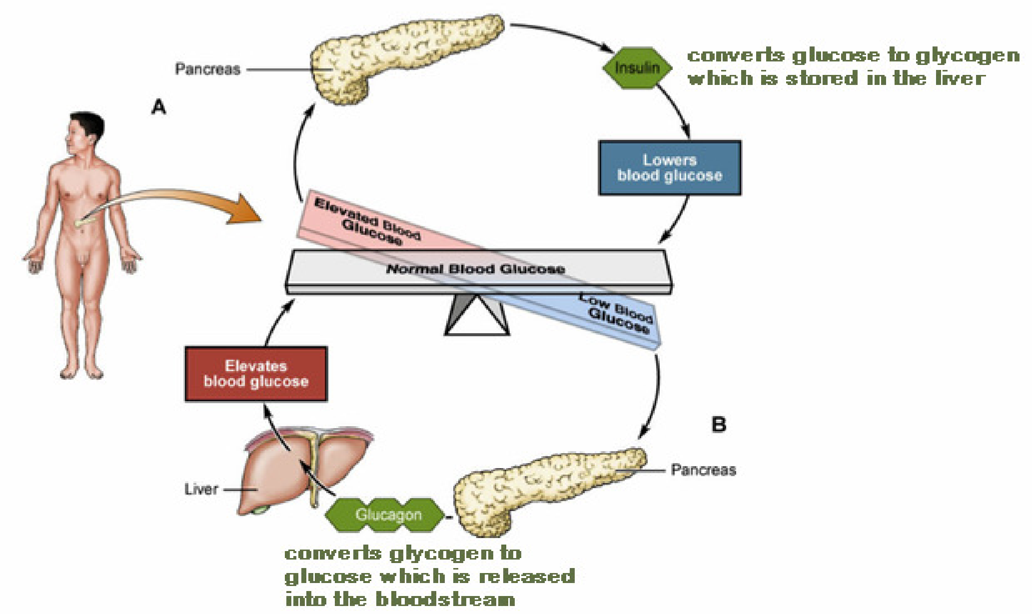
Structure of a bacterium

The normal control of bacterial cell activities depends on its chromosomal material



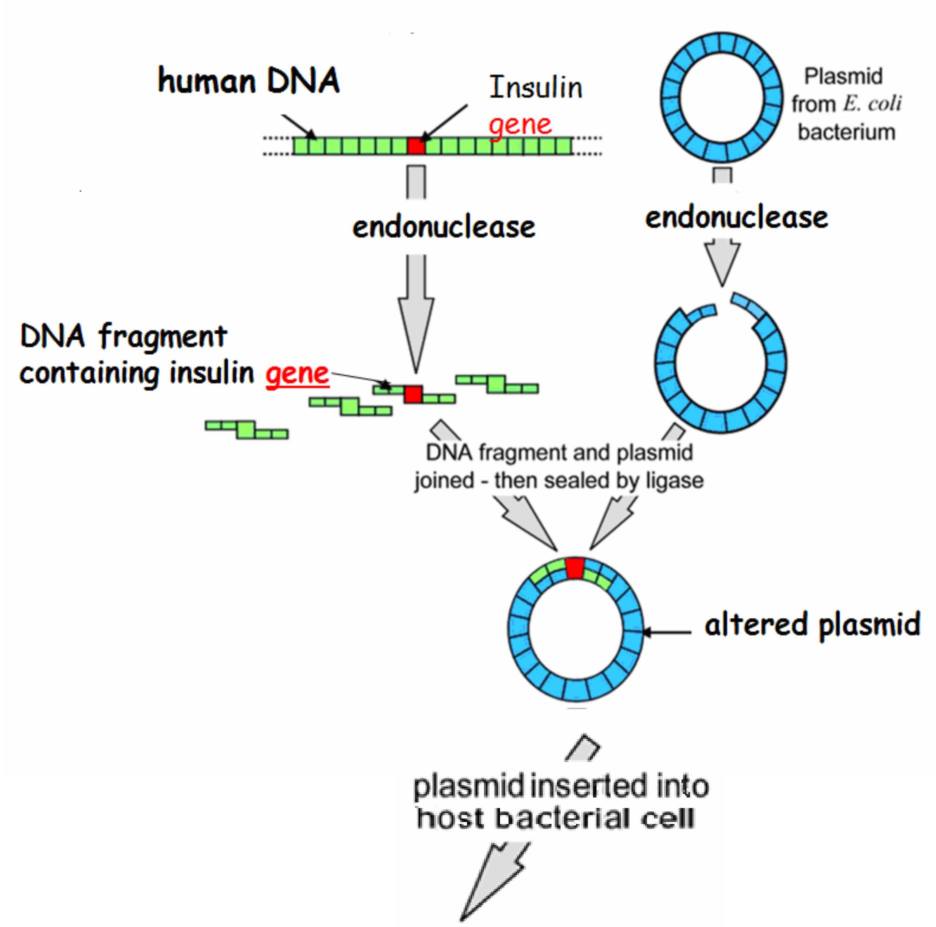
Genetic Engineering

Genetic engineering is the process by which **genes**, pieces of chromosomal DNA, are **transferred from one living thing to another**. This can occur naturally when the bacterium *Agrobacterium tumifaciens* transfers part of its DNA to a plant and this DNA integrates into the plant's genome (causing disease - the production of tumours and associated changes in the plant's metabolism), or it can be done artificially in a laboratory.
Genes can be transferred from a different organism (e.g. humans) into bacteria allowing them to make new substances such as **insulin** (or from a spider into a goat to make spider silk).
As a result of genetic engineering, bacteria may produce increased quantities of products e.g. useful drugs such as insulin.
Insulin is used to reduce the level of glucose in the blood of diabetics. The need for an unlimited supply of insulin is increasing as our lifestyle has changed and the number of people with diabetes is increasing.
Insulin is a hormone produced in the body to convert excess sugar to glycogen, which is stored in the liver.



The Stages in the Process of Genetic Engineering

The process of genetic engineering is made up of the following stages (see diagram) –



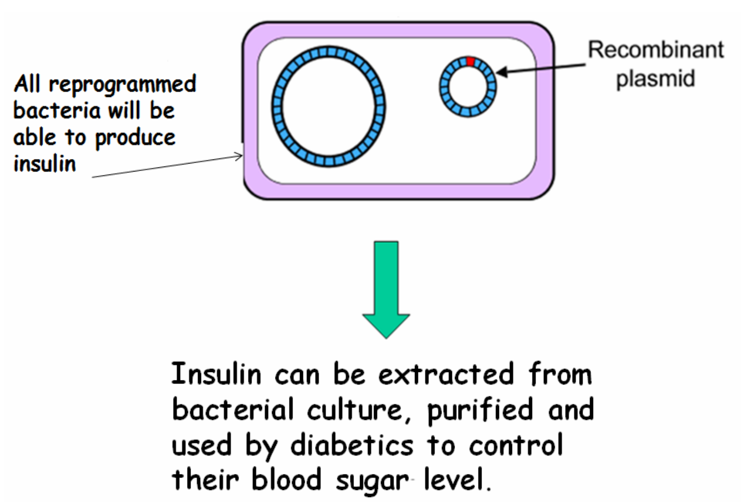
1. Identification of the required gene for human insulin (from a cell of a non diabetic human)

2. Cutting out the insulin gene from the source chromosome, using an enzyme called endonuclease

3. Extraction of a plasmid from a bacterial cell

4. Opening up of the plasmid using endonuclease

5. Insertion of the insulin gene into the vector/ bacterial plasmid using the enzyme ligase



6. Insertion of the altered (recombinant) plasmid into the bacterial 'host' cell

7. Duplication of the altered plasmid and growth and multiplication of the bacterial cell

8. Mass production of insulin by plasmids that express the 'foreign 'gene

9. Extraction and purification of insulin

Advantages and Disadvantages of Genetic Engineering

Advantages

Genetic engineering uses reprogrammed bacteria and yeast. Given suitable conditions, these micro organisms multiply at a rapid rate and make large quantities of the desired product.

Genetic engineering has made possible the production of a wide range of substances that are of great medical and commercial use to Man.

Disadvantages

The initial development of a strain of micro organism reprogrammed exactly to requirements is very expensive.

There is the possibility of genetically engineered bacteria being released into the environment and having some harmful effects.

Applications of Genetic Engineering

Medical Applications

Product	Normal source and function	Medical application
Insulin	Made by pancreas; controls blood sugar level	Given to people with diabetes mellitus to control their blood sugar level
Factor VIII	Chemical present in blood; required for clotting	Given by injection to sufferers of haemophilia whose blood fails to clot
Human growth hormone	Made by cells in pituitary gland; controls normal growth and development	Given by injection to children who do not make enough of their own

Commercial applications

Reprogrammed bacteria produce enzymes that are added to detergents to digest difficult stains.

Rennin is an enzyme secreted by the stomachs of young mammals. It causes milk proteins to coagulate. This curdling of milk is an essential stage in cheese making. In the past, rennin for cheese making was extracted from the stomach of calves. Genetic engineers now transfer the rennin gene from calves to yeast cells and can mass produce rennin needed for the cheese making industry in this way.

Transgenic Multicellular Organisms

Agrobacterium tumefaciens is a bacterium present in the soil. It invades wounded plant tissue – it injects a plasmid into a plant cell and some of the plasmid's genetic material becomes incorporated into the plant's DNA. Agrobacterium is therefore a 'natural genetic engineer'. It provides scientists with the opportunity to introduce into crop plants desirable genes from other organisms that have been inserted into one of Agrobacterium's plasmids.

Transgenic Crop Plants

Crop plant	Role of inserted gene	Beneficial effect
apple	Blocks chemicals that promote ripening	Extends shelf life of fruit
pea	Produces insecticide protein	Leaves can resist caterpillar attacks
strawberry	Production of antifreeze chemical	Fruit is protected against frost damage
tomato	Blockage of the production of an enzyme	Fruit is prevented from becoming soft and mushy

Future applications of Genetic Engineering

In the future it is possible that farmers will grow transgenic crops for their insulin, human growth hormone or for their blood clotting agent.
Already some animal genes have been inserted into plants.
Using *Agrobacterium tumefaciens*, scientists have produced a transgenic variety of tobacco plant that contains the gene for haemoglobin.
Being able to produce blood products this way in the future could reduce our dependency on blood donors.

Therapeutic use of cells

As we continue to develop new technology we may be able to use stem cells to grow human body tissues to treat accident/ burns victims and reduce our dependency on organ donors.

Photosynthesis

Chemistry of Photosynthesis

Photosynthesis occurs in the **chloroplasts** of green plant cells and is the means by which green plants make their own food. It is a complex series of chemical reactions, controlled by enzymes.

$$\text{Carbon Dioxide + water} \xrightarrow[\text{Chorophyll}]{\text{Light}} \text{Glucose + Oxygen}$$

Photosynthesis involves 2 stages:

- the **light dependent stage** called **photolysis** (occurs in the grana of the chloroplast) and

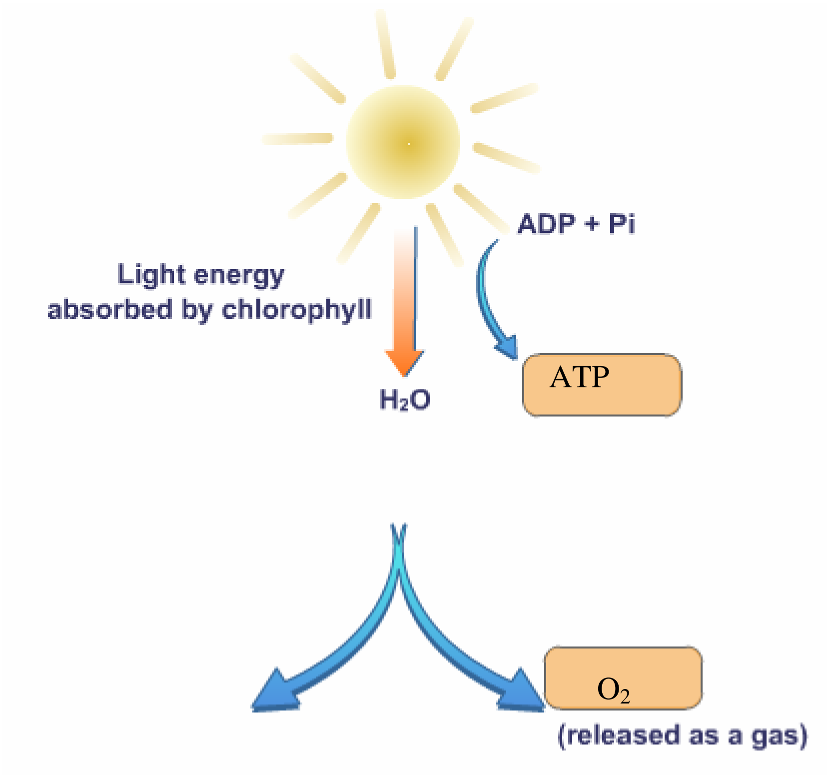
- the **temperature dependent stage** called **carbon fixation** or the Calvin cycle (occurs in the stroma of the chloroplast)

Photolysis

This light dependent stage occurs in **the chloroplasts**. Light energy is trapped by chlorophyll, and converted into chemical energy (ATP).

Light energy is used to split molecules of water into hydrogen and oxygen, a process called photolysis of water. The oxygen is released as a by-product.

Energy from the light is also made available for the synthesis of ATP from ADP and inorganic phosphate (P_i). This process is called. The hydrogen and the energy held by ATP are essential for the second stage of photosynthesis.



Excess oxygen diffuses out of the cell

Carbon Fixation

In the second stage of photosynthesis, the **ATP** and **hydrogen from photolysis and carbon dioxide from the air** are essential to produce glucose molecules in a series of enzyme controlled reactions known as carbon fixation.

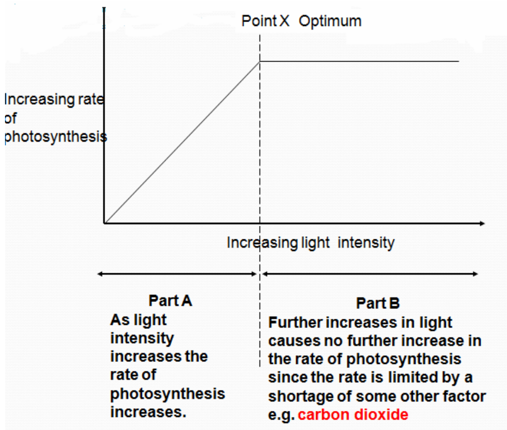
Fate of Carbohydrate made by Photosynthesis

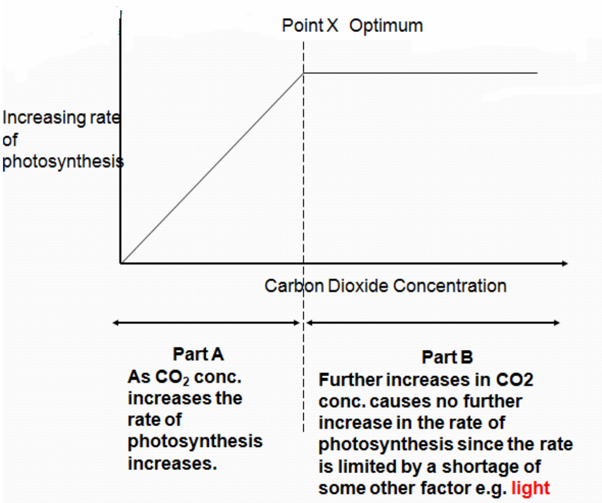
- The **glucose** sugar made by photosynthesis can be used as a **respiratory carbohydrate** to provide energy for other reactions (see note on respiration)
- The glucose molecules an be joined together into long chains to make **starch**, the **storage carbohydrate**
- Glucose can be converted to make the **structural carbohydrate** called **cellulose** for new plant cell walls

Limiting factors in Photosynthesis

There are several factors that can limit the rate of photosynthesis:

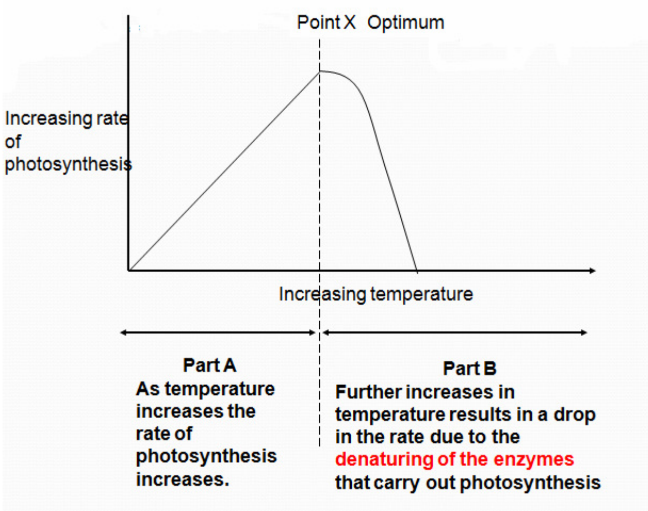
- Lack of **water**. Water is required for the light dependent stage (photolysis)
- Lack of **light**. In the absence of light photolysis could not occur and there would be no ATP or hydrogen made. Since these are essential for the carbon fixation stage no more glucose will be made.





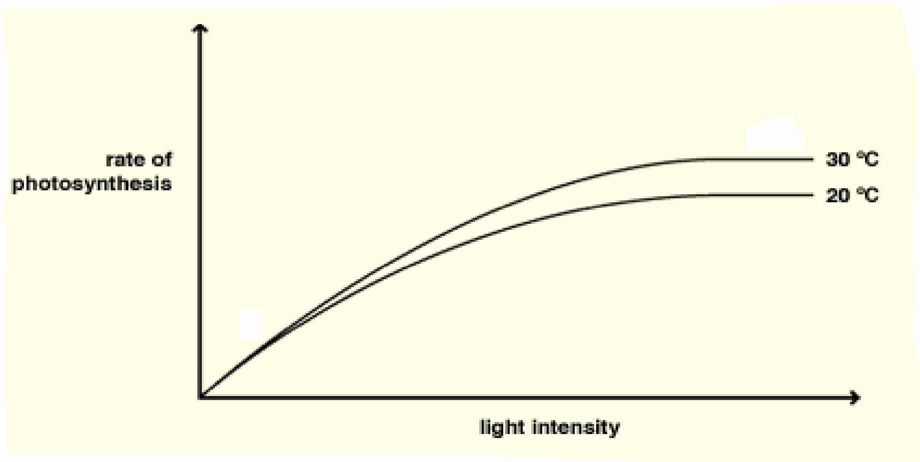
- If **carbon dioxide concentration** is low it will slow the rate of photosynthesis as it is needed for the carbon fixation stage, which is temperature dependent,

- Low **temperature** will reduce the rate of photosynthesis, which is controlled by enzymes with an optimum temperature. Above the optimum temperatures the enzymes become denatured and photosynthesis will stop.



- If the rate of photosynthesis is limited, the rate of growth of the plant will also be reduced, as there will be less carbohydrate available to make energy (by respiration). The energy is needed to make new cells by mitosis.

In any question on limiting factors, the factor on the X axis, in this case light intensity, remains a limiting factor for as long as the graph continues to rise. When the graph levels off, the rate of photosynthesis is being limited by other factors such as temperature or carbon dioxide concentration. When temperature is increased from 20°C to 30°C we see the rate of photosynthesis increase.



Respiration

Respiration is the name given to the reactions that supply the cell with energy. This energy is stored as ATP (adenosine triphosphate) until it is required.

- The first is called **Glycolysis** and oxygen is not required for this stage.
- The next stage requires oxygen.

glucose + oxygen ⟶ ENERGY + carbon dioxide + water

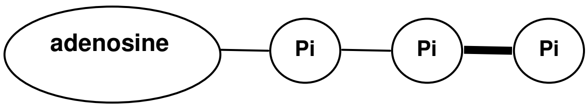
$(C_6H_{12}O_6)$ + $(6O_2)$ ⟶ ENERGY + $(6CO_2)$ + $(6H_2O)$

The Mitochondrion

- The **mitochondria** are the **site** of respiration and **ATP** (energy) **production** in cells.
- They are sausage shaped organelles found in the cytoplasm of living cells.
- Cells requiring a lot of energy possess many mitochondria *e.g.* sperm, liver, muscle, neurones and companion cells

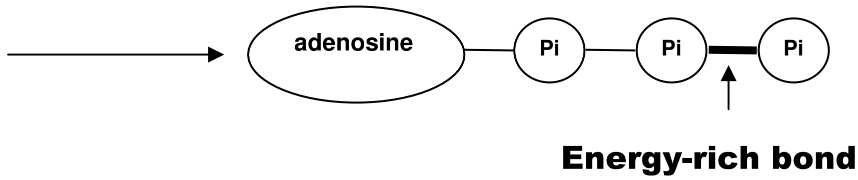
ATP and Energy Production

- **ATP** is found in all living cells.
- It is a chemical that **stores energy** so that it can be released when **required for active transport, muscle cell contraction, protein synthesis, transmission of nerve impulses and cell division**
- **ATP** (adenosine triphosphate) is a molecule composed of ***adenosine*** and three ***inorganic phosphate*** **(Pi)** molecules.

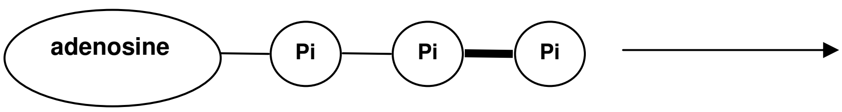


- ATP is made by joining ADP (adenosine diphosphate) to a molecule of inorganic phosphate using energy released from certain chemical reactions that occur in the cell.

ADP + Pi + **Energy**



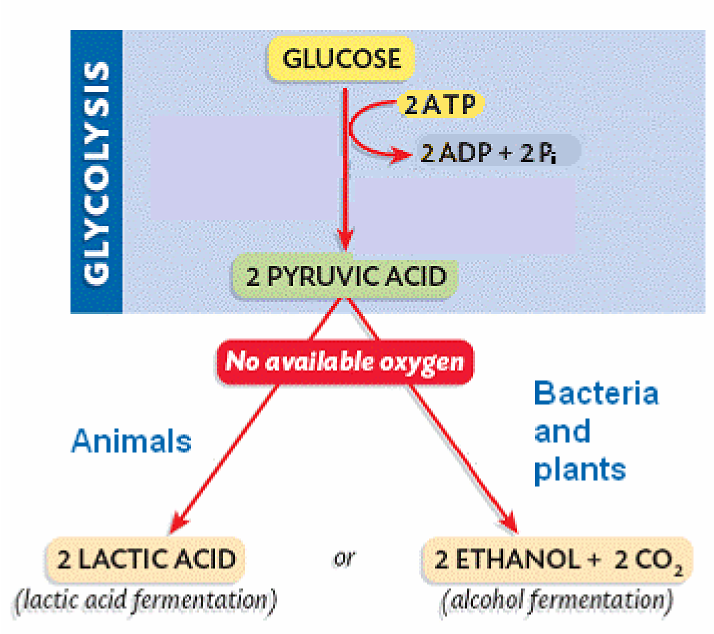
- If the '**energy-rich**' bond joining the **last** inorganic phosphate molecule to the rest of the molecule is broken (by enzyme action) then the **stored energy is released.**



Energy +ADP + Pi

Glycolysis

- The first reaction is called **glycolysis** and **occurs in the** cell **cytoplasm**.



- Glycolysis does **not require oxygen** and is often called **'glucose splitting'** and involves the breakdown of **6C Glucose** into **2 x 3C Pyruvate** molecules.
- **2ATP are produced.**
- **Hydrogen is released** and transported to the next stage**.**

Respiration in the Mitochondria

- Respiration can occur in **aerobic** (with oxygen present) or in **anaerobic** conditions (in the absence of oxygen).
- Respiration **starts in** the cell's **cytoplasm** and is **completed** in the **mitochondria**.
- **2ATP** are made from each glucose molecule during **anaerobic** respiration
- A total of **38ATP** is made from each glucose molecule during **aerobic** respiration, so aerobic respiration is more efficient