

Biology

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[This is Unit 2 Biology, Additional Biology. This section comes after Core Biology in an AQA Course (Unit 1)]

B2-1 : Cells

Structure of Animal and Plant Cells

The following features are those which *all* cells (both animal and plant) share in common:

- they all have a **nucleus** which holds the genetic information and controls cell activity
- they are all filled with **cytoplasm** which is needed for chemical reactions
- they have a **cell membrane** which controls substances entering/leaving the cell
- there are **ribosomes** where protein synthesis takes place
- they have **mitochondria** which release energy during respiration

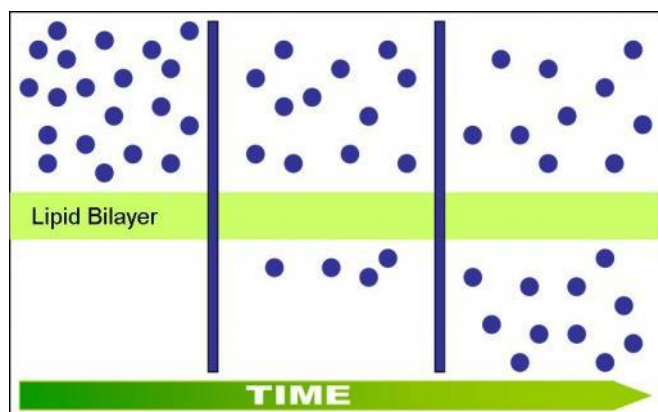
...however, some plant cells vary in that:

- all plant cells have a **cell wall** made from cellulose which strengthens the cell
- most plant cells have **chloroplasts** which are green and make food in photosynthesis
- most plant cells also have a **permanent vacuole** filled with cell sap in the cytoplasm

Substances Entering and Leaving Cells

There are three ways which substances can get in and out of cells...

When the particles in a gas or liquid (any substance in a solution) are spread out, we call it **diffusion**. It is the **net movement** of particles from an area of high concentration to an area of a lower concentration. Net movement explains which direction particles have moved. The diagram below shows the process of diffusion.



As you can see, in the first “stage,” all of the solution is found on the outside of the cell membrane. Through diffusion, the solution begins to enter the cell through the membrane and spreads out. By the third “stage,” there is an equal amount of particles of the solution in and out of the cell.

Another method of movement of substances is **osmosis**. Osmosis is the movement of *water* from an area of high concentration to an area of low concentration across a *semi-permeable membrane*.

Now then, there are three main things you need to know:

- an **isotonic solution** is the same concentration as the cytoplasm inside the cell, so when added the cell is not affected
- a **hypotonic solution** has a greater concentration than the cell and more water moves into the cell than out
- a **hypertonic solution** has a lower water concentration than the cell, causing more water to move out than in

Because there is no cell wall to keep a strong structure in an animal cell, an animal cell will (a) burst when introduced to a hypotonic solution and (b) shrivel up and become useless/die when introduced to a hypertonic solution. But the cell walls that plant cells have is sturdy enough to hold it, so here is what happens with osmosis in plant cells:

- when an isotonic solution is added, the cell remains as it normally is, because it is of the same concentration as the cytoplasm – this means that an *animal cell could also survive being introduced to an isotonic solution*
- when a hypotonic solution is added, the cell becomes **turgid** and looks as though it will burst; this is because too much water is in the cell – but the cell wall prevents it from “popping”
- when a hypertonic solution is added, the cell becomes **flaccid** and shrivels up – this is when the cell membrane has completely pulled away from the cell wall, the cell becomes weak – because too much is leaving the cell

The third and final method of movement of substances is through **active transport**. Salts can be taken up cells against a concentration gradient by active transport.

A few things you may need to know:

If red blood cells are placed into distilled water, they burst. This is called **haemolysis**.

Amoeba use **contractile vacuole** to get rid of excess water.

B2-2 : Plants Producing Food

Photosynthesis

Plants make their own food using this process called **photosynthesis**.

carbon dioxide + water (+ light energy) → glucose + oxygen

6CO₂ + 6H₂O (+ light energy) → C₆H₁₂O₆ + 6O₂

The cells in the leaves of plants contain **chloroplasts**, which contain green substances called **chlorophyll**. Throughout photosynthesis, light energy is absorbed by chlorophyll and this energy is used to convert carbon dioxide (in the air) and water into a simple sugar called **glucose**. The chemical reaction also produces oxygen which is released into the air.

Plants are perfectly adapted for a number of reasons:

1. most leaves are broad, larger surface area for light to fall on
2. they have air spaces to allow carbon dioxide in and oxygen out
3. they have veins which bring water to the leaves of the plant

Limiting Factors of Photosynthesis

Photosynthesis tends to happen at different rates based on the conditions it is taking place in. There are four main limiting factors:

The first is **light intensity**. As you can probably imagine, the more light available, the more photosynthesis can be done. If there is very little or no light, no photosynthesis can be done, regardless of the other conditions. The general rule is the brighter the light, the faster the rate of photosynthesis.

The second being **carbon dioxide levels**. Plants need carbon dioxide to photosynthesise and produce glucose. As the atmosphere only contains 0.04% carbon dioxide, the rate of photosynthesis can be seriously affected by this factor.

The penultimate factor is **temperature**. Because photosynthesis takes place in living organisms – plants – it is controlled by enzymes, which work best at around 40°C and are destroyed above temperatures of above 45°C, making photosynthesis impossible.

The last factor is **water availability** which really speaks for itself. Water, like carbon dioxide, is needed for photosynthesis to take place – hence water must be available and the right amounts are necessary.

Use of Glucose and Nutrients

Plants use glucose in several ways:

- **respiration**: plants respire all the time, day and night, which involves the breakdown of glucose using oxygen to provide energy for their cells
- **transport and storage**: the food made from photosynthesis in the leaves is needed all over the plant, which is why it must be transported around the plant to keep a constant supply of the food made (see below)

There are two types of transport systems in a plant. The **phloem** is made of living tissue and transports sugars made by photosynthesis around the plant (in all directions). The **xylem** is the other transport tissue. It carries water and mineral ions from the soil around the plant (i.e. only upwards). Xylem tubes are made from what used to be living tissues, but the tubes are now made from dead tubes which formed as dead cell walls corroded away.

Plants can be largely affected by mineral deficiency. If a plant is deprived of **nitrate** it will not grow to be very big. The adult plant will be significantly smaller and visibly feeble in comparison with a plant with a fair supply of nitrates. If a plant is deprived of **magnesium** the leaves will turn yellow because magnesium is needed to make chlorophyll (and it is chlorophyll which turns leaves green).

B2-3 : Energy Flows

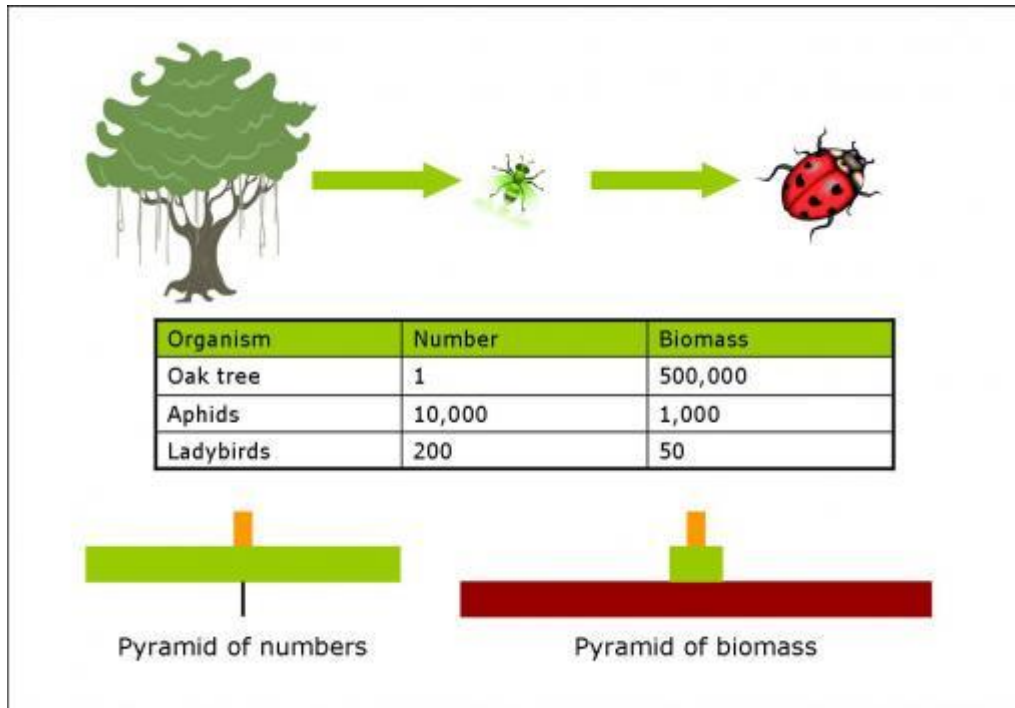
Biomass

In photosynthesis, green plants use some of the light energy coming from the sun; so some of the energy is stored in the substances which make up cells of the plant. This new plant material is said to add to the **biomass**. Biomass is the *living material in an animal or plant*. In effect, all biomass originates from energy from the sun.

The biomass made by plants is passed on through the **food chain** or **food web**, into the animal which eats the plant. Usually (looking at a food chain), there are more producers than primary consumers,

and more primary consumers than secondary consumers, etc. We can represent this using a **pyramid of numbers**, but it is often the case that this does not accurately reflect what is happening really.

To show what happens more accurately, we draw the total amount of biomass at each **trophic level** (stage of the pyramid) as a **pyramid of biomass**.



Why are the Levels of Biomass Different?

The biomass at each stage of the pyramid should be the same according to the theory behind it, but there are a few reasons not all of the energy from one stage will get through to the second, and so on:

- not all of the organisms at one stage are eaten by the above stage
- some material taken in is released as waste

So at each stage of the food chain the amount of biomass gets less.

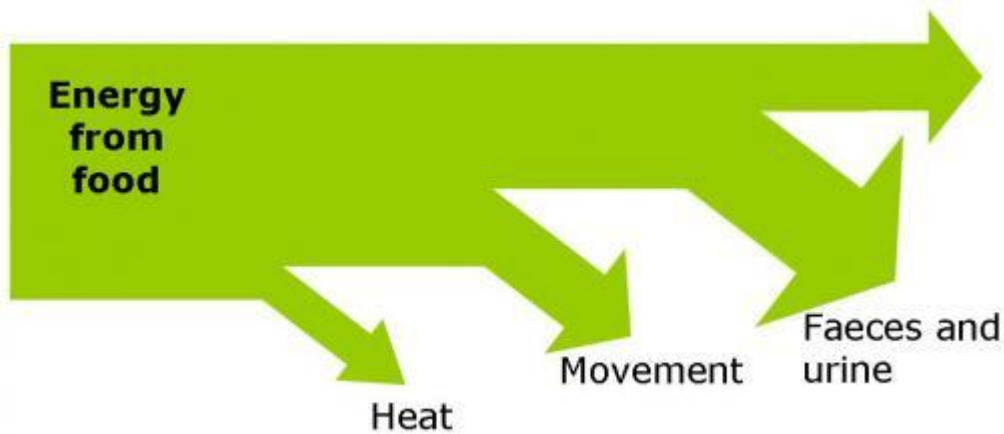
Losing Energy

There are a number of ways in which energy can be lost:

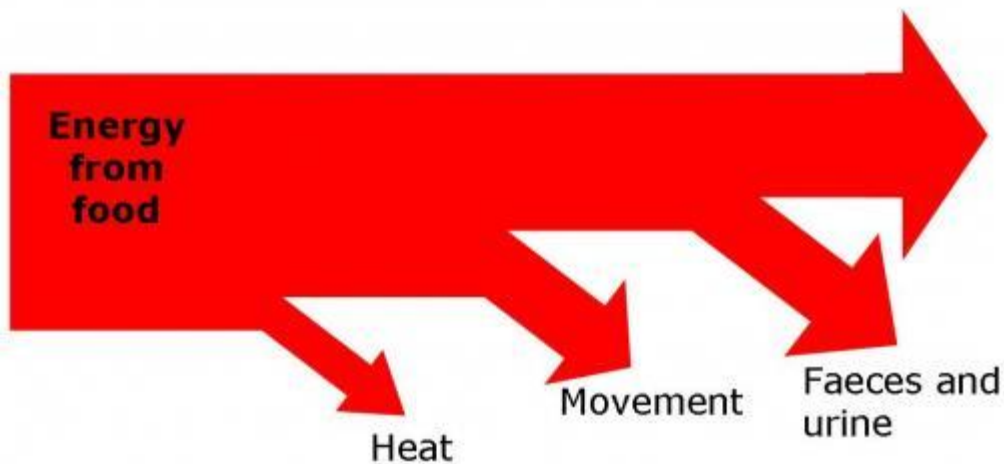
- Although the biomass an animal eats is a source of energy, not all of the energy can be used. Herbivores, for example, cannot digest all of the plant material they eat, so the material which they don't digest is passed as **faeces**. Whilst carnivores can digest more of the meat they eat, they still need to produce waste, because they cannot stomach hooves, claws, bones and teeth, so again, some biomass is lost in faeces
- When an animal eats more protein than it needs, it will break down the excess urine and pass it out as **urea** in the **urine**. Through this way and the previous way, biomass and energy are lost from the body
- Part of the biomass eaten by an animal is used for **respiration** in the cells, which supplies all the energy an animal needs for the living processes to take place

- Energy is used to allow the muscles to contract, which happens during **movement** - the muscles produce heat as they contract
- Biomass is also lost in **keeping a constant body temperature**

We can use a **Sankey diagram** to show the input of energy and to show how it is transferred into useful and un-useful ways. The Sankey diagram below shows how energy is transferred in a *herbivore*.



Now when we compare it to that of a *carnivore* as in the Sankey diagram below:



...it is evident that a herbivore loses a lot more energy from the food it eats through faeces and urine than a carnivore. This is represented by bigger arrows meaning more energy.

Decay

Some animals feed on dead animals – these are known as **detritus feeders**. When these feeders, such as certain types of worms, eat dead bodies, the process of **decay** begins. This is the eating of dead animals and plants and producing waste materials. **Decay organisms** then break down the waste and dead plants and animals. Decay organisms are microorganisms – fungi and bacteria.

Decay is a lot faster a process when the conditions are warm and wet. All of the produced materials from the waste are recycled.

The Carbon Cycle

There is a constant stream of processes happening everywhere which affects the amount of carbon dioxide going in and out of the atmosphere. For example, photosynthesis from plants removes a lot of carbon dioxide, but respiration from plants and animals puts carbon dioxide back in. Decay is

another process which contributes towards carbon dioxide production; as does feeding and burning (combustion). The chain of processes which put carbon dioxide is called the **carbon cycle**.

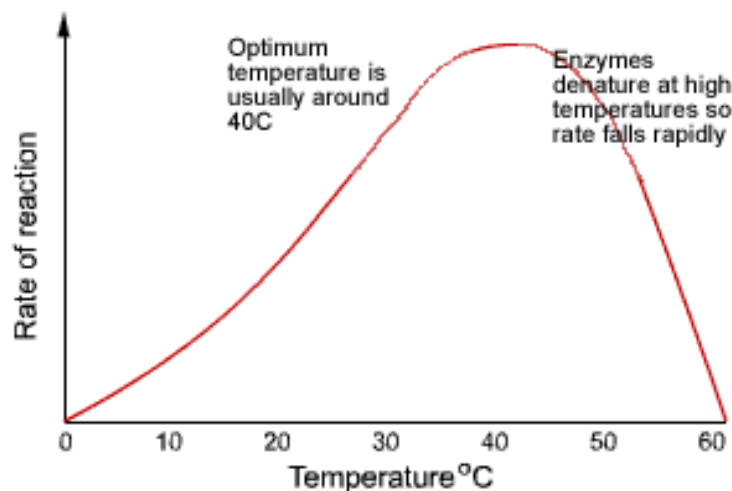
B2-4 : Enzyme Action

The Structure of Enzymes

An **enzyme** is a **biological catalyst**. That's the simplest definition you should know. They speed up reactions. An enzyme is a protein and each one has its own particular shape. Part of the structure of an enzyme has room for other molecules to fit in – this is called the **active site**. The shape of the active site changes with high temperatures, and this means that the enzyme can no longer function – we say the enzyme has been **denatured** (the scientific name for destroyed). As you will come to understand in the Chemistry Unit of this site, enzymes lower the required amount of energy for a reaction to take place (the “**activation energy**”).

Limiting Factors

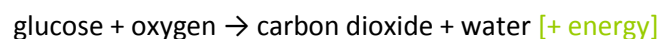
There are a number of factors which affect enzyme action. General reactions are quicker in warmer conditions where the molecules vibrate more violently; and enzymes are able to further the speed of these reactions – but only to a certain point. Temperatures at around 40°C and above (although temperatures might vary between different enzymes) tend to denature enzymes, destroying them and making them functionless. So we say that enzymes in general have an **optimum** temperature (usually of around 36°C). The graph below shows how temperature affects rate of reaction with an enzyme.



Temperature is not the only factor affecting enzyme action – acidity and alkalinity is important, also. Any substance which is too acidic or too alkaline – the active site is likely to change in this case too, and the enzyme would stop working.

Aerobic Respiration

Respiration is happening constantly in all animals and plants. The equation for respiration is:



The site where respiration takes place is in the **mitochondria**. As you can see, energy is produced in the process. This energy released is used for several other processes:

- building up larger molecules from smaller ones
- enable muscle contraction in animals

- maintaining a constant body temperature in mammals/birds
 ...and another use is to build nitrates, sugars and other nutrients in plants which are then turned into amino acids and later into proteins

Digestion

Digestion requires breaking down large insoluble molecules to smaller soluble molecules. Enzyme action assists this. There are a number of **carbohydrases** (enzymes) which are involved in the digestive system. The table shows the main three, where they are produced and what they do.

Carbohydrase	Production Site	Function
Amylase	salivary glands, pancreas, small intestine	Catalyses the digestion of starch into sugars in the mouth and small intestine
Protease	stomach, pancreas, small intestine	Catalyses the breakdown of proteins into amino acids in the stomach and small intestine
Lipase	pancreas, small intestine	Catalyses the breakdown of lipids (fats) into fatty acids and glycerol

Protease enzymes in the stomach work best under acidic conditions. For this reason, glands in the stomach produce hydrochloric acid to make it very acidic. This is one way in which our bodies naturally speed up digestion.

Amylase and lipase in the small intestine work best with alkaline conditions – so the liver produces **bile** which is stored in the gall bladder. Bile is squirted into the small intestine which neutralises the stomach acid, making the conditions slightly alkaline.

Commercial and Industrial Uses

We have a number of uses for enzymes in today's world:

- enzymes are used in *biological washing powders* to digest food stains
- protease is used to pre-digest some baby foods, making it more easily consumed by babies
- **isomerases** are used to convert glucose into **fructose**, a much sweeter glucose, so less is needed in foods, therefore the foods are less fattening
- we have carbohydrases to convert starch into sugar syrup for use in food

B2-5 : Homeostasis

Homeostasis

Your body is constantly trying to maintain constant internal conditions. The processes which try and do this are known altogether as **homeostasis**. Some of the things our bodies do in this process are:

- excrete carbon dioxide, the waste product of respiration, through the lungs
- converting unused amino acids into **urea** by the liver and excreted by the kidneys in **urine** (urine can be stored in the bladder)
- controlling the water and ion content of our cells by **osmosis** to prevent too much or too little moving in/out

Your brain has a **thermoregulatory centre** which works with receptors on the skin to detect changes in temperature. The thermoregulatory centre controls what your body does when a change in temperature occurs. When the temperature increases, blood vessels near the skin's surface **dilate** allowing more blood to flow through the skin capillaries – causing heat to be lost by radiation. The sweat glands will also produce more **sweat**, which gets evaporated – and the energy required for evaporation comes from the skin's surface – this use of energy cools us down.

When the temperature decreases, however, the blood vessels near the skin surface **constrict** and *less* blood flows through the skin capillaries – less heat is radiated, meaning we prevent ourselves from cooling down. Also, we tend to *shiver* – muscles contract very quickly, and this of course requires respiration and some of the energy produced in respiration comes out as heat energy.

Blood Sugar Levels

Your body is also permanently trying to control blood sugar. The pancreas monitors and controls the level of sugar in your blood. When blood glucose level rises, for example, after eating a meal, **insulin** is released and targets the liver. The liver responds to the insulin and the liver cells absorb the glucose from the blood. The glucose that is not needed is converted into **glycogen**, or sometimes fats which are stored in fat cells.

When blood sugar levels drop, the amount of insulin being produced is affected. Insulin production slows down until the blood glucose level returns to normal. This is known as **negative feedback** (the term “negative feedback system” is used to describe an operation where output reduces input). When blood sugar levels are low, **glucagon** is produced which has the opposite effect on the liver to glycogen.

When blood sugar levels are too low, it is likely to go into a coma. This is why our bodies' production of the two hormones insulin and glucagon is so vital.

When our bodies are unable to produce enough insulin, and don't possess the ability to lower blood glucose levels, **diabetes** develops. There are two types of diabetes...

1. We call the first **Type 1 diabetes** or “early-onset” which occurs when the carrier is quite young
2. The second is obviously **Type 2 diabetes** or “late-onset” which will occur during adulthood

Diabetes can rarely be controlled by diet, but it is possible. Otherwise **insulin injections** are necessary to people who have diabetes, because their own bodies cannot supply enough insulin to them.

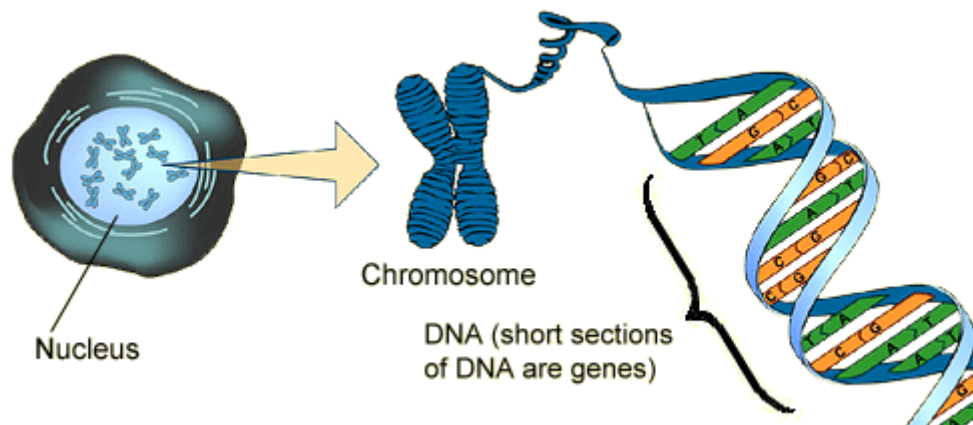
B2-6 : Inheritance & Variation

Genetic Structures

DNA (which stands for **deoxyribose nucleic acid**) molecules are very complex and long. The DNA carries the genetic coding which determines the characteristics of a living animal.

“Except for identical twins, each person’s DNA is unique. This is why people can be identified using DNA fingerprinting. DNA can be cut up and separated, forming a sort of ‘bar code’ that is different from one person to the next.”

Short sections of your DNA are called **genes**. Each gene has a specific order for the **amino acids** to be arranged in. Amino acids are made every three “letters” of your genes. There are **A, C, G** and **T** proteins and they are assigned an ordering. For example, your genes might be A, C, A, T, A, A, T, G, C in which case ACA is one amino acid, TAA is a second and TGC is another. Your DNA is what makes **chromosomes**. Chromosomes are made from very long strands of DNA molecules. The diagram below shows the relationship between chromosomes, DNA and genes.



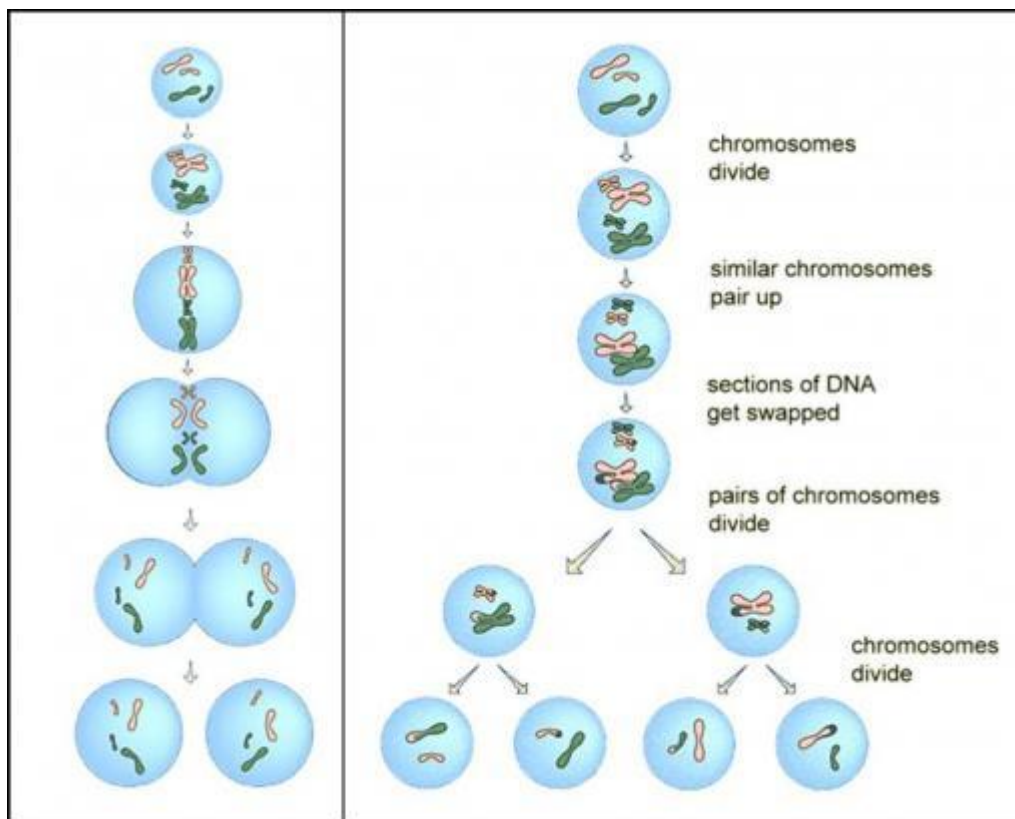
Genetics in Sex Cells

Every cell in the human body has 23 pairs of chromosomes – with the exception of sex cells (**gametes**). There is one pair in each cell that determines whether or not a person is male or female. If this pair is an “**XX**” chromosome pair, you are female, and someone with “**XY**” is male. XX means that they are the same; and XY means different. In the diagram here, you can see that one cell is from a male and one from a female. The one on the left being female and the one on the right male. As you can see – it is only *one* pair in the whole group that is affected by gender.



Cell Division

Cell division is necessary for the **growth** of any organism. Growth is not the only reason however, cells divide for repair of damaged tissues or even replacement of dead tissues. Some cells divide via **mitosis** which produces two identical offspring cells. A copy of each **chromosome** is made in the cell before it divides, so both the produced cells are genetically identical to each other and the parent. *Sex cells*, however are produced from a different process, called **meiosis**. During meiosis, a cell divides in two, and each of these cells produced only contain *half* the number of chromosomes other cells have (23 chromosomes rather than 23 pairs – the offspring cells only contain one chromosome from each pair). Remember that *only sex cells (gametes)* are produced from meiosis. In either process, mitosis or meiosis, the original cell is the **parent cell** and the offspring cells produced are called **daughter cells**.



The process on the left of the diagrams above is *mitosis*. As you can see, one cell makes copies of its own chromosomes so that when it splits, the daughter cells are genetically identical to the parent and each other. The diagram on the right shows *meiosis*. The annotations show the process as it goes along.

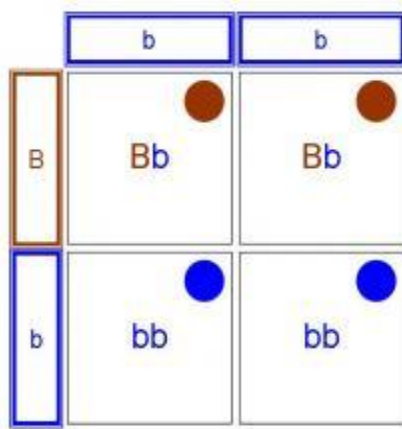
Stem Cells

Stem cells, found in the embryo, are **unspecialised cells**. They have the potential to “grow into” any other cells. The term we use to describe this is **differentiate**. In animals, stem cells aren’t continually produced into adulthood – which is why we use **embryonic** stem cells for research. There is much controversy over the ethicality of such research. The stem cells come from aborted embryos, or “spare” embryos from fertility treatment. People believe this to be unethical – because a lot of people think we are destroying life purely for **stem cell research**. The problem is that scientists believe we could use stem cells to cure **Parkinson’s Disease**, rebuild bones and cartilage and repair the immune system from damage. The current legal position on the situation is that stem cell research is *legal* to an extent, but many want this to change.

With plants however, stem cells are being constantly produced. In an animal embryo, the stem cells are produced and then each go onto develop (differentiate) into **specialised cells**, so that they can only reproduce *that specific* cell again. In a plant, *only* stem cells are ever produced, and they then travel to the specific place in the plant they need to be and differentiate there.

Inheritance

We each have genes which control our characteristics, these are called **alleles**. If an allele is overpowering enough to “mask” another allele, it is said to be a **dominant allele**; and the one being masked is **recessive**. An example is eye colour. The allele for brown eyes is dominant to the allele for blue eyes. We represent recessive and dominant alleles using different-case letters. For example, with eye colour, we could use **B** to represent brown eyes and **b** for blue eyes. The letters we pick don’t really matter (although it makes sense for it to be the first letter of the *dominant* allele), but we should keep the letters the same – just change the case. We can plot these letters in a **Punnett square** to predict the outcome of breeding based on the alleles possessed by parents.



This is a Punnett square. It shows the parents’ alleles across the top and down the left-hand side – in this case one parent has blue eyes (bb) and one parent brown (Bb). The reason Bb is brown eyes instead of blue, even though the person has one of each allele – is because the brown eye allele is dominant. This explains why it is possible for two parents with brown eyes to have a blue eyed baby – if both the parents had brown eyes *but* carried the blue eye allele (Bb), and both the blue eye alleles crossed during reproduction – the result would be *bb* – blue eyes. Because the brown eye allele is dominant, a person must have both blue eye alleles to have blue eyes (bb) as Bb results in brown eyes.

Back to the Punnett square above then. As you can see...

- In the top left, the *b* and *B* cross – resulting in *Bb* – brown eyes
- In the top right, *b* and *B* cross again – resulting in *Bb* – brown eyes
- In the bottom two squares, *b* crosses with *b* both times – *bb* – blue eyes

We use a Punnett square to predict the outcome of reproduction using the parents alleles, so with this data we can present it in one of two ways. We can either write a ratio, or a percentage. You might say there’s a 50% chance of the baby having blue eyes, or you could say the ratio of brown eyes to blue eyes is 1:1.

Cystic Fibrosis and Huntington’s Disease

There are a number of disorders which are passed down from generation to generation through genetics. One of these disorders is **cystic fibrosis**, a disorder affecting **cell membranes**. The good news is the allele for cystic fibrosis is recessive, but it is possible for both parents to be carriers yet not have the disorder (**Cc**) but still produce an offspring with the disorder. However, *both* parents *must* carry the recessive allele as either *Cc* or *cc* for the child to inherit the disorder, but only *one* parent needs to carry the recessive allele for the child to inherit the allele and not the disorder itself.

	C	c
c	CC	Cc
c	Cc	cc

This is the Punnett square to show the possible outcomes for a child when both parents carry the recessive cystic fibrosis allele but don't have the disorder themselves (Cc). As you can see, the possible outcomes are CC (does not carry the allele), cc (has the disorder) and Cc (has no disorder but carries the allele).

We can say there is a 75% chance of the child carrying the allele, or a 3:1 ratio. Or we can say there is a 25% chance of the child inheriting the disorder from his or her parents. It depends on what you're asked in an exam.

A second disorder which can be inherited is called **Huntington's Disease** and this one affects your **nervous system**. Unlike cystic fibrosis, the allele for the disorder is *dominant*, so even if only *one* parent carries the allele, the child can inherit it.

The Punnett square below shows the possible outcomes for a child when only one of the parents has the disorder. As you can see, even if only one parent has it, there is a 50% chance of the offspring also having the disorder. This is because the allele which does not have Huntington's is recessive (h) and so you must have *hh* to be free of the disorder.

	h	h
H	Hh	Hh
h	hh	hh

The term we use to describe someone who does not have a specific disorder but carries the allele, along with those who do carry the allele is a **carrier**.

The name of the man who worked out that dominant and recessive characteristics were inherited was **Gregor Mendel**, a Buddhist monk. He found out that recessive characteristics existed because he noticed that the colour of peas could be completely different to that of the parent when bred. He published his findings, yet as a small unknown monk, no one came to hear of them; and those who did wouldn't take his theories seriously as a monk, not a scientist. It wasn't until

many years after his death that people rediscovered his ideas and came to accept them.

We use the term **homozygous** to describe a pair of the same alleles ("homo" meaning same). In the above example then, *hh* is homozygous. This can be broken down into two different types. *HH* is **homozygous dominant**, meaning both the alleles in the pair are dominant, whereas *hh* is **homozygous recessive** - both the alleles are the recessive allele. And if the pair consists of two different alleles, *Hh*, we say it is **heterozygous** ("hetero" meaning different to).