Cell Division

In order for cells to grow they have to divide. They divide by a process called **mitosis**.

Mitosis is useful as it can be used to **replace damaged cells/repair tissues** and for the **growth and development** of an organism.

Mitosis involves the creation and movement of chromosomes. DNA is a long molecule. On this DNA there are MANY genes which code for characteristics e.g. blood type. The DNA is then copied and coiled up to form a chromosome.

Therefore – gene < DNA < Chromosome < Nucleus < Cell.

One cell divides once to form two new **genetically** identical cells. Mitosis takes **three** stages known as the **cell cycle**:

Stage 1 - Before a cell can divide it needs to grow and increase the number of sub-cellular structures such as ribosomes and mitochondria. The DNA **replicates** to form two copies of each chromosome.

Stage 2 – The chromosomes line up in the centre of the cell and are then split and pulled to each end of the cell. **The nucleus divides**.

Stage 3 - Finally the cytoplasm and cell membranes divide to form two **genetically** identical cells.

How long is part of the cell cycle?

We can estimate how long it takes for a cell to divide by mitosis.

Imagine we observe 120 cells and 42 happen to be undergoing division during a 24 hour observation. How long does it take for these cells in **minutes**?

42 out of 120 = 42/120

24 (hr) x 60 (**min**) = 1440 **min**

42/120 x 1440 min = 504 minutes.

Prokaryotes (bacteria) divide by **binary fission**.

Bacteria can reproduce rapidly. For example they can divide by **binary fission** once every 20 minutes.

We can calcualte how many cells there might be (after division) over a given time.

E.g. A bacterium divides every 30 min. How many after 2.5 hours?

Step 1) Convert to same units:

Step 2) Divide the total time by how often they divide:

Step 3) Enter 2 to the power of number of divisions into your calculator and press =

Diffusion

Diffusion is the net movement of particles from a high to a low concentration (down a concentration gradient).

Exam tip - The only substance that doesn't diffuse is liquid water. Water = OSMOSIS.

https://www.youtube.com/watch?v=pdqo5CZDtes

Diffusion is how cells absorb and excrete substances. They absorb oxygen, glucose amino acids and excrete carbon dioxide and urea.

Rate of diffusion can be increased by:

- Increasing temperature. This provides more kinetic energy for particles so they move faster.
- Larger surface area of membrane/cell. This means more particles can cross the membrane at once.
- Short diffusion distances. This means particles don't have to diffuse as far.
- Steeper concentration gradient. The bigger the difference between two concentrations the faster the particles diffuse. This is a concentration gradient.

Osmosis

Osmosis is the net movement of **WATER** across a **partially permeable** membrane from a **dilute solution/high concentration of water** to a **concentrated solution/low concentration of water** solution.

Exam tip – Dilute solutions have lots of water in them. Concentrated means less water and more dissolved substances such as sucrose/salt etc.

Partially permeable = allows some substances through but not others e.g. water but not starch

https://www.youtube.com/watch?v=g7phKY726X0&t=43s

Rate of osmosis can be increased by:

- Increasing temperature. The water molecules gain kinetic energy so they move faster.
- Larger surface area of membrane/cell. This means more water can cross the membrane at once.
- Steeper concentration gradient. The bigger the difference between the two solutions the faster the rate of osmosis.

Examples – If an animal cell is placed in a dilute solution, water will enter it by osmosis. It crosses the cell membrane because it moves from the dilute solution on the outside of the cell into the concentrated solution inside the cell (because it will contain stuff!). As more and more water enters the cell it will gain mass. It may even burst.

The same happens with a plant cell. However, they have a strong cell wall which stops them bursting.

IF the solution on the outside is MORE dilute than the cell. The opposite happens and the cells shrivel up.

A piece of potato was left in a dilute solution. Its **cells** gained mass. It went from 2.3g to 4.8g in 1 hour.

How much mass did it gain per minute?

What was the % increase in mass?

Exam tip - If we place material in a solution and there is ZERO CHANGE then it must mean the concentrations are the same.

Analysing an Osmosis Investigation

We can look on graphs and find zero change to predict the concentration of a material.

Plot a graph of the date below. Use your graph to find the concentration of the leaf cells:

Sucrose Concentration	% change in mass of leaf cells
0.0	11.0
0.5	5.0
1.0	1.0
1.5	-0.5
2.0	-4.0

What was the independent variable?

What was the dependent variable?

What would have to be controlled in an investigation such as this? Tip they are adding leaves to different solutions and then measuring their mass after an unknown amount of time.

Before measuring the mass of the leaf students 'blotted' the leaf with kitchen towel. Why did they do this?

Why did we plot **%** change and not just change in mass of leaves?

Using control variables makes ANY investigation **valid**. To make an investigation **reliable** we have to do what?

Active Transport

Active transport is the **net** movement of particles from a **low concentration** to a **high concentration** (against a concentration gradient) which requires **energy.** Released by **respiration** which occurs in mitochondria.

Exam tip – In order for ALL of a substance to be completely absorbed it has to be done by active transport (after initial diffusion).

For example in the digestive system glucose is initially absorbed into the blood by diffusion and then later active transport. Why do you think this has evolved?

Cells which carry out active transport include root hair cells and cells in the small intestine. They use carrier proteins to carry out active transport.

Exchange Surfaces

Most organisms require specialised exchange surfaces to absorb useful substances (glucose, oxygen, amino acids) and secrete waste products (carbon dioxide, urea).

This is because **large organisms** have a **small surface area:volume** ratio. Exchange surfaces therefore aim to increase surface area:volume ratio. This promotes diffusion, active transport and osmosis.

A large surface area to volume ratio = fast diffusion etc

A small surface area to volume ratio = slow diffusion etc

What is the surface area to volume ratio of a cube with 1cm sides?

Surface area = 6 sides x area of one side

= 6 x (1x1)

= 6

Volume = area of one side x length of one side

= (1x1) x 1

= $1cm^3$

So ratio is 6:1

What about a cube with 3cm sides?

Common features that exchange surfaces have:

Thin sides – create a short diffusion distance

Large blood supply – maintains a large concentration gradient

Folded membranes – increases surface area

Examples include fish gills, lungs, small intestine. Plants have roots and leaves for exchange (but they don't have a blood supply!)

Organisms such as bacteria DO NOT have specialised exchange organs. This is because they are very small so **have a very large surface area to volume ratio** – so are able to meet their demands for oxygen and glucose by absorbing these substances by simple diffusion through their cell membrane.

What are enzymes and how do they work?

Enzymes are specialised **protein** molecules. We call them biological catalysts because they speed up **metabolic** reactions (those that happen in the body) without being used up.

They are **specific** because one enzyme catalyses one specific reaction (they bind with one type of reactant molecule which we call **substrate**).

https://www.youtube.com/watch?v=smtCH5HX44o

We describe the way they work as the **lock and key** hypothesis.

If the substrate is not complementary to the active site it will not bind and no reaction happens. Sometimes the active site **changes shape** to prevent the substrate binding – we say the enzyme is **denatured**. It no longer works. It is **irreversible**!!

Enzymes also require specific conditions to work correctly. We call these **optimum conditions**. They are affected by temperature (in the body it must be 37°c) and pH (could be **any** pH).

How temperature affects enzymes

Changing the temperature affects enzyme action (rate of reaction).

As you increase the temperature the rate of reaction also increases. This is because enzymes and substrate molecules have **more kinetic energy** and so **collide more**. This happens up to the optimum temperature (where rate of reaction reaches its maximum).

In the human body the optimum temperature is **37c**. Enzymes in plants usually have a lower optimum temperature.

Above the optimum temperature **bonds** in the enzyme start to **break**. The active site **changes shape** and this means the substrate **can't bind** to it anymore. The enzyme has **denatured**.

How pH affects enzymes

Changing the pH affects enzyme action.

All enzymes have an optimum pH – the maximum rate of reaction occurs at this point. Above and below this pH the rate is lower. This is because enzymes denature (the active site **changes shape** and this means the substrate **can't bind** to it anymore).

Exam tip – for pH the enzyme is denatures at pH values above/ below the optimum pH. **ONLY high** temperatures cause enzymes to denature. Low temperatures make them react slowly.

The Heart and Circulatory System

The circulatory system's main function is to transport oxygen and glucose to every cell in the body **for respiration**. It is then used to remove carbon dioxide at the lungs and urea at the kidneys.

It uses blood, the heart and blood vessels.

Humans have a **double circulatory system**:

1) Right side of heart sends **deoxygenated blood** to the lungs to remove carbon dioxide and collect oxygen. It then returns to the heart.
2) Left side of heart sends this **oxygenated blood** to cells in the rest of the body and then returns to the heart.

[This means that blood cells, in one full circuit, moves through the heart **twice**!]

It is the job of the heart, which is made of **cardiac muscle**, to **contract** and **pump** this blood round the circulatory system.

How the heart works

The heart pumps blood in a cycle of steps. These are the same for both sides of the heart:

- Blood enters the **left**/**right** atrium from the **vena cava**/ **pulmonary vein**.
- The **left**/**right** atrium wall contracts and pushes the blood into the **left**/**right** ventricle through the open valves.
- The ventricle wall contracts. The blood enters the **aorta**/**pulmonary artery** through the open valves. They push against the valves between the ventricle and atrium forcing them to shut.
- The blood in the arteries then push against valves in the heart to prevent blood from flowing backwards. Blood only flows in one direction.

Exam tip – you will need to use the names of the arteries, veins, ventricles and atria.

The heart has its own supply of oxygenated blood via **coronary arteries. This supplies oxygen, for respiration, to release energy for cardiac muscle contractions.**

Plant Transport

Plants require a transport system. They have phloem and xylem.

Phloem

- Phloem is made from living cells connected end to end by small pores. This allows sap to flow from one cell to another.
- Phloem transports dissolved sugars (sucrose/glucose) produced by photosynthesis.
- Substances can move from the leaves to roots and in the opposite direction.
- This movement of substances is called **translocation**.

https://www.twig-world.com/film/plant-transport-1187/.

Xylem

- Xylem is made from dead hollow cells joined end to end forming a long tube.
- Xylem is strengthened by the molecule **lignin** – it is this that forms 'wood'.
- Xylem transports water and mineral ions from the roots to the leaves.
- This movement of water is called the **transpiration stream**.
- Remember water and minerals enter a root via root hair cells. Water enters by osmosis. Minerals enter by active transport.

Transpiration

- Transpiration is the loss of water vapour from a leaf through stomata.
- Water vapour **diffuses** out of the stomata (it's a gas) down a concentration gradient as there is a higher concentration in the leaf and a lower concentration in the air.
- Transpiration creates the **transpiration stream** as water in xylem moves upwards in order to replace water lost in the leaves. **Water is therefore drawn up the xylem**.
- Water has to then be drawn from the roots in order to replace the moving water in the xylem.

Preventing The Spread of Pathogens

Humans can reduce the spread of communicable disease:

1) Being hygienic – For example washing hands **before food preparation**, between seeing patients or after you have sneezed. This removes pathogens from the hands.
2) Destroying vectors – Using insecticides to destroy insects that act as vectors or destroying their habitat e.g. drain swamps to prevent malaria.
3) Isolate infected individuals – Known as a quarantine this prevents people passing on pathogens to others.
4) Vaccination – People cannot develop the disease and therefore cannot pass it on to someone else. **Herd immunity**.

If we are exposed to a pathogen we have a primary and secondary defence system:

Primary defence PREVENTS the entry of a pathogen:

1) The skin acts as a barrier and produces sebum – an oil that repels pathogens. http://www.bbc.co.uk/education/clips/zx69jxs
2) Mucus in nose trap pathogens
3) Trachea and bronchi secrete mucus to trap pathogens
4) Cilia in trachea WAFT mucus to the throat to be swallowed
5) The stomach contains HCl which kills pathogens
6) Tears in eyes contain enzymes which kill bacteria. Tears are antiseptic.

Secondary Defence

Secondary defence destroys pathogens AFTER entry. It uses the immune system which involves white blood cells: https://www.youtube.com/watch?v=btF3iJC1QHo

1) White blood cells **engulf** pathogens and digest them. This is called **phagocytosis**

2) White blood cells produce **antibodies**. These attach to SPECIFIC **antigens** on the surface of pathogens. This destroys them. Only one type of antibody can fit to one type of antigen. http://www.bbc.co.uk/education/clips/zy4c87h

3) White blood cells produce **antitoxins**. These bind and counteract toxins produced by bacteria.

A person becomes **immune** to a pathogen when white blood cells can produce the correct matching antibody **rapidly** to destroy the pathogen. E.g. after being re-infected with chickenpox.

Vaccination

Vaccinations prevent the spread of pathogens (see previous notes) and they stop someone developing a disease.

Vaccinations make your body immune to a pathogen. This is different to natural immunity as you don't show symptoms.

Here's how vaccination came about: https://www.youtube.com/watch?v=sJRJeOxX6no

How they work:

1) A **dead or inactive** pathogen is injected into a person using a syringe.
2) The dead pathogen has antigens on its surface. This triggers white blood cells to produce matching antibodies.
3) When exposed to a living pathogen, the white blood cells will produce the same **matching/specific** antibodies **rapidly** to a high concentration – destroying the pathogen.
4) The person is immune. Memory cells have been produced.

Positives:

A) Epidemics can be prevented as those who have been vaccinated cannot pass on the pathogen. This is known as **herd immunity**.
B) Many communicable diseases that were once common are now rare e.g. smallpox and polio.

Negatives:

A) They don't always work and provide immunity.
B) Some people can have a bad reaction and show side effects.

During and after an infection/vaccination the concentration of antibodies change in our blood. The antibody concentration increases rapidly after the second infection to a high concentration. It then decreases slowly. This kills the pathogen, prevents symptoms and prevents re-infection.

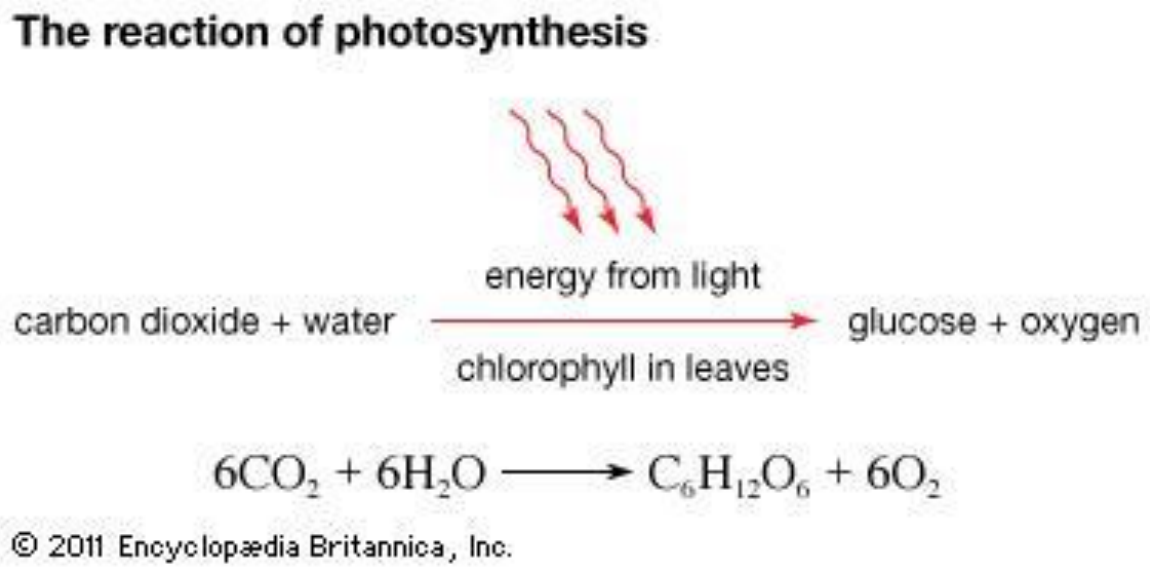
Photosynthesis

Photosynthesis is how plants make glucose.

It involves light energy being **absorbed by chlorophyll** (in chloroplasts) which is used to react carbon dioxide with water. This produces glucose and oxygen. Oxygen is a waste product – but is used by organisms on the planet for respiration.

[This video shows what would happen if we were to run out of oxygen https://www.youtube.com/watch?v=n_MI9UiYwJA AND show video of how to grow a planet ep 1 from 11:30 to 23:40]

Photosynthesis is a chemical reaction. It takes in energy from the environment – therefore it is an **endothermic** reaction.



Aerobic respiration and anaerobic respiration

Respiration IS NOT BREATHING (that is ventilation). It is an exothermic **chemical reaction**.

There are two types of respiration – **aerobic** and **anaerobic**.

Aerobic respiration **requires oxygen**.

Aerobic respiration takes place in mitochondria within cells. It releases **more** energy than anaerobic respiration as it fully oxidises the glucose (it is completely broken down).

This is the equation for aerobic respiration:

Glucose + Oxygen → Carbon dioxide + Water

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Anaerobic does **not** require oxygen.

It takes place when oxygen cannot be delivered to your cells quickly enough. It usually takes place in muscle cells during exercise.

It releases **less energy** than aerobic because it does **not completely breakdown** glucose – it isn't fully oxidised.

The equation in animals is:

Glucose → Lactic acid

The equation in plants and yeast is:

Glucose → Ethanol + Carbon dioxide

When yeast anaerobically respires we call it **fermentation**. This is useful in baking or brewing. Bread rises because of the carbon dioxide produced. Beer and wine is alcoholic because of the ethanol produced.

Respiration investigations

We can investigate rate of respiration. We do this by measuring the volume of carbon dioxide produced and divide by time OR we measure the distance a bubble travels in a capillary tube and divide by time (similar to a potometer).

We measure volumes of any gas produced using a measuring cylinder or a more **precise** **gas syringe**.

We usually use invertebrates or yeast in respiration investigations.

To make the investigation:

- Reliable = repeat and remove anomalies from mean calculation
- Valid = use control variables such as same temperature, age/mass/species/number of organisms/ volume/ concentration of oxygen provided/ type of exercise/ length of time for investigation
- Precise = use more precise equipment such as a gas syringe instead of counting bubbles produced/ use smaller intervals

DNA Structure

DNA is a **polymer** of nucleotides

Each nucleotide contains a sugar molecule, a phosphate and a nucleic base (nitrogen-based).

Sugar + phosphate form a “backbone” of the double helix molecule

The four different bases (A, T, C, G) join together to form pairs:

A-T and C-G

This is called complementary base pairing.

The order of the base pairs determines what amino acid is put in place and in which order. Only 20 different amino acids are used. 3 bases = 1 amino acid.

There are parts of DNA that do not code for protein. These **non-coding** sections switch genes on and off and therefore control which proteins will/will not be made.

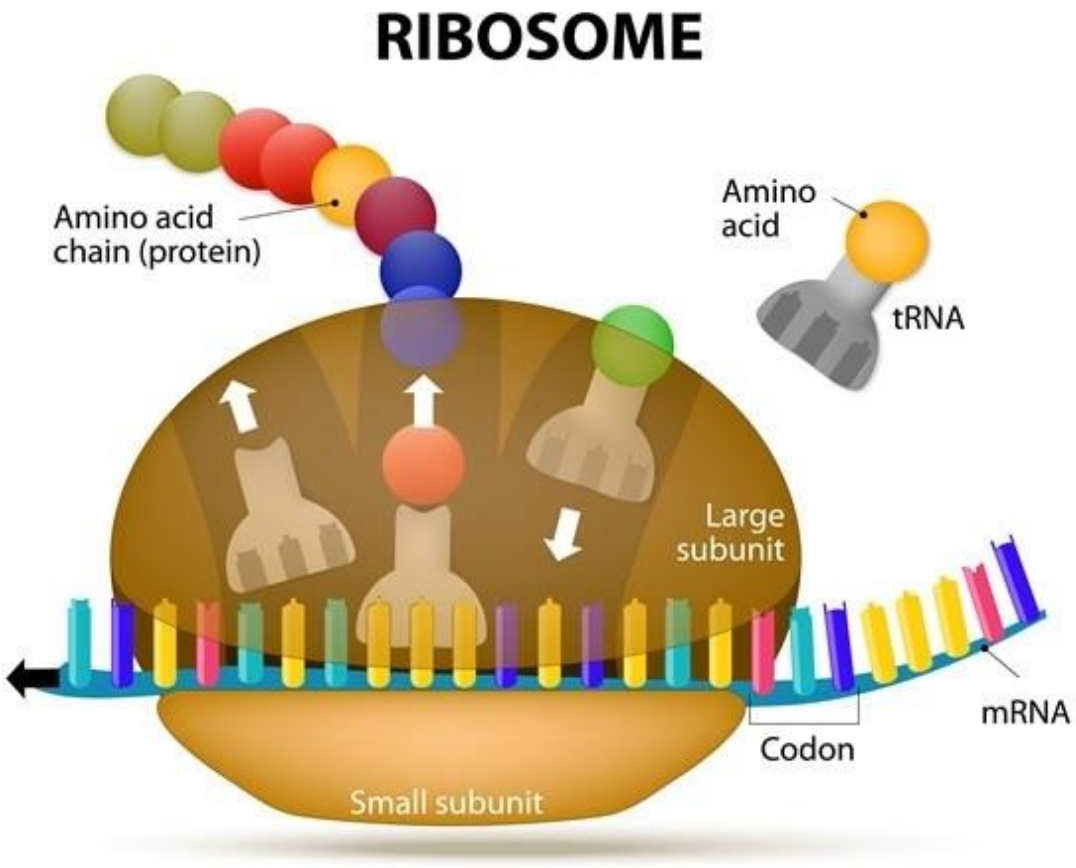
Protein Synthesis

Making protein from a number of amino acids bound together is called protein synthesis.

Protein synthesis happens in the cytoplasm of the cell with the help of **ribosomes**.

The DNA code will determine which protein is made. DNA can't leave the nucleus to travel to the ribosomes. A copy of one of the DNA strands is made – mRNA (**messenger**).

The mRNA travels to the ribosome and instructs which amino acids should be assembled. The needed amino acids are carried to the ribosome by carrier molecules.



Every three base pairs on the mRNA will code for one amino acid.

The protein formed is then folded into a specific shape. This enables it to do its job e.g. active site of an enzyme.

Different orders of bases means different orders of amino acids which create different shapes.

Evolution

Evolution is a change in the inherited characteristics of a population over time through a process called **natural selection**. This may result in the formation of a new species.

The theory of evolution states all species of living things have evolved from simple life-forms which first developed more than **3 billion years ago.**

Evolution occurs via natural selection:

A) Individuals within a species show **variation** (differences in a characteristic) due to differences in their genes. This is a result of **mutation** or **sexual reproduction**/meiosis.
B) Individuals with characteristics most suited to the environment **survive and breed** (describe).
C) The genes for these suitable **characteristics are passed on to the next generation**.

Speciation:

A man known as **Alfred Russel Wallace** was someone else involved in the development of the theory of Natural Selection. He came up with the theory at roughly the same time as Darwin. This prompted Darwin to write his book. He then spent his life gathering evidence to promote Natural Selection. He was also a pioneering figure who developed the idea of **speciation**.

A species is a group of organisms that can breed (successfully) to produce fertile offspring.

New species arise due to the following processes:

1. **Isolation** - two populations of a species become separated e.g. by a geographical boundary like an ocean.

2. **Genetic Variation** - each population has a range of **alleles** (versions of a gene) controlling characteristics. New mutations occur in each population.

3. **Natural Selection** - each population is in a different environment; therefore, **different alleles are selected** and passed on to the next generation in each population.

4. **Speciation** - eventually the two populations become so genetically different interbreeding between them is no longer successful. No fertile offspring produced. You have two new species. This takes many generations.

   Extension – two new species are formed when the chromosome number changes in one of the populations. If they then breed together – infertile offspring are made e.g. liger/zorse. This is because they have an ODD number of chromosomes – they can't pair up during meiosis.

Exam tip – you may need to suggest examples of isolation/different environments depending on the question