Edexcel Biology GCSE

Topic 1: Key Concepts in Biology

Notes

(Content in **bold** is for higher tier only)

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1.1 - Eukaryotic and Prokaryotic Cell Functions

All living things are made of cells, which can either be **prokaryotic or eukaryotic**.

Animal and plant cells are **eukaryotic**. They have a:

- Cell membrane
- Cytoplasm
- Nucleus containing DNA

Bacterial cells are **prokaryotic** and are much smaller. They have a:

- Cell wall
- Cell membrane
- Cytoplasm
- Single circular strand of DNA and plasmids (small rings of DNA found in the cytoplasm)

The structures mentioned above **(e.g. cell membrane)** are examples of **organelles** - structures in a cell that have different functions. These **organelles** all have a specific function.

In animal and plant cells...

Structure	Function
Nucleus	• Contains DNA coding for a particular protein needed to build new cells. • Enclosed in a nuclear membrane.
Cytoplasm	• Liquid substance in which chemical reactions occur. • Contains enzymes (biological catalysts, i.e. proteins that speed up the rate of reaction). • Organelles are found in it
Cell membrane	• Controls what enters and leaves the cell
Mitochondria	• Where aerobic respiration reactions occur, providing energy for the cell
Ribosomes	• Where protein synthesis occurs. • Found on a structure called the rough endoplasmic reticulum.

Only in plant cells…

Structure	Function
Chloroplasts	• Where photosynthesis takes place, providing food for the plant • Contains chlorophyll pigment (which makes it green) which harvests the light needed for photosynthesis.
Permanent vacuole	• Contains cell sap • Found within the cytoplasm • Improves cell's rigidity
Cell wall (also present in algal cells)	• Made from cellulose • Provides strength to the cell

Bacterial cells are **prokaryotic**, so do not share as many similarities in the type of organelles as animal and plant cells do.

In bacterial cells…

Structure	Function
Cytoplasm	See above
Cell membrane	See above
Cell wall	Made of a different compound (peptidogylcan)
Chromosomal DNA (circular)	As bacterial cells have no nucleus, this floats in the cytoplasm
Plasmids	Small rings of DNA - code for extra genes to those provided by chromosomal DNA
Flagella	Long, thin 'whip-like' tails attached to bacteria that allow them to move

1.2 - Specialised Cells and Their Functions

Cells specialise by undergoing **differentiation**: a process that involves the cell gaining **new sub-cellular structures** in order for it to be suited to its role. Cells can either differentiate once early on or have the ability to differentiate their whole life (these are called stem cells). In animals, most cells only differentiate once, but in plants many cells retain the ability.

Examples of specialised cells in animals:

1. Sperm cells: **specialised to carry the male's DNA to the egg cell (ovum) for successful reproduction**
    - **Streamlined head** and **long tail** to aid swimming
    - **Many mitochondria** (where respiration happens) which supply the energy to allow the cell to move
    - The **acrosome** (top of the head) has digestive **enzymes** which break down the outer layers of membrane of the egg cell
    - Haploid nucleus - the word **haploid** simply means that it has 23 chromosomes, rather than the 46 that most other body cells have

2. Egg cells: **specialised to accept a single sperm cell and develop into an embryo**
    - Surrounded by a special cell membrane which can only accept one sperm cell (during **fertilisation**) and becomes impermeable following this
    - Lots of mitochondria to provide an energy source for the developing embryo
    - Large size and cytoplasm to allow quick, repeated division as the embryo grows

3. Ciliated epithelial cells: **specialised to waft bacteria (trapped by mucus) to the stomach**
    - Long, hair-like processes called **cilia** waft bacteria trapped by sticky **mucus** (produced by nearby goblet cells) down to the stomach, where they are killed by the stomach acid. This is one of the ways our body protects against illness.

Examples of **specialised cells in plants:**

1. **Root hair cells**: specialised to take up water by osmosis and mineral ions by active transport from the soil as they are found in the tips of roots
    - Have a large surface area due to root hairs, meaning more water can move in
    - The large permanent vacuole affects the speed of movement of water from the soil to the cell
    - Mitochondria to provide energy from respiration for the active transport of mineral ions into the root hair cell

2. **Xylem cells**: specialised to transport water and mineral ions up the plant from the roots to the shoots
    - Upon formation, a chemical called lignin is deposited which causes the cells to die. They become hollow and are joined end-to-end to form a continuous tube so water and mineral ions can move through
    - Lignin is deposited in spirals which helps the cells withstand the pressure from the movement of water

3. **Phloem cells**: specialised to carry the products of photosynthesis (food) to all parts of the plants
    - Cell walls of each cell form structures called sieve plates when they break down, allowing the movement of substances from cell to cell
    - Despite losing many sub-cellular structures, the energy these cells need to be alive is supplied by the mitochondria of the companion cells.

1.3 - Microscopy

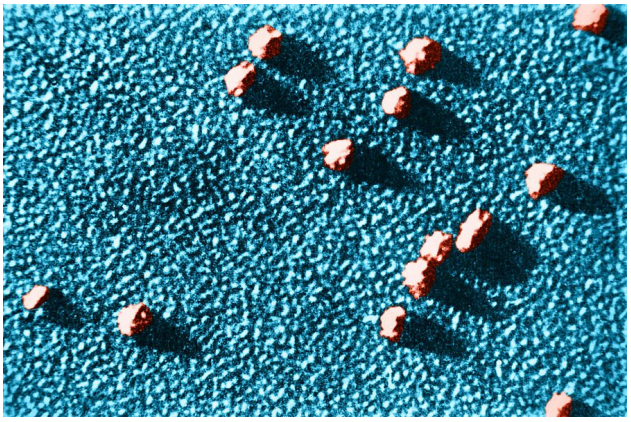
Extremely small structures such as cells cannot be seen without microscopes, which enlarge the image.

The first cells of a cork were observed by Robert Hooke in 1665 using a **light microscope.**

- It has two lenses
- It is usually illuminated from underneath
- They have, approximately, a maximum magnification of **2000x** and a resolving power (this affects resolution: the ability to distinguish between two points) of **200nm** The lower the RP, the more detail is seen.
- Used to view tissues, cells and large sub-cellular structures

In the 1930s the **electron microscope** was developed, enabling scientists to view deep inside sub-cellular structures, such as mitochondria, ribosomes, chloroplasts and plasmids.

- Electrons, as opposed to light, are used to form an image because the electrons have a much smaller wavelength than that of light waves
- There are two types: a **scanning electron microscope** that create 3D images (at a slightly lower magnification) and a **transmission electron microscope** which creates 2D images detailing organelles
- They have a magnification of up to **2,000,000x** and resolving power of **10nm** (SEM) and **0.2nm** (TEM)



The discovery of the electron microscope has allowed us to view many organelles more clearly - especially **very small structures such as ribosomes** (see image). Transmission electron microscopes (TEMs) in particular, have been used to **discover viruses** such as **poliovirus, smallpox and Ebola** - and are still used for this function today. This is useful as viruses are much smaller than bacteria, andare very hard to identify using a standard light microscope.

Electron microscopes are also used to examine proteins in much greater detail than can be achieved with a light microscope, which has led to many important scientific discoveries.

1.4 - Size, Scale and Estimations and 1.5 - Units and Standard Form

Common calculations in microscopy:

1. Magnification of a light microscope: **magnification of the eyepiece lens x magnification of the objective lens**
2. Size of an object: **size of image/magnification = size of object** (this formula can be rearranged to obtain the other values, make sure you are in the same units!)

When working with calculations, it is common to come across very large or small numbers. **Standard form** can be useful when working with these numbers.
Through multiplying a certain number by a power of 10, it can get bigger or smaller. To be able to compare the size of numbers while using standard form, the 'number' which being multiplied by a power of 10 needs to be between 1 and 10.
Examples:

- $1.5 \times 10^{-5} = 0.000015$
- $3.4 \times 10^{3} = 3400$

Cells and organelles are extremely small, and we can use **orders of magnitude** to understand how much bigger or smaller one is from another:
If an object is 10 times bigger than another then we say it is 10^{1} times bigger.
If an object is 1000 times bigger than another then we say it is 10^{3} times bigger.
If an object is 10 times smaller than another then we say it is 10^{-1} times smaller.

Prefixes go before units of measurement (such as 'centimetres') to show the multiple of the unit.

Prefix	Multiply unit by...
Centi	0.01
Milli	0.001
Micro	0.000, 001
Nano	0.000, 000, 001

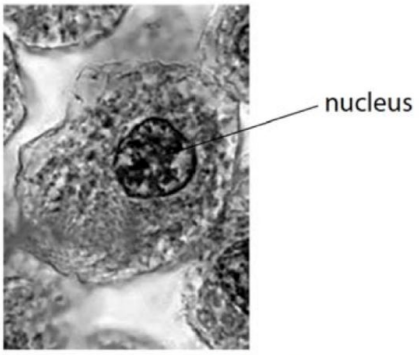
Estimations are useful in Biology when we don't know how many of something there is, or if it would take too long to count. For example, if we take a 1m x 1m square **sample** of grassland and count the number of a particular species of plant (e.g dandelions) in that square, we can estimate the number of dandelions in the whole field by **multiplying** that number by however many 1m x 1m squares can fit in the field. For example:

One 1m x 1m square contains **15 dandelions**
The entire field measures 50m x 50m, so it fits **50 of the 1m x 1m squares**
Multiply 15 by 50: 15 x 50 = **750 dandelions in the whole field**

Remember that 750 is just an **estimate** - the real number will likely be different! The more squares we look at (or 'sample') the **closer we will get to the real number**.

1.6 - *Core Practical: Investigating Biological Specimens*

Figure 7 shows an image of an animal cell taken using a microscope with a 10× eyepiece lens and a 40× objective lens.



(Source: © Ed Reschke/Getty Images)

Figure 7

(b) (i) The total magnification of the animal cell is

(1)

- ☒ **A** ×50
- ☒ **B** ×140
- ☒ **C** ×400
- ☒ **D** ×4000

Using microscopes is an important part of investigating biological specimens. We should be familiar with the parts of a light microscope:

Eyepiece - This is the part of microscope that we look through to view specimens.
Barrel - The upper part of the microscope that can be moved up or down to focus the image.
Turret - The part of the microscope that is rotated to change the magnification lens in use.
Lens - The lens increases the magnification of the specimen. See Section 1.13.
Stage - The flat surface on which we place the specimen.

To use a light microscope, you should:

1. Place the slide on the stage and look through the eyepiece lens
2. Turn the focus wheel to obtain a clear image
3. Start with the lowest objective lens magnification
4. Increase the magnification of the objective lens and refocus.

It is important to remember all 4 steps to gain full marks in a question about microscopy.

In order to use specimens with a light microscope, you have to first **prepare the slide.** This is done using the following method:

1. Take a thin layer of cells from your sample by either **peeling** them off or **using a cotton bud**
2. Add a small amount of the correct chemical stain (you will be told by your teacher which stain to use). Chemical stains are used to make some parts of the specimen more visible when you look at them through the microscope.
3. Apply the cells to your glass slide by placing them on or wiping the cotton bud against it.
4. Carefully lower a **coverslip** onto your slide, taking care to avoid air bubbles.

You should know how to perform magnification calculations. Remember:

Magnification = measured size / actual size
Actual size = measured size / magnification
Total magnification = objective lens magnification x eyepiece lens magnification

1.7, 1.8 and 1.9 - Enzymes: Mechanisms, Denaturation and Factors Affecting Enzyme Activity

Enzymes are biological **catalysts** (a substance that increases the rate of reaction without being used up)

- Enzymes are present in many reactions - allowing them to be **controlled**.
- They can both break up large molecules and join small ones
- They are protein molecules and the shape of the enzyme is vital to its function.
- This is because each enzyme has its own uniquely shaped **active site** where the **substrate** binds.

The Lock and Key Hypothesis (a simplified explanation of how enzymes work):

1. The shape of the substrate is complementary to the shape of the active site (matches the shape of the active site), so when they bond it forms an **enzyme-substrate complex.**
2. Once bound, the reaction takes place and the products are released from the surface of the enzyme.

Enzymes can only catalyse (speed up) reactions when they bind to a substrate that has a **complementary shape**, as this is the only way that the substrate will fit into the active site. This is called **enzyme specificity.**

Enzymes require an optimum **pH** and **temperature**, because they are proteins. They also need an optimum **substrate concentration** (see below).

- The optimum temperature **in humans** is a range around 37 degrees Celsius (body temperature). This temperature is different in other organisms.
    - The rate of reaction increases with an increase in temperature up to this optimum, but above this temperature it rapidly decreases and eventually the reaction stops.
    - When the temperature becomes too hot, the bonds that hold the enzyme together will begin to break.
    - This changes the shape of the active site, so the substrate can no longer 'fit into' the enzyme.
    - The enzyme is said to be **denatured** and can no longer work
- The optimum pH for most enzymes is 7 (neutral), but some that are produced in acidic conditions, such as the stomach, have a lower optimum pH.
    - If the pH is too high or too low, the forces that hold the amino acid chains that make up the protein will be affected.
    - This will change the shape of the active site, so the substrate can no longer fit in.
    - The enzyme is again said to be **denatured,** and can no longer work.

- As the substrate concentration (concentration of the substance **binding to the enzyme**) increases, the rate of reaction will increase - up to a point.

    - This is because, as substrate concentration increases, the rate at which enzyme-substrate complexes can be formed increases.
    - This only occurs up to a point, however - this is called the **saturation point,** and increasing the substrate concentration above this will have no effect on the rate of reaction. The saturation point is **different for every enzyme.**

1.10 - *Core Practical - Effect of pH on Enzyme Activity*

In this practical, we are looking at how pH affects the rate of activity of a particular enzyme.

The enzyme being used is called **amylase** - which breaks down carbohydrates such as starch into simple sugars such as **maltose** (see section 1.12 below). We can use **iodine (dark orange colour)** to check for the presence of starch in the solution at any time. When starch is present, the iodine solution will turn to a **blue-black colour.**

Amylase has an optimal pH, and we can use this experiment to estimate what it might be.

Materials required:
1% amylase solution, 1% starch solution, iodine solution, labelled buffer solutions of different pH.

1. Place single drops of iodine solution on each well of a tray.
2. Label a test tube with the pH to be tested. Place it in a water beaker with 50ml cold water and place this above a Bunsen Burner for 3 minutes.
3. Place $2cm^3$ of amylase solution, $2cm^3$ of starch solution and $1cm^3$ of the buffer pH solution in a test tube and start a stopwatch.
4. After 10 seconds, use a pipette to place a drop the solution into one of the wells containing iodine solution. The mixture should turn blue-black to indicate that starch is still present and has not yet been broken down.
5. Repeat Step 4 after another 10 seconds. Continue repeating until the solution remains orange, and record the time taken
6. Repeat Steps 1-5 with a buffer solution of different pH.
7. Record your results on a graph of pH (on the x-axis) and time taken to complete reaction (on the y-axis).

Why do we use a Bunsen Burner and water beaker?
We use this equipment to keep the solution at a relatively constant temperature throughout the reaction (temperature is a control variable in this experiment).

What results do we expect to see?
The optimal pH of amylase will be at whichever pH the reaction completes in the shortest time. This should be somewhere around pH 7.0.

1.11 - Rate Calculations for Enzyme Activity

Rate calculations are very useful in Biology, and are especially important to determine how fast an enzyme is working (**the rate of reaction**). To perform a rate calculation, we use the formula:

Rate = Change / Time

Change refers to the change in the substance being measured (in this case, the enzyme) and time refers to the time taken for that change to occur.

Proteases are a type of enzyme used to break down proteins. So as an example, if we added 5g of protein to a solution containing specific protease enzymes, and it took 30 minutes to convert ('use up') all the protein:

Rate = change / time
Rate = 5g / 30 minutes
Rate = 5g / 0.5 hours

Rate = 10g / hour - this is the rate at which the enzyme is catalysing the reaction, and may change depending on temperature, pH and substrate concentration.

1.12 - Enzymes as Biological Catalysts

1. **Carbohydrases** convert carbohydrates into **simple sugars**
    - Example: amylase breaks down starch into maltose.
        - It is produced in your salivary glands, pancreas and small intestine (most of the starch you eat is digested here)

2. **Proteases** convert proteins into **amino acids**
    - Example: pepsin, which is produced in the stomach, other forms can be found in pancreas and small intestine.

3. **Lipases** convert lipids (fats) into **fatty acids** and **glycerol**
    - Produced in the pancreas and small intestine.

Soluble glucose, amino acids, fatty acids and glycerol pass into the bloodstream to be carried to all the cells around the body.

They are used to build new carbohydrates, lipids and proteins, with some glucose being used in respiration. Building these new carbohydrates, lipids and proteins requires some different, more complex enzymes to increase the rate of reaction.

1.13B ***Higher and Biology Only** - Core Practical: Investigating Macronutrients*

We can perform special food tests to identify the presence of starch, reducing sugars, protein, and lipids (fats and oils).

Nutrient being tested for	Reagent/Test	Method
Starch	Iodine solution	Add iodine solution to the food sample. If starch is present, the colour will change from orange to blue-black.
Reducing sugars	Benedict's Solution	Add $2cm^3$ of the sample solution and $2cm^3$ of blue Benedict's solution to a test tube. Place in a boiling water bath for 5

		minutes, or until there is no further change in colour. Presence of reducing sugar is indicated by a colour change to reddish-brown.
Protein	Biuret Test (Potassium hydroxide and copper sulfate)	Add 1cm^3 of 40% potassium hydroxide to the food sample, and then add the same amount of 1% copper sulfate. Shake well and observe colour change if protein is present (blue -> violet)
Lipids (fats and oils)	Emulsion Test	Add 2cm^3 ethanol to food sample and shake thoroughly. Add 2cm^3 deionised water and shake thoroughly. If lipids are present, this will be indicated by the formation of a white emulsion layer at the top of the sample.

How could we improve these experiments?

We should use a control in each experiment to ensure we know what a positive and negative result looks like. For example, a positive control for the Biuret test would be anything containing protein (e.g egg white) whereas a negative control would be a solution that does not contain protein (e.g distilled water).

1.14B **Higher and Biology Only** - Calorimetry

Calorimetry is a way to measure the energy taken in and given out during a chemical reaction. We can use this to measure the amount of 'energy' (calories) in food.

To do this, we can:

1. Take a tube of 50ml cold water.
2. Record the starting temperature of the water.
3. Place the test tube at 45 degrees and hold a burning food sample just beneath it.
4. When the food is burned up, record the final temperature of the water.

We can work out the energy transferred to the water using the equation:

Energy transferred = mass of water x 4.2 x temperature increase

Energy transferred is measured in Joules (J)
Mass of water is measured in grams (g)
4.2 is a constant that refers to the 'specific heat capacity' of water - we need this to convert between temperature (degrees Celsius) and energy (Joules). It is measured in J/g.
Temperature increase is measured in degrees Celsius.

1.15 - Transport in and Out of Cells

Substances like **oxygen, glucose and waste products** need to be transported in and out of cells constantly to support life processes. This transport generally occurs in one of **3 ways**:

Diffusion - a form of passive transport (does not require energy). It is important to remember that molecules move in every direction and collide with each other, but the net (or resultant) movement is from an **area of high concentration to one of low concentration.**

Osmosis - osmosis is also a form of passive transport (does not require energy) but **it only applies to water.** The same rules as diffusion apply - however there is no such thing as 'concentration of water', so we say that movement is from a dilute solution to a more concentrated solution, across a **selectively permeable membrane.** Another way to think about this is that movement of water occurs from an area of high solute concentration to lower solute concentration (e.g if the solute was salt, from more 'salty' solution to less 'salty' solution).

Active Transport - active transport is a form of transport that **does require energy.** This energy comes from ATP, which is the molecule produced in respiration. Active transport is used to move molecules **against a concentration gradient** (i.e from an area of low concentration to an area of high concentration).

1.16 - Core Practical - Osmosis in Potatoes and 1.17 - Percentage Gain and Loss of Mass

A useful example to measure percentage gain or loss of mass is potato disks. This can be achieved by the following method:

1. Cut potato into small discs of equal size (e.g 2cm diameter).
2. Blot the potato disks gently with tissue paper to remove excess water.
3. Measure the initial mass of each disk.
4. Place the disks in sucrose solutions of different concentrations (1%, 2% etc)
5. Blot with tissue paper again and record new mass.

6. Find difference in mass (end mass - start mass) and use the percentage change equation to calculate percentage gain or loss of mass.

The percentage change equation is (change in mass / start mass) x 100.
Make sure to **record your final result as a percentage (%).**

What are the independent, dependent and control variables in this experiment?

- We are **changing** the concentration of the sucrose solution so this is the independent variable.
- We are **measuring** the change in mass of the potato disks, therefore this is the dependent variable.
- We are controlling the diameter of the disks (2cm) therefore this is a control variable.

What is happening in this experiment?

Water is moving **by osmosis** from a **more dilute solution** (in the potato) to a **more concentrated solution** (the sucrose solution) **across a selectively permeable membrane** (the cell membranes of all the potato cells holding water).