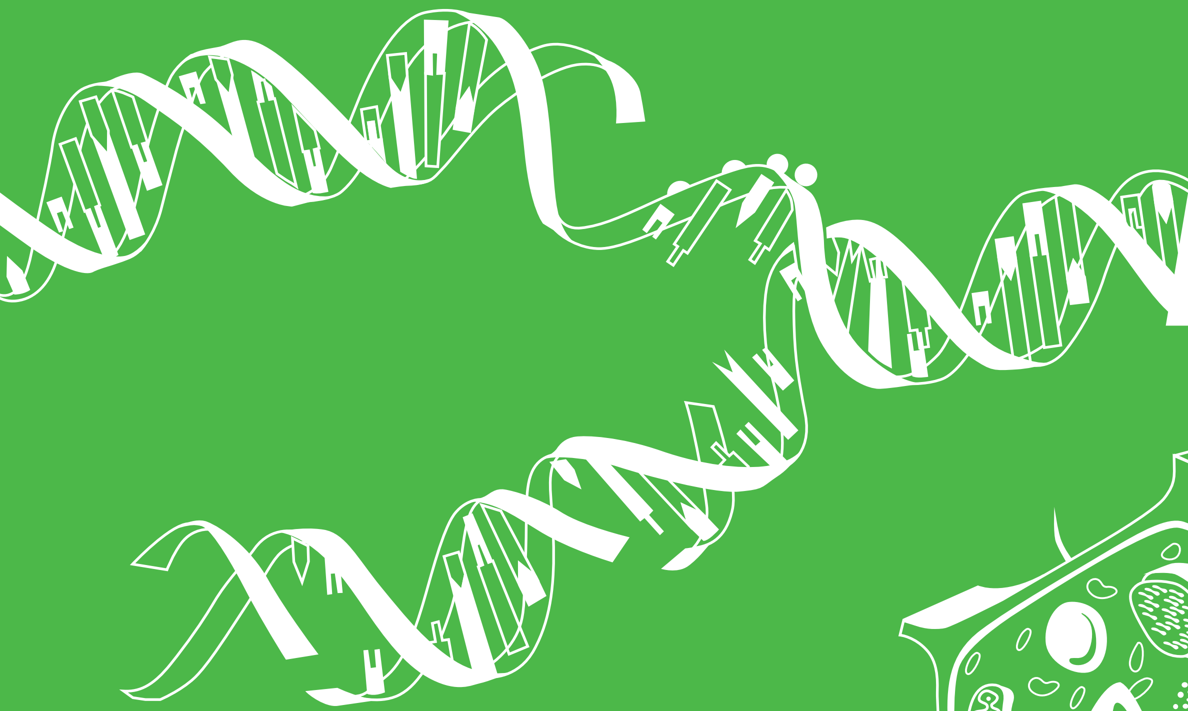

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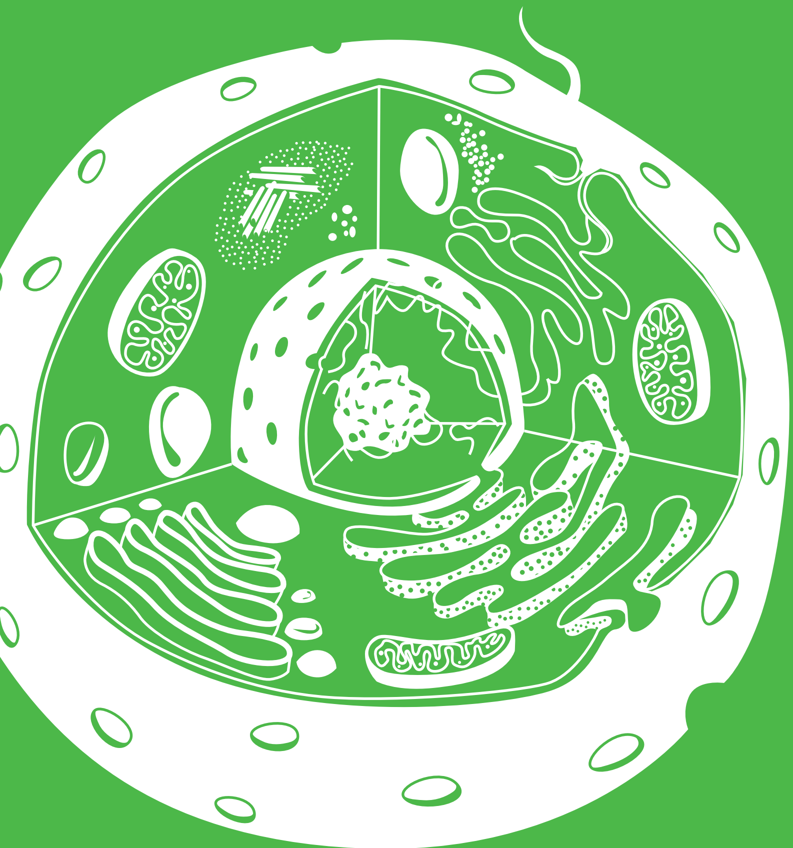


LEVEL 2 BIOLOGY

LIFE PROCESSES AT THE CELLULAR LEVEL

NCEA Workbook Answers

Part One

The Foundations

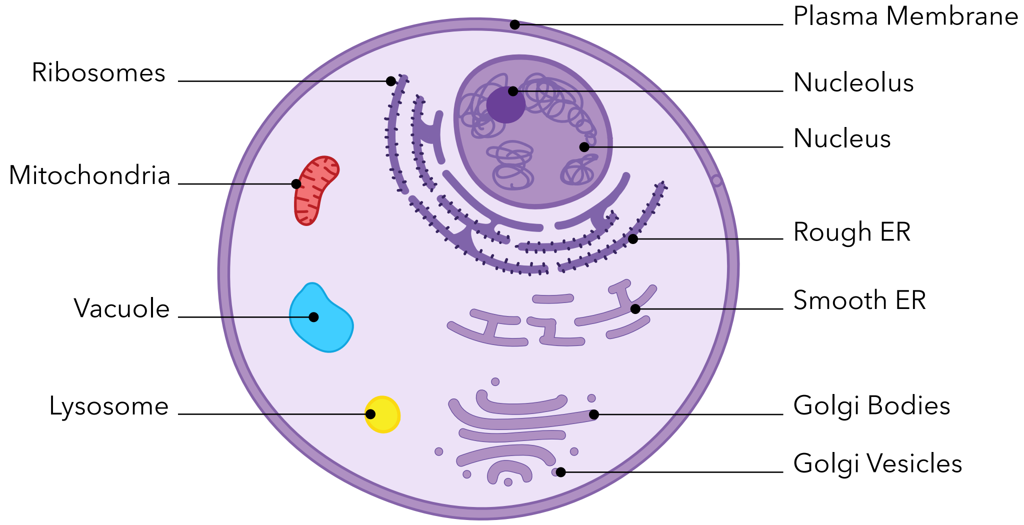
1. Cells and Organelles

a. A cell is the basic building block of life. It is the smallest biological unit that can be considered alive. That means it's the smallest biological unit that carries out MRS GREN life processes; anything smaller, like an organelle or protein, by itself, doesn't carry out all the life functions.

b. An organelle is a membrane-bound structure inside the cell (specifically eukaryotic cells, not bacteria); a compartment that carries out particular functions. Organelles are kind of like the organs of the cell. Our organs carry out functions for our bodies, like our hearts that pump blood; organelles in cells carry out functions for the cell.

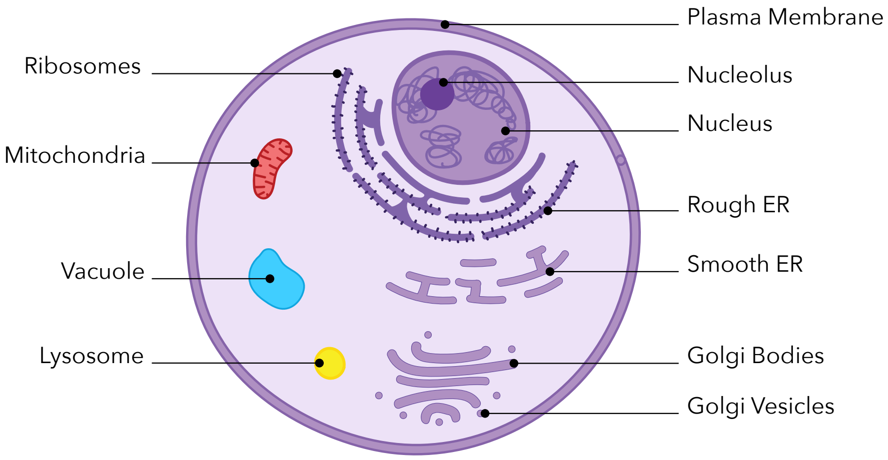
c. Examples of organelles that could be listed:
Chloroplast, mitochondria, nucleus, lysosome, vacuole, vesicle, nucleus, golgi body, endoplasmic reticulum (ER).

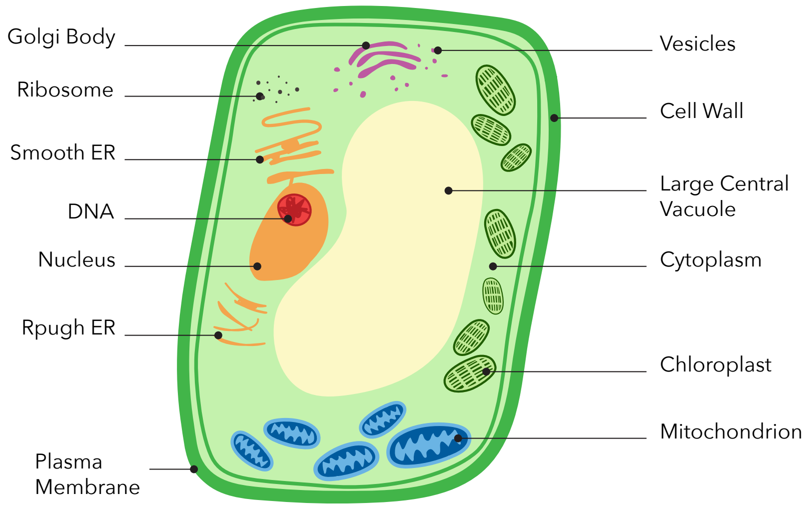
d.



Answers

e./f.



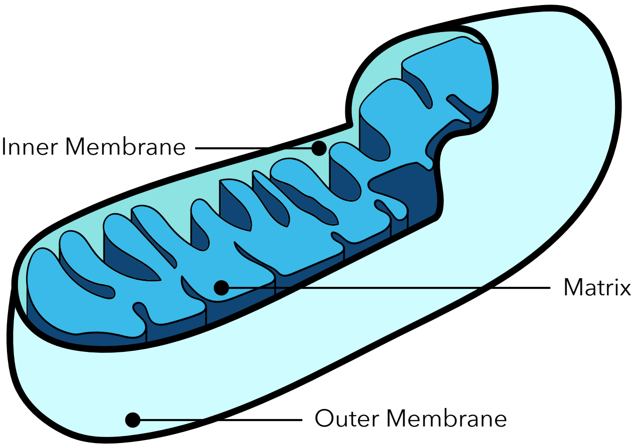


g. Animal and plant cells are both building blocks of life for their organisms. Both are small, too small to see without a microscope, bound by plasma membranes, and have cytoplasm and organelles inside. Animal and plant cells have the following organelles in common: mitochondria, vesicles, vacuoles, Golgi body (also known as the Golgi apparatus), ER (rough and smooth) and nucleus. Both have ribosomes, and DNA in the nucleus. Plant cells have chloroplasts, which animal cells do not. In a plant cell, the vacuole is also larger and takes up more space inside the cell. Plant cells also have a cell wall made of cellulose which is rigid and lies outside the cell membrane. This gives the plant cell strength and structure.

h. MRS GREN describes the life processes of living organisms. Each of these can be seen at the cellular level:

M = movement
R = respiration
S = sensitivity
G = growth
E = excretion
N = nutrition

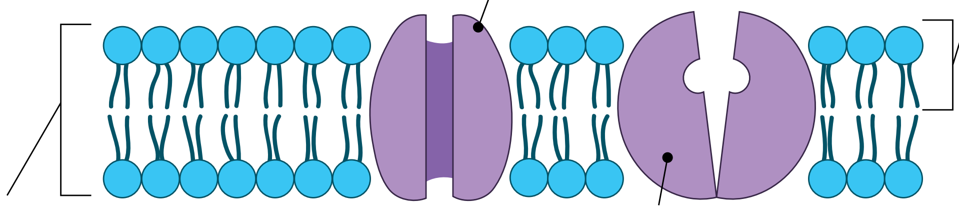
i.



j. Mitochondria are the powerhouses of the cell (haha). Mitochondria extract energy from the food we eat using a series of chemical reactions. This converts the chemical energy in the chemical bonds in food molecules into energy the cell can use.

k. The nucleus stores the DNA, the genetic information of the cell that provides all the instructions for the cell. The nucleus keeps this important DNA safe.

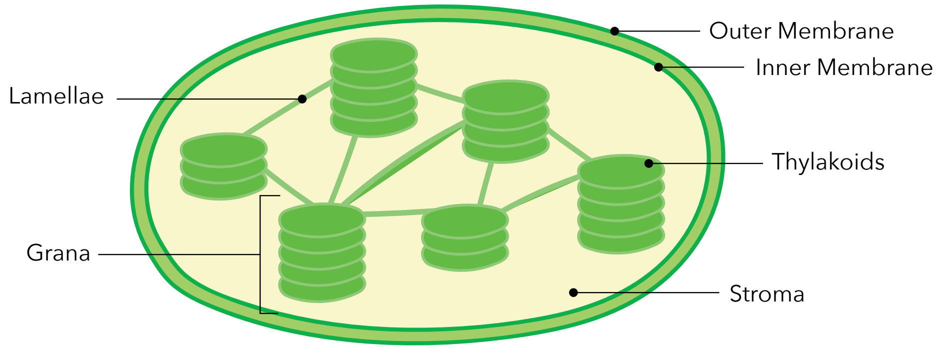
l.



m. The semipermeable membrane is a boundary between the cell and its environment. It keeps the inside of the cell in and the environment out. This helps the cell choose what will enter and exit from it which is important for maintaining life processes (MRS GREN).

n. The phospholipid bilayer is what the cell membrane is made from. It is two layers of phospholipids. Therefore a 'bilayer'. Phospholipids are a type of fat molecule with a phosphate at one end (represented by the circle). The end with the phosphate likes water, the end without the phosphate (represented by two squiggly lines) does not. The phospholipids arrange so all the phosphate heads point outwards – into the cell, or into the environment. This makes a stable membrane around the cell.

o.



p. A chloroplast carries out photosynthesis, which captures energy from sunlight and uses it to produce food molecules (glucose) from smaller molecules (CO2 and H2O) in a series of chemical reactions. The organism can then use the food molecules to sustain itself in MRS GREN life processes.

q. **Cell membrane:** A phospholipid bilayer (two layers of phospholipids, a type of fat) surrounding the cell. Keeps the cell contents in and the environment out. Controls what enters and exits the cell, so the cell can regulate its internal environment.

Ribosomes: Small molecules in the cell which carry out translation of mRNA into polypeptides during protein synthesis i.e. they make proteins for the cell.

Endoplasmic reticulum: A complex network of interconnected flattened tubes called cisternae. These are made from phospholipids like the plasma membrane. Rough ER has ribosomes on its surface; smooth ER does not. Rough ER is involved in protein synthesis and common in cells that secrete proteins. Smooth ER is involved in making steroid hormones (like testosterone and oestrogen) and lipids (fats). It also stores calcium ions, important for muscle contractions.

Golgi bodies: These are also flattened membranous tubes called cisternae, look like a stack of pancakes. Processes and packages macromolecules (large molecules like proteins and lipids) for excretion and movement around the cell. Packages these into vesicles. Found in high numbers in cells that secrete.

Vesicles: Small, membrane-bound sacs that contain some cytoplasm and other contents, like proteins, lipids or carbohydrates. Vesicles transport these substances around the cell to different organelles, or the cell membrane. Cell's postie service, delivering between organelles.

Cell wall: Rigid cellulose structure found outside the cell membrane in plant cells. Gives cell strength. Is porous, so molecules can move through it.

Vacuoles: Small to large, membrane-bound sacs containing fluids; may contain substances like proteins, lipids, carbohydrates, pigments and more. Storage centres for the cell. Plant cells have a large central vacuole taking up most of the space inside, helps to maintain the strength and structure of the cell by pushing on the cell wall when full of water (turgid)

Lysosomes: Membrane-bound organelles containing digestive enzymes. Break down waste and recycle molecules in the cell, such as damaged and denatured proteins into their amino acid building blocks so they can make new proteins.

r. • **Semi-permeable plasma membrane** which forms a boundary between the cell interior and the outside environment.
- **Cytoplasm**, the jellylike fluid inside the cell.
- **A nucleus** containing DNA, the genetic material of the cell.
- Membrane-bound organelles like the **ER and Golgi body**.
- **Ribosomes** which translate mRNA into proteins.
- **Proteins** which carry out various functions inside the cell.
- **Mitochondria** which are the powerhouses of the cell and extract energy from food molecules to power the cell.

2. Enzymes and Proteins

a. A protein is a biological macromolecule (large molecule). It is a polymer, made up of amino acids. This polymer is folded up into a specific 3D structure. Proteins are very numerous and important in the cell and have many functions.

b. An enzyme is a biological catalyst. Enzymes speed up chemical reactions in the cell, without themselves being used up in the reaction. Each type of enzyme has a specific reaction that it will speed up.

c. An enzyme is a protein which has the function of increasing the rate of reaction for a chemical reaction that occurs in a cell.

d. A catalyst is a substance which speeds up a chemical reaction by lowering the activation energy of the reaction. It does this by offering an alternative pathway for the reaction to proceed that requires less energy. Catalysts are not products or reactants, they are not used up or changed by the reaction, they just help it go faster.

i. An enzyme increases the rate of a specific chemical reaction in the cell by lowering the activation energy, which it does by offering an alternative pathway for the reaction. In short, it speeds up a specific reaction in the cell.

ii. An enzyme is a biological catalyst, which means it is an organic molecule made in/by the cell (i.e. a protein) which acts as a catalyst speeding up the rate of other reactions in the cell. Other catalysts that can speed up reactions include inert, non-biological catalysts like the metal platinum, these are not biological catalysts. Saying an enzyme is a 'biological' catalyst distinguishes it from these other kinds.

e. The activation energy of a reaction is the energy that the products need to react. If products don't have at least this much energy when they collide, they will just bounce off each other rather than reacting.

f. Anabolic means building up; catabolic means breaking down. An example of an anabolic reaction is a protein being built up from amino acids, or DNA being built up from nucleotides. We start with smaller molecules and combine them using chemical reactions to make bigger molecules. An example of a catabolic reaction is breaking down starch into glucose molecules or breaking a protein down into amino acids. We start with a bigger molecule and break it down into smaller parts.

g. There are different kinds of enzymes. Each enzyme will only catalyse a specific reaction. We say that enzymes are 'specific' for their reactions.

h. The substrate of an enzyme is one or more of the reactants in the reaction the enzyme catalyses. The substrate molecules are the reactants that bind to the enzyme during the reaction. This lowers the activation energy needed for the reaction so that they can react to form the product.

i. The active site of an enzyme is where its substrate binds during the reaction. Each enzyme has a specific site where the substrate binds; it can't bind just anywhere. This has a specific shape and 3D structure that allows the substrate to fit and bind but not other molecules. This is one of the reasons why enzymes are specific and don't catalyse all reactions. Only some substrates can fit in and bind to their active sites.

j. In the lock and key model of enzyme activity, the substrate molecules perfectly fit into the active site of the enzyme. They slot into and bind to the enzyme active site, fitting together like a lock and a key. The enzyme catalyses the reaction and the final product is released. The enzyme has an empty active site now and is ready to catalyse another reaction.

k. In the induced fit model of enzyme activity, the substrate molecules initially don't fit perfectly into the active site of the enzyme but are still able to slot in and bind. When they bind, the enzyme undergoes a change in conformation (shape) so that the active site fits around the substrate molecules better. This tighter fit enables the reaction to be catalysed. The final product is then released, and the enzyme returns to its original shape. Only the particular substrate molecules can induce a fit with the enzyme active site.

l. Induced fit model.

m. Denaturation is when a protein breaks because it has been subject to environmental conditions that it cannot withstand, such as extreme pH or temperature. A denatured protein can no longer carry out its function. For example, if an enzyme denatures, it can no longer catalyse its reaction anymore. Proteins denature when the environmental conditions break the bonds that hold them together in their 3D structure.

n.

1. pH.
2. Temperature.
3. The concentration of substrate present.
4. The concentration of cofactors present (if the enzyme needs a cofactor).
5. Presence or absence of inhibitors.

o. As the temperature is raised, the rate of reaction initially increases. This is because raising the temperature adds heat energy to the solution. This gives the molecules more energy, so they move faster (have more kinetic energy) and are more likely to collide. The more frequently they collide, the more frequently reactions occur. The molecules are also more likely to have enough energy to overcome the activation energy, so when they do collide, they react successfully more often. At higher temperatures, the substrate molecules will, therefore, bind to the enzyme more frequently, so the reaction occurs more.

   However, if the temperature gets too high, the enzymes will start to denature. The heat energy breaks the chemical bonds holding them in their shape, and this makes them unable to catalyse reactions. So if the temperature gets too high, the enzymes start denaturing; fewer enzymes mean fewer biological catalysts to catalyse the reaction and so fewer and fewer reactions occur.

p. Each enzyme has a specific pH range it functions well in. Outside of this range, the enzyme molecules start to denature and eventually all will be denatured and unable to catalyse the reaction. The pH range that is optimal differs for different enzymes. pH disrupts the enzyme because some of the bonds that hold the enzyme in its 3D shape are ionic bonds between positive and negative parts of the enzyme molecule. The pH of the surrounding environment affects the charges on these parts of the enzyme and can cause them to become uncharged (if it's the wrong pH) so that the bonds break.

q. The more substrate molecules in solution (higher substrate concentration) the more opportunities there are for the substrate molecules to collide with the enzymes for the reaction to occur. Therefore, the rate of reaction is increased.

r. A cofactor is a substance that an enzyme needs to work properly. Not all enzymes need cofactors. Cofactors are common ions such as Mg^{2+}, Cu^{2+} or Fe^{2+}. They can also be organic molecules like FDD, coenzyme Q10 or haem. Cofactors bind to the active site of the enzyme and help facilitate catalysis. They are not themselves used up in the reaction so they're not considered substrates.

   i. A coenzyme is a cofactor which is an organic molecule, like haem.

   ii. If an enzyme needs a cofactor to function properly, the concentration of cofactors will affect the enzyme activity. If the concentration is low, there will not be enough cofactor molecules for every enzyme, so only some of the enzyme molecules can undertake catalysis, so the rate of reaction will be low. Increasing the cofactor concentration increases the rate of reaction for an enzyme that needs a cofactor. However, at a certain point, the activity won't increase with cofactor concentration anymore because there will be enough cofactor for all of the enzymes. Increasing the concentration further just means surplus cofactor.

s. An inhibitor is a molecule which binds to an enzyme and blocks its active site so that the substrate can't bind. This stops the enzyme from catalysing the reaction. A high concentration of inhibitors will dramatically decrease the rate of reaction because many of the enzymes will be blocked and unable to catalyse.

i. Examples can be: lead (Pb) and other heavy metals, like mercury (Hg), cadmium (Cd), arsenic (As) and chromium (Cr). Some are poisons, like cyanide. Some antibiotics or medicines used to kill pathogens like fungi and bacteria. These inhibitors disrupt enzymes involved in key life processes like respiration in the pathogens, which kill them. One example is penicillin.

ii. Inhibitors decrease enzyme activity by binding to an enzyme and blocking its active site so the substrate can't bind.

3. Cell Transport

a. The transport of molecules into and out of the cell and between organelles within the cell.

i. Into a cell: water, glucose or other simple carbohydrates, CO_2 (for plants), O_2 (for animals), ions like Ca^{2+} and K^+, H^+.
Out of a cell: water, CO_2 (for animals), O_2 (for plants), ions like Ca^{2+} and K^+, H^+.

b. The plasma membrane regulates what can travel into and out of the cell; it is like border control. The tightly packed phospholipids mean that larger molecules cannot easily pass through the cell membrane and are kept out, while smaller molecules can be 'screened' so the cell can make decisions about what enters and exits.

c. Able to be moved through. If something is permeable to water, for example, that means water can move through it easily, with little resistance.

i. Selectively permeable means that the cell membrane is permeable to some substances but not others i.e. it is selective; it will let some molecules in or out but block the movement of others.

d. Active transport requires an energy input (usually in the form of ATP)
Passive transport does not require energy input (no ATP required).

e. *i.* A substance dissolved in another substance. For example, if we dissolve table salt in water, the NaCl is the solute.

ii. The substance that a solute is dissolved in. For example, if we dissolve table salt in water, the water is the solvent.

iii. A solution refers to both the solute and the solvent together. For example, a solution of table salt in water.

iv. The number of molecules in solution per unit of volume. For example, 5 molecules per ml, 20 mols per litre.

f. A concentration gradient is where there is a high concentration of a molecule in one location and a low concentration in another location. For example, if we have a fish tank and we drop in some dye at one end, there is a high concentration of dye molecules at that end and a low concentration at the other. We would say there is a concentration gradient in the tank.

g. Diffusion is the movement of particles down a concentration gradient. That is, from a high concentration of that particle to a low concentration. If we think about our previous fish tank example, over time, the dye molecules will move from the side where we dropped them in and disperse throughout the tank, so that all of the water in the tank becomes coloured. The particles move from the high concentration to the low concentration until the concentration is equal everywhere. This is diffusion.

i. Diffusion is a passive process because it does not require an input of energy or ATP. It will happen naturally whenever there is a concentration gradient and the particles are free to move.

ii. Simple diffusion is the diffusion of molecules across the cell membrane without any assistance. Very small, non-charged particles can move freely through the plasma membrane, into and out of the cell, along their concentration gradient. These particles don't need any extra assistance to cross the plasma membrane.

iii. Examples:
O_2 – oxygen
CO_2 – carbon dioxide
Small fats (lipids)

h. Osmosis is the diffusion of water molecules down a concentration gradient, from a high concentration of water molecules to a lower concentration of water molecules, across a semipermeable membrane. Note that this is the movement of water molecules specifically. If we think about a solution of saltwater, a concentrated solution has a lot of salt molecules and not much water, so from the point of view of the water, this is a low concentration of water molecules. A dilute salt solution has many water molecules and not much salt, so a high concentration of water. Water molecules would move from the dilute solution to the concentrated solution and cause the two solutions to be the same concentration. The semi-permeable membrane between the solutions stops the solute particles from diffusing, so only water can move between solutions.

i. Osmosis is a passive transport process because it doesn't require an energy input of ATP. Water will naturally move down its concentration gradient via osmosis if it can.

i. Facilitated diffusion is the diffusion of molecules across the plasma membrane, down their concentration gradient, but the molecules cannot get through the plasma membrane by themselves. Very large or charged/polar molecules have difficulty getting through the phospholipid membrane by themselves; they need help to cross the membrane. They still move by diffusion, down their concentration gradient, but a protein like a channel protein provides a 'gateway' for them to cross the membrane.

i. Passive transport. No energy input or ATP needed. This is still diffusion (which is passive) it just has some extra proteins involved.

j. Passive transport processes like diffusion rely on the molecules moving around in solution. If we warm up the solution and add heat energy to it, the molecules have more kinetic energy, so they move faster and diffusion is faster. However, the proteins involved in facilitated diffusion will denature if the temperature becomes too high which will stop facilitated diffusion.

Diffusion also happens faster if the concentration gradient is higher, if there is a bigger difference between concentrations. It happens faster if the particles are smaller as they can move faster at the same temperature (and need less kinetic energy to move a small particle quickly than a big one!)

k. Both pinocytosis and phagocytosis involve the plasma membrane wrapping around the substance to be transported into the cell. In pinocytosis ("cell drinking") the plasma membrane pinches in and wraps around a droplet of liquid. In phagocytosis ("cell eating") the plasma membrane extends outwards and engulfs a food particle. These are both active transport processes. They require an input of energy in the form of ATP for the membrane to move.

l. An ion pump is a specialised protein embedded in the cell membrane that transports (pumps) ions across the membrane, against their concentration gradient. The ion binds to the protein, which then changes shape to push them through the membrane.

m. Both channel and carrier proteins are embedded in the plasma membrane of the cell and used to transport substances in and out. A channel protein aids facilitated diffusion. It acts like a gateway through which larger and charged/polar molecules can move down their concentration gradient, by diffusion, into or out of the cell. This is a passive transport process, not requiring input of energy/ATP. A carrier protein transports molecules across the membrane against their concentration gradient. One example is an ion pump. This is active transport and requires an input of energy/ATP.

n.
1. Phagocytosis.
2. Pinocytosis.
3. Carrier protein/ion pump.

o.
1. Simple diffusion.
2. Facilitated diffusion.
3. Osmosis.

p. Active transport processes require ATP input, so increasing the amount of ATP available in the cell will enable them to occur more quickly. For carrier proteins/ion pumps, having more of them in the membrane allows more of the substance to be moved per second.

q. All of the cell transport processes rely on crossing the plasma membrane, so more surface area (and therefore more plasma membrane) means more places to cross and therefore a faster rate of transport. Increasing the surface area means that there is more plasma membrane for osmosis and diffusion to occur across and also means the plasma membrane can fit more carrier proteins, ion pumps or channel proteins in it.

4. Photosynthesis

a. Photosynthesis is the process by which a plant captures energy from sunlight and uses it to build up glucose (food) molecules from smaller carbon molecules (i.e. CO_2). The energy from the sun is used to form the new chemical bonds between the carbon molecules to build glucose. Photosynthesis is the series of chemical reactions that allows this.

i. Plants and algae can undergo photosynthesis; animals and fungi cannot.

ii. Photosynthesis occurs in the leaves and stems of plants, in spongy mesophyll and palisade cells. It occurs in the chloroplasts within these cells.

b.

Carbon dioxide gas + water ⟶ glucose + oxygen gas

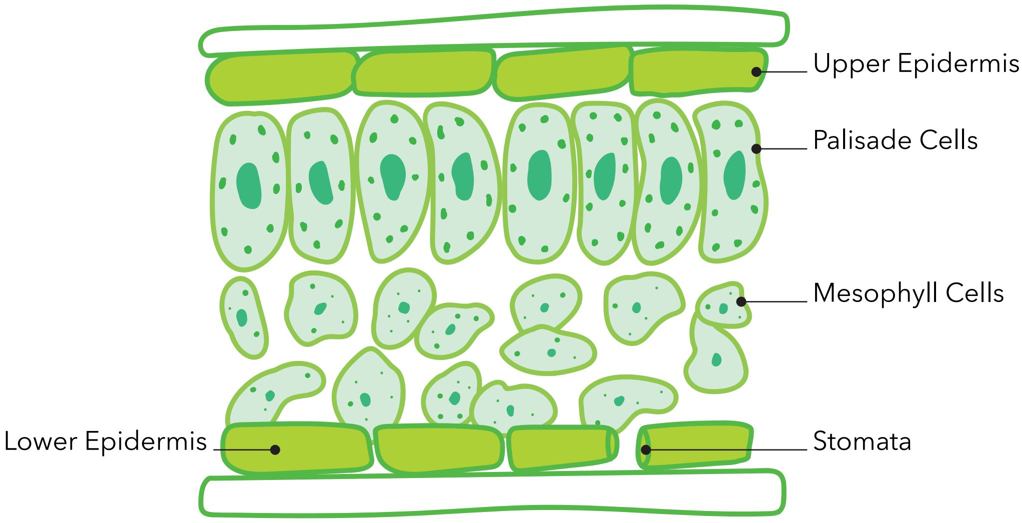
$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

i. Reactants: carbon dioxide, water.
The cells need to be exposed to light energy.

ii. Products: glucose, oxygen.

iii. To produce food molecules for the plant for nutrition.

c.



The epidermis is a layer of clear cells on the surface of the leaf, i.e. the leaf's 'skin'. These cells are transparent and thin for maximum light absorption. They have a waxy layer to help the leaf retain water and keep pathogens out/protect the leaf.

The palisade layer is a layer of brick-like photosynthetic cells found near the upper surface of the leaf. They are packed with chloroplasts which are arranged near the plasma membrane of the cells for maximum light absorption. This also reduces the distance CO_2 needs to travel when diffusing into the cell. The palisade cells are tightly packed to ensure they catch as much light as possible.

The spongy mesophyll layer is the bottom layer of photosynthetic cells. These contain fewer chloroplasts and catch any light that passes through the palisade layer without being captured. There are lots of air spaces in this layer for easier gas exchange. Cells are spaced out so that there is more area available for carbon dioxide to diffuse in and oxygen to diffuse out.

Stomata are pores in the epidermis of the leaf which open to allow gases to diffuse in and out of the leaf. Most stomata are found on the bottom of the leaf in the lower epidermis. They can close to reduce evaporation from the leaf in high temperature/windy conditions to stop the leaf from drying out too much.

d. Chlorophyll is a pigment molecule which absorbs light energy and captures it for the plant to use in photosynthesis. It appears green coloured to us. Chloroplasts are organelles found in plant cells and are where photosynthesis happens. Chloroplasts contain chlorophyll which is why they look green.

e. Leaves appear green due to the presence of chlorophyll. Chlorophyll reflects green light, so it appears green to us as this is the colour reaching our eyes.

f. The many thylakoid membranes increase the surface area for light capture. The thylakoid

membranes hold the chlorophyll molecules. The stroma of the chloroplast is where carbon dioxide is used to produce glucose. This requires enzymes and CO_2 which are dissolved in the liquid of the stroma.

g. Light-dependent phase.
Light-independent phase.

i. In the light-dependent phase, the chloroplast uses the chlorophyll molecules to capture energy from sunlight for use in the reactions. This energy is used to split water molecules into H^+ ions and O_2 gas, which is released as a by-product. The H^+ ions are used to make $NADP^+$ into NADPH, which is used later in the chemical reactions.
In the light-independent phase, the CO_2 molecules and the NADPH are used to make glucose. ATP is used. A series of chemical reactions are needed for this.

h. *1.* Temperature.

2. Light intensity.

3. Wavelength of light.

4. CO_2 concentration.

i. Photosynthesis relies on enzymes, so increasing the temperature increases the rate of reaction, up until the enzymes are denatured, after which the rate of reaction decreases with increasing temperature.

CO_2 is one of the reactants needed for photosynthesis, so increasing its concentration increases the rate of photosynthesis up until another factor, such as light, becomes limiting and the cell becomes saturated with CO_2.

Increasing light intensity increases rates of photosynthesis up to a point, because energy from light is needed for the reaction. Adding more light energy means more reactions can occur. However, at a certain point, all of the chlorophyll molecules in the leaf are saturated with light and cannot absorb any more, and other factors become limiting. Increasing light beyond this point won't increase the rate of reaction.

Particular wavelengths of light are better absorbed by the chlorophyll molecules. Red and blue light are well absorbed, green light is absorbed less. If the light the plant receives is mostly red or blue, then this provides more energy for photosynthesis so the rate of reaction increases. If the light is mostly green, less is absorbed, and so this provides less energy for photosynthesis and the rate of reaction is less.

i. Photosynthesis is a series of chemical reactions catalysed by enzymes, which are proteins. Without these enzymes, the reactions would occur too slowly to produce enough food for the plant or not at all.

j. A plant could:

1. Grow more leaves, therefore producing more cells with chloroplasts and more surface area for absorbing light.
2. Position its leaves so that they don't overlap/shade other leaves.
3. Grow bigger leaves with more surface area and therefore more cells to absorb light.
4. Open its stomata to allow more CO_2 to enter the cells.

5. Respiration

a. Respiration is the process by which a cell breaks down glucose food molecules to release energy. Breaking the chemical bonds in the glucose molecule releases the energy stored in those bonds. This released energy is stored in an ATP molecule so that the cell can use it later for other life processes. Respiration is the series of chemical reactions that allows this.

i. Anaerobic respiration occurs in the absence of oxygen and oxygen is not a reactant for this reaction. This produces lactic acid in animals and ethanol in plants and fungi. It doesn't produce as much energy/ATP.

Aerobic respiration occurs in the presence of oxygen. Oxygen is a reactant involved. This produces CO_2 and water, which are the byproducts. Aerobic respiration produces more energy/ATP.

b. All cells can carry out respiration, whether plant or animal.

i. Respiration occurs in the mitochondria of every cell in the organisms. Every cell does respiration to provide energy for its own life processes.

c.

$$\text{Glucose + oxygen} \longrightarrow \text{carbon dioxide + water}$$
$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

i. Reactants: glucose, oxygen.
Conditions: adequate temperature, adequate concentrations of oxygen and glucose.

ii. CO_2 and water, ATP/energy.

d. Respiration releases energy from food molecules (glucose) for the cell to use in life processes (the rest of MRS GREN).

e. The outer membrane is permeable so molecules like oxygen can easily enter and CO_2 can easily exit.

The inner membrane is highly folded into many cristae. This increases the surface area for the reactions of respiration to occur.

The matrix is a fluid-filled space where the reactants and enzymes needed for the reactions are dissolved.

The mitochondria itself is rod-shaped to allow greater surface area.

f. ATP, or adenosine triphosphate is a molecule which stores the energy released from food molecules (glucose) during respiration. When the chemical bonds in the glucose molecule are broken, energy is released. This energy is captured and stored in the ATP until the cell can use it for another reaction or life process.

g. *1.* Glycolysis.

2. Krebs cycle.

3. Respiratory chain.

i. Glycolysis is the first stage of respiration. In glycolysis, the glucose molecule is broken down into smaller, 3-carbon molecules. This happens in the cytoplasm, so not in the mitochondria at all. This produces a small amount of ATP, two hydrogen atoms, and smaller carbon molecules.

Krebs cycle is the second stage of respiration. In the Krebs cycle, the smaller carbon molecules from glucose undergo a series of chemical reactions which releases energy from them. This produces a little more ATP. It occurs in the liquid matrix of the mitochondria where the enzymes are dissolved. Carbon dioxide is a waste product of this reaction.

Respiratory chain is the third stage of respiration. In this stage, the hydrogen molecules produced during glycolysis and the Krebs cycle are used to produce a large amount of ATP. This requires many specialised proteins which are found on the cristae of the mitochondria.

h. Temperature: Increasing temperature increases the rate of reaction until the temperature becomes too high and denatures enzymes.
Concentration of oxygen or glucose: Higher concentrations increases the rate of reaction.
The number of mitochondria in the cell: More mitochondria = more respiration possible.

i. Increase oxygen concentration by increasing oxygen intake, e.g. panting.
Produce more mitochondria in the cells.

6. Cell Cycle

a. The cell cycle is a series of events that occur in a cell during its lifetime, as it grows and prepares to divide.

i. The cell cycle enables a cell to grow bigger and to divide. This is important because, without cell division, the single-celled zygote could never develop into a larger adult organism. Also, cell division is needed for repair (e.g. because of injury) and reproduction (e.g. to produce gametes) and replacement (e.g. of skin cells).

b. During the interphase stage of the cell cycle, the cell will carry out its usual functions, grow, and accumulate nutrients. The cell may prepare to divide if it is big enough by replicating organelles and replicating the DNA and chromosomes.

c. During the mitotic phase of cell division, the cell undergoes the process of dividing into two new cells. In mitosis, the chromosomes condense into the characteristic X-shapes we're used to seeing. The nucleus disappears and chromosomes are divided between either end of the cell, which then splits. Cytokinesis is the stage where the cell physically divides into two.

d. A chromosome is one very long DNA molecule containing many genes.

i. In eukaryotes, like animals and plants, chromosomes come in pairs. Both chromosomes of the pair have the same genes in the same order all the way down. A pair of chromosomes like this are called homologous chromosomes.

e. During the interphase stage of the cell cycle, the cell is busy growing, accumulating resources and carrying out its usual cell functions. It might prepare to divide by producing extra organelles and copying its DNA. It would then go from having two copies of every chromosome (2n) to having four copies (4n).

During mitosis, the cell begins to divide and distribute its chromosomes and organelles between the two new daughter cells. It goes from having 4n chromosomes back to having 2n again.

7. Mitosis

a. Mitosis is the process by which a cell replicates its chromosomes and organelles and then divides to produce two identical daughter cells.

i. Mitosis is needed to produce new body cells. Mitosis is therefore needed for growth, repair and replacement.

b. When chromosomes replicate, initially, both copies are joined at their middle. The two identical copies are each referred to as a chromatid until they separate, and then they are referred to as chromosomes.

c. The centromere is the middle part of the chromosome that is constricted. This is where chromatids are joined.

d. The chromosomes have already replicated during interphase. In the first stage of mitosis, they condense down and coil up tightly. The nuclear membrane disappears. The chromosomes line up along the centre of the cell and the spindle fibres form. The chromosomes separate so that one of each duplicate goes to each end of the cell. A new nucleus forms around the chromosomes in each cell and the cell prepares to divide into two.

e. Spindles are networks of fibres that extend out from each end of the cell to attach to and separate the duplicate copies of chromosomes during cell division.

f. Stage of life: Mitosis occurs more in organisms that are growing fast (e.g. young babies, germinating seedlings).

Availability of nutrients and energy: Cells divide when they grow big enough. If there are lots of nutrients and energy available, cells can divide more frequently.

Location of cells: In organs requiring frequent repair or replacement (like skin).

Environmental factors: Since mitosis uses enzymes, factors that affect enzyme rate of reaction like temperature, pH etc. affect mitosis.

8. DNA Replication

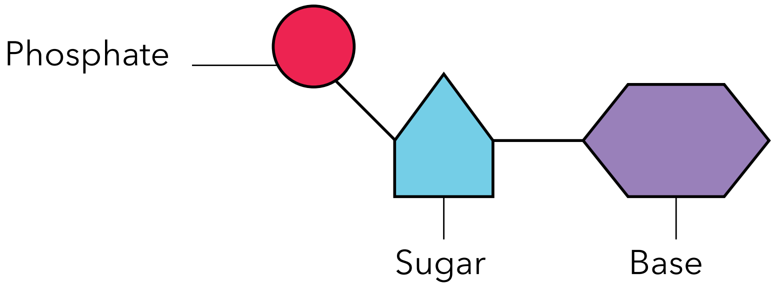
a. DNA is the genetic information found in the cell and passed from parent to offspring. It is a biological macromolecule (large molecule) that carries the genes. DNA contains all of the instructions necessary to produce the proteins the cell needs and direct the cells' activities.

i. Sugar, phosphate, nitrogen bases.

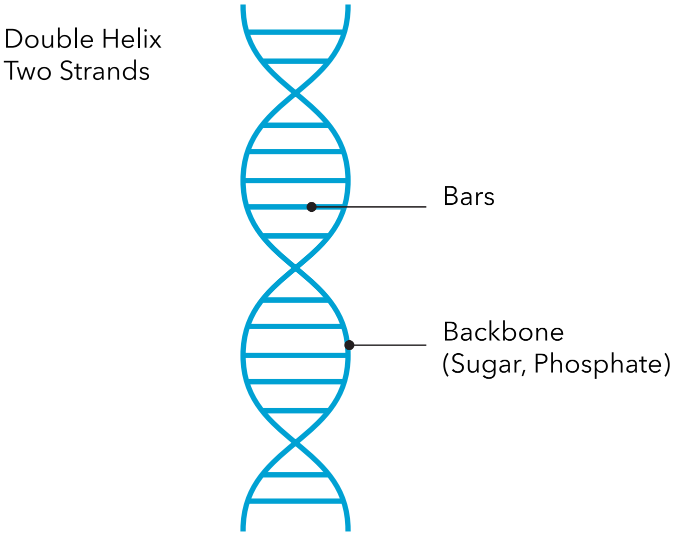
ii. Sugar and phosphate form the backbone, the nitrogen bases are found paired up in the middle.

b. Nucleotides are the basic building blocks of DNA. A nucleotide consists of a sugar, phosphate, and base.

i.



c.



DNA is a double-stranded molecule that forms a double helix. The sugar and phosphate form the backbone while the bases are found in the middle. The two strands of DNA run in opposite directions.

i. A, T, C, G
Adenine, thymine, cytosine, guanine.

ii. A and T base pair; C and G base pair.

d. A nucleotide is a nitrogen base attached to a sugar and a phosphate.

e. If two things are parallel, they run side by side but never touch and the size of the gap between them doesn't change.

i. In DNA, the two sugar-phosphate backbone strands run antiparallel. This means they are parallel to each other, but each strand runs in the opposite direction to the other.

f. DNA replication is the process by which DNA copies itself to produce a new, identical DNA molecule.

i. Before a cell can divide to produce a new cell, it needs to make a copy of all of its DNA to give to the new cell. Otherwise, the new cell won't have any instructions to direct its functions.

g. *i.* Firstly, the parent DNA molecule unzips. The pairs of bases in the centre become separated. An enzyme unwinds the DNA molecule and breaks the hydrogen bonds between these bases. Another enzyme ensures the unwinding strands don't become knotted.

ii. Secondly, new nucleotides base pair with the exposed base pairs on either strand. They bond according to the complementary base pairing rules.

iii. Thirdly, enzymes move down the backbones and join the sugar-phosphate backbones of the nucleotides together. On the leading strand, this is continuous. On the lagging strand, the enzyme works in blocks, joining the backbones of a few nucleotides, before separating and rejoining onto the DNA strand.

iv. At the end of the process, two new DNA molecules are produced that are identical. Each winds up to form a helix.

h. DNA replication is semi-conservative because each new DNA molecule has one parent strand in it, i.e. the parent strands are conserved.

i. The complementary base pairing rules mean that each parent strand can act as a template to create the new strand of DNA. This ensures that the new DNA molecules produced are identical.

Part Two

Developing Skills

a. Chloroplasts and mitochondria are both membrane-bound organelles. They have an outer membrane enclosing them that keep their interior separate from the rest of the cell cytoplasm. This allows them to have different concentrations of products, reactants and enzymes inside compared to the rest of the cell. Both have many membranes inside to increase the surface area for reactions. In mitochondria, the interior membrane is folded to form cristae. In chloroplasts, the interior membrane forms a series of flat discs called thylakoids, stacked on top of each other to form grana, with tubes connecting the grana called lamellae. The inner membranes in both are involved in their respective biological reactions. The interior liquid of the chloroplast is called the stroma; in the mitochondria, it is called the matrix. In both cases, the liquid contains enzymes that catalyse the reactions and is where the products and reactants are dissolved.

Chloroplasts carry out photosynthesis. This is the process by which a plant captures energy from sunlight and uses it to build up glucose (food) molecules from smaller carbon molecules (i.e. CO_2). The energy from the sun is used to form new chemical bonds between the carbon molecules to build glucose. Photosynthesis is the series of chemical reactions that allows this.

Mitochondria carry out respiration. This is the process by which a cell breaks down glucose to release energy. Breaking the chemical bonds in the glucose molecule releases the energy stored in those bonds. This released energy is stored in an ATP molecule so that the cell can use it later for other life processes. Respiration is the series of chemical reactions that allows this.

b.
- Chloroplasts
- Mitochondria

A high density of chloroplasts is found in plant organs that carry out photosynthesis and are most exposed to the light, such as leaves and stems. Most chloroplasts are found in the palisade cells at the upper surface of the leaf where there is maximum light exposure. A high density of mitochondria is found in cells with high energy needs, such as cells in muscles.

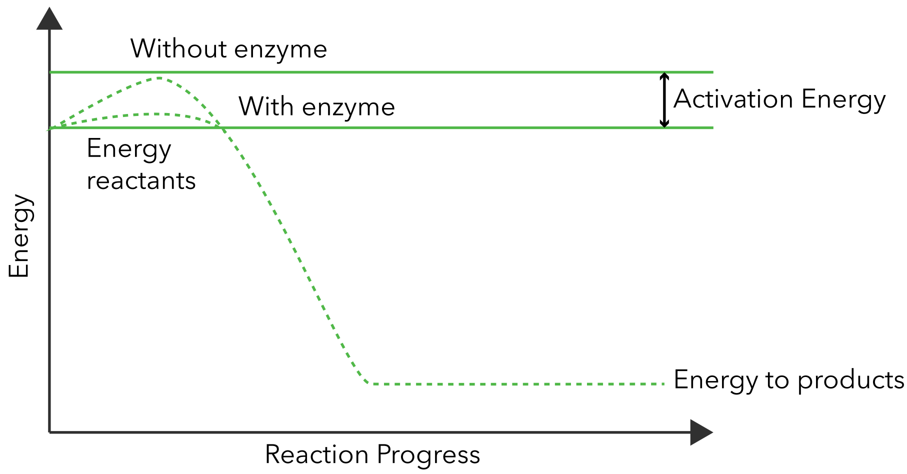
c. Both rough and smooth ER consist of flattened membranous sacs. Rough ER has ribosomes embedded in its surface; smooth ER does not. The ribosomes of rough ER make proteins, so rough ER is very involved in the production of proteins and their packaging for secretion from the cell. Rough ER is therefore commonly found in cells that secrete lots of protein. Smooth ER is involved in producing steroids, such as the hormones testosterone and oestrogen, and lipids. It also stores calcium ions. Calcium ion storage is especially important in muscles for for muscle contraction, so smooth ER is high in muscle cells and also cells that secrete hormones and lipids.

d. Many of the life processes described by MRS GREN involve a series of chemical reactions catalysed by enzymes. For example, respiration, represented by R, is a series of enzyme catalysed reactions. Without these enzymes, the reactions wouldn't occur fast enough to sustain the organism or at all. Respiration takes food molecules and releases energy from them, so without enzymes, the organism could not get energy from its food for other life processes. Without energy, cells and organisms could not undertake movement, sensation, reproduction or excretion.

Enzymes are also involved in digesting and breaking down food molecules, which is part of nutrition. They are involved in the chemical reactions of photosynthesis which produces food for plants. Without enzymes, organisms could not process nutrients from their environment which they need in order to build structures in their cells and grow.

Finally, enzymes are involved in the DNA replication and cell division. These produce cells for growth and also to produce gametes for reproduction.

e.



With or without the enzyme, the reactants still start with the same amount of energy, so the lines start in the same place. For the reaction to proceed, an energy input is needed. This is represented by the activation energy, shown on the graph as the bump in energy as the reaction starts. When the enzyme is present, the activation energy required is less and the bump in the graph is smaller. Without or without the enzyme, the products still have the same amount of energy, so the graphs end in the same place.

f. Enzymes have an optimal pH for their activity. The optimal pH for a particular enzyme is determined by its 3D structure and the bonds holding it in this structure. Many bonds responsible for holding the enzyme in its shape are ionic bonds that are affected and disrupted by the surrounding pH in the solution. If the pH is too far outside of the range for that enzyme, the bonds holding it in its structure will be broken and the enzyme will denature. This means it loses its shape, and the active site is broken, and therefore it can't catalyse the reaction that it usually would.

Over time, organisms have evolved enzymes which function well in the environment the enzyme would usually catalyse reactions in. For example, pepsin is an enzyme in the stomach (a very acidic environment), and so its optimal pH is 1-2, which is acidic. However, pepsin would be denatured if placed in the small intestine, where the pH is basic. Trypsin, which digests proteins in the small intestine, works best at pH 7-8, like the pH in this organ. It would be denatured in the stomach. The optimal pH for an enzyme relates to the environment in the organism it usually functions in.

g. Cell transport is needed to get materials in and out of a cell. Without it, a cell could not bring in resources, such as nutrients and water (N of MRS GREN), and oxygen and glucose for respiration (R of MRS GREN), and it would not be able to remove waste products (excretion, E of MRS GREN). If the cell could not bring in nutrients, glucose and oxygen, it would not have the raw materials to grow (G of MRS GREN). It could not undergo respiration because it would run out of the necessary reactants. This means it could not produce the energy needed for other life processes, such as movement (M of MRS GREN) and sensing (S). Without the ability to bring in new resources, grow, and extract energy from food for other life processes, the cell could not divide either, so it could not reproduce (R of MRS GREN). Without the ability to remove them, toxic waste products would build up (E for Excretion).

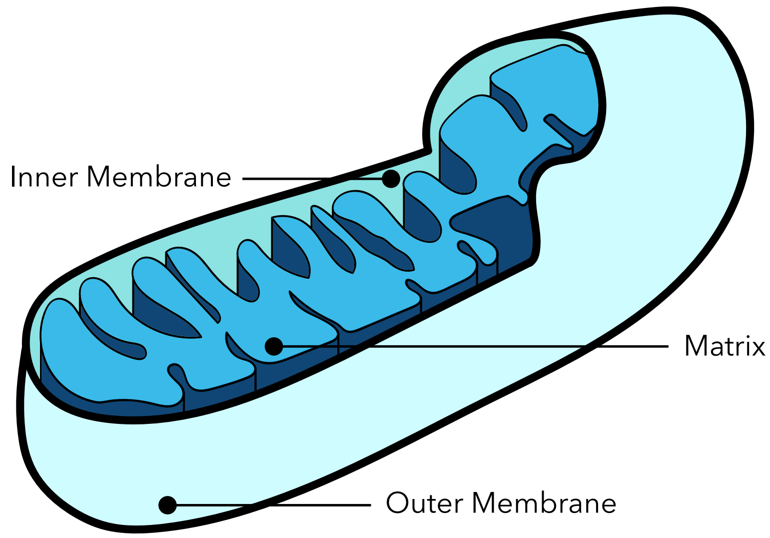
h. Proteins embedded in the cell membrane help to transport substances across the membrane. Channel proteins provide a gateway for molecules which are too big or charged to pass through the plasma membrane unaided. The molecules can then diffuse into or out of the cell. Carrier proteins help carry molecules into the cell against their concentration gradient, and ion pumps help pump ions into or out of the cell against their concentration gradient. Proteins are therefore very important for cell transport as they allow molecules that otherwise could not cross the plasma membrane by themselves to get into or out of the cell.

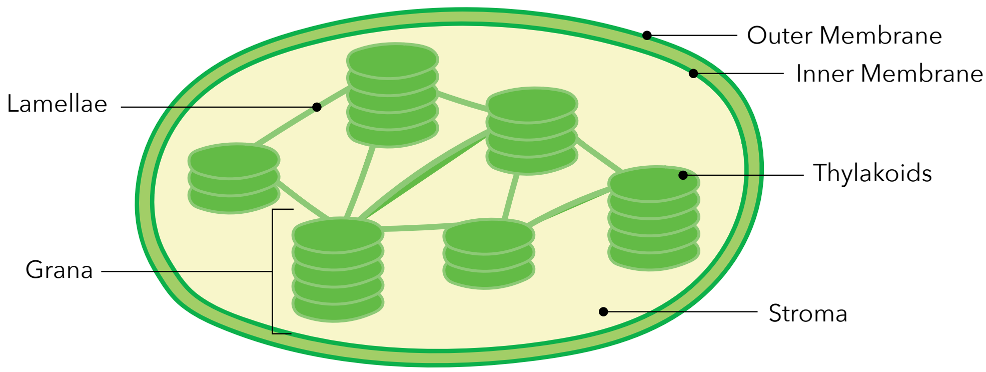
Proteins, in the form of enzymes, are also involved in respiration, which extracts energy and stores it as ATP for the cell. Many cell transport processes are active meaning they require an energy input, which comes from ATP. Without enzymes to catalyse the reactions, there would be no ATP.

i. Chloroplasts produce food molecules (glucose) for organisms that have them. They take energy from the environment (in the form of sunlight) and carbon dioxide from the atmosphere, and use the energy to combine the CO_2 molecules into glucose. This provides some nutrition (N from MRS GREN) for the organism. The organism can then use these food molecules in respiration (R). Respiration is the series of chemical reactions by which the organism breaks down the glucose to release the energy from the chemical bonds and then store it in ATP for later use by the cell. Respiration provides the energy for other cell processes such as reproduction, sensation and movement.

Section Two
Exam Skills & Mixed Practice

Question One: Chloroplasts and Mitochondria





Both organelles are the sites of different enzyme catalysed reactions. Chloroplasts are the site of photosynthesis. This captures energy from sunlight and uses it to build glucose molecules from CO_2 and H_2O, producing O_2 as a byproduct. Mitochondria are the site of respiration. This breaks down glucose (such as that produced in photosynthesis), releasing energy from the chemical bonds to be stored in ATP for the cell, with CO_2 as a byproduct.

Chloroplasts and mitochondria are both rod-shaped membrane-bound organelles. The interior liquid of the chloroplast is the stroma; in the mitochondria, this is the matrix. In both, the liquid has enzymes to catalyse the reactions and is where the products and reactants are dissolved. Both organelles have many membranes inside to increase the surface area for reactions. In mitochondria, the internal membrane is folded to form cristae. In chloroplasts, the interior membrane forms a series of flat discs called thylakoid.

The rod-shape provides more surface area for diffusion and transport of substances in and out of the organelle. For both, the outer membrane keeps the interior liquid separate from the cell cytoplasm. This allows the organelles to have different concentrations of products, reactants and enzymes than the rest of the cell. Increasing the substrate concentration increases the reaction rate. In mitochondria, the matrix is the site of the Krebs cycle which modifies the products from glycolysis and produces some ATP and CO_2. In chloroplasts, the stroma is the site of the light-independent reactions which fix CO_2 into glucose.

The inner membranes in both have enzymes. In chloroplasts, the thylakoid membranes also have chlorophyll, a green pigment that captures light energy, as well as enzymes involved in the light-dependent reactions. These catalyse reactions that convert $NADP^+$ into NADPH, to be later used in the light-independent reactions, and catalyse the splitting of water, which produces H+ ions (for the $NADP^+$) and O_2 as a byproduct. In mitochondria, the cristae are the site of the respiratory chain that produces the majority of the ATP in respiration.

A high density of chloroplasts is found in the plant organs that carry out photosynthesis and are most exposed to the light, such as leaves and stems. More chloroplasts are found in the palisade cells at the upper surface of the leaf where there is maximum light exposure. A high density of mitochondria is found in cells with high energy needs, such as cells in muscles.

Question Two: Transport

Answering the question:

When answering this question, make sure to discuss each of the factors for all three processes. Describe it and talk about what affects its rate.

Diffusion, facilitated diffusion and osmosis all involve the movement of molecules down their concentration gradient, which means from an area with a high concentration of that molecule to an area where there is a low concentration.

Diffusion can be the free movement of any molecule down its concentration gradient. Facilitated diffusion occurs when a molecule uses a channel protein in the cell membrane to diffuse into or out of the cell. The molecule still moves down its concentration gradient, but it is too bulky or charged to cross the plasma membrane by itself, so it needs assistance.

Osmosis is specifically the movement of water down its concentration gradient, across a semipermeable membrane. Water molecules move from where there is a high concentration of them and low concentration of solute (dilute solution) to where there is a low concentration of water molecules and high concentration of solute (concentrated solution). The semi-permeable membrane (which only lets water through) prevents the solute molecules from undergoing diffusion.

All three are passive transport processes. This means they don't require energy input in the form of ATP. In all three, the concentration becomes equal between the two areas.

All three processes are affected by the difference in concentration between the areas the molecule is moving between. A higher difference in concentration means a faster rate of diffusion, facilitated diffusion or osmosis. All three are affected by the amount of membrane surface area. More surface area to move across means a faster rate of movement. For facilitated diffusion, the more channel proteins there are in the membrane, the faster the rate of diffusion as there are more entrances into or out of the cell. Smaller molecules diffuse faster (but osmosis is always the movement of water, so not relevant for osmosis). Higher temperatures cause the molecules to move more quickly and increase the rate for all processes. However, if the temperature is too high, the channel proteins will denature and facilitated diffusion will stop.

Question Three: Mitosis

Answering the question:

Start by answering part a:

1. When does DNA replication happen?
2. Why is DNA replication needed?

DNA replication happens before the cell divides in mitosis, in the interphase of the cell cycle. The DNA needs to replicate so there is an extra copy of each of the chromosomes to pass onto the new cell that will be produced in mitosis. This allows the new cell to have identical genetic information and function the same.

Next up, we need to answer part b. Below are some questions you might find useful to think about when answering your question. Use these to help structure your answer. To answer this question, it is helpful to first think about the relationship between the different elements, for example, what is the relationship between factors that affect DNA replication (like temperature) and different times of the year (e.g. temperature in summer vs. winter)? Remember to refer to the keywords, concepts and skills you brainstormed above:

1. Define mitosis.
2. Explain the purpose of mitosis.
3. Explain why different cells in the plant would have different rates of mitosis (i.e. link cell type/ function to the purpose of mitosis).
4. Explain how the different factors of temperature, water availability, light and photosynthesis could affect the rate of mitosis.
5. Explain how these factors change at different times of the year and link this to the rate of mitosis of the different cells at each time of year.

Mitosis is cell division that produces two identical daughter cells. Before mitosis, the DNA replicates. During mitosis, the two DNA copies are separated into two new daughter cells. Mitosis is needed for growth, repair, and replacement of cells in the plant. The cells in the root and shoot apical meristem in plants undergo mitosis to produce the new roots, shoots, leaves and flowers for the plant so it can grow. The phloem cells do not undergo mitosis because they do not have a nucleus and DNA, so they can't divide. The phloem cells are responsible for transporting sugars and nutrients around the plant, not for producing new growth, so they don't need to undergo mitosis.

Mitosis requires DNA replication and other chemical reactions to occur. Enzymes are needed to catalyse the steps involved. Chemical reactions (including those catalysed by enzymes) have a greater rate of reaction when the temperature is warmer. This is because the molecules move more quickly, so they collide with each other and react more often. Also, the molecules have more energy so are more likely to have enough energy to meet the activation energy for the reaction. However, if it is too warm, the enzymes can denature and then the rate of reaction will decrease as they can no longer catalyse the reactions.

Mitosis and DNA replication also require an input of energy from ATP, so how quickly mitosis and DNA replication happen depends on how much ATP the cells produce. ATP is produced during respiration, so the rate of mitosis is linked to the rate of respiration. Respiration happens at a faster rate when the temperature is warmer and when the concentration of reactants is higher. The reactants for respiration are glucose and O_2. Glucose is made by the plant during photosynthesis.

Photosynthesis is the series of enzyme-catalysed reactions that capture light energy from sunlight and use it to build glucose molecules out of CO_2 from the atmosphere. During the process, H_2O molecules are split to produce H^+ and O_2, with the H^+ becoming part of the glucose molecule. The photosynthesis reaction is also increased by temperature, as well as by the concentration of reactants (CO_2 and water). Likewise, if there is more light, there is more energy available for photosynthesis. This means when water and light are readily available, photosynthesis happens faster, producing more glucose for respiration. Therefore more energy/ATP is made that can be used for mitosis and cell division. This means the plant can grow faster and produce new roots, leaves, shoots and flowers quickly when there is an ample supply of water and light. Increasing the amounts of water and light will increase the rate of photosynthesis until another limiting factor comes into play, such as the concentration of CO2 available. Therefore, the rate of mitosis will also increase as the amount of light and water increases.

The available light and the temperature increase during spring and summer, then decrease in autumn. Winter is the darkest and coldest time of the year. The availability of water is greatest in spring, autumn, and winter, and least in summer. Although, in winter, the water might freeze if it is cold enough and then the plant can't absorb it from the soil through the roots. This means water can be limited in winter. The shoot and root apical meristem cells have the greatest rate of mitosis inspring when the temperature and light intensity/day length is increasing and there is plenty of spring when the temperature and light intensity/day length is increasing and there is plenty of water. Mitosis in spring produces new leaves to capture the increasing light levels, new shoots and flowers, and root growth so that the plant can extract more water from the soil. It also produces cells to store starch for the plant to use for energy later. In summer, the temperature is warmer and there is plenty of light, but there may not be enough water for the reactions and the temperatures may be too high for the enzymes in photosynthesis, respiration and DNA replication to function optimally. In autumn, light levels and temperature drop and the rate of photosynthesis, respiration and mitosis decrease. The plant is done growing and flowering for the year. In winter, there is less light, and it is cold, which slows down reactions. The plant loses its leaves, so it can no longer capture light energy efficiently. Photosynthesis reduces, reducing respiration and mitosis.

Section Three
Practice Exam

Question One: Photosynthesis

a. Carbon dioxide + Water —Sunlight Energy→ Glucose + Oxygen

b. The purpose of photosynthesis is to produce glucose molecules (i.e. food) for the plant. The plant can then use this glucose in cellular respiration to release energy for use in other cell processes. Photosynthesis takes CO_2 and H_2O and uses energy captured from sunlight to combine them to make the glucose.

c. Water: water enters the plant through the roots from the soil. Roots have tiny, single-celled projections called root hairs for absorbing the water. Water molecules move into the root hair cells of the plant by osmosis. Osmosis is the movement of water down its concentration gradient, from a high concentration of water (dilute solution) to a low concentration of water (concentrated solution) and across a semipermeable membrane. It is a passive process; no energy input from ATP is required. The root hair cells have a high concentration of solutes such as mineral ions, dissolved glucose and oxygen etc. The surrounding soil, when wet, has a comparatively low concentration of solutes and a lot of water, so water moves across from the soil and into the root cells across the semipermeable membranes of the plant cells. Having root hairs increases the surface area of membranes available for osmosis.

Carbon dioxide: CO_2 enters the plant through the leaves and stem i.e. the aboveground organs. The CO_2 enters through tiny pores in the leaf, called stomata, which are surrounded by a pair of cells, called guard cells, that can tighten to close the pore. Once inside the leaf, the CO_2 is used up in photosynthesis, so the CO_2 concentration in the leaf is always being reduced, and the CO_2 concentration in the leaf is lower than that of the atmosphere outside the leaf. The CO_2 diffuses down its concentration gradient from the atmosphere into the leaf, where it can then diffuse across the cell membranes of photosynthetic cells like the palisade cells. This is a passive process; no energy input from ATP is required.

d. In the photosynthesis, the plant captures light energy from sunlight. It uses this light energy to generate bonds between CO_2 molecules and H^+ ions that come from water in a series of enzyme-catalysed reactions. This produces glucose molecules. The plant splits water molecules using enzyme-catalysed reactions to make the H^+, which generates O_2 as a byproduct. The H^+ joins onto and is carried by $NADP^+$ which becomes NADPH until it's needed in a later reaction.

Photosynthesis occurs in chloroplasts in plant cells like palisade cells in the leaf. The chloroplasts have stacks of membranes, called thylakoids, inside. These have enzymes for the reactions. A stack of thylakoids is called grana and there are tubes between them called lamellae. Having stacks of membranes increases the surface area for the reactions. The liquid interior of the chloroplast surrounding the grana and lamellae is called the stroma. It also has enzymes for reactions. Photosynthesis occurs in two stages. In the light-dependent reactions, the light energy is captured by chlorophyll pigment molecules embedded in the thylakoids. The light energy is used to split water molecules, releasing H^+. ATP is produced by another enzyme and used to store the captured energy. The NADPH carries the H^+. The second stage is the light-independent reactions. These occur in the stroma. In them, a series of enzymatic reactions join CO_2 molecules, using the H^+ and ATP from the light-dependent reactions, to form glucose.

Water and CO_2 are both reactants for photosynthesis, so are needed for it to happen. Increasing the concentration of water would increase the light-dependent reactions that use it, but only up until the water splitting enzymes were at capacity. Once there is enough H_2O for all of the water-splitting enzymes, then more water is surplus and increasing water further won't increase photosynthesis. Also, the rate at which the H^+ from the water is used depends on the rate of the light-independent reactions. The $NADP^+$ needs to be cycled back once it drops the H^+ off, so if the light-independent reactions occur too slowly, there won't be enough $NADP^+$ for the water splitting, which will slow it down. The light-independent reactions are affected by the concentration of CO_2. Increasing CO_2 concentration will increase the rate of photosynthesis. However, this is only until the enzymes in the reactions are saturated with CO_2, at which point, more CO_2 can't make the reactions go faster. Likewise, NADPH and ATP from the light-dependent reactions are needed, so if these reactions slow down because there is not enough water, for example, then the light-independent reactions will also slow down, even if there is abundant CO_2. The rate of each phase corresponds to the factor in shortest supply.

Question Two: Respiration and Enzymes

a. Cellular respiration extracts energy from food molecules for the cell to use in other life processes, such as movement and reproduction. The energy extracted is stored in ATP molecules for use in other processes.

b. Enzymes are proteins which act as biological catalysts. They speed up chemical reactions in the cell by lowering the activation energy of the reaction, without themselves being used up. Each enzyme has an active site which the substrate (reactant) can bind to. Enzymes are specific, so that only particular substrates can bind to the active site of any given enzyme. This is determined by the shape of the active site and the substrate molecule. Once the substrate binds to the active site, the enzyme helps the reaction to take place and then releases the product.

Cellular respiration is a series of chemical reactions catalysed by enzymes. Increasing the temperature initially increases the rate of respiration because it increases the rate of reaction for the enzyme. When the solution is warmer, the molecules have more kinetic energy and move faster, so they collide with the enzyme and the active site more frequently. This means they bind more frequently so the reaction takes place more times each second. With higher energy, more of the molecules also have enough energy to overcome the activation energy and react.

However, if the temperature is too high, such as when the mussel is in direct sunlight and not submerged, the enzyme can be denatured. The high temperatures break the weak bonds that hold the enzyme in its 3D shape. This distorts the active site so that the substrate can no longer bind. As the temperature increases above the optimum for the enzyme, more and more of the enzymes denature and the reaction rate for respiration is less and less.

Increasing the concentration of oxygen, such as when the mussel is submerged in oxygenated water, increases the rate of respiration. Oxygen is one of the substrates/reactants of the respiration reactions, as the equation shows:

Oxygen + glucose $\longrightarrow$ carbon dioxide + water and energy (ATP)

Therefore, if there is more oxygen to bind to the enzyme active sites, more reactions can take place. However, after a certain point, increasing the oxygen concentration no longer increases the rate of reaction because all of the enzymes have their active sites bound already. The cell is saturated with oxygen. At this point, one of the other factors becomes the rate-limiting step.

Cadmium is a heavy metal and an inhibitor of enzyme activity. Cadmium can bind to the active site of the enzyme which blocks the substrate from binding so that the reaction can no longer proceed. If there is a high concentration of cadmium in the water, then many of the enzymes would have their active sites blocked and the rate of respiration would dramatically decrease. A low concentration of cadmium allows many of the enzymes to still function so respiration can continue, albeit at a slightly lower rate.

Question Three: Cell Transport

In facilitated diffusion, the ion moves down its concentration gradient from an area of high concentration, like the soil, to an area of low concentration, like the root hair cell. The ion cannot cross the root hair cell plasma membrane on its own because it is charged. Instead, it relies on a channel protein to let it in. The channel protein is embedded in the membrane and acts as a gate into the cell. This process does not require energy input from ATP; it is passive transport.

In active transport, the ion moves against its concentration gradient from an area of low concentration, like the soil, to an area of high concentration, like the root hair cell. A carrier protein or ion pump protein embedded in the plasma membrane binds the ion. The protein then changes shape, pushing the ion across the membrane as it does so. This process requires energy input/ATP and is active transport.

Factors that affect both facilitated diffusion and active transport are temperature, the surface area of the membrane and the number of channel/carrier proteins in the membrane.
A higher temperature when the soil/roots are warmer, the molecules have more kinetic energy and move faster, so they collide with the channel/carrier proteins and bind to them more frequently. This means they are transported more frequently. However, if the temperature becomes too high, the channel/carrier proteins could be denatured. The high temperatures break the weak bonds that hold the proteins in their 3D shape. This distorts them so they can't bind the substrate anymore. As a result, less and less proteins are functional to transport the molecules across the membrane.

A higher surface area means more surface available for the ions to contact the root hair cell and cross over into it. It also means more space for channel and carrier proteins, and therefore more opportunities for the molecules to enter.

A greater difference in concentration between the inside and outside of the cell increases the rate of facilitated diffusion, but does not affect active transport, since this is already against the concentration gradient. The rate of active transport is affected by the amount of ATP available in the cell, which is affected by the rate of respiration. Active transport is therefore affected by factors that impact respiration, such as the concentration of oxygen and glucose. If there is plenty of oxygen and glucose, the rate of respiration increases, there is more ATP available as a result, and more active transport occurs. Facilitated diffusion does not require an energy input so is unaffected by this.

