Achievement Standard 91156

Demonstrate understanding of life processes at the cellular level

BIOLOGY

2.4

Externally assessed 4 credits

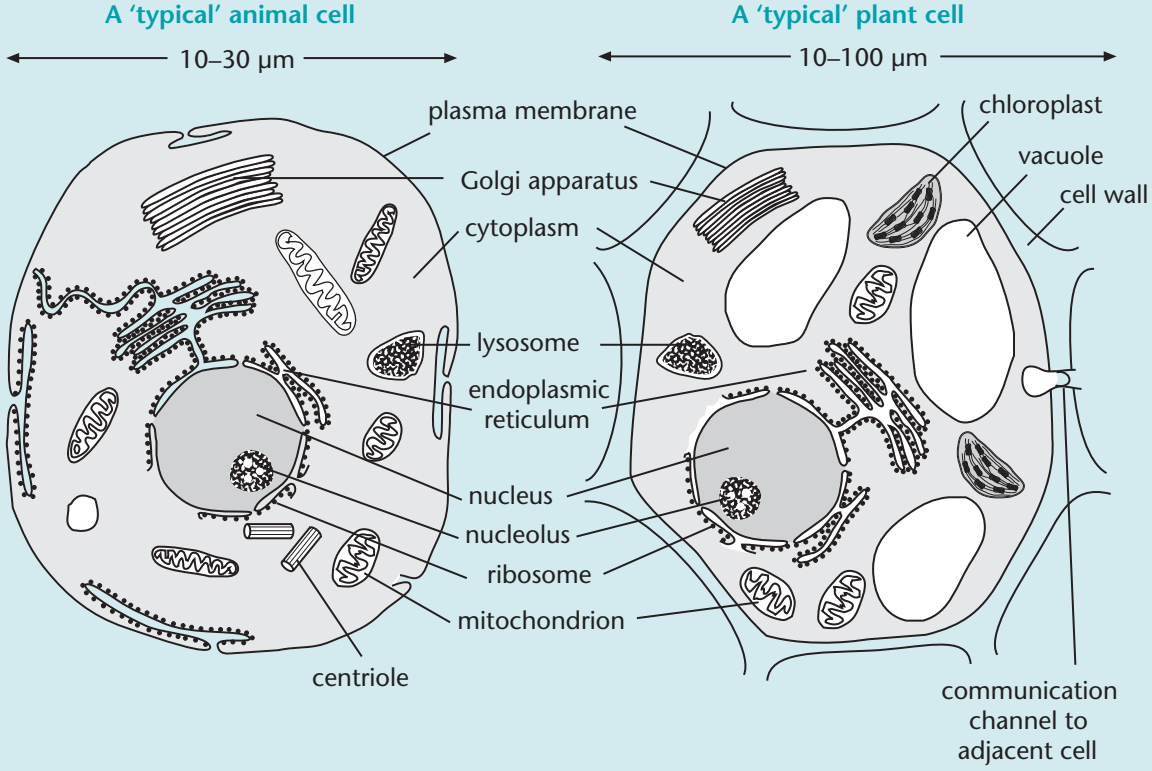
This Achievement Standard covers three life processes carried out by cells: cell division, photosynthesis and respiration. The first section of this chapter provides information about organelles, transport and enzymes. Questions in the examination will expect you to use this information on organelles, transport and enzymes in answers about cell division, photosynthesis and respiration.

Cells

The following section discusses:

- movement of materials (including diffusion, osmosis, active transport)
- enzyme activity (specific names of enzymes are not required)
- reasons for similarities and differences between cells, such as cell size and shape, and type and number of organelles present.

Animal and plant cells



The structure of a cell is linked to the function of the cell. Size and shape of a cell, and the organelles within the cell, are linked to the way it carries out its function within the organism.

Function and features of organelles

Organelle	Function	Features
Plasma membrane	Holds cell contents together, semi-permeable to control entry and exit of materials (e.g. salts, dissolved food and gases, hormones).	All cells have a plasma membrane made of a phospholipid bi-layer. The plasma membrane can be very long and highly folded in cells that absorb materials.
Cell wall	Present only in plants. Provides structure for the cell and support for the plant as a whole.	Made of cellulose; plasma membrane is just inside the cell wall, holding the cell contents.
Centriole	Present only in animal cells. Forms spindle fibre for cell division.	Contains 9 groups of microtubules.
Chloroplast	Present only in plants. Contains chlorophyll, carries out photosynthesis.	Grana discs catch light to split water. Carbon fixing and synthesis of glucose occur in the stroma liquid.
Chromosome	Contains information in the genetic code to give instructions for all life processes.	Made up of DNA and proteins tightly coiled up.
Cytoplasm – watery liquid	Holds dissolved foods and gases.	Cytoplasmic streaming carries materials around cells.
Endoplasmic reticulum (ER)	Surface area for reactions and transport system, moves the code for proteins (mRNA) from nucleus to the ribosomes.	Rough ER is covered in ribosomes, smooth ER is not.
Golgi bodies	Package proteins into a form usable by the body and transport them out of the cell.	More numerous in cells that produce a lot of proteins (e.g. mucus-secreting cells).
Lysosomes	Collect cell wastes.	Contain digestive enzymes to break down worn-out parts of cells.
Mitochondrion	Site of respiration; energy from glucose released as ATP. Internal folds provide a large surface area for reactions.	Numerous in cells that require a lot of energy (e.g. cells moving material out of the cell, muscle cells).
Nucleus	Holds chromosomes, controls cell activity.	Usually spherical in shape, surrounded by nuclear membrane.
Nuclear membrane	Membrane around outside of nucleus.	Double-layered membrane with pores to allow movement of materials between nucleus and cytoplasm.
Ribosomes	Site of protein synthesis (e.g. saliva, digestive enzymes, hormones).	Found along ER; more numerous in cells that produce proteins, such as enzymes.
Vacuoles	Storage of materials, usually water in plants, or starch granules. Contractile vacuoles expel excess water.	More numerous in plants; contain water and give the cell strength by turgidity. Full vacuoles give tightly packed cells.

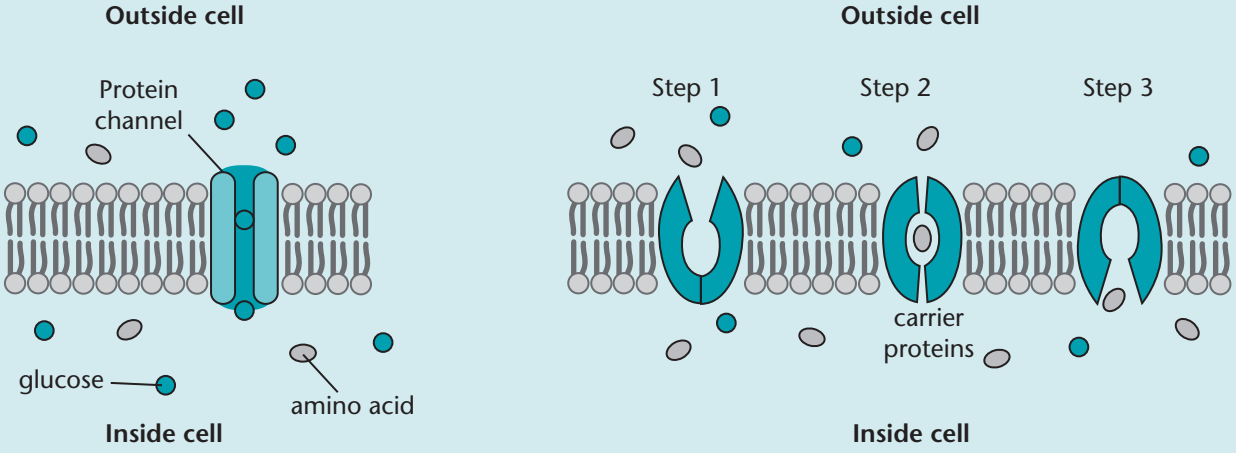
Transport of materials

Water, food and gases must move into cells and wastes must move out. Water constantly moves through plasma membranes from an area of high water potential to an area of lower water potential. At **osmotic equilibrium**, concentrations of solutions inside and outside a cell are the same, so there is no total water movement.

Passive transport

Passive transport is the movement of materials when no energy is used.

- **Diffusion** – movement of materials from an area of higher concentration to an area of lower concentration.
- **Osmosis** – movement of *water across a semi-permeable membrane* from an area of higher water potential to an area of lower water potential.
- **Facilitated diffusion** – movement of materials such as glucose, amino acids, sodium ions and chloride ions through protein channels and by carrier proteins embedded in the plasma membrane, as shown in the diagram.



The rate at which passive transport takes place increases with a high concentration gradient, small molecule size and in higher temperatures.

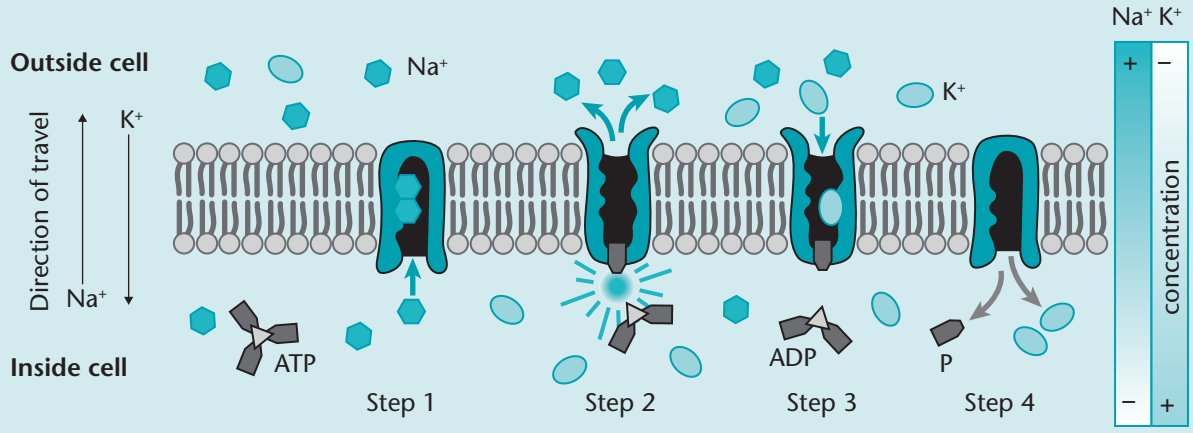
Active transport

Active transport requires energy, in the form of ATP, to move materials into and out of a cell. ATP is produced by cell respiration.

Pinocytosis – *liquid* is engulfed by wrapping membrane around a droplet to take it into the cell.

Phagocytosis – *particles* are engulfed by cells.

Ion pumps – Plasma membranes can pump ions (e.g. Na^+ and K^+) into and out of cells against a concentration gradient, as shown in the diagram.



Secretion

The Golgi body produces small, membrane-bound vesicles containing materials such as enzymes and hormones. These materials are secreted by **exocytosis** – a vesicle membrane joins onto the plasma membrane and the vesicle's contents are expelled from the cell.

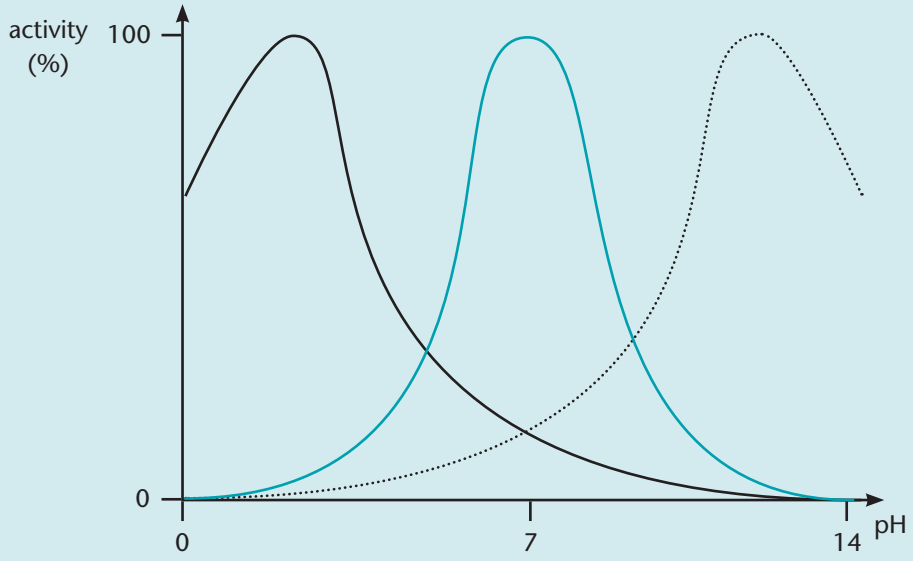
Enzymes

Enzymes are proteins that act as biological catalysts, controlling the speed of chemical reactions. Enzymes increase the rate of reactions so living things are able to operate the way they do. Without enzymes, many chemical reactions would occur too slowly. Enzymes control different reactions:

- **Anabolic reactions** build molecules up, e.g. making proteins
- **Catabolic reactions** break molecules down, e.g. digestion

Enzymes are:

- specific – each chemical reaction is catalysed by a different enzyme
- temperature dependent – enzymes work more slowly in lower temperatures and **denature** in high temperatures; each enzyme has an optimum temperature at which its activity is greatest
- damaged by changes in pH – each enzyme has an optimum pH at which its activity is greatest
- reused many times (e.g. peroxidase recycles to break peroxide down 6 million times per second).



The graph shows rate of activity of 3 different enzymes in conditions of increasing pH: to the left is a low-pH enzyme, in the centre a neutral-pH enzyme, to the right a high-pH enzyme.

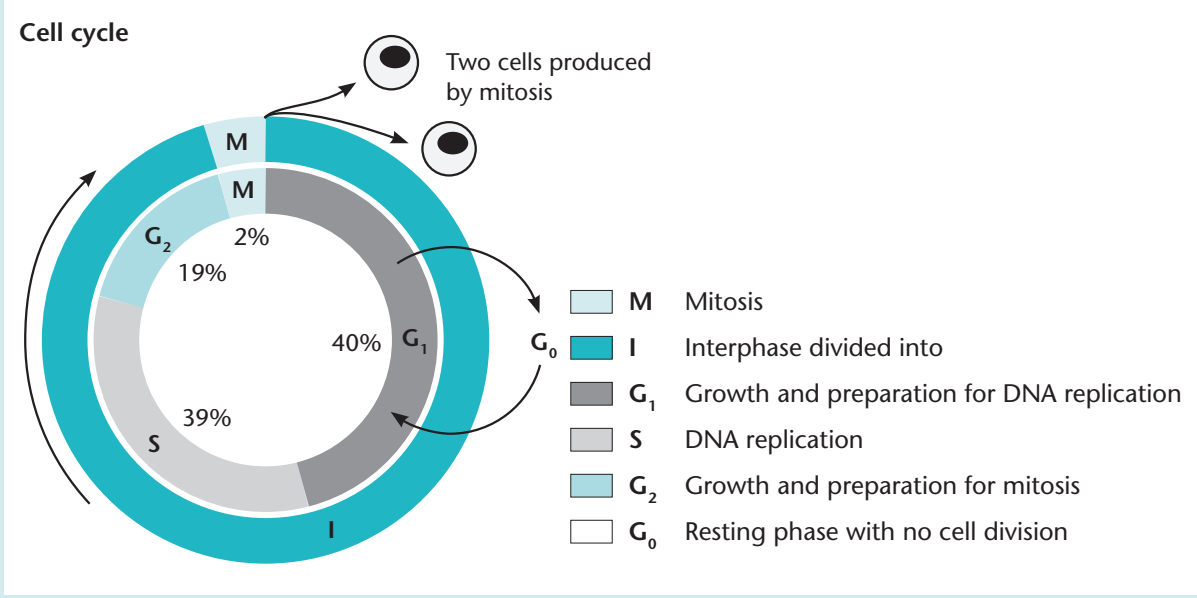
Cell division

This section covers DNA replication and mitosis as part of the cell cycle. The section discusses:

- details of cell division as cell division relates to the overall functioning of the cell (specific names of stages are not required)
- factors affecting cell division.

Cell cycle

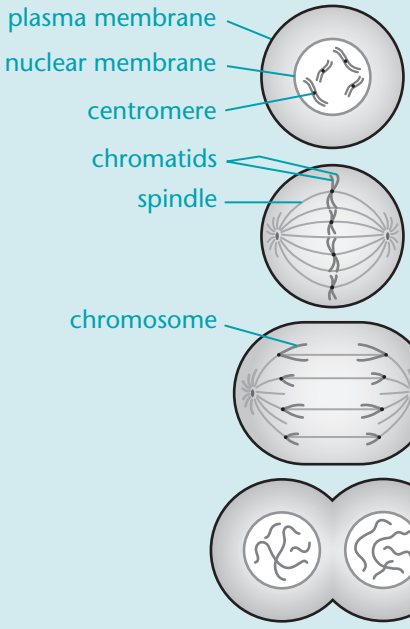
After cell division, the cell goes into a period of rapid growth that leads to a resting phase with no division, or to the beginning of preparations for another division. Preparation begins with production of the nucleotides and enzymes to be used in DNA replication. DNA replication occurs, followed by a second phase of cell growth and preparation for mitosis. This preparation involves production of the materials needed for spindle formation and a new plasma membrane. In the following diagram percentages show the proportion of time the cell spends in each phase of the cell cycle.



Mitosis

Mitosis is cell division that results in the formation of two cells, each with a complete copy of the genetic material in the original cell.

The diagram shows the main stages in mitosis. In this example, the original parent cell has only two pairs of homologous chromosomes.



Chromosomes have shortened and thickened and appear as two chromatids joined by a centromere.

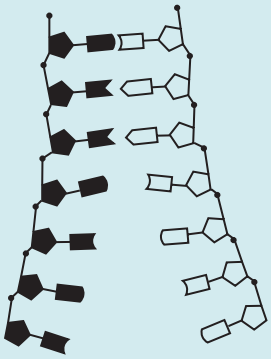
Nuclear membrane has disappeared and spindle has formed. Chromosomes line up in the centre of the cell. Spindle fibres attach to each centromere.

Spindle fibres contract; the chromatids separate at the centromere and are drawn to each end of the cell.

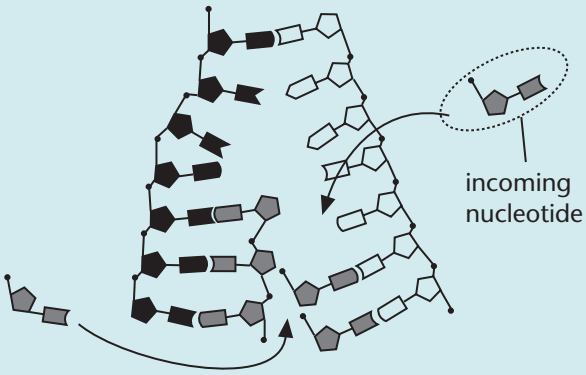
Nuclear membranes form around each set of chromosomes. The cell divides between each nucleus, resulting in two cells.

DNA replication

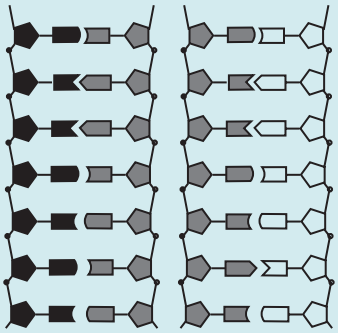
DNA contains the genetic information a cell requires for life processes. When a cell divdes, an exact copy of the DNA in all the chromosomes is made so both new cells have all the genetic information.



1. DNA is unwound by helicase (enzyme) to expose bases on both strands.



2. Nucelotides from within the nucleus assembled opposite each strand by enzyme DNA polymerase, using energy from ATP to join together. Because of the way deoxyribose and phosphate molecules are joined to each other along the DNA chain, one strand is copied in a straightforward manner, while the other strand is copied in a sequence of steps in the opposite direction. Many different sections of DNA are copied at the same time.



3. The two DNA molecules formed are identical.

Key
- A
- T
- G
- C

Factors affecting cell division

Availability of energy and materials – cell division requires energy, enzymes and certain molecules, e.g. nucleotides, phosphate bi-lipids, proteins. The cell must prepare for each division by ensuring that these requirements are stored and available when needed.

Stage of life of organism – cell division occurs rapidly during periods of growth and repair in infancy / childhood / early development in animals; following the breaking of dormancy and during seasonal growth in plants; and after damage to the organism, when repair of tissue is necessary.

Location of cell in organism – mitosis occurs at a higher rate in areas where most growth, repair and replacement of cells is occurring, e.g. skin, hair follicles, bone marrow, root and shoot tips.

Environmental factors – mitosis and DNA replication involve enzymes so the speed at which these processes take place is affected by factors that affect enzymes, such as temperature and pH. The presence of mutagens such as alcohol and radiation changes the rate of cell division – rate increases in cancer cells.

Surface area to volume ratio – the greater the surface area of a cell, the greater the rate of diffusion of substances into and out of the cell. A *smaller* cell has a *greater* surface area to volume ratio and a comparatively greater rate of diffusion than a large cell. Molecules quickly reach the centre of a small cell.

Cells grow until their size means the rate of diffusion is too slow to supply the cell centre with materials. They then stop growing or divide into two smaller cells.

Plant cells have a large, fluid-filled vacuole in the centre of the cell – materials, such as oxygen needed for life processes, quickly diffuse into organelles around the outside of the vacuole.

NCEA practice

Questions
Cells and cell division

Question One: Cell division

Year 2013
Ans. p. 109

Mitosis occurs during the life cycles of both animals and plants.

1. Describe what is meant by 'mitosis'.

The process of DNA replication is usually referred to as semi-conservative replication.

2. Explain the process of chromosome replication, and explain why the process is known as semi-conservative replication.

   You may draw a labelled diagram(s) in the box provided to support your answer.

Year 2012
Ans. p. 109

Question Two: Transport in cells

The movement of materials between cells and within cells is crucial to the functioning of all processes at a cellular level.

Discuss the processes of diffusion, osmosis and active transport.

In your answer you should compare and contrast the processes, in terms of their similarities and differences, and provide an example of each process as it occurs in an animal *or* a plant cell.

Question Three: Cells dividing

Year 2012
Ans. p. 109

DNA replication is the starting point for cell division. In common with other cellular processes, the replication of DNA is reliant on the presence of a number of enzymes and the rate at which they can carry out their function.

The rate of enzyme activity can be affected by factors such as temperature, pH, substrate, concentration, co-enzymes and enzyme poisons.

Discuss how any *three* of these factors can change the rate of enzyme activity, and why this would be important in the case of DNA replication.

Year 2011
Ans. p. 110

Question Four: DNA replication

DNA replication occurs at different rates during the lifetime of a plant or an animal.

Evaluate this statement, including in your answer:

- a description of what DNA replication is
- an explanation of how the process occurs
- a discussion of why the rate of DNA replication varies during the lifetime of a plant or an animal.

A labelled diagram may be used to support your answer.

Answers and explanations

A ('Achieved') is given if answer includes relevant **descriptions** and *M* ('Merit') when answer includes relevant **explanations**. *E* ('Excellence') is given when answer includes **relevant descriptions and explanations linked together into a discussion** that gives a full answer to the question.

Words/phrases like 'therefore', and 'however' show the linking of ideas and are what makes a piece of text an explanation (*M*) or discussion (*E*) rather than a description (*A*).

Achievement Standard 91156 (Biology 2.4): Demonstrate understanding of life processes at the cellular level

2.4 Cells and cell division

Question One: Cell division

p. 7

1. Important points: cell division, two cells formed, same number of chromosomes. For example: Mitosis is a process of *cell division* in which one cell divides *into two cells* where each cell has the *same number of chromosomes* as the original single cell.

(**A** – describes *two* out of: cell division, two cells, same number of chromosomes)

2. Important points: Unwinding, separation of base pairs, separated strands become template, new nucleotides form new strands, base pairing rule (A with T, C with G), exact copy. Semi-conservative – half from original, half new. See diagrams on pages 6 and 110. For example:

   The process of chromosome replication begins with enzymes causing the *unwinding* of the DNA in the chromosome. The hydrogen bonds between the two bases in each *base pair* are broken so that the *two strands* in the DNA molecule *separate.* The two strands become a *template* so new nucleotides can form new hydrogen bonds with existing bases on each of the two strands – A with T and C with G. The *base-pairing* rule ensures that the two DNA molecules formed are *exact copies* of the original DNA. The sugar and phosphate molecules in the new nucleotides bond together to form the sides of the DNA strand. DNA replication is called semi-conservative because each new DNA molecule formed has *one strand from the original DNA molecule* and one strand that is *newly formed* from nucleotides in the nucleus of the cell.

(**A** – describes *three* out of: unwinding, base pairs separate, nucleotides added, base pairing, half new strands; **M** – explains the process of replication (e.g. base pairs separate so two strands act as a template, base pairing results in exact copies) *AND* why called semi-conservative (e.g. each final strand has one side from original DNA and one that is newly formed))

Question Two: Transport in cells

p. 8

The words in **bold** are examples of key words important in possible answers to this question. The words in *italics* are used to 'compare and contrast'.

A *similarity* between the three methods is that they all transport materials across cell membranes. The simplest method is diffusion, which is the movement of materials from an area of high concentration to an area of low concentration without requiring energy from ATP. An example is the diffusion of oxygen into the cell. As oxygen is being continually used up in respiration, its concentration remains low on the inside of cells, so oxygen continues to diffuse in.

By comparison, 'active transport' refers to a number of **different processes** that **require energy** from ATP to transport a range of different materials, often **against their concentration gradient**. For example, an ion pump requires energy from ATP to pump sodium ions out of the cell against the concentration gradient for the sodium ions and potassium ions into the cell against their concentration gradient.

Osmosis, *in contrast* to diffusion and active transport, is the **movement of only water, through a semi-permeable membrane**, from an area of **high water potential** to an area of **low water potential**. For example, the root-hair cells of plants absorb water from the soil by osmosis. The high concentration of sugars and other nutrients inside the cells cause fewer free water particles to be available, which lowers the water potential inside the cell. This allows water in the soil to move from an area of high water potential to the area of low water potential inside the cells.

The input of energy from ATP during active transport is a *major difference* between the transport of materials by active transport and by diffusion and osmosis. *Another important difference* is that during diffusion and osmosis, materials are moved with the concentration or water potential gradient, but in active transport, materials are transported against their concentration gradient.

(**A** – describes diffusion (e.g. movement down a concentration gradient), osmosis (e.g. movement of water through a semi-permeable membrane), and active transport (e.g. movement of materials that requires energy; **M** – explains similarities (e.g. transport across membranes) or differences (e.g. energy required/energy not required, with or against the concentration/water potential gradient; **E** – uses examples to compare and contrast diffusion, osmosis and active transport)

Question Three: Cells dividing

p. 9

The words in **bold** are examples of key words important in possible answers to this question.

Because DNA replication involves enzyme-controlled reactions, the **rate of DNA replication changes when the rate of activity of different enzymes changes**. If conditions are **optimum for enzyme activity**, then **DNA replication can occur** more quickly than if conditions are not optimum, so cell division speeds up, which accelerates the rate of growth, repair and replacement of cells. For example, an **increase in temperature**, up to the optimum temperature, **increases the activity** of enzymes because heat energy increases the **movement** of both the substrate molecules (DNA nucleotides) and of enzymes. This makes **collisions** between the substrate molecules and the enzymes more likely to occur and more likely to be effective in bringing about a reaction, so reactions take place quickly. At the **optimum temperature, the activity of the enzyme is at its optimum – different enzymes have different optimum temperatures**. Above the optimum temperature, the heat energy causes stress

in the bonds holding the enzyme in its special shape, so the enzymes begin to d**enature**. At even higher temperatures, enzyme activity stops, because all the enzymes have become denatured. Therefore at those temperatures DNA replication occurs very **slowly or stops**.

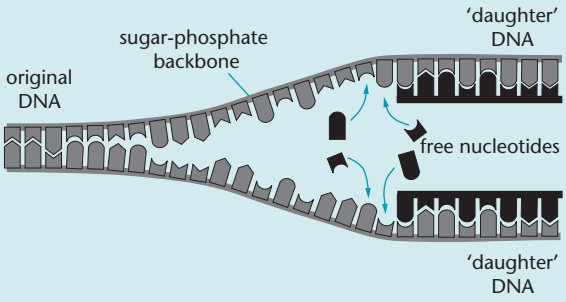
Some enzymes require a co-enzyme in order to function. If the co-enzyme is in **limited supply, not all of the enzymes present can work at maximum** speed, so the lack of a co-enzyme can reduce enzyme activity or stop it completely.

Different enzymes have different optimum pH levels at which their activity is at its maximum. At **pHs above or below the optimum, enzyme activity is reduced because the enzyme's shape changes and it becomes denatured**. If the pH is significantly different from the optimum, enzyme activity can stop.

(**A** – describes how or why *three* factors change the rate of enzyme activity (e.g. pH above or below the optimum pH reduces enzyme activity, enzyme poisons can bind onto the enzyme and stop its activity); **M** – explains how each factor changes the rate of enzyme activity (e.g. pH above or below the optimum pH reduces enzyme activity by denaturing the enzyme); **E** – discussion links how factors change rate of enzyme activity to the rate of DNA replication)

Question Four: DNA replication

p. 10



DNA replication is the process by which a double-stranded DNA molecule is copied to produce two identical double-stranded DNA molecules. The first step in the process is the unwinding of DNA by the enzyme helicase. The bases are then separated and DNA polymerase enzymes begin to add nucleotides to each of the strands by using the existing exposed bases as a template. Nucleotides are joined up, following the complementary base-pairing rule A–T and C–G, all the way along the two strands. This produces two complete, identical double-stranded DNA molecules, which then wind up again.

DNA replication is part of the cell cycle that occurs in preparation for mitosis. If the cell is in a rapidly growing area of the organism (e.g. apical meristem of a plant), the rate of DNA replication is high because the rate of cell division is high, so the DNA will have to be replicated to go into the new cells formed. When the cell is in an area that is growing slowly, the rate of DNA replication is low. When the area gets to a stage that it is not growing, the rate of DNA replication is very low because cell division is not occurring so there is no need to produce copies of the DNA.

(**A** – describes what DNA replication is, how the process occurs, why rate changes (at least three correct points);

M – explains how and why DNA replication occurs and how the rate varies (at least two correct points);

E – discusses how and why DNA replication occurs and how the rate varies (all points covered correctly))

Question Five: Cell division

p. 11

1. To produce an exact copy of the DNA so that after cell division each of the two daughter cells has a copy of all the genetic material contained in the original cell.
2. (See diagram in answer to Question One.) The first step is the unwinding of the DNA molecule. The bases are then separated and DNA polymerase enzymes begin to add nucleotides to each of the strands by using the existing exposed bases as a template. Nucleotides join up, following the complementary base-pairing rule A–T and C–G, all the way along the two strands. This produces two complete, identical double-stranded DNA molecules, which then wind up again. The process is called semi-conservative replication because each of the two DNA molecules that are produced has one strand from the original DNA and one strand produced during replication.

(**A** – describes DNA replication or why known as semi-conservative (at least three correct points);

M – explains how DNA replication occurs and why known as semi-conservative (at least two correct points))

3. The rate of mitosis is affected by temperature – for example, in spring temperatures rise, and the rate of mitosis in plants increases to produce new cells for leaves, xylem and phloem. To produce new cells, the plant must have a store of energy and all the raw materials that are needed to produce exact copies of the DNA and extra cell membranes. If the energy or materials become limited, the rate of mitosis decreases.

   Mitosis occurs at a higher rate in young organisms because they are growing quickly. The rate is also higher in plants when they are germinating as the new plant increases in size by producing many new cells.

   Mitosis occurs at different rates in different cells because some cells are found in locations that are growing (e.g. long bones in children) or involved in repair (e.g. after muscle damage) and replacement of cells (e.g. skin) so mitosis is occurring at a high rate. Other cells are in locations that are not involved in any of these processes, new cells are not needed and therefore the rate of mitosis is low in these cells.

(**A** – describes factors affecting the rate of mitosis or the stages of life when the rate of mitosis is higher or locations in an organism where the rate of mitosis is higher (at least three correct points);

M – explains how factors affect the rate of mitosis or why some stages of life of an organism have a higher rate of mitosis or reasons some locations in an organism have a higher rate of mitosis (at least two correct points);

E – discussion linking the factors to show how / when / where the rate of mitosis changes in an organism (all points covered correctly)

Question Six: Organelles and enzymes

p. 12

1. Lysosome: contains enzymes; Golgi body: packages materials into vesicles.

(**A** – both correct)

2. Enzymes are proteins so they have a particular shape, allowing them to catalyse only the one type of substrate. For example, the enzyme amylase can only break down starch into glucose – it cannot break down cellulose or proteins because its shape does not fit these other chemicals.

   Each enzyme requires particular conditions to function. For example, the protease enzymes in the stomach work in very acid conditions but lose their shape so do not function in neutral or alkaline conditions.

(**A** – describes specific substrates and/or conditions (at least three correct points);

M – explains, with examples, both the specific substrates and conditions required for enzymes to work (at least two correct points))

3. The rate of enzyme activity increases, up to a point, as the amount of enzyme available increases. This is because there is more enzyme available to work on the substrate molecule(s). After the maximum point has been reached, further increases in the amount of enzyme do not result in increased rate of enzyme activity because something else is limiting the rate e.g. the amount of substrate present.

   The presence of enzyme poisons, such as mercury and lead ions, reduces the rate of enzyme activity because they can change the shape of the enzyme or block the active site of the enzyme. If high concentrations of these poisons are present, the rate of enzyme activity will become less and less as the poisons become attached to more and more enzymes.

   Some enzymes function only when another chemical, called a co-enzyme, is present, e.g. a magnesium ion, vitamin C. If the co-enzyme is absent, the rate of activity is nil or very low. As the concentration of the co-enzyme increases, more and more of the enzyme becomes activated so the rate of activity