Candidate Name	Centre Number					Candidate Number				
StemUp Model Solution										

AS BIOLOGY

COMPONENT 1

Basic Biochemistry and Cell Organisation

SPECIMEN PAPER

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**8**	
2.	**14**	
3.	**10**	
4.	**18**	
5.	**16**	
6.	**9**	
Total	**75**	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.
Write your name, centre number and candidate number in the spaces at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

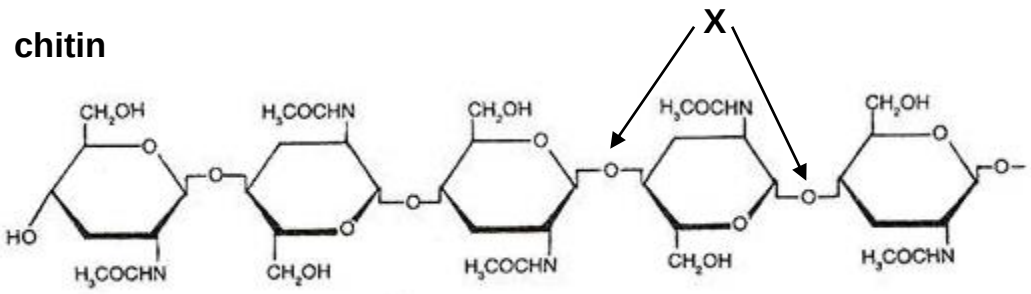
The number of marks is given in brackets at the end of each question or part-question.
The assessment of the quality of extended response (QER) will take place in question 6.

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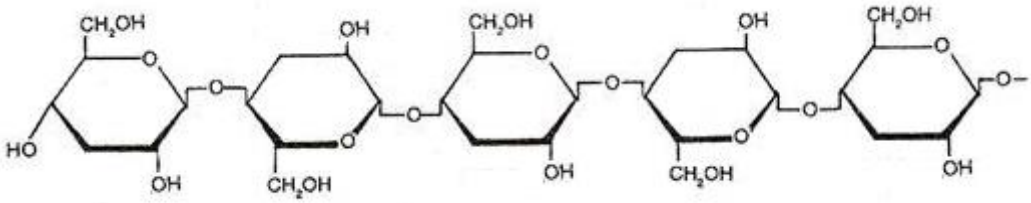
*Answer **all** questions.*

1. Chitin and cellulose are polysaccharides found in the cell walls of some organisms. The structures of these polysaccharides are shown in the diagrams below.

chitin



cellulose



(a) Identify the type of bond labelled **X** on the diagram. [1]

β-1,4 glycosidic bond

(b) Describe **one** similarity and **one** difference between the structures of chitin and cellulose. [2]

Similarity: In both, alternate monosaccharides are rotated by 180° (β-1,4 links).

Difference: In chitin the –OH on C2 of cellulose is replaced by an –NHCOCH$_3$ group.

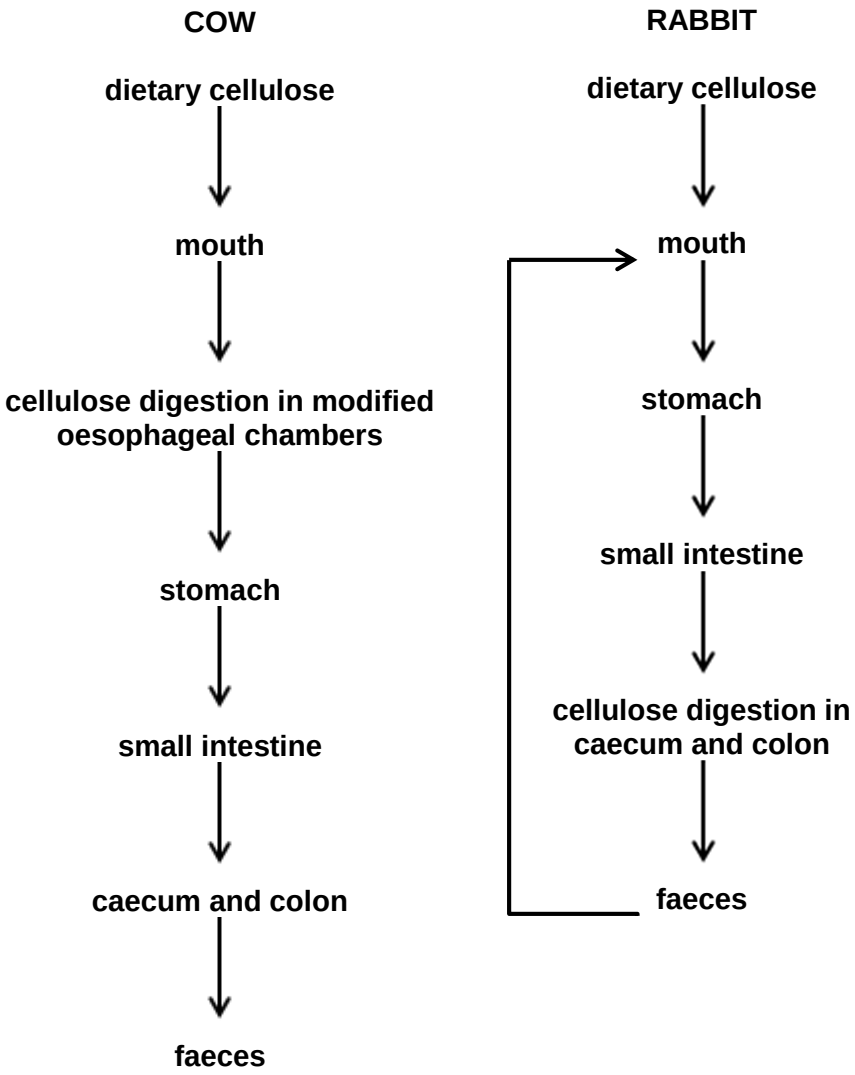
(c) Explain how the structures of these molecules are different to that of starch. [2]

In cellulose and chitin hydrogen bonds form cross-links between adjacent (parallel) polysaccharide chains.

In starch, hydrogen bonds coil the polysaccharide chain to form a helix, so the chains are not cross-linked to each other.

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(d) In herbivores, cellulose is digested by cellulase enzymes secreted by bacteria living in the gut. The diagrams below show the site of cellulose digestion in cow and in a rabbit.



Explain why it is necessary for the rabbit to ingest its faeces but not for the cow. [3]

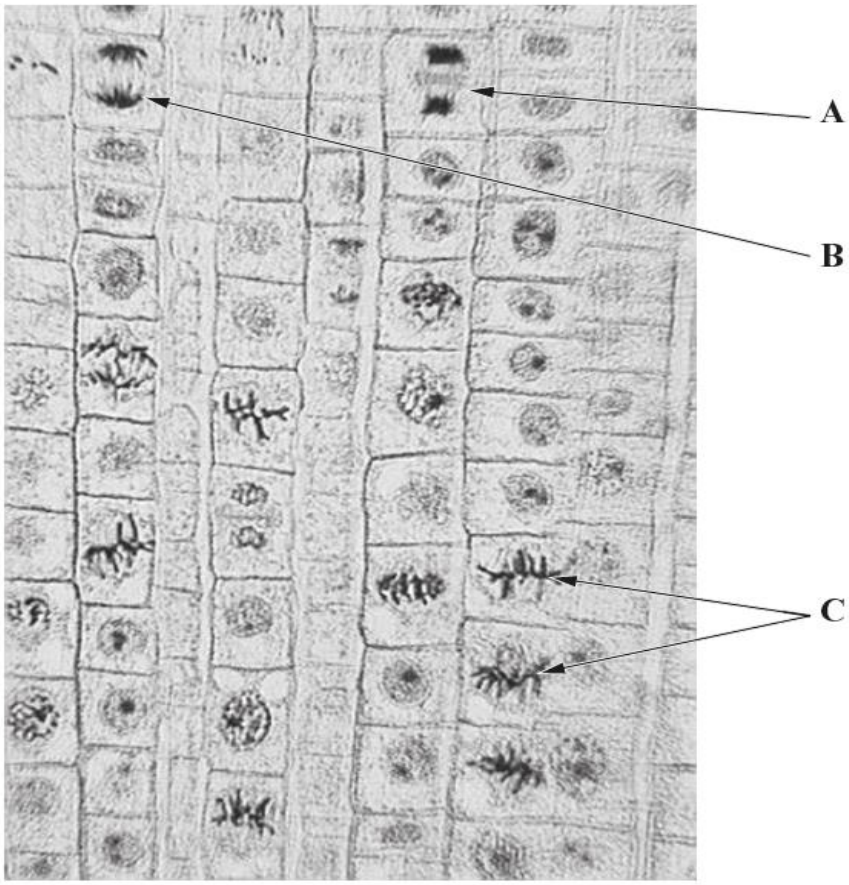
. The stomach and small intestine are the main areas of digestion and absorption. In the cow, bacteria digest cellulose before these, so the digested food can be absorbed. In the rabbit, cellulose is digested after these, so it eats its faeces to complete digestion and absorb nutrients.

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2. Colchicine is an alkaloid compound derived from the corm and other parts of the autumn crocus, *Colchicum autumnale*. Colchicine induces the disassembly of microtubule fibres and thus stops the mitotic process so that chromosome morphology and number can be studied.

The photograph below shows a preparation of garlic (*Allium sativum*) root tip using colchicine to show different stages of the mitotic cell cycle.



(a) (i) Name the stages shown in **A** and **C.** [1]

Stage **A**.....Telophase.....

Stage **C**.....Metaphase.....

(ii) Explain why the disassembly of microtubules would stop mitosis at the different stages that can be observed. [2]

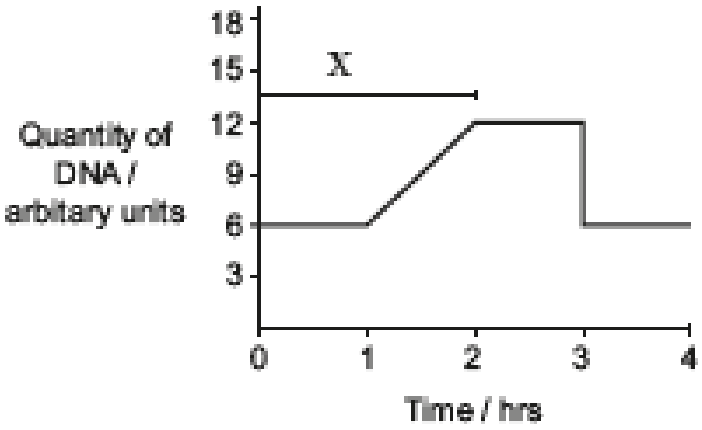
Microtubules are used to form the spindle apparatus, so the spindle cannot form to separate or move the chromatids.

(iii) Explain the purpose of the process occurring during the stage labelled **B**. [2]

To separate each pair of sister chromatids, pulling a copy of each chromosome to opposite poles, so that each resulting nucleus will be genetically identical.

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(b) The quantity of DNA in the nucleus of an animal cell was monitored for a period of four hours as shown in the graph below.



(i) Name the stage in the cell cycle which is represented by the time period labelled **X** on the graph above. [1]

Interphase

(ii) Using evidence from the graph give a reason for your answer in part (b)(i). [1]

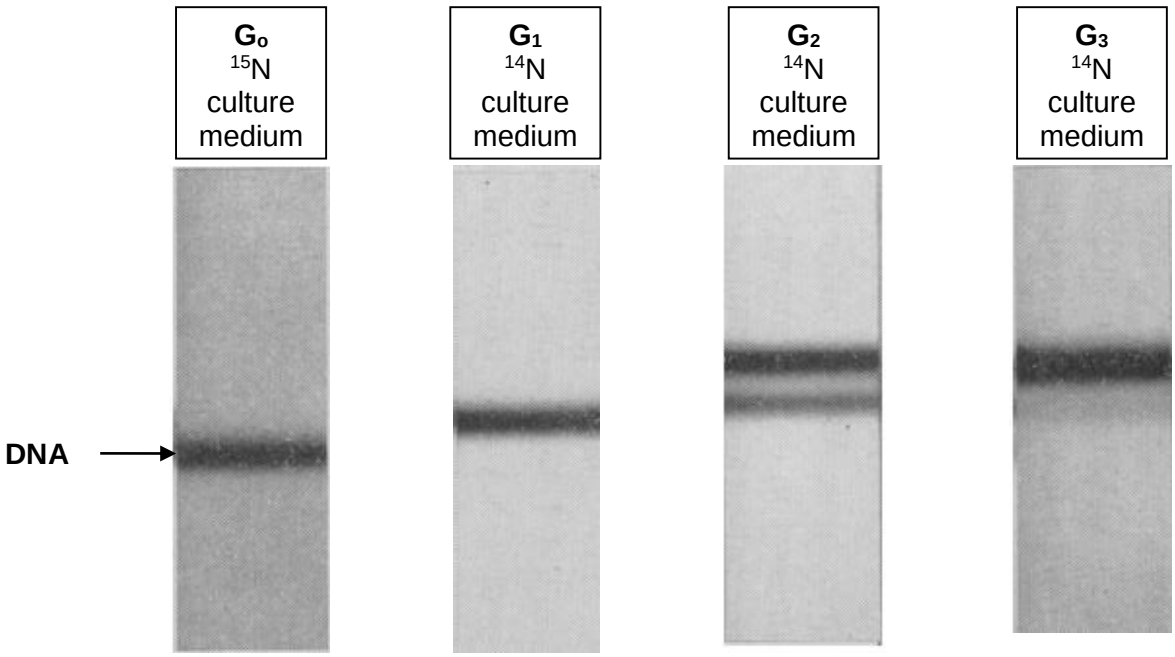
The quantity of DNA has doubled, from 6 to 12 arbitrary units, as the DNA replicates.

(iii) What additional evidence would be needed to conclude if the cell is undergoing mitosis or meiosis? Explain your answer. [1]

Observe the cell for a longer period of time: if the DNA quantity doubles again (back to 12) the cell division is mitosis, but if it halves again (to 3) it is meiosis.

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(c) Experiments conducted in the 1950s proved that DNA replication is semi-conservative. The experimental procedure involved growing bacteria with the heavy ^{15}N isotope of nitrogen until the entire DNA contained ^{15}N. The bacteria were then grown for several generations (**G**) in culture medium containing the ^{14}N isotope of nitrogen. At each stage samples of DNA were extracted and separated using ultracentrifugation. The results from one of these experiments are shown in the image below.



(i) Name the part of the DNA molecule which contained the ^{15}N. [1]

The nitrogenous (organic) bases

(ii) State what is meant by **semi-conservative** replication and explain how the results shown above support this theory. [5]

Each DNA strand is used as a template, so each new DNA molecule has one original strand and one new strand.

G0: all the DNA is heavy due to ^{15}N.

G1: all the DNA is intermediate as each ^{15}N strand acted as a template for a new ^{14}N strand.

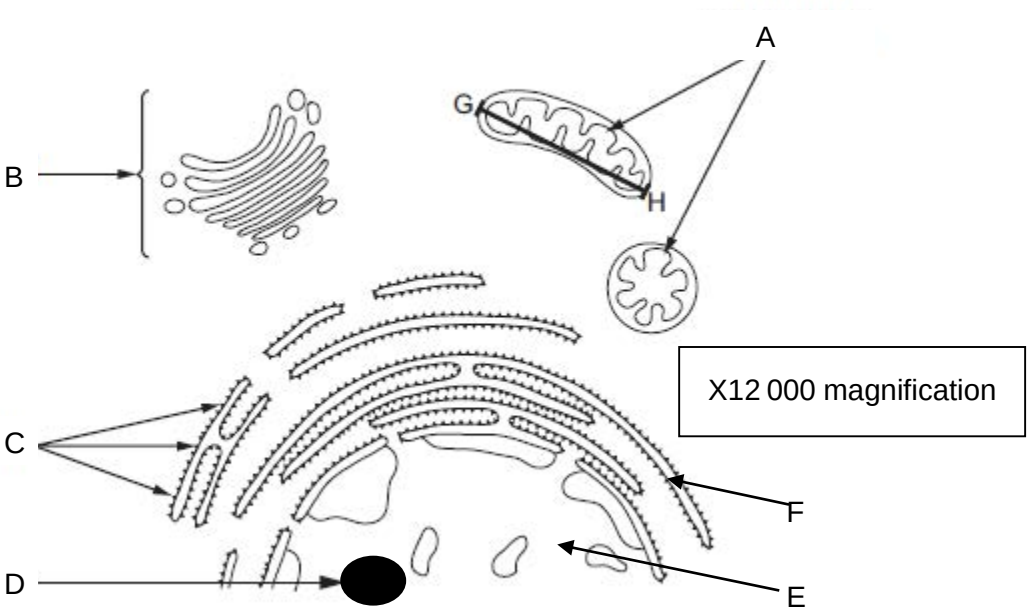
G2: half is light due to ^{14}N strands acting as templates; half is intermediate as it has an original ^{15}N strand.

G3: more light ^{14}N DNA, as more ^{14}N strands act as templates.

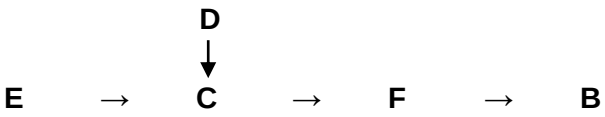
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3. The production and secretion of functional proteins from a cell involves a number of cell organelles. The drawing shows part of a generalised animal cell.



(a) Some of these organelles shown above are involved in the production of a functional protein as shown in the flow chart below:



(i) State how organelles **B** to **F** work together in this particular sequence. [5]

E (DNA) carries the genetic code and is transcribed into mRNA.

D (nucleolus) is involved in the production of ribosomes (rRNA).

C (ribosomes) translate the mRNA to form a polypeptide chain.

F (rough endoplasmic reticulum) transports the polypeptides to the Golgi body.

B (Golgi body) processes, modifies and packages the protein (into vesicles for secretion).

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(ii) Suggest the role of organelle A in the production of functional protein. [1]

Production of ATP (in aerobic respiration) to provide the energy for peptide bond formation and amino acid activation.

(b) (i) Calculate the actual size of organelle **A** between **G** and **H**. Express your answer using the most appropriate unit. [2]

Length of G to H on drawing = 24 mm

Actual size = 24 × 1000 ÷ 12 000 = 0.002 mm

= 2 μm

Answer 2 μm

(ii) Organelle A is similar in size to prokaryotic cells and has structures in common with them. This led the biologist, Lynn Margulis, to conclude that this organelle evolved from ancient prokaryotes. The theory of endosymbiosis proposes that these ancient prokaryotes were engulfed by other bacterial cells and both benefited from the relationship. This association is thought to have led to the evolution of eukaryotic cells.

Using your knowledge of cell structures and processes described, justify this conclusion. [2]

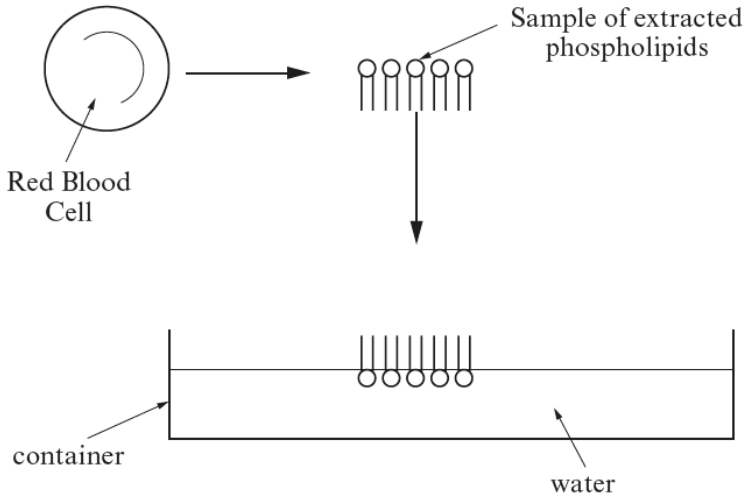
A is a mitochondrion; like prokaryotes it has a loop of DNA and 70S ribosomes.

It has two membranes, as if a bacterium had been engulfed by another cell.

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4. (a) In 1925, two scientists, Gorter and Grendel investigated the arrangement of phospholipids in the plasma membrane. Their investigation involved the removal of the phospholipids from the surface membrane of red blood cells in 10 cm^3 of blood. The phospholipids were then placed on the surface of water and allowed to spread out to form a single layer called a monofilm.



(i) Explain fully why the phospholipid molecules are arranged as shown in the container in the diagram above. [2]

Phosphate heads are hydrophilic (polar) and are attracted to the water.

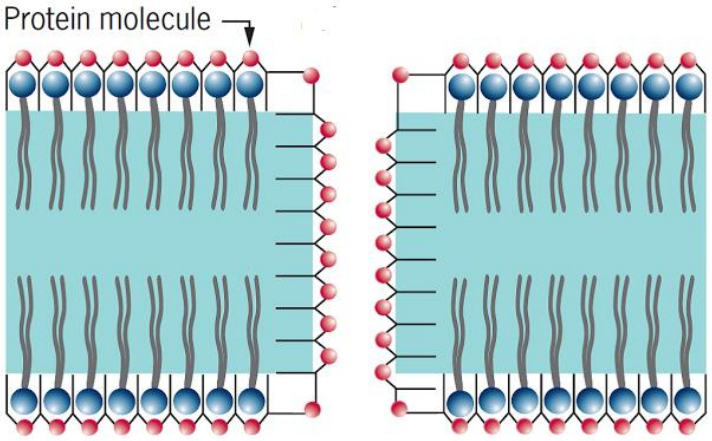
Fatty acid tails are hydrophobic (non-polar) and are repelled by water.

(ii) The area covered by all of the phospholipids in the monofilm was found to be 12.2 m^2. It was concluded that the total surface area of the intact red blood cells was 6.1m^2. Justify how Gorter and Grendel reached this conclusion. [2]

The cells' surface area is half the monofilm area, as the phospholipids form a bilayer in the membrane, with hydrophilic heads facing the polar water on both sides.

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(b) In 1935, Davson and Danielli, proposed a model for the structure of the plasma membrane that built on the findings of Gorter and Grendel together with the discovery that the plasma membrane contained proteins. A diagram to show their proposed structure is shown below.



(i) Describe how this model differs from the currently accepted model of the plasma membrane structure. [3]

Now proteins are also embedded in the bilayer, not just outside the heads: there are intrinsic and extrinsic proteins.

Many proteins are present but they are not linked together in a layer as in the diagram.

A channel (pore) is formed by a single protein, not lined with protein.

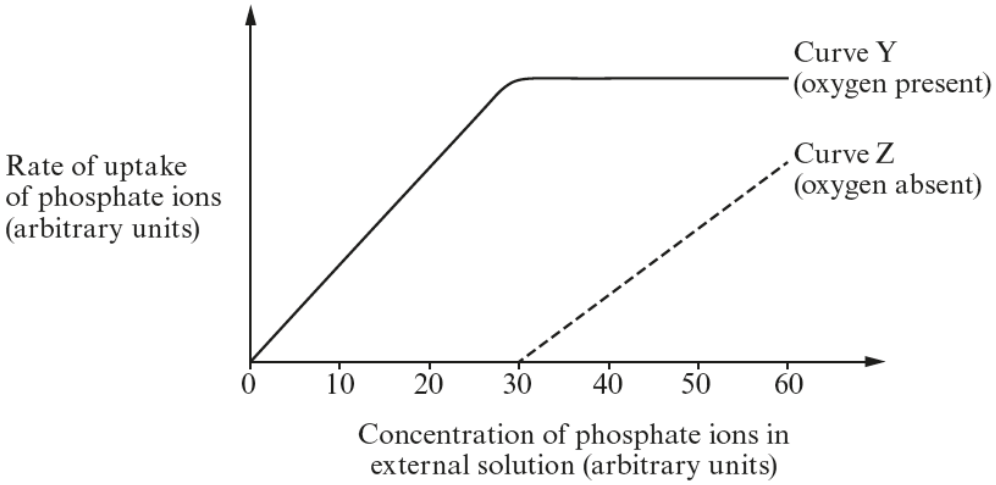
(ii) The currently accepted model is called the fluid-mosaic model. Explain why it has been given this name. [2]

Mosaic: the protein molecules are scattered and embedded in the membrane.

Fluid: the protein and phospholipid molecules are free to move.

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(c) An investigation was carried out on the uptake of phosphate ions in root tissue. The root tissue was cut into discs of uniform size and each disc was added to an equal volume of solution containing phosphate ions of varying concentrations. The experiment was first carried out with oxygen present and then repeated with oxygen absent. The results are shown in the graph below.



(i) Explain why pH and temperature would have to be kept constant in this experiment. [3]

A change in temperature changes the kinetic energy of the molecules and therefore the rate of uptake. A high temperature could denature the membrane proteins. pH changes could alter the tertiary structure of membrane proteins.

(ii) Using the results shown on the graph, what conclusions can be drawn about the uptake of phosphate ions by the cells. Justify your conclusions. [6]

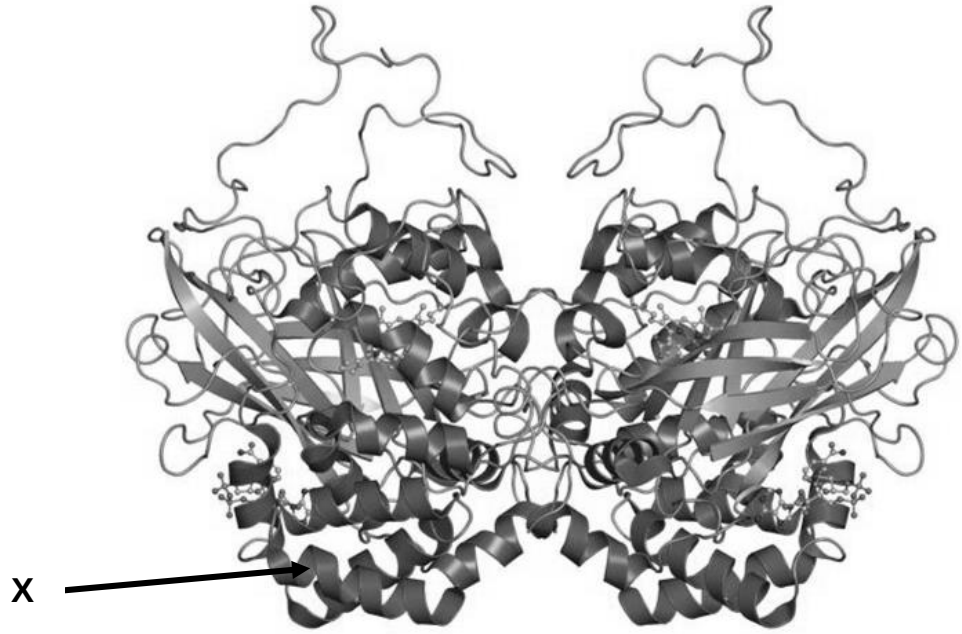
Phosphate concentration inside the cells must be 30 a.u., as without oxygen there is no uptake below 30 a.u. Without oxygen, uptake must be by facilitated diffusion. With oxygen, below 30 a.u., it is active transport, as uptake is against the concentration gradient and ATP is present. With oxygen, above 30 a.u., uptake is by both active transport and facilitated diffusion. At high phosphate concentrations all the carrier proteins are in use, so they become a limiting factor.

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5. Catalase is an enzyme which is found in high concentrations in many tissues including potato tissue. This enzyme catalyses the breakdown of hydrogen peroxide into oxygen and water.

Catalase is composed of a tetramer of four polypeptide chains each bonded to a haem group containing an atom of iron. A diagram of the structure of catalase is shown in the diagram below.



(a) (i) Explain why this protein is said to have a quaternary structure. [1]

It has four polypeptide chains bonded together to produce a functional protein.

(ii) Identify the name of the type of protein structure labelled **X** on the diagram and explain how this structure is formed. [1]

Alpha helix (secondary structure). Hydrogen bonds form between the polar H atom of an amino (–NH) group and the O atom of a –C=O group further along the polypeptide chain, coiling it.

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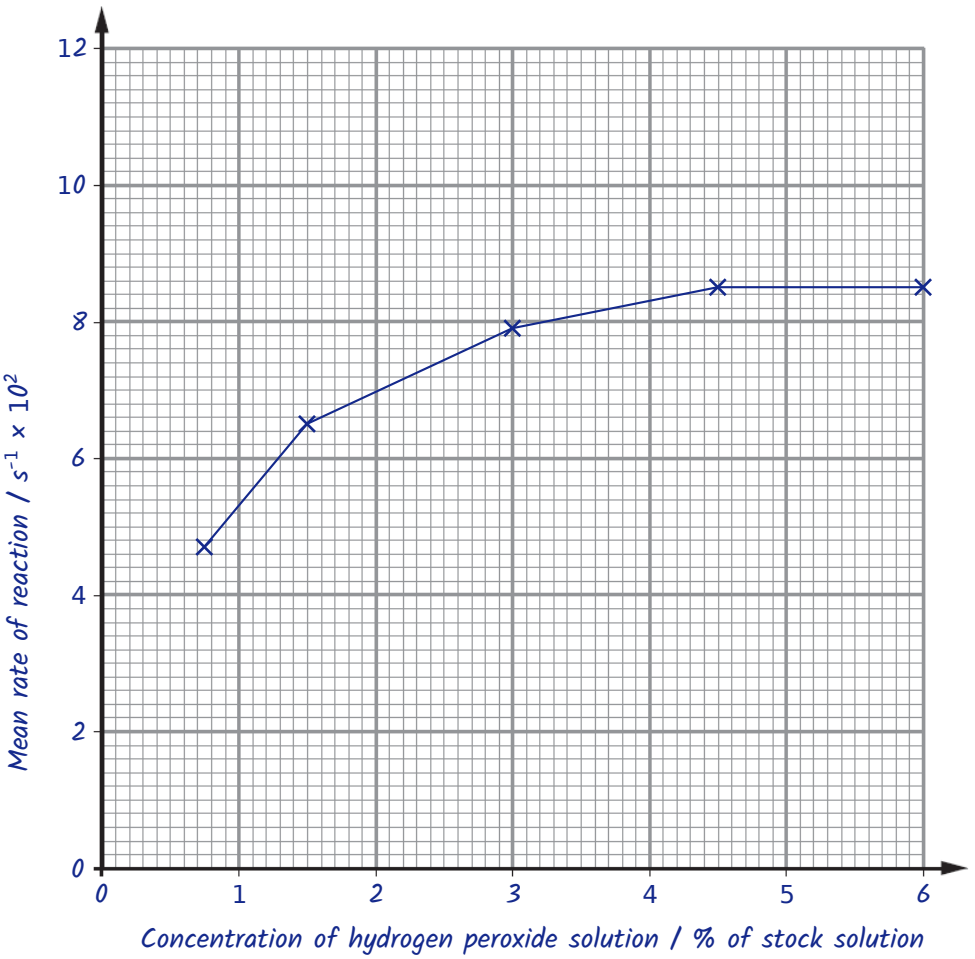
A student investigated the action of the enzyme catalase. The student homogenised 1g of potato tissue in 5cm^3 of water and soaked discs of filter paper of 5mm diameter in the potato extract. The filter paper was then pushed to the bottom of a test tube containing a fixed height of hydrogen peroxide solution and the time taken for the filter paper to reach the surface of the liquid was recorded. Using the same hydrogen peroxide solution, the experiment was repeated twice to obtain three results for a range of hydrogen peroxide concentrations.

The results of the student's investigation are shown below.

Concentration of hydrogen peroxide solution (% of stock solution)	Time taken for filter paper disc to reach the surface (s)				Mean rate of reaction ($s^{-1}10^2$)
	Trial 1	Trial 2	Trial 3	mean	
0.75	20	21	23	21.3	4.7
1.50	19	15	12	15.3	6.5
3.00	13	13	12	12.7	7.9
4.50	11	12	12	11.7	8.5
6.00	12	10	13	11.7	8.5

(b) (i) Calculate the mean rate of reaction for the 0.75% hydrogen peroxide solution and write your answer in the table. [1]

(ii) Plot the data on the graph below. [3]



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(iii) Explain the shape of the graph. [6]

Between 0.75% and 4.50% hydrogen peroxide: as the concentration of hydrogen peroxide increases the rate of reaction increases, because more enzyme-substrate complexes are formed per unit time. So the concentration of hydrogen peroxide is the limiting factor. Above 4.50%: as the concentration increases the rate of reaction remains constant, because all of the active sites of catalase are occupied (the catalase is saturated). So the concentration of catalase is now the limiting factor.

(c) Apart from human error, suggest two sources of error which could have led to inaccuracies occurring within this experiment and two ways in which these could have been minimised. [4]

The reaction is exothermic, which would affect the rate: use a water bath to control the temperature. Using the same hydrogen peroxide solution each time, its concentration would decrease: use fresh solution for each trial. pH could vary: use a buffer.

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6. Some scientists have claimed that without liquid water, life could not exist on Earth. With reference to the properties of water, explain why water is claimed to be essential for life on this planet.
(The quality of extended response will be assessed in this question.) [9QER]

Water is a polar molecule, as the oxygen atom is slightly negative (δ−) and the hydrogen atoms are slightly positive (δ+). This means water molecules form hydrogen bonds with each other, so water is a liquid over the usual range of temperatures found on Earth, providing a medium for life.

Water can also form hydrogen bonds with other ionic and polar molecules, so it is an excellent solvent. Glucose, amino acids and ions dissolve in it, so it is the medium in which metabolic reactions take place in the cytoplasm, and it can transport these molecules, e.g. in blood plasma, in phloem and in xylem.

Due to hydrogen bonds, water molecules stick to each other (cohesion) and to the walls of the xylem vessels (adhesion), so a continuous column of water can move up through the xylem from roots to leaves in the transpiration stream.

Cohesion between water molecules at the surface also gives liquid water a high surface tension, which provides a habitat for some organisms such as pond skaters.

Water has a high specific heat capacity, as a large amount of energy is needed to break the hydrogen bonds and raise its temperature. This helps organisms, which are mostly water, to maintain their body temperature at a fairly constant level, so enzymes work near their optimum. It also means aquatic habitats such as lakes and oceans have a fairly stable temperature.

Water has a high latent heat of evaporation, as a large amount of energy is needed to evaporate it. So it can be used to cool bodies, e.g. the evaporation of sweat in mammals or of water during transpiration in leaves removes a lot of heat. It also means aquatic habitats do not disappear easily through evaporation.

Other properties are also important. Water is transparent, so light can pass through it and aquatic plants can photosynthesise. Ice is less dense than liquid water, so it floats

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and forms an insulating layer on the surface, stopping the water beneath it from freezing so organisms can survive in winter.

Finally, due to its polar nature water is a reactant in many biochemical reactions, e.g. in hydrolysis reactions that break glycosidic and peptide bonds in digestion, and in photosynthesis, where photolysis of water provides electrons, protons and oxygen.

Therefore, because of its polarity and hydrogen bonding, and the thermal properties that result, liquid water is essential for life on Earth.

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