Surname	StemUp Model Solution	Centre Number	Candidate Number
Other Names			2

GCE AS

B400U10-1

S19-B400U10-1

BIOLOGY – AS component 1
Basic Biochemistry and Cell Organisation

TUESDAY, 21 MAY 2019 – AFTERNOON

1 hours 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**9**	
2.	**10**	
3.	**12**	
4.	**15**	
5.	**9**	
6.	**11**	
7.	**9**	
Total	**75**	

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ADDITIONAL MATERIALS

In addition to this paper you will require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

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. If you run out of space, use the additional page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of quality of extended response (QER) will take place in question **7**.

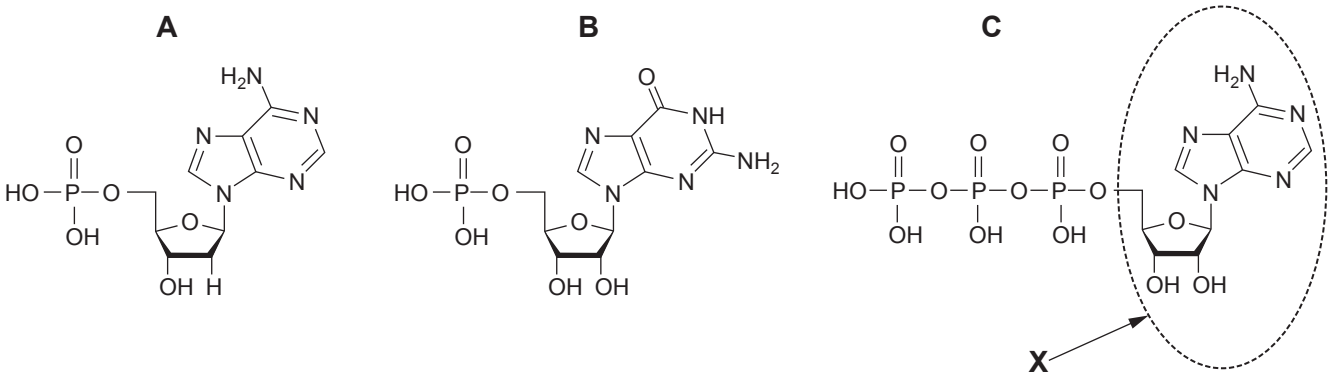
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Answer **all** *questions.*

1. Nucleic acids and related molecules are found in all forms of life on Earth. The diagrams below show the structural formulae of three molecules called nucleotides.



(a) (i) Identify the **type** of nitrogenous base found in all three molecules. [1]

Purine

(ii) Explain why molecule **C** is sometimes referred to as the *universal energy currency*. Include reference to the structure of the molecule in your answer. [3]

Molecule C is ATP, which is found in all cells of all organisms and is the common source of energy for reactions.

It has three phosphate groups; energy is stored in the high energy bonds between the phosphate groups.

This energy is released when the bonds between the phosphates are broken (hydrolysed), an exergonic reaction.

(iii) Name the **region** of molecule **C** labelled **X** on the diagram. Use this information to identify the base found in molecule **B**. [2]

X Adenosine

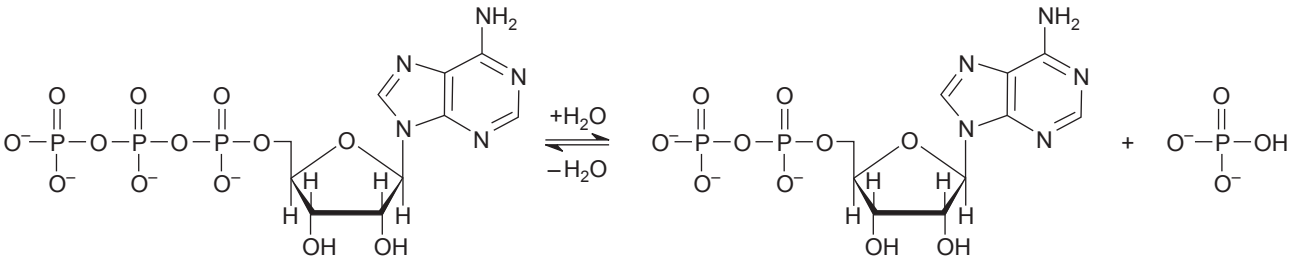
Base in molecule **B** Guanine

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(b) Molecule **C** is mainly synthesised in two organelles found in eukaryotic cells as shown in the equation below.



(i) Name **two** organelles which synthesise molecule **C**. [1]

Mitochondria

Chloroplasts

(ii) State whether the synthesis of molecule **C** is endergonic or exergonic. Explain your answer. [1]

Endergonic, because energy is needed (taken in) for the reaction to join the phosphate to ADP.

(iii) The removal of all three phosphate groups from molecule **C** one after the other would release a total of 75.4 kJ mol^{-1} of energy. Assuming the removal of the first and second phosphate groups yield the same quantity of energy, calculate the available energy stored in the bond between the third phosphate and the pentose sugar. [1]

Energy from each of the first two phosphates = 30.6 kJ mol^{-1}

75.4 − (2 × 30.6) = 75.4 − 61.2 = 14.2

Available energy = *14.2* kJ mol^{-1}

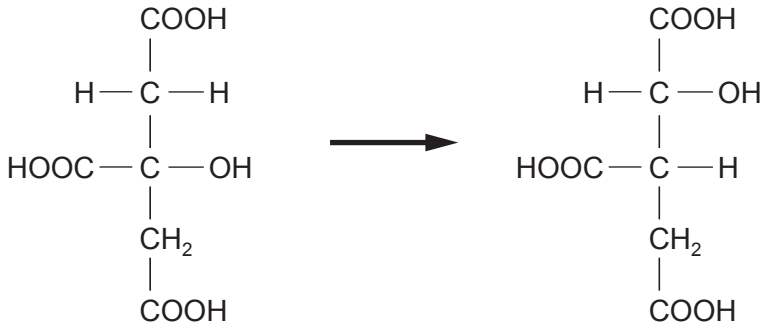
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2. Citrate and isocitrate are two of the molecules found in a metabolic pathway in mitochondria. The structures of these molecules are shown below.



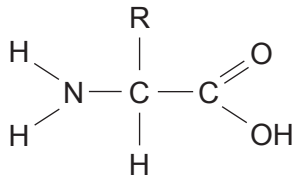
Citrate **Isocitrate**

(a) Explain why these molecules are termed **structural isomers**. [1]

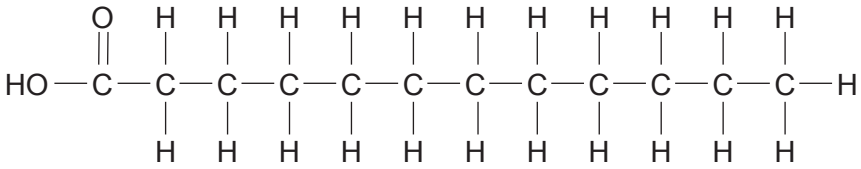
They have the same molecular formula but a different arrangement of atoms (structure).

The –COOH group is found in several different biological molecules. Two of these molecules are shown below.

X



Y



(b) (i) Name the type of molecules **X** and **Y**. [1]

X Amino acid

Y Fatty acid

(ii) State what is represented by **–R** in molecule **X**. [1]

A variable (functional) group, which differs between amino acids.

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Molecule **Y** is found as a component of a group of molecules that are involved in energy storage and thermal insulation in many organisms.

(iii) Name this group of molecules and describe how you would test for their presence in a sample of food. [3]

Lipids (fats and oils).

Test: shake the food sample with ethanol, then add an equal volume of water and shake.

A positive result: it becomes white and cloudy (forms an emulsion).

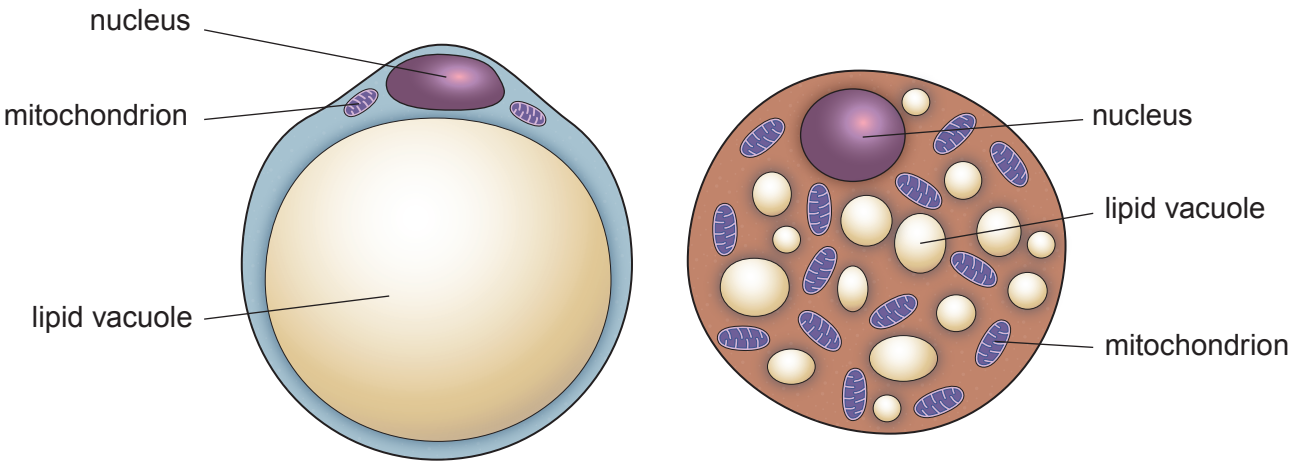
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Adipose tissue is found in mammals in two different forms: white adipose tissue and brown adipose tissue. The distribution of each form varies depending upon the species. Seals, which live in cold water, have a thick layer of white adipose tissue under their skin. In addition, other areas of a seal's body have a high proportion of brown adipose tissue.

Drawings of the cells that make up each type of adipose tissue are shown below.



white fat cell **brown fat cell**

(iv) The diameter of the lipid vacuole in the white fat cell measured 80 μm. Calculate the volume of the lipid vacuole located in the white fat cell. Use the formula given. [2]

Volume= $\frac{4}{3}\pi r^3$

π = 3.14

$r = 80 \div 2 = 40\ \mu m$

$V = 4/3 \times 3.14 \times 40^3$

$= 4/3 \times 3.14 \times 64\ 000$

$= 267\ 946.7$

Volume = 267 947 μm^3

(v) Brown and white fat cells in seals help them survive in **cold** water. Using the information provided, suggest how the structure of each type of fat cell is an adaptation for the survival of the seal. Explain your answer. [2]

White fat cell: has a large lipid vacuole, so the thick layer of white fat provides thermal insulation, reducing heat loss to the cold water.

Brown fat cell: has many mitochondria, so a high rate of respiration releases heat, keeping the seal warm.

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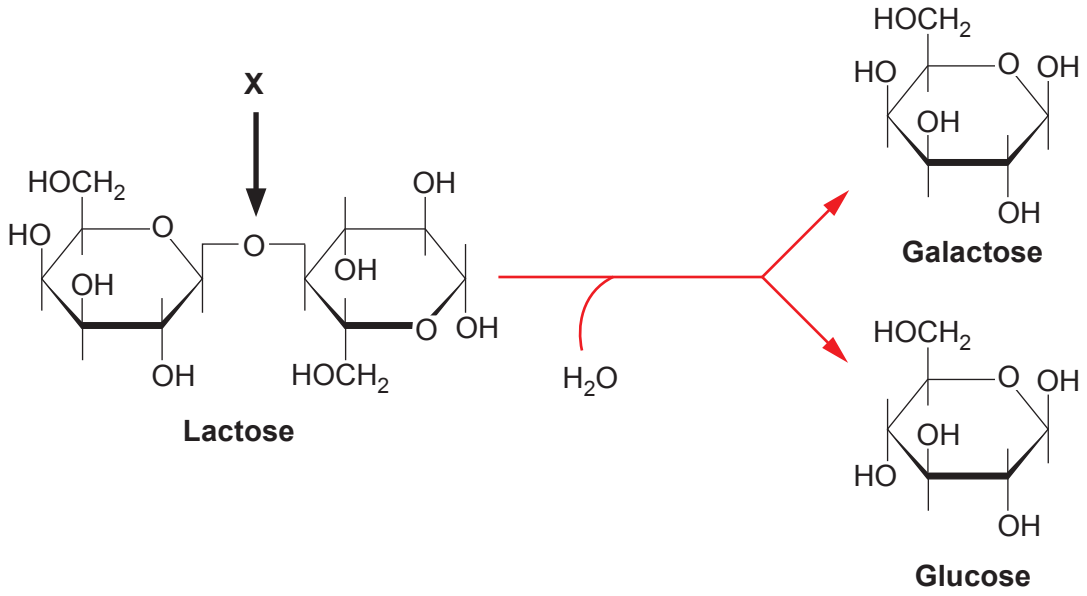
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3. Some people cannot drink cow's milk as they are lactose intolerant. They lack the enzyme lactase that catalyses the breakdown of lactose into galactose and glucose.



(a) (i) If lactase is present, bond **X** is broken in this reaction. Name this type of bond and the type of reaction that breaks this bond. [2]

Bond X Glycosidic

Reaction Hydrolysis

(ii) Explain how you can identify that the isomer of glucose shown in the diagram above is β-glucose. [1]

The hydroxyl (OH) group on carbon 1 points upwards (above the ring).

(b) (i) The rate of enzyme activity can be altered by the presence of inhibitors.

Explain why galactose can act as a competitive inhibitor of lactase. [1]

Galactose has a similar shape to lactose (the substrate), so it is complementary to the active site and binds to it, preventing enzyme-substrate complexes forming.

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Students investigated the effect of inhibition of lactase by galactose.
They added a fixed concentration of lactase to different concentrations of lactose solution and measured the rate of monosaccharide formation. The experiment was repeated with a fixed concentration of galactose added to the lactose solutions. All volumes used were controlled for each solution in both experiments.

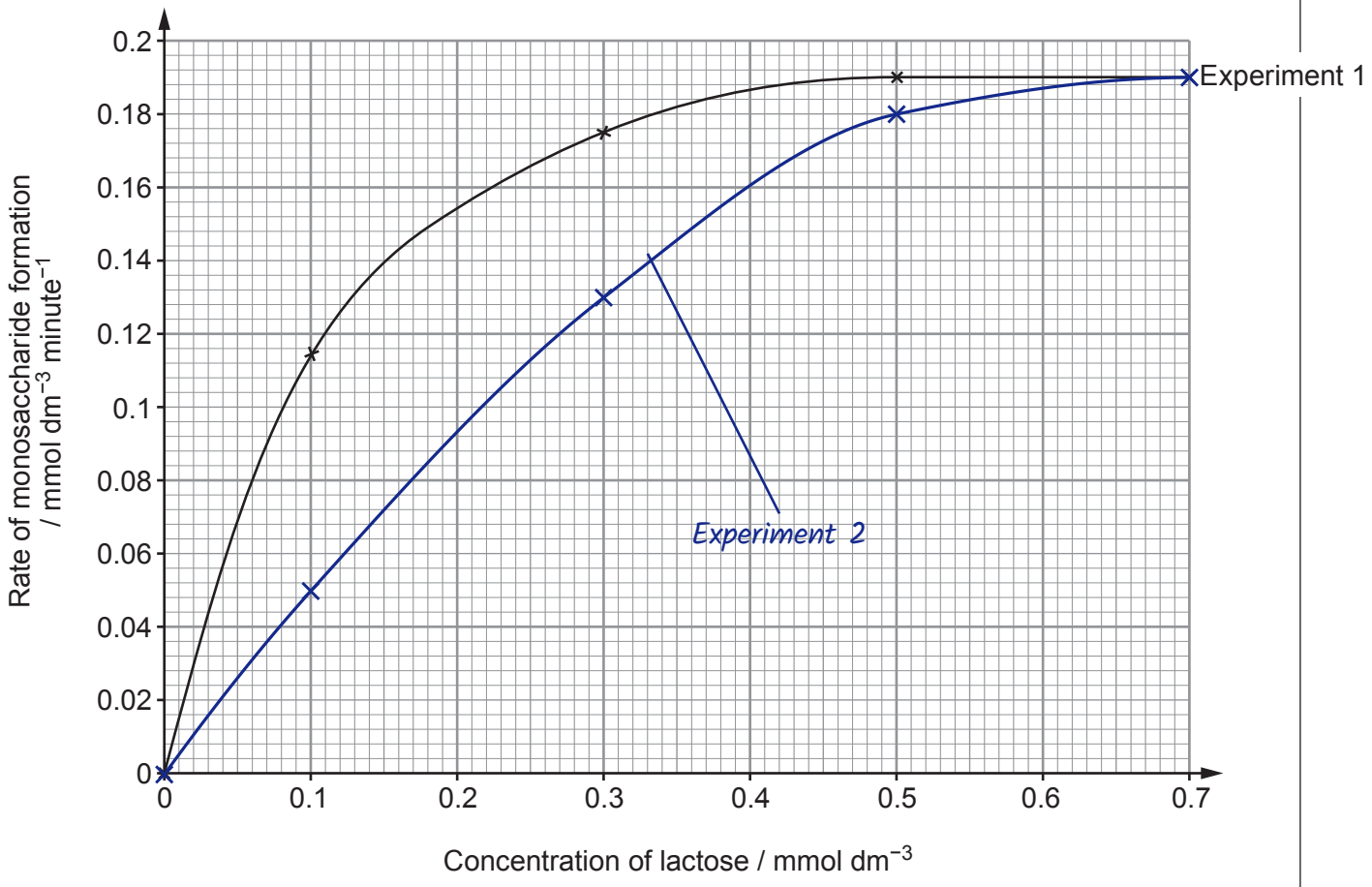
The results are shown below.

Concentration of lactose / mmol dm^{-3}	**Rate of monosaccharide formation / mmol dm^{-3} minute^{-1}**	
	Experiment 1 (without galactose)	**Experiment 2 (with galactose)**
0.00	0.000	0.000
0.10	0.115	0.050
0.30	0.176	0.130
0.50	0.190	0.180
0.70	0.190	0.190

(ii) The results for Experiment 1 have been plotted on the graph paper below.

Plot the results for Experiment 2 **on the same axes**. [2]

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(iii) Explain how the results show that galactose acts as a competitive inhibitor of lactase. [2]

At low lactose concentrations the rate is reduced with galactose (e.g. 0.050 compared with 0.115 at 0.10 mmol dm^{-3}). At high lactose concentrations the rate reaches the same maximum (0.190) as without the inhibitor, as lactose outcompetes galactose.

(iv) Describe how the graph would look if galactose was a non-competitive inhibitor of lactase. [1]

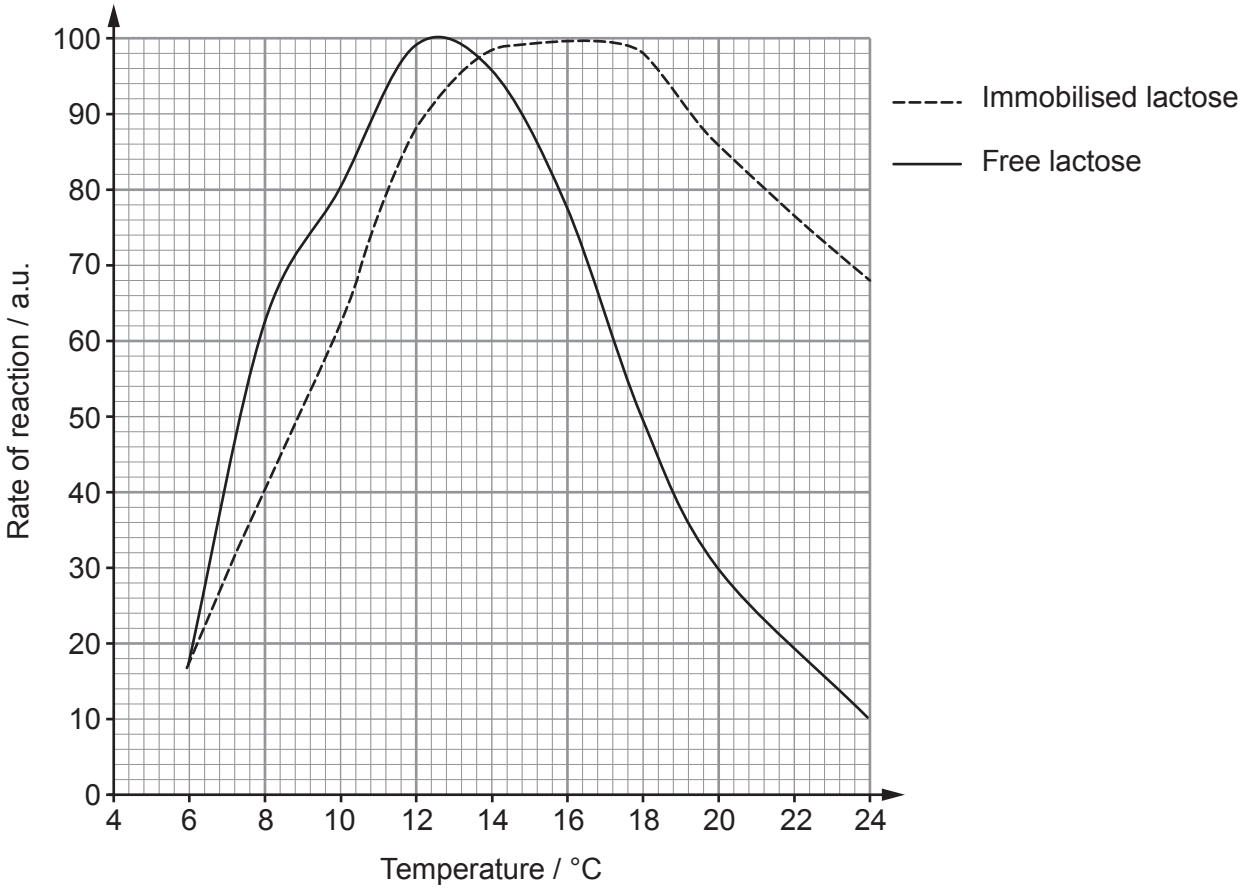
The rate would be reduced at all lactose concentrations, and the maximum rate would never be achieved (the curve levels off lower).

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(c) Lactose free milk can be produced using bacterial lactase which has been immobilised in beads made from an inert substance, such as alginate.
An experiment was carried out to compare the activity of free and immobilised lactase at different temperatures. The results are shown in the graph below.



(i) Explain why the immobilised lactase works at its maximum rate over a wider range of temperatures than the free lactase. [2]

The alginate bead gives stability and protection from higher temperatures, as more energy is required to overcome the weak (hydrogen) bonds holding the enzyme's shape. So the shape of the active site is maintained at higher temperatures, and the enzyme is not denatured as easily.

(ii) Explain why the substance used to immobilise the lactase must be inert. [1]

It must not react with the enzyme or substrate, so it does not affect the shape of the active site.

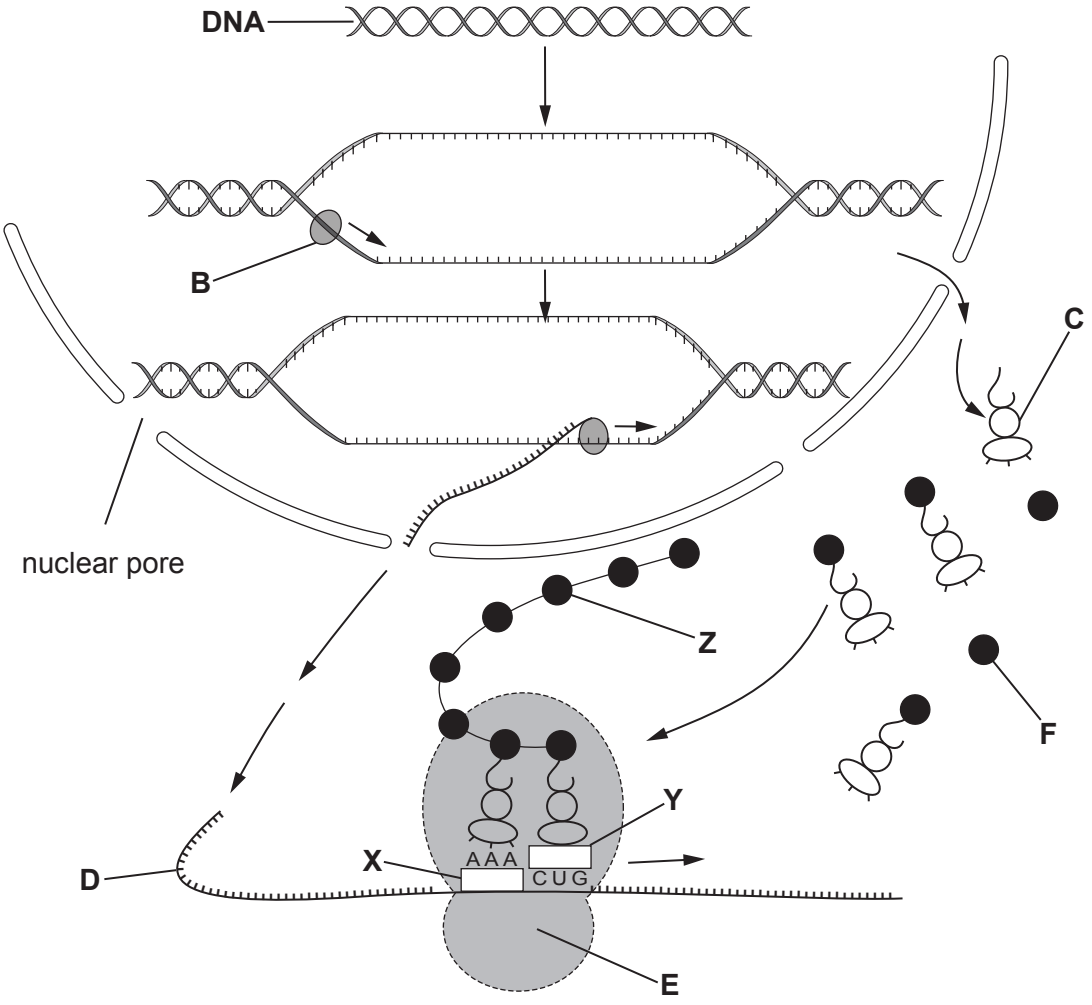
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4. The diagram below summarises the process of protein synthesis which involves both DNA and RNA.



(a) Use some of the letters from the diagram to identify the following molecules involved in protein synthesis. [1]

mRNA D

tRNA C

rRNA E

(b) (i) The structures labelled **X** and **Y** on the diagram are sequences of bases. Complete the table below. [2]

Base Sequence	Name of the sequence	Bases in the sequence
X	Codon	UUU
Y	Anticodon	GAC

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(ii) Describe and explain how a change in the base sequence of **X** could affect the primary structure of molecule **Z**. [3]

Three bases (a codon) on mRNA code for one amino acid.

A change in the base sequence of codon X (e.g. a substitution) could result in a different amino acid, as a different tRNA molecule (anticodon) would bind.

This may result in a different sequence of amino acids in polypeptide Z, changing its primary structure.

(c) It was originally proposed that **one gene** carried the code for **one enzyme**. This was revised to become the **one gene – one protein** hypothesis. It is now known as, the **one gene – one polypeptide** hypothesis.

Using your knowledge of protein structure and function explain why the two previous versions of this hypothesis are no longer accepted. [2]

Not all proteins are enzymes, e.g. haemoglobin or collagen, so one gene, one enzyme is wrong.

Some proteins are made of more than one polypeptide (quaternary structure, e.g. haemoglobin has four), each coded for by a different gene, so one gene, one protein is wrong.

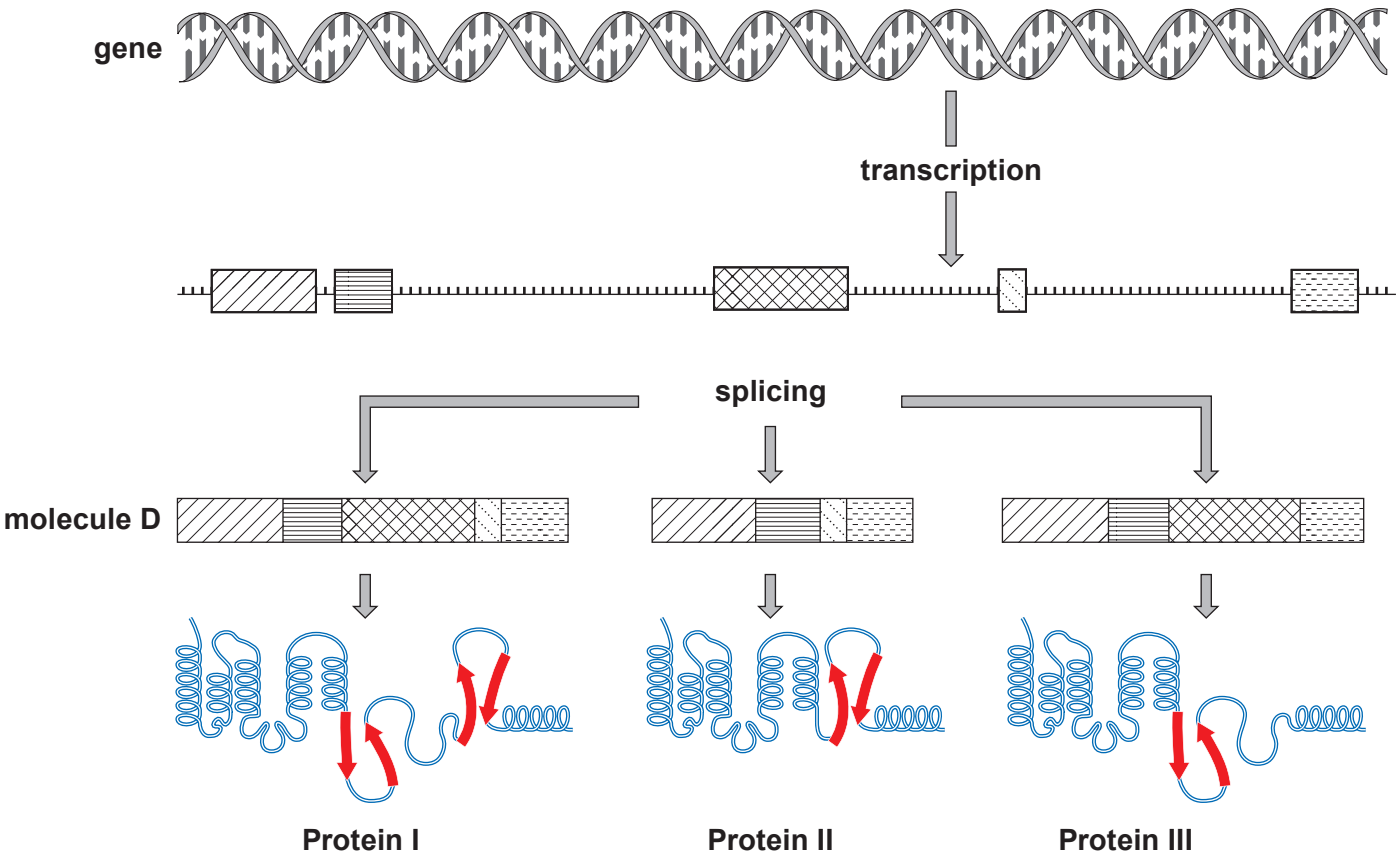
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In the 1960s, it was estimated that the human genome contained more than 2 000 000 genes. Analysis has since shown that much of the genome is made up of non-coding regions and that the coding regions contain about 20 000 genes that code for polypeptides. However, over 1 000 000 different polypeptides are produced by our cells.

The diagram below shows how different proteins can be produced from the same gene.



(d) Describe the process of transcription. [3]

DNA helicase unzips the DNA double helix by breaking the hydrogen bonds between complementary base pairs.

One strand of DNA acts as a template, exposing unpaired bases.

RNA polymerase adds complementary RNA nucleotides (A with U, C with G) and forms phosphodiester bonds between them, making pre-mRNA.

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(e) (i) State the names given to the: [1]

coding regions Exons

non-coding regions Introns

(ii) With reference to the gene shown in the diagram and your own knowledge of protein synthesis, explain how **different** proteins can be produced from a single gene. [3]

During splicing the pre-mRNA is cut to remove the introns, and the exons are joined together.

The exons can be joined in more than one (alternative) arrangement, producing different mRNA molecules, as shown by molecule D.

Each mRNA codes for a unique sequence of amino acids, so each protein folds differently into a different tertiary structure, giving proteins I, II and III.

15

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5. Brown seaweeds of many types grow on rocks around the shores of the UK. One of these species is called *Fucus vesiculosus*.



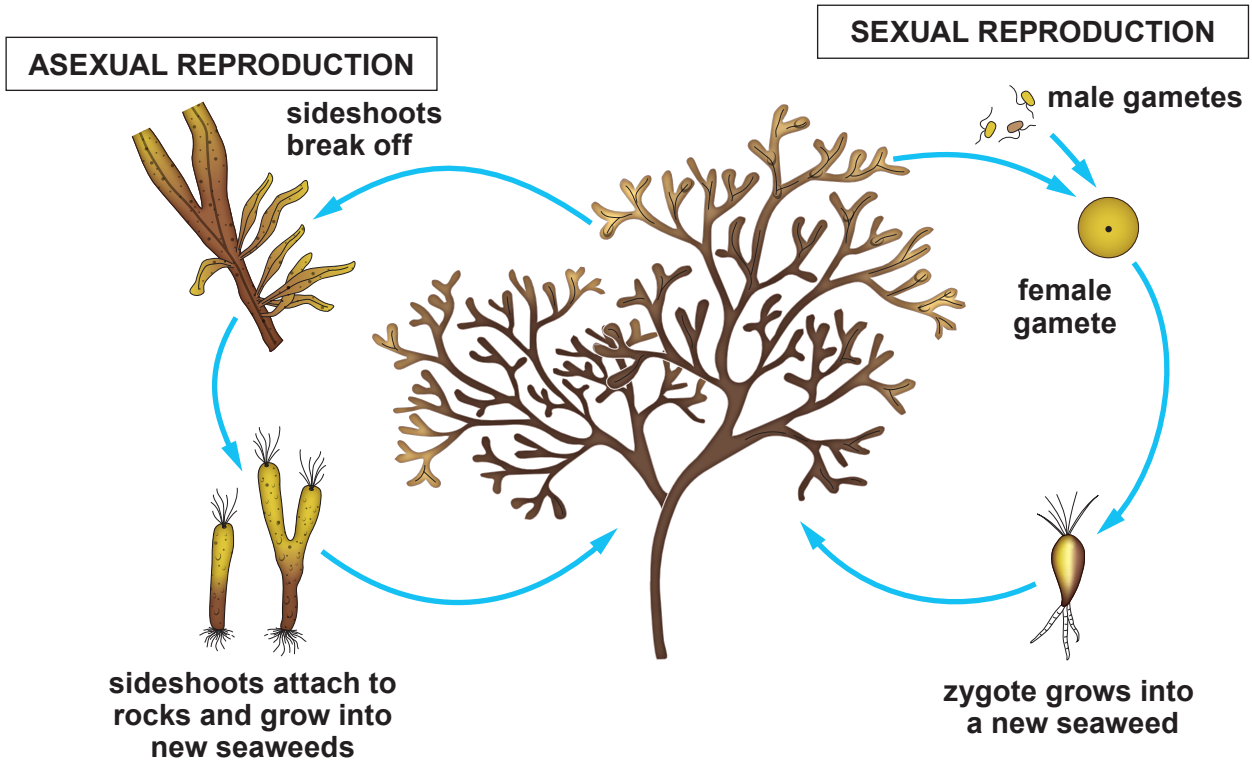
It is classified in the Kingdom Protoctista even though its cells contain chlorophyll.

(a) Name the domain to which *F. vesiculosus* belongs and list the **other** Kingdoms of organisms found in this domain. [2]

Domain Eukaryota

Other Kingdoms in this domain Fungi, Plantae, Animalia

(b) This type of seaweed can reproduce both sexually and asexually as shown in the diagram below.



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During sexual reproduction gametes are produced in specialised structures.
The process involves both meiosis and mitosis:

- In the production of female gametes, one cell divides first by meiosis which is followed by a single mitotic division.
- In the production of male gametes, one cell divides first by meiosis which is followed by four mitotic divisions.

(i) Calculate the number of male and female gametes produced from one cell. [2]

Meiosis: 1 cell → 4 cells; one mitosis: 4 × 2 = 8

Number of female gametes = *8*

Meiosis then four mitoses: $4 \times 2^4 = 4 \times 16 = 64$

Number of male gametes = *64*

(ii) Suggest why gamete production in *F. vesiculosus* involves both meiosis and mitosis. [2]

Meiosis halves the chromosome number to produce haploid gametes and brings about genetic variation.

Mitosis then produces large numbers of gametes, increasing the chance of fertilisation.

(iii) Explain why new seaweeds produced by sexual reproduction would be genetically different to each other and different to those produced by asexual reproduction. [3]

Asexual reproduction produces genetically identical clones by mitosis.

In sexual reproduction, crossing over at chiasmata during prophase I of meiosis and independent assortment of chromosomes at the equator during metaphase I and II produce genetically different gametes.

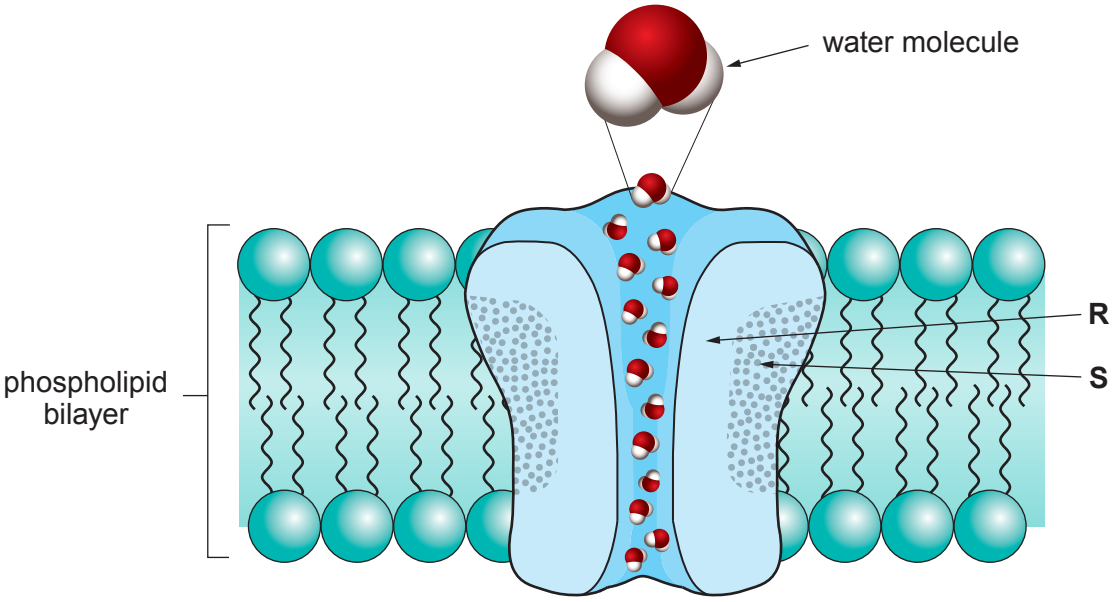
Random fertilisation of a random egg by a random sperm gives further genetic variation.

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6. The presence of aquaporin proteins in cell membranes speed up the movement of water molecules by osmosis. The diagram below shows water molecules travelling through an aquaporin in the plasma membrane of a cell.



(a) (i) Explain why water molecules cannot easily diffuse through the phospholipid bilayer. [1]

Water is a polar molecule and the centre of the membrane (fatty acid tails) is a hydrophobic region.

(ii) Identify which region of the aquaporin molecule labelled **R** and **S** is non-polar. Explain how you arrived at your answer. [1]

S is non-polar (hydrophobic R groups), as it is adjacent to the fatty acid tails of the phospholipids.

(b) Water passes from one plant cell to another down a water potential gradient.
Water potential is affected by two opposing forces, pressure potential (ψ_p) and solute potential (ψ_s).

$$\psi_{cell} = \psi_p + \psi_s$$

A practical was carried out to determine the water potential of red onion cells by placing red onion tissue in different concentrations of sucrose solution and observing them under a microscope. The total number of cells in the field of view was counted together with the number of plasmolysed cells. The percentage of plasmolysed cells was then calculated for each concentration of sucrose solution.

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The results are shown in the table.

Concentration of sucrose solution / mol dm^{-3}	Solute potential / kPa	Plasmolysed cells / %
0.1	−269	2
0.2	−526	12
0.3	−790	18
0.4	−1052	36
0.5	−1322	56
0.6	−1596	70
0.7	−1882	81
0.8	−2180	98
0.9	−2580	100

(i) Explain why the water potential of the cell can be assumed to be equal to the solute potential of the solution that causes 50 % plasmolysis. [1]

At incipient plasmolysis the pressure potential = 0, as the cell membrane is just pulling away from the cell wall, so ψcell = ψs.

(ii) Use the results in the table to estimate a value for the water potential of the onion tissue. [1]

About −1200 kPa

(iii) Outline how the data in the table could be used to determine a more accurate estimate of the onion tissue water potential. [2]

Plot a graph of percentage plasmolysed cells (y axis) against solute potential of the solution (x axis) and draw a line of best fit. Read across from 50% plasmolysed to the line and down to the x axis to find the solute potential, which equals the water potential.

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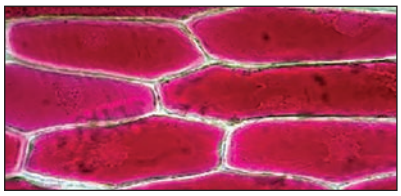
(iv) State how the procedure could be modified to improve reliability and accuracy. [2]

Reliability *Observe more pieces of onion tissue from each solution (or count more cells in each piece) and calculate a mean.*

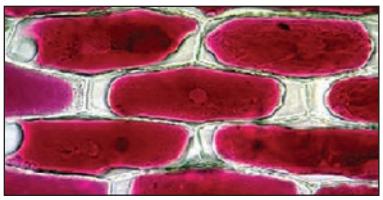
Accuracy *Use a narrower range of concentrations around 50% plasmolysis, e.g. 0.40 to 0.60 mol dm^{-3}.*

Photographs of some of the cells from the red onion tissue used in the investigation are shown below.

S



T



(v) State the terms used to describe the cells above. [1]

S *Turgid*

T *Plasmolysed*

(vi) Red onion tissue was placed in a solution with a solute potential of −1800 kPa. After 30 minutes, the cells appeared like those shown in **T** above. Explain this observation. [2]

The external solute (water) potential of −1800 kPa is more negative than the water potential of the cells. So water moves out of the cells by osmosis, the vacuole shrinks and the cell membrane pulls away from the cell wall.

11

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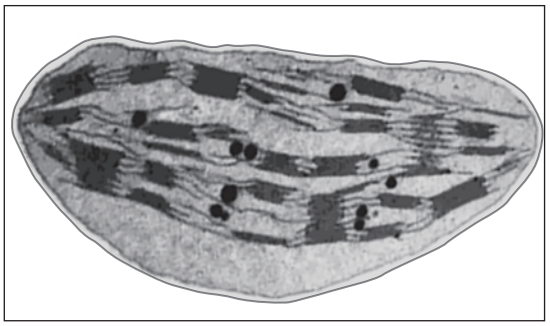
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7. A symbiotic relationship is the interaction between two different species living in close physical association to the advantage of both.

In 1967, Lynn Margulis proposed the theory of endosymbiosis and suggested that mitochondria and chloroplasts evolved from free-living prokaryotes that were taken into other prokaryotic cells by endocytosis to form the first eukaryotic cells.

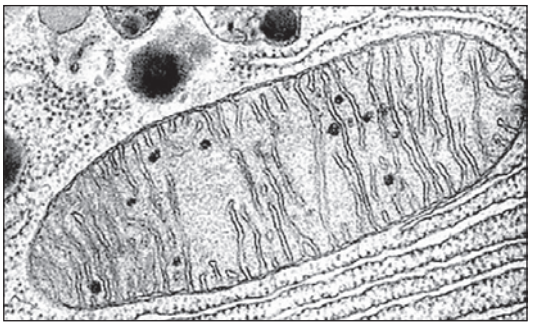
The electron micrographs below show the detailed structure of a chloroplast and a mitochondrion.

Chloroplast



1 µm

Mitochondrion



0.5 µm

Compare the structures of mitochondria and chloroplasts to prokaryotes.

Describe and explain how the double membrane observed in both organelles was formed, and how this supports the theory of endosymbiosis.

Suggest the advantages of this symbiotic relationship to the mitochondria, the chloroplasts and the newly formed eukaryotic cell. [9 QER]

Comparison with prokaryotes: like prokaryotes, both mitochondria and chloroplasts contain their own circular DNA, which they use for self-replication, dividing independently of the cell. Both contain 70S ribosomes, the same size as prokaryotic ribosomes, used for the production of their own proteins. They are a comparable size to bacteria (about 1 to 10 µm). Chloroplasts contain chlorophyll, like photosynthetic bacteria (cyanobacteria), and the cristae of mitochondria are similar to the mesosomes of bacteria, which may be involved in respiration.

Formation of the double membrane: the host prokaryote engulfed the free-living prokaryote by endocytosis. Infoldings or extensions of the host plasma membrane surrounded the prokaryote and fused to form a vesicle, which moved into the cell, taking in the organelle.

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So the organelle has a double membrane: the inner membrane is the original bacterial cell membrane and the outer membrane comes from the host cell membrane surrounding it. This supports endosymbiosis, as a double membrane is just what endocytosis of a whole prokaryote would produce. Instead of being digested, the engulfed prokaryotes eventually became a permanent feature of the cell.

Advantages: the relationship initially provided a temporary benefit, which eventually became an evolutionary advantage. The mitochondria and chloroplasts gain protection inside the host cell, and the host supplies them with raw materials (e.g. glucose, CO_2, water and mineral ions).

The new eukaryotic cell gains compartmentalisation, so reactions are kept separate and more efficient. Mitochondria give it an internalised energy source, producing large amounts of ATP by aerobic respiration, and chloroplasts give an internalised nutrient supply of sugars by photosynthesis.

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