HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**18S7___**
CENTRE NUMBER		**INDEX NUMBER**	

BIOLOGY — 9744/01

Paper 1 Multiple Choice — **26 September 2019**

Additional Materials: Multiple Choice Answer Sheet — **1 hour**

INSTRUCTIONS TO CANDIDATES

1. Write your **name**, **CT group, Centre number** and **index number** in the spaces provided at the top of this cover page.
2. Fill in your particulars on the Multiple Choice Answer Sheet. Write your **NRIC number** and shade accordingly.
3. There are **thirty** questions on this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**.

   Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.
4. At the end of the paper, you are to submit **only** the Answer Sheet.

INFORMATION FOR CANDIDATES

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The used of an approved scientific calculator is expected, where appropriate.

This document consists of **24** printed pages.

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1 A student made notes describing photomicrographs of four cells.

cell 1 Grey cytoplasm at edge of cell contains many black lines and spots. Large white area in centre of cell.

cell 2 Grey cytoplasm contains many black lines and spots which fill the entire cell.

cell 3 Pale blue cytoplasm surrounds a single dark blue spot.

cell 4 Many green structures are enclosed within a rectangular shape with visible boundaries.

Which table identifies the type of cell and the type of microscope used to take each photograph?

A

	animal cell	plant cell
electron microscope	1	2
light microscope	3	4

B

	animal cell	plant cell
electron microscope	1	2
light microscope	4	3

C

	animal cell	plant cell
electron microscope	2	1
light microscope	3	4

D

	animal cell	plant cell
electron microscope	2	1
light microscope	4	3

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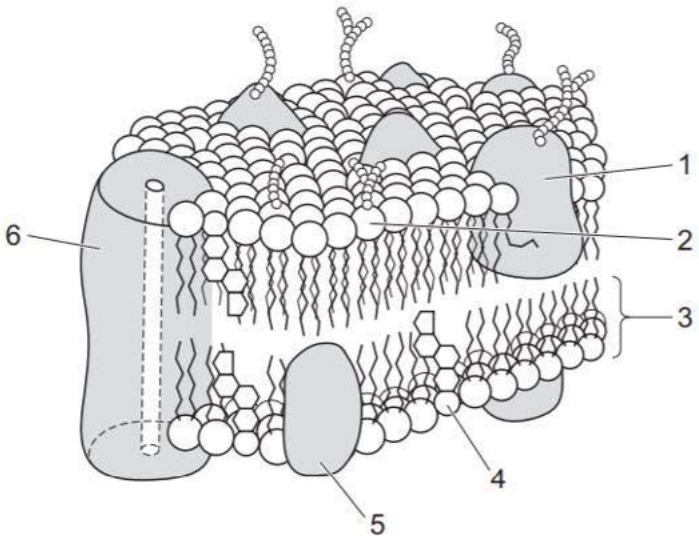
2 The diagram shows the structure of the cell membrane with molecules labelled 1 to 6.



Which row correctly identifies function of two of the numbered molecules?

	molecule	function	molecule	function
A	1	acts as an antigen	4	stabilises the membrane
B	2	acts as an receptor	5	active transport
C	3	facilitated diffusion	4	regulates the fluidity of the membrane
D	6	active transport	5	acts as an enzyme

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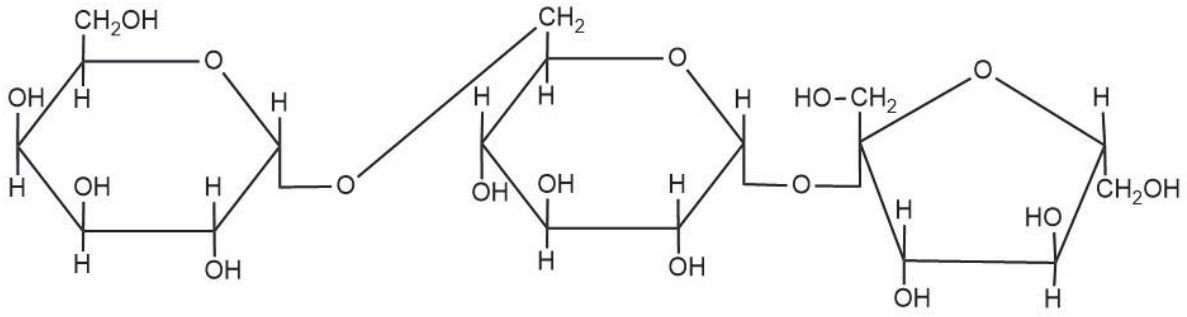
3 Raffinose is the most abundant trisaccharide found in nature.

The diagram shows the structure of raffinose.



Which statement correctly describes raffinose?

A Raffinose is made up of two hexoses and one pentose.

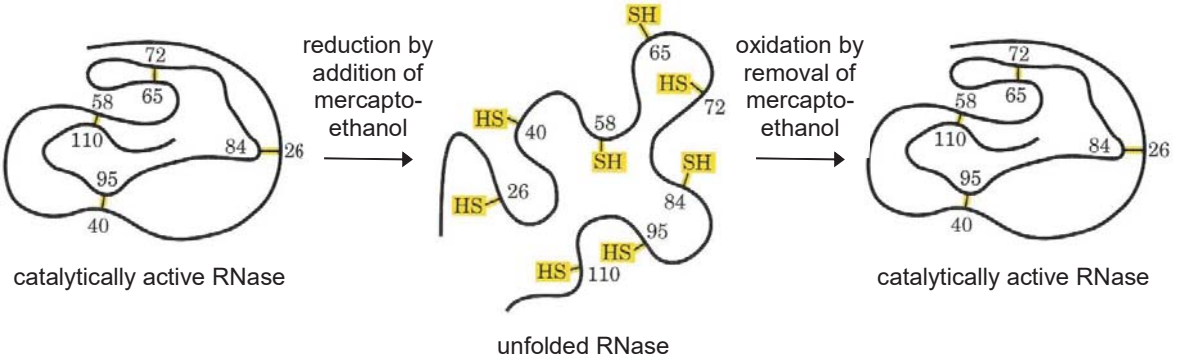
B Raffinose gives rise to three different types of sugar monomers upon complete hydrolysis.

C Raffinose is made up of monosaccharides joined by α(1,6) glycosidic bond and α(1,4) glycosidic bond.

D When raffinose is boiled with Benedict's solution for five minutes, a brick-red precipitate is observed.

4 Christian Anfinsen was awarded the Nobel Prize in 1972 for his work on the structure of ribonuclease (RNase).

The diagram shows Anfinsen's experiment on the denaturation and renaturation of RNase.



What conclusion can be made based on these observations?

A Unfolded RNase, with all disulfide bonds broken, is still enzymatically active.

B Amino acid sequence of RNase determines its tertiary structure.

C Denaturation of RNase requires energy input in the form of heat.

D Renaturation of RNase requires more information encoded by the *RNase* gene.

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5 An investigation was carried out on the effect of temperature on an enzyme-catalysed reaction.

The enzyme and its substrate were initially placed into separate test-tubes and raised to the temperature required. They were then mixed and placed into four tubes, W, X, Y and Z.

These tubes were incubated for the time and at the temperature stated. The mass of the product formed was then measured. The results are shown in the table.

Tube	incubation time / s	incubation temperature / °C	mass of product / μg
W	30	25	2.5
X	30	45	5.0
Y	600	25	32.0
Z	600	45	10.0

Which conclusion is valid?

A For every 10°C increase in temperature, the rate of the reaction doubled.

B The shorter the incubation time, the more product is formed.

C The activation energy gained at 25°C is lower than that at 45°C.

D The rates of reaction in both tubes Y and Z differ markedly due to denaturation.

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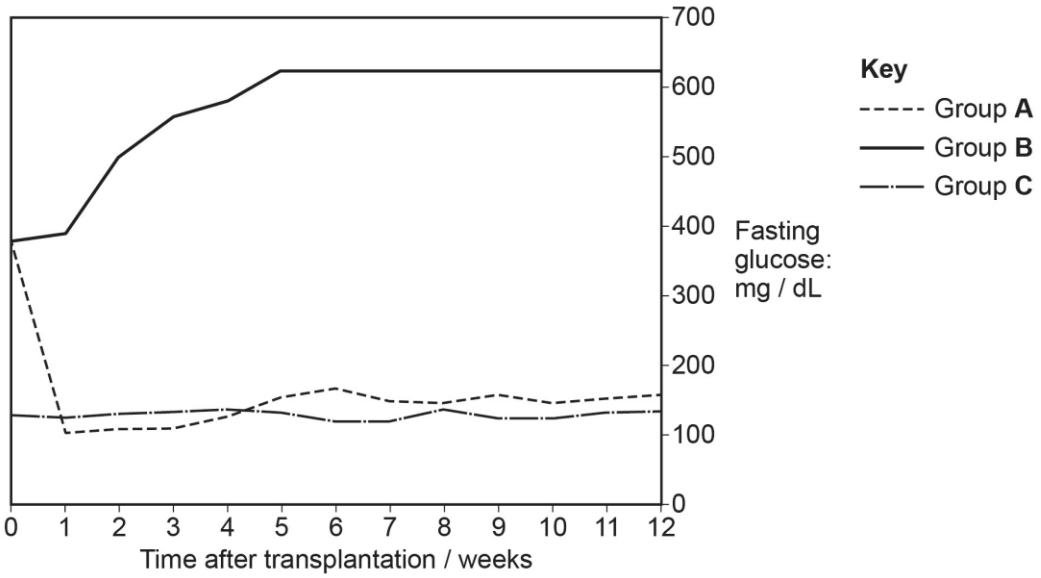
6 Scientists investigated the use of induced pluripotent stem cells (iPS cells) to treat type I diabetes in mice. The scientists used four transcription factors to reprogramme skin cells to form iPS cells.

The scientists then stimulated the *in vitro* differentiation of iPS cells into pancreatic cells.

The scientists set up three experimental groups:

- Group **A** – 30 mice with type I diabetes received pancreatic cell transplants derived from iPS cells.
- Group **B** – 30 mice with type I diabetes were left untreated.
- Group **C** – 30 mice without diabetes were left untreated.

The scientists measured the blood glucose concentration of all the mice on a weekly basis for 12 weeks. The results obtained are shown in the graph.



Which statements are valid?

1 Each of the four transcription factors bound to the promoter region of specific genes and stimulated transcription by allowing RNA polymerase to bind.

2 The use of iPS cells is effective in treating diabetes.

3 Mice and humans are mammals and hence this investigation will be useful in determining similar effectiveness of such a treatment.

4 Short-term and long-term effects are not known in humans.

A 1, 2, 3 and 4 **B** 1 and 2 only **C** 2 and 3 only **D** 3 and 4 only

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7 A short piece of DNA, 19 base pairs long, was analysed to find the number of nucleotide bases in each of the polynucleotide strands. Some of the results are shown in the table.

	number of nucleotide bases			
	A	C	G	T
strand 1				4
strand 2		7		5

1 Strand 1 has three nucleotide bases containing C.

2 The ratio of purine to pyrimidine in strand 2 is the same as that in strand 1.

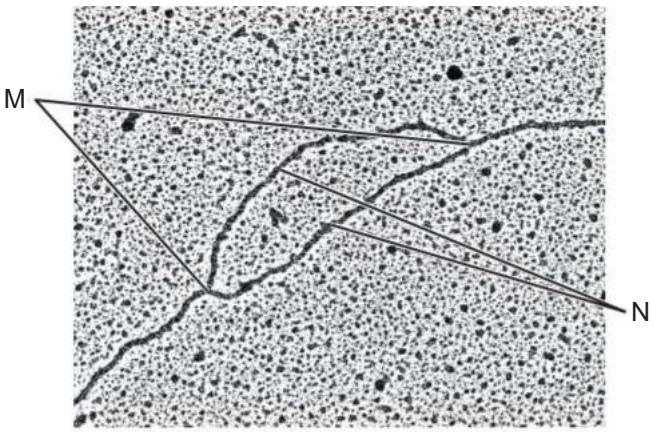
3 There are 48 hydrogen bonds between strands 1 and 2.

4 Replacing thymine with uracil in strand 2 will result in more hydrogen bonds between the two strands.

Which statements are correct?

A 1 and 2 **B** 1 and 3 **C** 2 and 4 **D** 3 and 4

8 The diagram shows a transmission electron micrograph of a replication bubble. Structures labelled M and N are the replication forks and origin of replication respectively.



Which statement is **not** valid?

A Each daughter strand will be synthesised both continuously and discontinuously.

B Synthesis of DNA at M will only allow formation of leading strand.

C N has a high proportion of A-T base pairs that allows for separation of the parental strands.

D DNA synthesis at N will proceed in the 5' → 3' direction on both strands.

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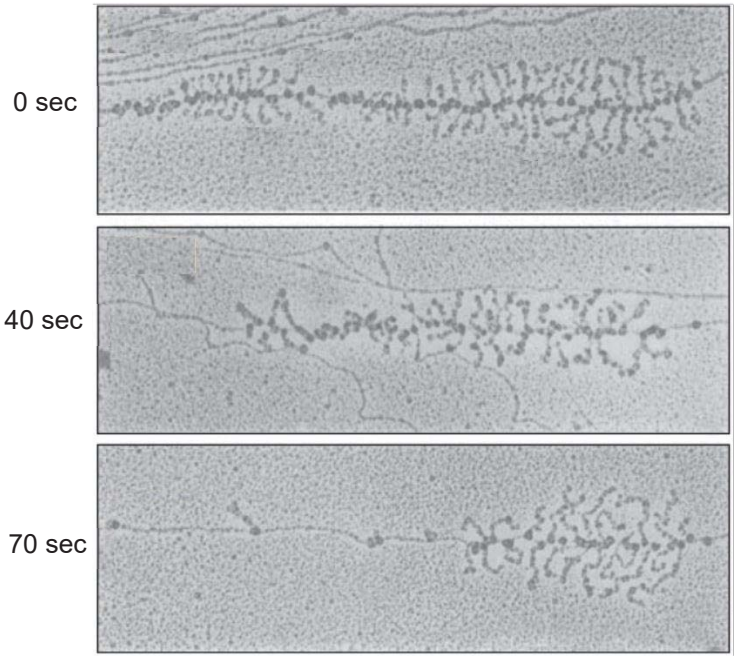
9 Rifampin is an antibiotic that fights bacteria and prevents the spread within the human body.

The diagram shows the effect of rifampin on transcription at 0, 40 and 70 seconds.



Which statements are correct?

1 There are no new transcripts formed.
2 There is no effect on transcription elongation.
3 The effect on RNA polymerase occurs only from 70 sec onwards.
4 The types of polypeptide synthesised becomes more varied.

A 1 and 2 **B** 2 and 4 **C** 3 and 4 **D** 1, 2 and 3

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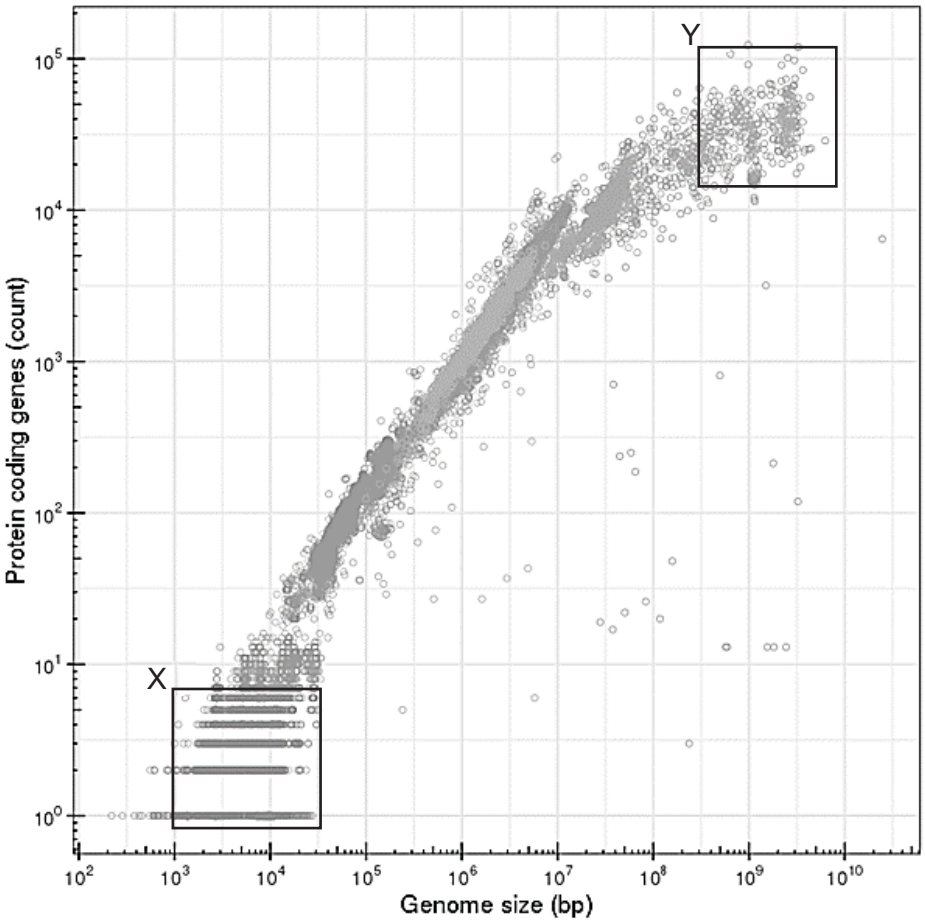
10 The relationship between genome size and number of protein-coding genes is represented in the scatter plot. The individual circles represent different organisms with the respective genome size.

Organisms with large genomes are grouped in the square labelled Y and those with small genomes are grouped in the square labelled X.



Which statement is correct?

A Organisms in **Y** are likely to have the highest gene density.

B There are more non-coding sequences in organisms in **Y** than **X**.

C The size of genes of organisms in **Y** are likely to be bigger than those in **X** due to the presence of exons.

D The complexity of an organism is directly proportional to its genome size.

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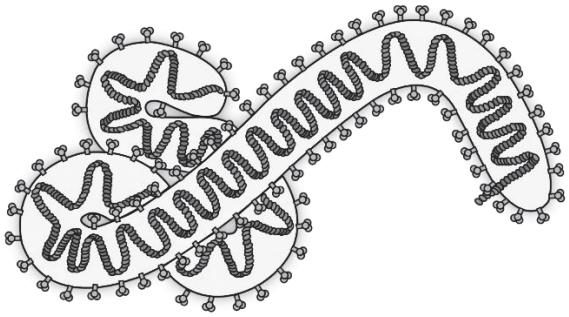
11 The telomere and centromere play important roles in maintaining the proper structure of chromosomes.

Which combination is correct?

	telomere	centromere
A	regulates the onset of cell senescence in eukaryotic and prokaryotic cells	remains constant in length throughout lifetime of a cell
B	prevents fusion of chromosomal ends in prokaryotes	contains genes coding for kinetochore complex proteins
C	prevent loss of structural genes during DNA replication	necessary for proper chromosomal segregation during binary fission
D	made up of DNA rich in tandem repeats	DNA exists as heterochromatin

12 Ebola viruses are RNA viruses endemic to regions of west and equatorial Africa. They are pathogens that are primarily transmitted by human-to-human contact with infected body fluids and result in high mortality.

The diagram shows the structure of the Ebola virus.



The RNA genome of Ebola viruses cannot be directly translated to synthesise viral proteins.

Which row correctly describes Ebola viruses?

	presence of envelope	genome	requires vector for transmission	release from host cells
A	absent	positive-sense RNA	yes	exocytosis
B	absent	negative-sense RNA	no	budding
C	present	positive-sense RNA	no	exocytosis
D	present	negative-sense RNA	no	budding

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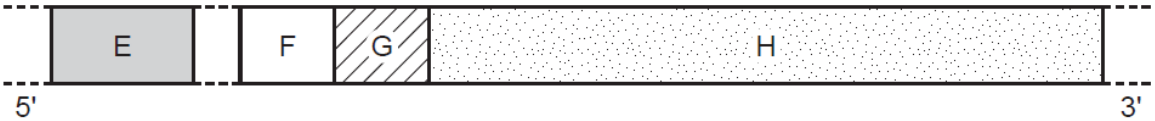
13 The diagram represents a length of DNA in bacterium *Escherichia coli,* which forms the *trp* operon and its associated regulatory gene.

Parts of the *trp* operon and its associated regulatory gene are labelled E, F, G and H. They have different functions.



Which correctly identifies the functions of E, F, G and H?

	E	F	G	H
A	binding of *trp* repressor protein	binding of DNA polymerase	binding of tryptophan co-repressor	codes for inducible enzymes
B	binding of *trp* repressor protein	binding of RNA polymerase	binding of tryptophan co-repressor	codes for repressible enzymes
C	codes for *trp* repressor protein	binding of DNA polymerase	binding of *trp* repressor protein	codes for inducible enzymes
D	codes for *trp* repressor protein	binding of RNA polymerase	binding of *trp* repressor protein	codes for repressible enzymes

14 Gene expression can be regulated by modification made to the poly-A tail of mRNA.

Which row is correct?

	modification by	type of regulation	outcome
A	exonuclease	transcriptional	rapid reduction in amount of protein produced
B	endonuclease	translational	rapid change to 3D conformation of protein produced
C	endonuclease	translational	rapid reduction in amount of protein produced
D	exonuclease	transcriptional	rapid change to 3D conformation of protein produced

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15 Sickle cell anaemia is caused by a change in the sixth amino acid of the β-globin polypeptide chain involving the amino acids glutamic acid (Glu) and valine (Val).

The DNA sequences for Glu and Val are shown in the table.

amino acid	DNA codes
Glu	CTT CTC
Val	CAA CAG CAT CAC

Which combination correctly shows the mutation to β-globin that will result in sickle cell anaemia?

	original DNA sequence	mutant DNA sequence	type of mutation	effect of change
A	CTC	CAC	missense	addition of hydrophobic residue
B	CTC	CAT	nonsense	loss of hydrophobic residue
C	CAC	CTC	missense	addition of hydrophobic residue
D	CAC	CTT	neutral	loss of hydrophobic residue

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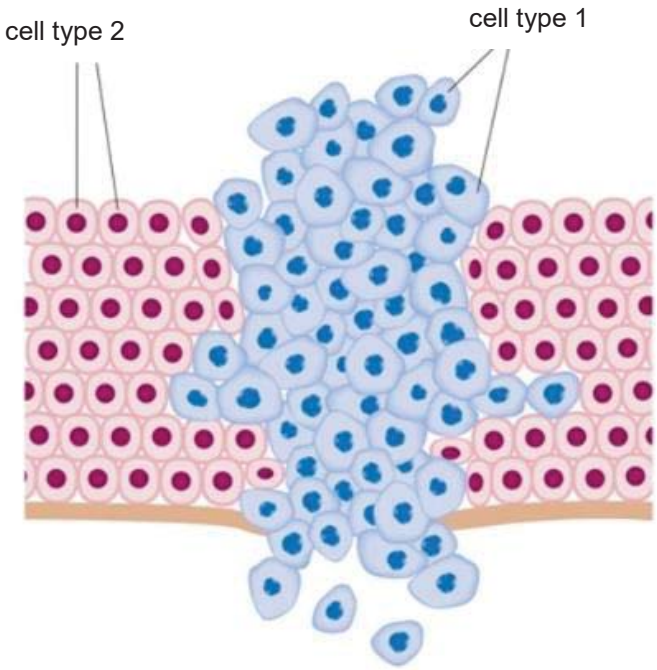
16 The diagram illustrates a tissue sample with two cell types labelled 1 and 2.



A student attempted to compare some of the characteristics of these two cell types as shown in the table.

characteristics of cell	cell type 1	cell type 2
hyperactive ras	N	O
normal p53	P	Q
contact inhibition between cells	R	S
secrete signals for increased formation of blood vessels	T	U
can enter the circulatory system	V	W
cell was previously irradiated with X-rays	X	Y

Which combination of letters links cell types 1 and 2 to their correct characteristics?

A N, S, V and X

B P, S, W and Y

C O, R, V and W

D S, T, U and X

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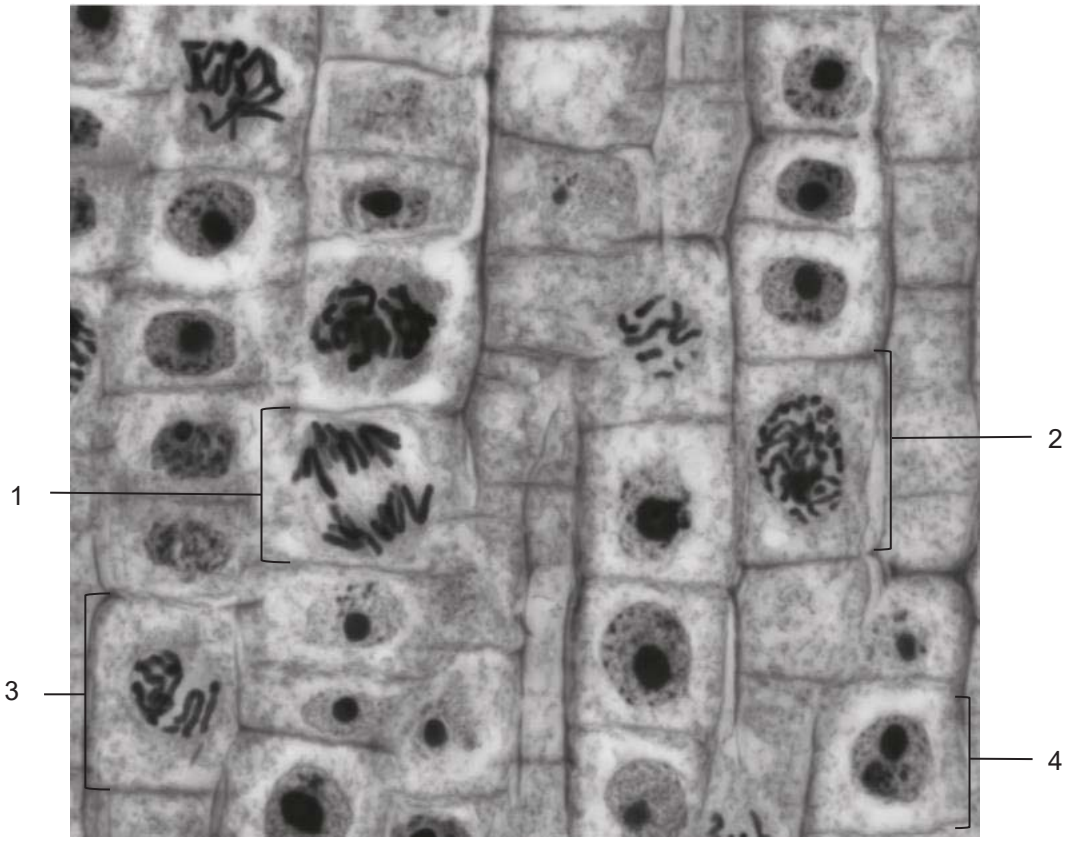
17 The photomicrograph shows plant cells in different stages of the mitotic cell cycle.



Which row matches the name of a stage, a description of some of the events happening at this stage and a cell undergoing this stage of the mitotic cell cycle?

	name of stage	description	cell
A	anaphase	Centromeres divide. Daughter chromosomes are pulled to poles of the cell in a V-shaped pattern.	1
B	prophase	Centriole pairs migrate to opposite poles of the cell.	2
C	metaphase	Spindle microtubules attach to the centromeres of chromosomes.	3
D	telophase	Cell plate develops across the metaphase plate of the cell. Chromatin decondenses.	4

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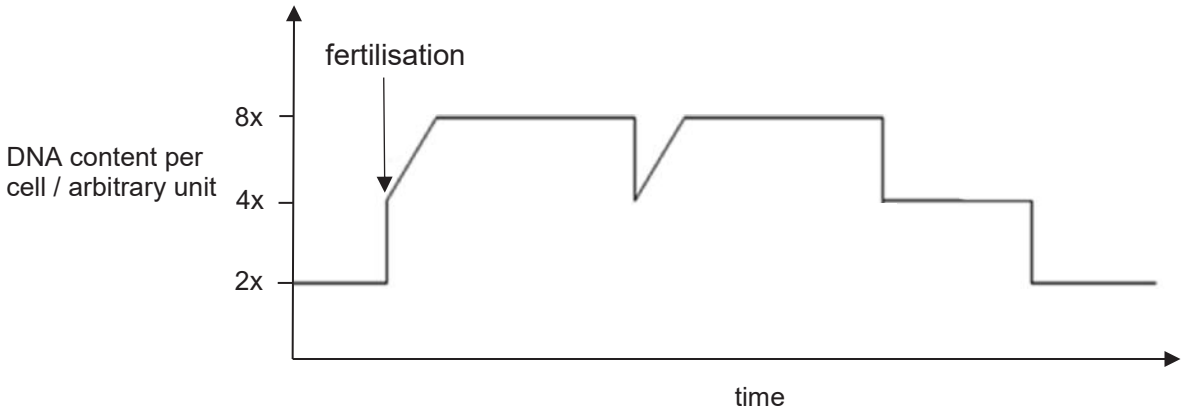
18 The graph shows changes in the DNA content within a cell at different stages of cell and nuclear division.



Which row is correct?

	DNA content per cell / arbitrary unit			
	fertilisation	end of meiosis 1	end of meiosis 2	end of mitosis
A	2x	4x	2x	4x
B	4x	4x	2x	4x
C	4x	4x	4x	8x
D	8x	8x	4x	8x

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19 Domestic goats, *Capra hircus*, show a wide range of coat patterns and colours.

One gene involved in coat colour and pattern has multiple alleles. Four of these alleles are:

- A, the allele for white, is dominant to all others
- A^b, the allele for badgerface (stripes on face) and A^g, the allele for grey, are codominant
- a, the allele for black, is recessive to all others

A cross between a black goat and a white goat produced a white goat. This white offspring was crossed with a grey goat. The genotype of the grey goat was not known.

Which combination correctly shows all the possible offspring genotypes and phenotypes that could result from the cross between the white offspring and the grey goat?

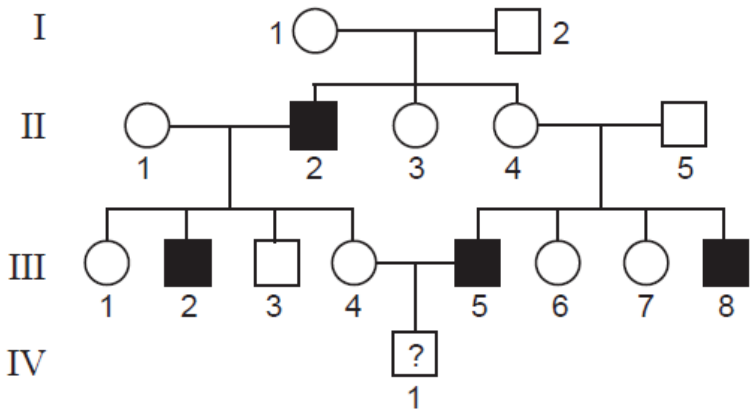
A Aa (white), aa (black) only

B AA^g (white), A^ga (grey) only

C AA^g (white), AA^b (white), A^ga (grey), A^ba (badgerface)

D AA^g (white), Aa (white), A^ga (grey), aa (black)

20 The pedigree shows red-green colour blindness that occurs amongst some individuals in a family.



Which statements are **correct**?

1 Individual II-3 and II-4 must be carriers of the recessive allele for red-green colour blindness.

2 The probability individual III-1 and III-4 are carriers of the recessive allele for red-green colour blindness is 0.50.

3 The probability individual IV-1 is colour blind is 0.50.

A 1 only **B** 3 only **C** 1 and 2 only **D** 2 and 3 only

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21 In *Drosophila*, the recessive eye mutation white is X-linked while another recessive mutation sepia (resulting in a dark eye) is autosomal. White is epistatic to the expression of sepia.

A cross between a true-breeding white-eyed female and a sepia male resulted in the following F_1 generation:

- wild-type females, which are double heterozygous, and
- white-eyed males.

Which is the correct phenotypic ratio of the F_2 generation when the F_1 generation is crossed?

A 3 wild-type male : 4 white-eyed male : 1 sepia male : 3 wild-type female : 4 white-eyed female : 1 sepia female

B 3 wild-type male : 4 white-eyed male : 1 sepia male : 6 wild-type female : 2 sepia female

C 6 wild-type male : 2 sepia male : 3 wild-type female : 4 white-eyed female : 1 sepia female

D 4 wild-type male : 3 white-eyed male : 1 sepia male : 4 wild-type female : 3 white-eyed female : 1 sepia female

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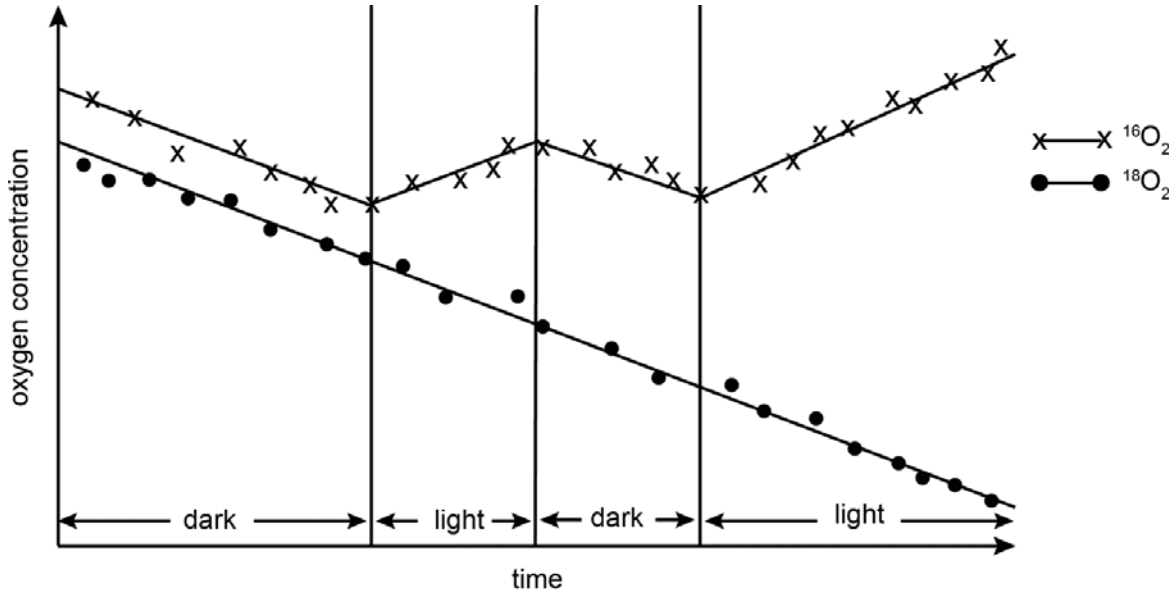
22 Unicellular algae were grown in a culture supplied with oxygen gas (O_2) and water (H_2O) containing the ^{16}O oxygen isotope. The algae were then briefly supplied with oxygen gas containing a mixture of ^{16}O and ^{18}O isotopes. Over the course of the next hour, lighting conditions were varied and the concentrations of the two isotopes in the culture were measured.



Which statements correctly explain the trends seen in the data?

1 The concentration of $^{18}O_2$ decreases at a constant rate irrespective of light or dark due to anaerobic respiration occurring at a constant rate in the algae.

2 The concentrations of both isotopes decrease at an equal rate in the dark due to both molecules fitting the active site of the last enzyme in the electron transport chain equally well.

3 The concentration of $^{16}O_2$ increases in the light due to photolysis of water, where the water molecules were previously produced by oxidative phosphorylation in the algae.

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

23 The enzymes decarboxylase and dehydrogenase are involved in aerobic respiration. They are labelled P and Q respectively in the table shown.

Which row is correct?

	glycolysis		link reaction		Krebs cycle	
	P	Q	P	Q	P	Q
A	✓	✓	×	✓	✓	✓
B	✓	×	✓	×	×	✓
C	×	✓	✓	✓	✓	✓
D	×	✓	✓	×	×	✓

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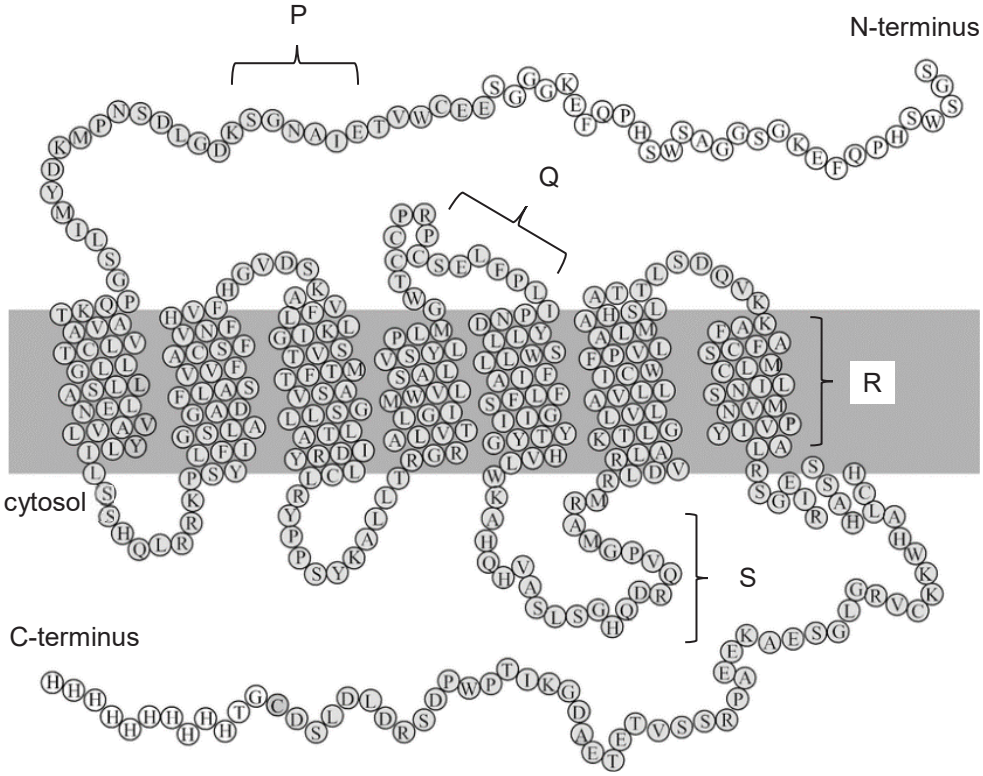
24 The diagram shows the molecular structure of a G-protein linked receptor (GPLR) embedded in a cell surface membrane.



Which statements correctly relate the properties of GPLR to the function it plays?

1 P is made up of hydrophilic amino acid residues for solubility in aqueous medium.

2 Q has variable amino acids between different types of GPLRs for activation of G-proteins.

3 R is made up of hydrophobic amino acid residues for stabilization within phospholipid bilayer.

4 S has amino acid residues that interact with G-proteins.

A 1 and 2 only **B** 3 and 4 only **C** 1, 3 and 4 **D** 1, 2, 3 and 4

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25 Regressive evolution is a change in a population over time that involves the loss of certain phenotypic characteristics. It is thought to be caused by either genetic drift or natural selection.

An example of regressive evolution is the loss of eyes in one form of the Mexican cavefish, *Astyanax mexicanus*. These eyeless cavefish live in caves that are in total darkness.

There are three theories to explain how the loss of eyes in the cavefish has occurred.

Theory 1
There is no advantage to having eyes in a cave that is in total darkness, where energy sources are scarce. Having eyes is a disadvantage as there may be an energy cost.

Theory 2
A mutation has occurred in a single gene. This mutation has two effects:
- a lack of eye development
- an increase in the number of chemoreceptors on the skin.

Theory 3
Various mutations occurred in the genes responsible for eye development over a period of time. By chance, these mutations increased in frequency in small isolated populations. Eventually this produced a population of eyeless cavefish.

Which row is correct about the cause of loss of eyes in cavefish *Astyanax mexicanus*?

	theory that describes genetic drift	theory that describes natural selection	reason for choice of theory that describes natural selection
A	3 only	2 only	more chemoreceptors allow detection of more food with less energy required
B	2 only	3 only	different mutations are advantageous in increasing the allele frequency by chance in small populations
C	3 only	1 and 2 only	availability of energy sources acts as the selection pressure and having more chemoreceptors is a selective advantage
D	1 and 2 only	1 and 3 only	having eyes is a selective disadvantage and the lower energy needed allows for the mutants to thrive in small populations

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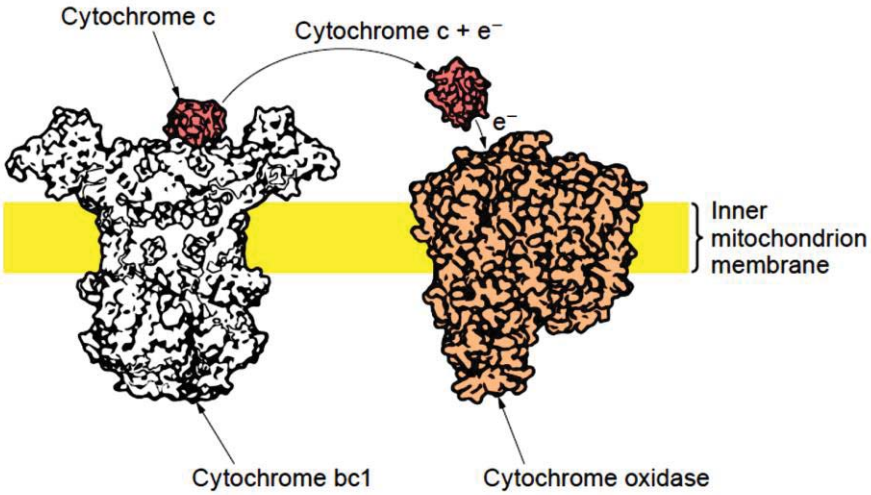
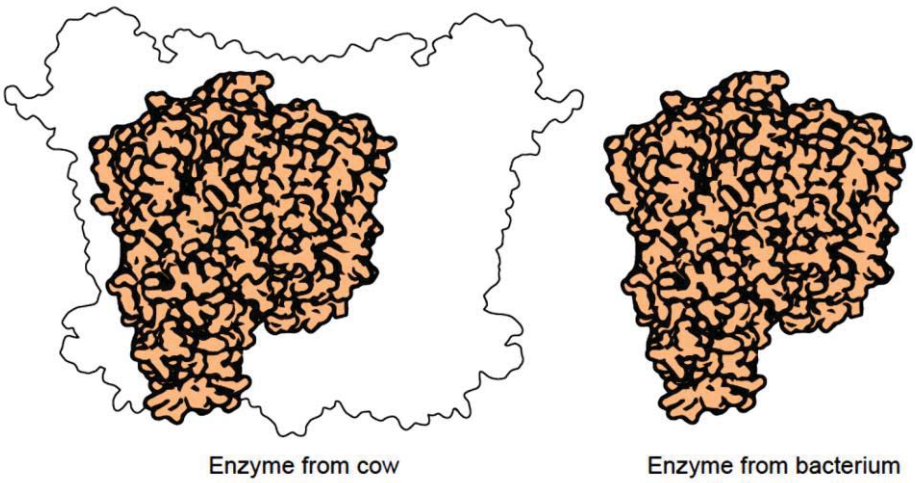
26 Cytochrome c is an electron carrier involved in oxidative phosphorylation. It is a protein that transfers electrons between two large proteins cytochrome bc1 and cytochrome oxidase that are found in the electron transport chain as shown in the diagram.



The cytochrome oxidase molecule is different in different species of organisms. The following diagram shows the enzyme from a cow and a bacterium. The shaded section in each represents the polypeptide chains, which are very similar in both organisms. This is the area of the enzyme that binds to the cytochrome c.



Which statements are correct in describing the role of cytochromes in evolution?

1 Cytochrome c detaches when it is reduced due to conformational changes to its structure.

2 The shaded regions represent the active site of cytochrome oxidase molecule and it is complementary in shape to the cytochrome c.

3 The base sequences for cytochrome c, cytochrome bc1 and cytochrome oxidase code for the respective polypeptide chains that are highly conserved in all organisms.

4 Homology and divergent evolution are observed.

A 1 and 2 only **B** 2 and 3 only **C** 3 and 4 only **D** 2, 3 and 4

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27 99.9% of all species that have ever existed on Earth are now extinct.

Which statement best explains this fact?

A Climate change events that are associated with large comet or asteroid impacts occur faster than organisms can evolve and adapt to new environmental conditions.

B Genetic variations within a population occur through random mutations, and given enough time, the environment will change in such a way that existing phenotypes will not survive.

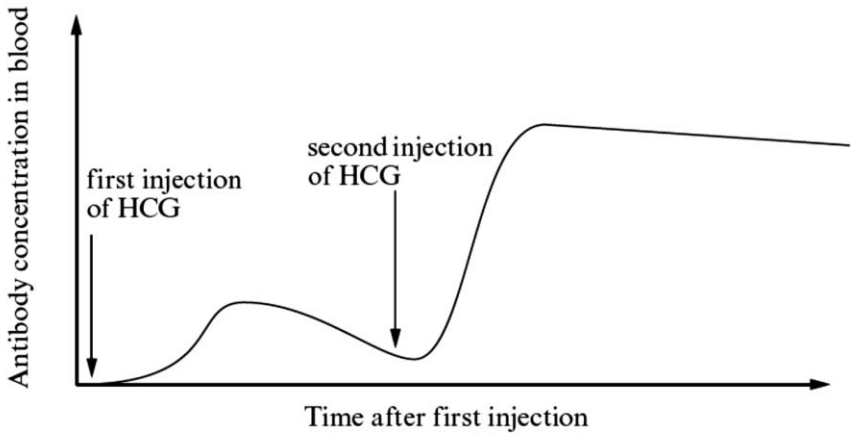
C The accumulation of random mutations in the genome of all organisms eventually leads to frameshift mutations in critical genes and are ultimately lethal.

D The rapid increase in global temperatures in the past 100 years, combined with ocean acidification, heavy metal contamination and ozone depletion caused by human activities have caused the rapid extinction.

28 Home pregnancy test kits are used to detect the presence of the hormone Human Chorionic Gonadotropin (HCG) using antibodies.

The production of antibodies against HCG involves injecting the hormone into an animal.

The diagram shows the effect of injecting HCG into the animal.



Which statements correctly explain the effects of HCG in bringing about immune responses?

1 After the first injection of HCG, antibody concentration is greater in the blood leading to a more rapid secondary immune response.

2 After the second injection of HCG, memory cells divide rapidly to produce large numbers of plasma cells.

3 The second injection of HCG lowers the affinity of antigen-presenting cells such as macrophages for the antigen.

A 1 only **B** 2 only **C** 1 and 2 only **D** 2 and 3 only

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29 Which row is correct for each disease?

	influenza	HIV / AIDS	tuberculosis	small pox
A	caused by an enveloped virus	causes reduction in number of T-lymphocytes	no effective antibiotics available	herd immunity resulted in its eradication
B	disrupts function of epithelial cells of respiratory tract	may be carried by a vector	air-borne infection	no effective vaccination available
C	yearly vaccinations required	vulnerable to opportunistic infections	tubercles formed in lungs rupture when immunity is weakened	caused by a *Variola* virus
D	carried by birds	caused by a retrovirus	caused by bacteriophage	transmitted from person to person

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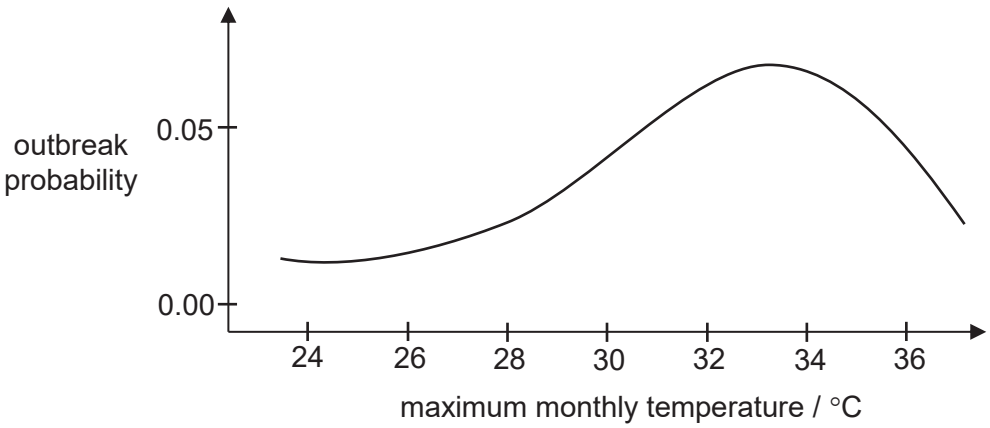
30 Nations in South and Southeast Asia have experienced large outbreaks of mosquito-borne infectious diseases such as dengue and Chikungunya.

A study has been conducted to investigate the relationship between maximum monthly temperature and outbreak probability of mosquito-borne infectious diseases.

The results are shown in the graph.



Which statements explain the effect of maximum monthly temperature on the outbreak of mosquito-borne infectious diseases?

1 As maximum monthly temperature increases beyond 33.5 °C, length of the mosquitoes' life cycle shortens and hence, outbreak probability increases.

2 As maximum monthly temperature increases beyond 33.5 °C, virus cannot develop and hence, outbreak probability decreases.

3 There will be a poleward shift, rather than a poleward expansion, in regions most susceptible to mosquito-borne disease outbreaks if global warming persists.

A 1 only **B** 3 only **C** 1 and 2 only **D** 2 and 3 only

---END OF PAPER---

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CANDIDATE NAME		**CT GROUP**	**18S7__**
CENTRE NUMBER		**INDEX NUMBER**	

BIOLOGY 9744/02

Paper 2 Structured Questions **30 August 2019**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

There are **six** question booklets (**I** to **VI**) to this paper. Write your **name**, **CT group, Centre number** and **index number** in the spaces provided at the top of this cover page.

There are **nine** questions.

Answer **all** questions in the spaces provided on the Question Paper.

INFORMATION FOR CANDIDATES

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

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

You are reminded of the need for good English and clear presentation in your answers.

For Examiners' Use	
1	/ 10
2	/ 9
3	/ 12
4	/ 11
5	/ 13
6	/ 13
7	/ 10
8	/ 15
9	/ 7
Total	/ 100

This document consists of **27** printed pages.

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BOOKLET I

QUESTION 1

In *Escherichia coli*, the catabolite activator protein (CAP) is a DNA-binding protein. CAP is involved in the transcription of genes that code for enzymes involved in sugar metabolism.

CAP is formed from two identical polypeptides, each of which is made up of 209 amino acids. Each polypeptide is organised into two distinct domains:

- a cAMP-binding domain (CBD) that contains a long α-helix to mediate dimerisation, and
- a DNA-binding domain (DBD).

Fig. 1.1 shows the structure of CAP.

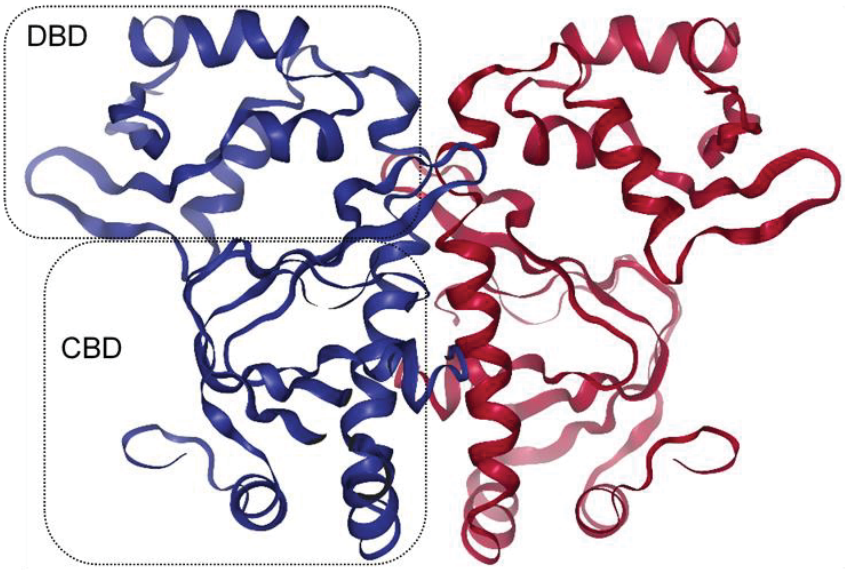

Fig. 1.1

(a) Describe the different levels of protein structure of CAP.

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..... [4]

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Fig. 1.2 is another diagrammatic representation of the structure of CAP. Upon binding of cAMP, CAP binds to a specific DNA sequence from which it can activate transcription.

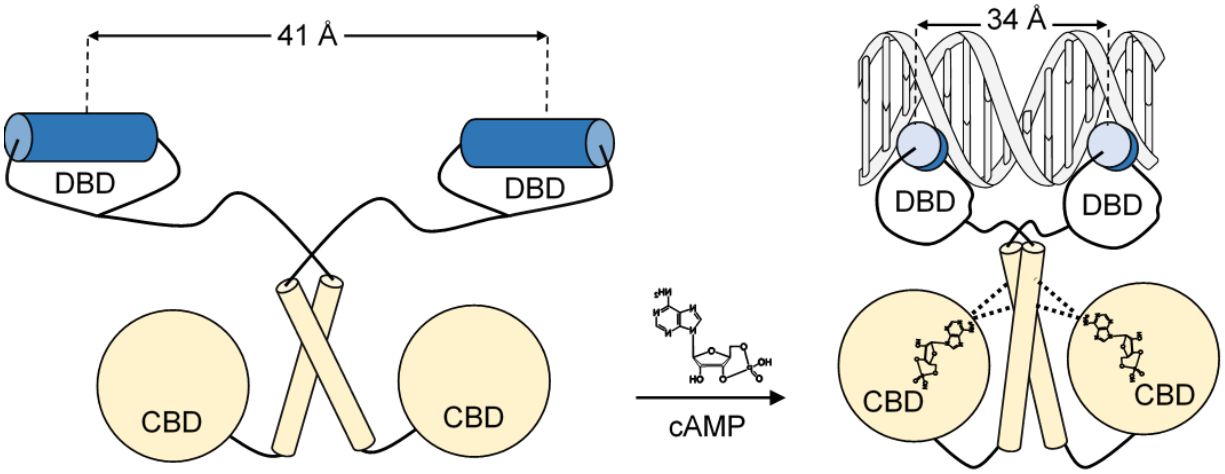

Fig. 1.2

(b) **(i)** Describe how binding of cAMP to CAP activates transcription.

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..... [3]

(ii) Identify the bond formed between CAP and DNA.

..... [1]

(c) With reference to Fig. 1.1 and Fig. 1.2, suggest why CAP is capable of undergoing allosteric regulation.

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..... [2]

[Total: 10]

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QUESTION 2

The development of a mouse from a fertilised egg into an adult is regulated by variations in DNA methylation.

Fig. 2.1 shows the developmental stages of a mouse with corresponding levels of DNA methylation. **R**, **S** and **T** represent the zygote, blastocyst and embryo respectively.

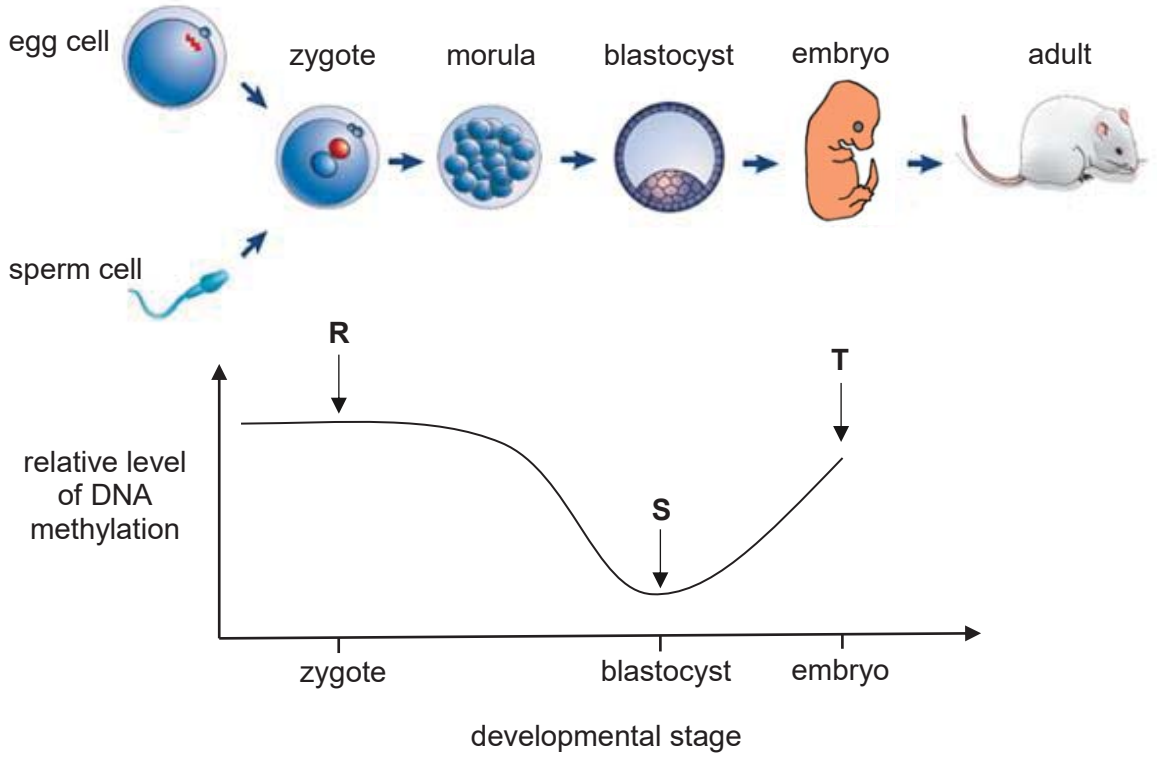

Fig. 2.1

(a) Compare the features of a cell derived from the zygote with that from the inner cell mass of the blastocyst.

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..... [3]

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(b) Explain how changes to DNA methylation from **R** to **S** bring about differentiation.

[4]

(c) At different developmental stages of the mouse, the control of the telomerase gene expression is crucial.

State and explain if the telomerase gene in cells is likely to be methylated from **T** to an adult mouse.

[2]

[Total: 9]

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QUESTION 3

Fig. 3.1 shows all the chromosomes present in one human cell during mitosis.

A scientist stained and photographed the chromosomes. In Fig. 3.2, the scientist has arranged the images of these chromosomes in homologous pairs.

Fig. 3.1

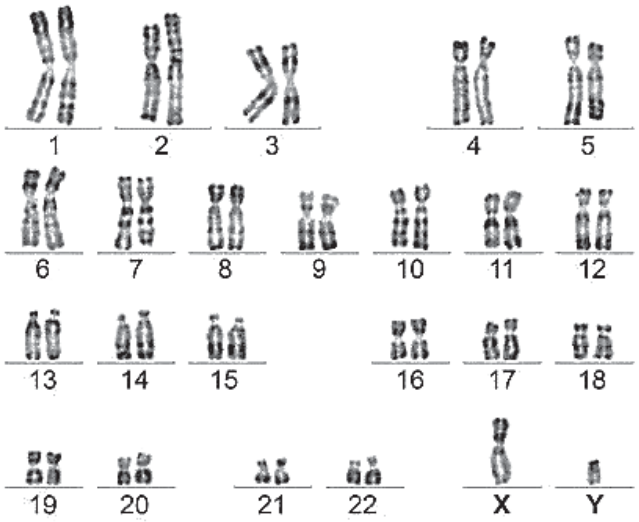

Fig. 3.2

(a) With reference to Fig. 3.1,

(i) explain why this cell was undergoing mitosis

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..... [2]

(ii) identify the stage of mitosis shown.

..... [1]

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(b) Explain why the scientist was able to arrange the chromosomes in homologous pairs as shown in Fig. 3.2.

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..... [3]

(c) The dark stain used on the chromosomes binds more to some areas of the chromosomes than others, giving the chromosomes a striped appearance.

Suggest ways in which the structure of the chromosome could differ along its length to result in the stain binding more in some areas.

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..... [2]

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Fig. 3.3 is an electron micrograph that shows a bacterium undergoing asexual reproduction.

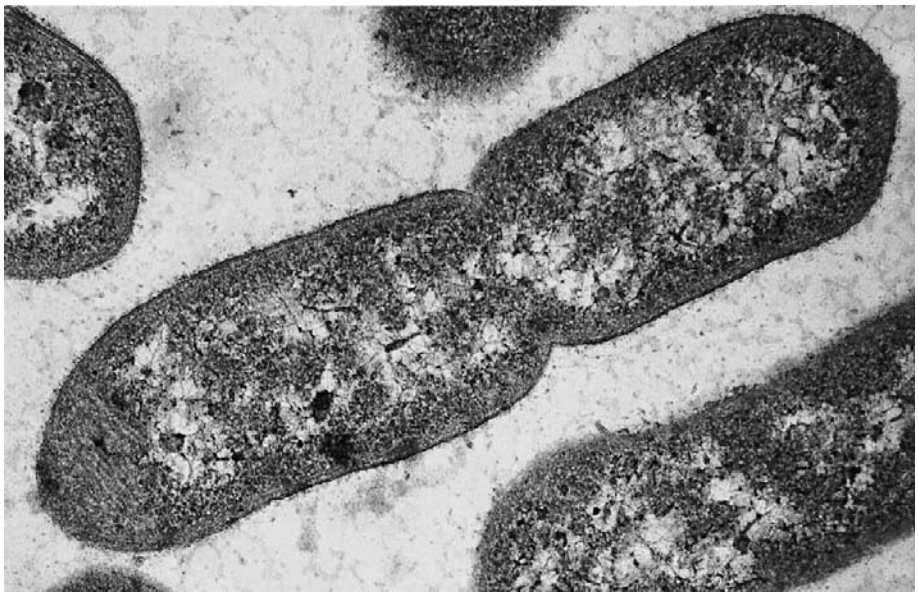

Fig. 3.3

(d) **(i)** Name the process of asexual reproduction shown.

..... [1]

(ii) Mitosis produces genetically identical daughter cells, similar to asexual reproduction in bacterial cells.

Outline how the process of asexual reproduction in bacteria results in genetically identical daughter cells.

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..... [3]

[Total: 12]

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QUESTION 4

Smoking is a common cause for cancer due to mutations caused by the chemicals inhaled.

A person who gives up smoking decreases their risk of developing lung cancer, a non-infectious disease.

(a) **(i)** Describe how smoking causes lung cancer.

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..... [2]

(ii) Explain why lung cancer is described as a non-infectious disease.

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..... [2]

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Caspase genes are considered cancer-critical genes and mutations to them are often found in smokers.

A generalised pathway involving several caspase proteins and the Poly-ADP-ribose polymerase (PARP) is shown in Fig. 4.1.

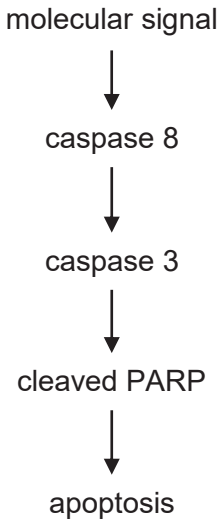

Fig. 4.1

(b) **(i)** Based on the information provided in Fig. 4.1, explain if the *caspase 8* gene should be considered a proto-oncogene or a tumour suppressor gene.

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(ii) Explain why a mutation to *caspase 8* gene is insufficient to cause cancer in smokers.

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..... [4]

[Total: 11]

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QUESTION 5

In mice, two recessive disorders, droopy ears and flaky tail, are caused by genes that are located 6 centimorgan (cM) apart on chromosome 3.

A researcher crossed a true-breeding mouse with normal ears (**D**) and a flaky tail (**f**) to a true-breeding mouse with droopy ears (**d**) and a normal tail (**F**).

The F1 offspring were then test crossed to mice with droopy ears and flaky tails, producing 100 offspring.

(a) **(i)** Define what is meant by a true-breeding mouse in this context.

.....

..... [1]

(ii) Given that the genes for ear and tail types are located 6 cM apart on chromosome 3, complete Table 5.1 with the expected numbers for each of the following phenotypes from the test cross.

Table 5.1

phenotypes	expected numbers
normal ears, flaky tail	
droopy ears, normal tail	
normal ears, normal tail	
droopy ears, flaky tail	

[1]

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(b) **(i)** Using the symbols provided, draw a genetic diagram to clearly show the results of the test cross.

[4]

(ii) Explain your results to **(b)(i)**.

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..... [2]

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The observed results of the test cross are shown in Table 5.2.

Table 5.2

normal ears, flaky tail	droopy ears, normal tail	normal ears, normal tail	droopy ears, flaky tail
51	46	2	1

A chi-squared (χ^2) test was carried out to compare the observed results with the expected results of the test cross.

The formula for the χ^2 test is given as follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Table 5.3 is the table of probabilities.

Table 5.3

degrees of freedom	probability		
	0.10	0.05	0.01
1	2.71	3.84	6.64
2	4.69	5.99	9.21
3	6.25	7.82	11.35
4	7.78	9.49	13.28

The calculated χ^2 value for the observed results is 2.03.

(c) Explain the conclusion that may be drawn from the calculated χ^2 value.

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..... [3]

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The researcher claimed that the observed test cross results can be simplified to 1:1 based on the parental phenotypes.

(d) Suggest why the researcher's claim is valid.

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[Total: 13]

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QUESTION 6

Fig. 6.1 is an electron micrograph of a secretory cell with structures labelled **X** and **Y**.

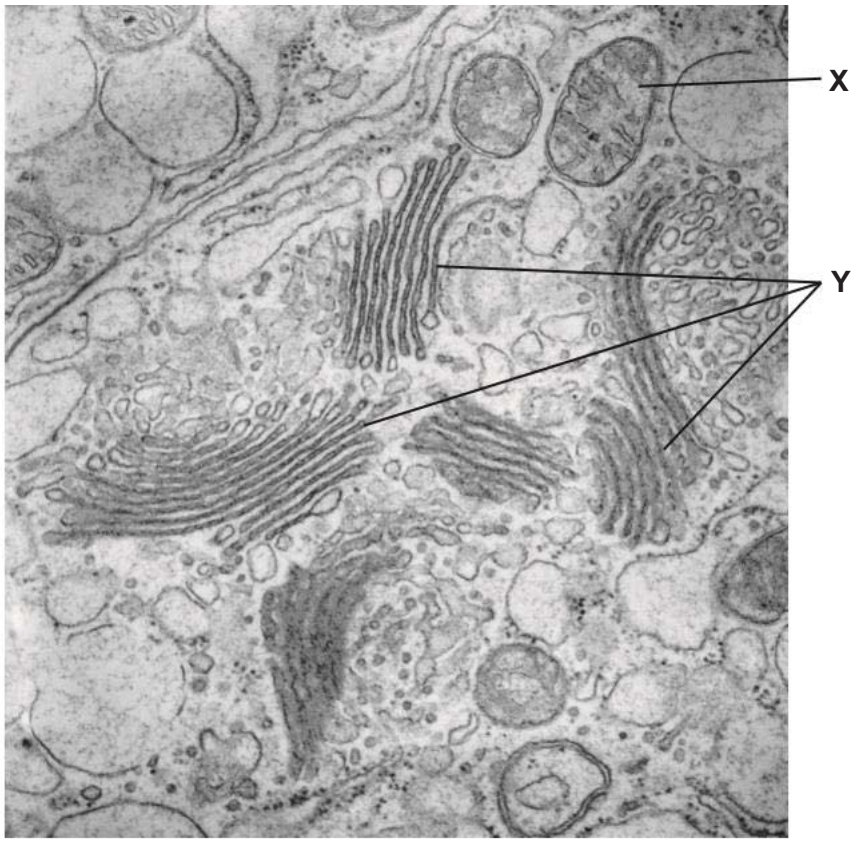

Fig. 6.1

(a) Identify structures **X** and **Y**. In each case, relate one visible feature that allows the structure to perform its functions.

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The chemiosmotic theory was first put forth by Peter Mitchell in 1961. It describes the synthesis of ATP using a proton gradient across a membrane in a mitochondrion or chloroplast.

In some of his experiments, Peter Mitchell used mitochondria that had been isolated from cells.

- The mitochondria were kept in liquid, in glass dishes, to which ADP, Pi and other substances were added.
- The temperature, pH and water potential were kept constant.
- After a period of time, he checked for the presence of ATP.

The contents of some of the dishes are shown in Table 6.1.

Table 6.1

dish	contents	ATP
1	mitochondria + ADP + Pi + acetyl CoA + oxygen	√
2	mitochondria + ADP + Pi + acetyl CoA	x
3	mitochondria + ADP + Pi + low concentration of protons	x
4	mitochondria + ADP + Pi + high concentration of protons	√

(b) Explain how the results from Table 6.1 support the chemiosmotic theory.

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..... [4]

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(c) **(i)** Account for the consequences to a mitochondrion if the water potential of the liquid in the dishes is less negative than the water potential of the mitochondrial matrix.

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..... [2]

(i) Explain the role of the mitochondrial matrix in aerobic respiration.

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[Total: 13]

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QUESTION 7

Fig. 7.1 shows the action of the hormone insulin on liver cells to regulate the concentration of blood glucose.

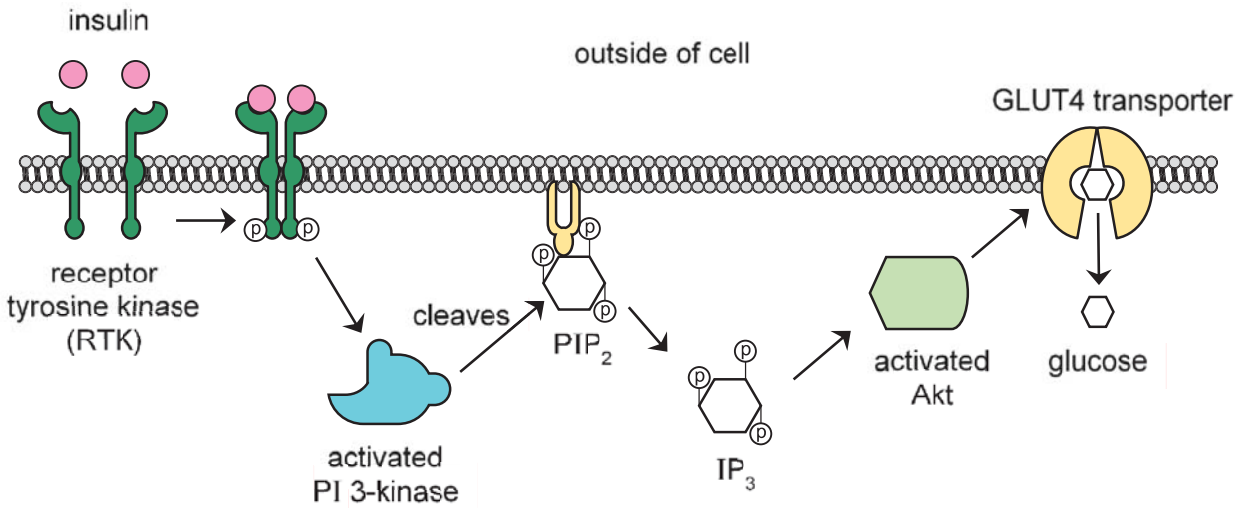

Fig. 7.1

(a) Outline the process of insulin-receptor interaction.

[4]

(b) Describe the nature of IP_3 and explain its significance in insulin signalling.

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..... [3]

(c) Explain how GLUT4 transporters regulate the concentration of blood glucose.

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..... [2]

(d) Liver cells may over time, lose their responsiveness to insulin, even though the concentration of insulin remains unchanged.

Suggest why this phenomenon may occur.

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..... [1]

[Total: 10]

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QUESTION 8

Two species of chimpanzees, the chimpanzee and the bonobo, are the closest living relatives of humans.

Fig. 8.1 is a diagram representing the current classification of chimpanzees and humans within the Family Hominidae.

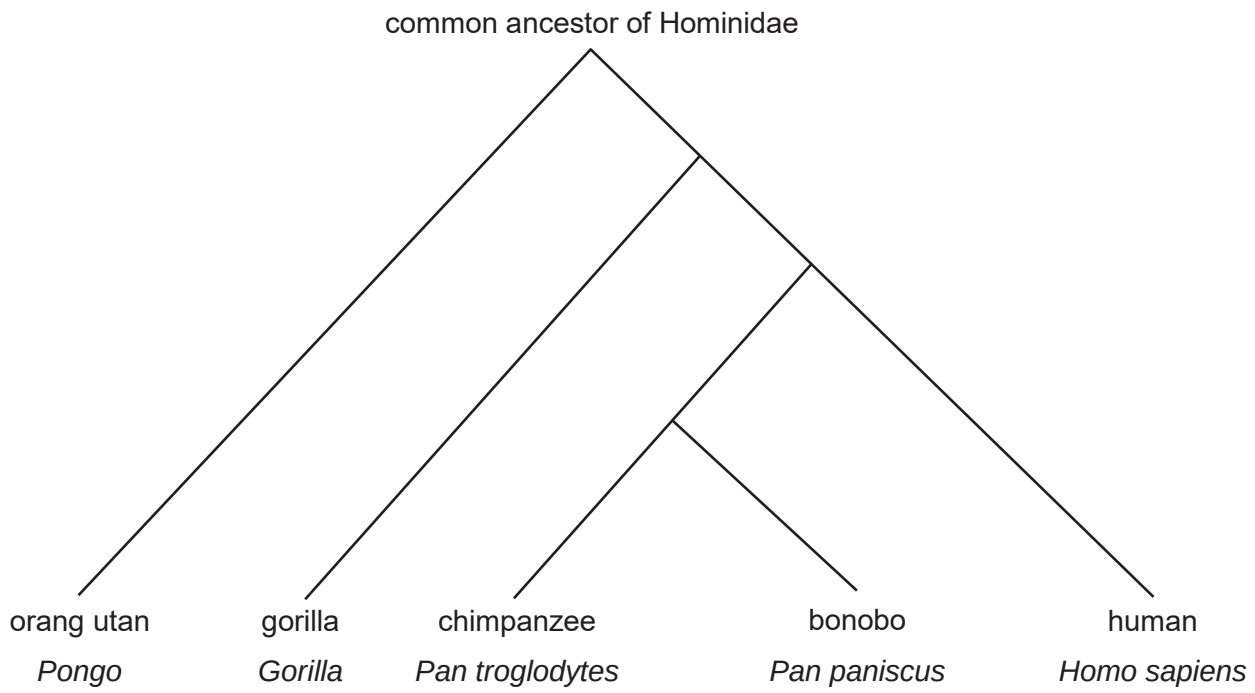

Fig. 8.1

(a) Describe how Fig. 8.1 can be interpreted as the current classification of chimpanzees and humans within the Family Hominidae.

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..... [2]

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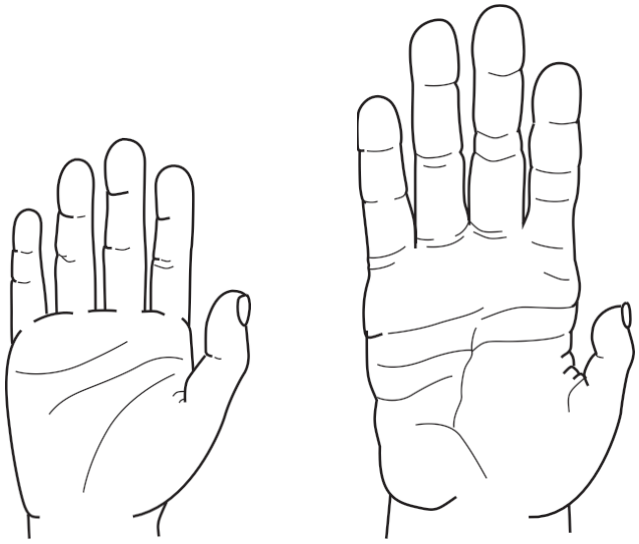
Humans and chimpanzees are currently classified within the same family. Chimpanzees were once classified separately from humans in the Family Pongidae along with gorillas and orang utans.

Fig. 8.2 shows a human hand and a chimpanzee hand.



H. sapiens *P. troglodytes*

Fig. 8.2

(b) Describe **two** differences between the two images that could have been used to classify humans and chimpanzees in separate families.

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..... [2]

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Differences between the nucleotide base sequences can be used to estimate the length of time since two species diverged from one another.

Fig. 8.3 shows the line of best fit for the differences in DNA between pairs of primate species plotted against the number of years since the two species diverged from a common ancestor.

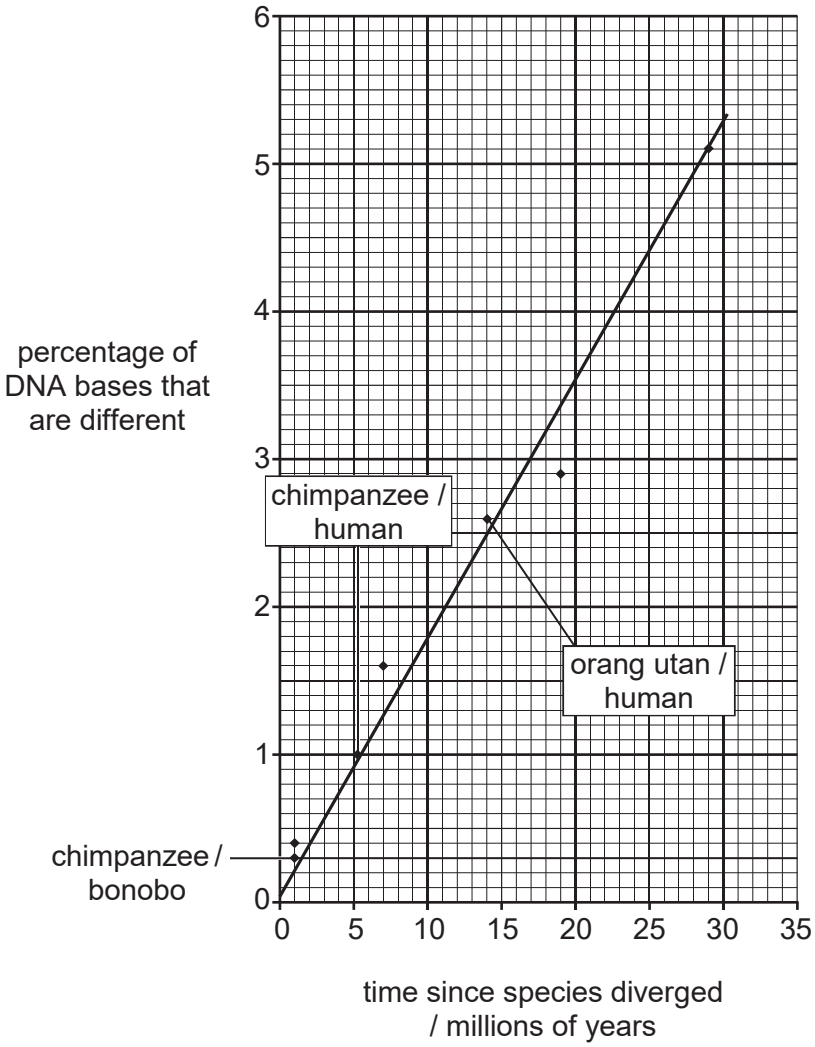

Fig. 8.3

(c) **(i)** Calculate the rate of DNA change using the data in Fig. 8.3.

answer ..... % per million years

[2]

(ii) The mutation rate in mammals can vary by as much as 20% between species.

Use Fig. 8.3 to calculate the time since the phylogeny of humans diverged from chimpanzees, and the range over which this estimate may vary.

time since divergence .....

range .....

[2]

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Some scientists have suggested that humans and chimpanzees should be reclassified as belonging to the same **genus**.

(d) Evaluate their suggestion using evidence from **Figs. 8.1 to 8.3 and** your own knowledge of the scientific basis for the classification of organisms.

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..... [6]

One type of gene is known as a homeobox gene. The base sequences of homeobox genes in humans and chimpanzees are almost identical.

(e) State a conclusion about the evolutionary relationship between humans and chimpanzees that can be drawn from this piece of evidence.

.....

..... [1]

[Total: 15]

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QUESTION 9

Plant biodiversity varies throughout the world and is dependent on many factors, particularly climate.

Fig. 9.1 shows the relationship between the number of plant genera and the mean annual rainfall in seven countries.

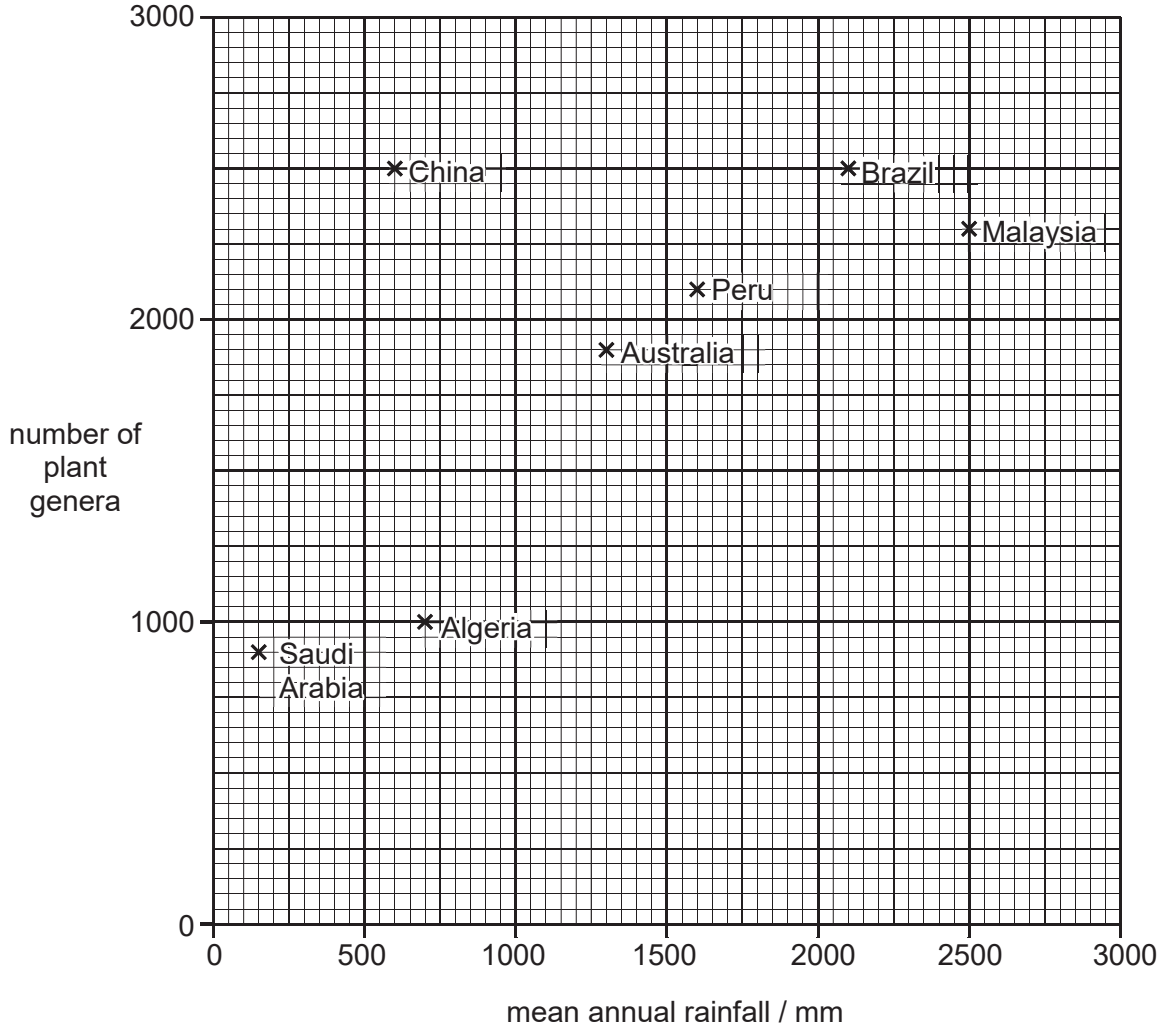

Fig. 9.1

(a) **(i)** Describe the relationship between the number of plant genera and the mean annual rainfall in these seven countries.

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..... [2]

Global warming has led to changes in rainfall in many parts of the world.

(ii) Discuss how changes in rainfall can affect plant biodiversity.

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The Millennium Seed Bank is located in the United Kingdom. So far it has successfully stored seeds from 10% of the world's wild plant species.

(b) Suggest the benefits to humans of conserving plant species.

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..... [3]

[Total: 7]

--- END OF PAPER---

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CANDIDATE NAME		**CT GROUP**	**18S7 ___**

CENTRE NUMBER					**INDEX NUMBER**				

BIOLOGY

9744/03

Paper 3 Long Structured and Free-response Questions

24 September 2019

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **name**, **CT group**, **Centre number** and **index number** in the spaces at the top of this cover page.

Section A

Answer **all** questions in the spaces provided on the Question Paper.

Section B

Answer any **one** question in the spaces provided on the Question Paper.

INFORMATION FOR CANDIDATES

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

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

You are reminded of the need for good English and clear presentation in your answers.

For Examiners' Use	
1	**/ 30**
2	**/ 8**
3	**/ 12**
4 or **5**	**/ 25**
Total	**/ 75**

This document consists of **14** printed pages.

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BOOKLET I
SECTION A

Answer **all** the questions in this section.

QUESTION 1

In bacteria, Cas9 is a nuclease enzyme that serves as a form of cellular defense. Cas9 binds to a guide RNA (gRNA) forming the Cas9-gRNA complex, which targets and cleaves bacteriophage DNA during a bacteriophage infection.

Fig 1.1 shows a summary of the natural activity of Cas9 with steps labelled **1** to **6**.

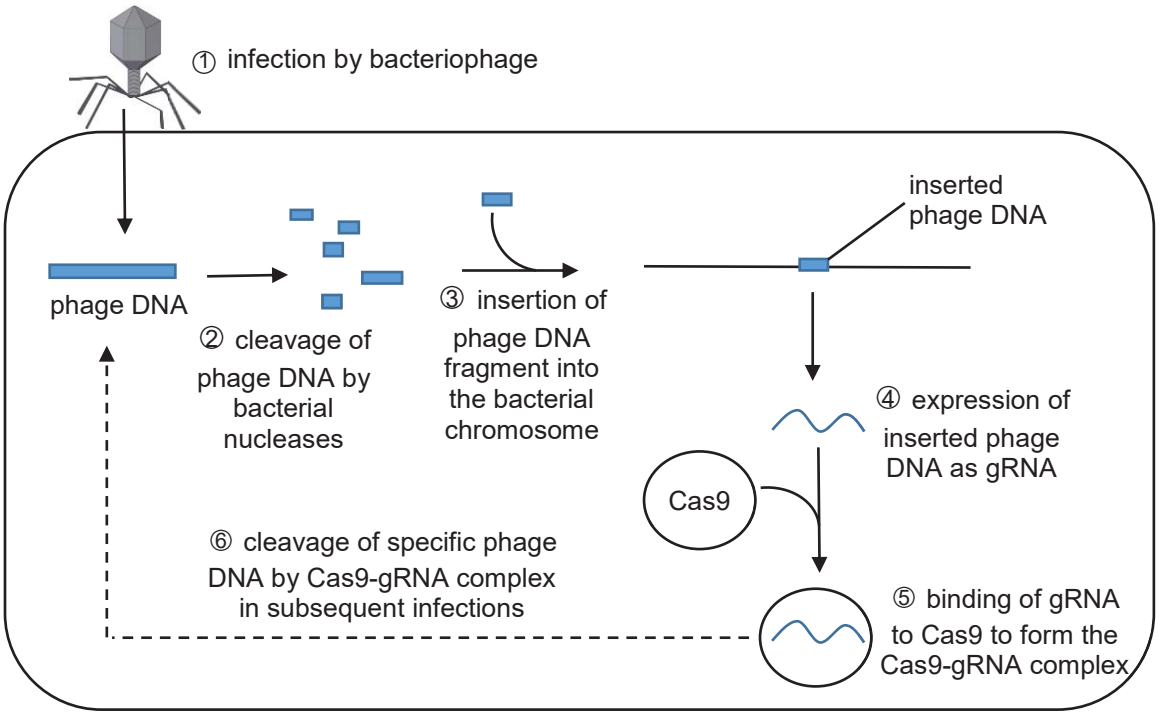

Fig. 1.1

(a) **(i)** Outline how the bacteriophage adsorbs to the host cell in step **1**.

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..... [2]

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(ii) Identify the process shown by step **4** and explain how gRNA is formed.

[4]

(iii) Suggest why Cas9 binds to gRNA in step **5** and not to phage DNA.

[2]

(iv) The *Cas9* gene is found in approximately 50% of all known bacterial sequences.

With reference to step **6**, explain how presence of the *Cas9* gene enhances the survival of the bacterial species.

[4]

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Gene editing is a new technique in genetic engineering. It involves the use of Cas9 in which DNA is deleted from the genome of a living organism.

To study the effects of Cas9, transgenic pigs can be used. Transgenic pigs have been genetically modified to contain the *GFP* gene coding for green fluorescent protein, originally sourced from jellyfish.

Cas9 is injected into pig zygotes along with gRNA that is complementary to the target *GFP* gene. Cas9 causes a deletion in the *GFP* gene in the zygotes, preventing its expression.

The toxicity and efficiency of the new technique were tested on four groups of pig zygotes. These pig zygotes were produced by *in vitro* fertilisation (IVF) using:

- ova from a female non-transgenic pig
- sperms from a male transgenic pig whose somatic (body) cells contained one copy of the *GFP* gene per cell.

The pig zygotes in three groups were injected with different concentrations of Cas9-gRNA complex **targeted at the *GFP* gene**.

The fourth group of pig zygotes (control group) was **not** injected with Cas9-gRNA complex.

(b) Explain why the *GFP* gene was chosen for testing the new technique.

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..... [2]

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Some of the zygotes in each group survived and after six days each had developed into a group of cells called a blastocyst.

The blastocysts were counted using a light microscope. A filter was then added to the microscope, so that only blastocysts expressing the green fluorescent protein showed up. These were counted and the results are summarised in Table 1.1.

Table 1.1

concentration of Cas9-gRNA complex / ng mm^{-3}	number of blastocysts seen under white light	number of blastocysts seen under filter
0 (control)	68	46
10	40	0
20	24	0
50	15	0

(c) **(i)** Calculate the percentage of zygotes in the control group that were transgenic.

Show your working.

..... % [1]

(ii) Explain whether the percentage you calculated for **(i)** is higher or lower than expected.

.....

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..... [2]

(iii) Name a statistical test that would allow you to test the significance of the difference between the percentage you calculated in **(i)** and the expected percentage.

..... [1]

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(iv) State the best concentration of Cas9-gRNA complex to use to cause a deletion in the *GFP* gene and give reasons for your choice.

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..... [3]

(d) Fig. 1.2 shows the results from a second trial of the new technique, analysed by gel electrophoresis.

- Lanes **1** to **4** show DNA from four pigs born after Cas9-gRNA complex was used to cause a deletion in a target gene coding for a cell surface protein.
- Lane **5** shows DNA from their surrogate mother.
- Lane **6** shows DNA from another normal pig for comparison.

The size of the DNA fragments is given in kilobase pairs (kbp) as shown in Fig. 1.2.

1kbp is 1000 base pairs of DNA.

The target gene measures 6kbp and codes for a cell surface protein that is essential for the porcine reproductive and respiratory syndrome virus (PRRSV) to infect cells in the pig's body.

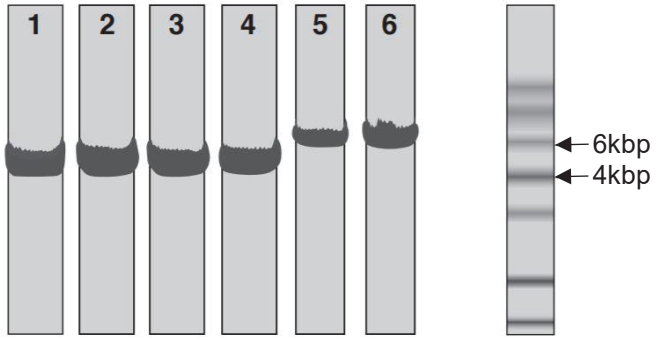

Fig. 1.2

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(i) Outline the principles of gel electrophoresis.

[3]

(ii) Explain what Fig. 1.2 indicates about the success of the new technique in causing a deletion in a gene in pigs so that they show resistance to PRRSV.

[4]

(e) Discuss the ethical implications of genetically editing pig zygotes for experiments.

[2]

[Total: 30]

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QUESTION 2

A global strategy to tackle malaria involves the rapid diagnostic testing (RDT) of individuals who may have malaria. This involves testing human blood samples for the presence of proteins specific to *Plasmodium*. RDT test sticks make use of monoclonal antibodies (mAbs).

mAbs are antibodies that are all identical to each other. mAbs are produced *in vitro* by fusing a plasma cell with a cancer cell to produce a hybridoma, which divides repeatedly to form many genetically identical cells that all produce the same antibodies.

Table 2.1 contains information about two RDT test sticks.

Table 2.1

test stick	*Plasmodium* protein tested for	species of *Plasmodium* that produce the protein
1	pLDH (parasite lactate dehydrogenase)	*P. vivax* *P. falciparum* *P. ovale* *P. malariae*
2	HRP-2 (histidine-rich protein 2)	*P. falciparum* only

Some details of the design of these RDT test sticks are shown in Fig. 2.1.

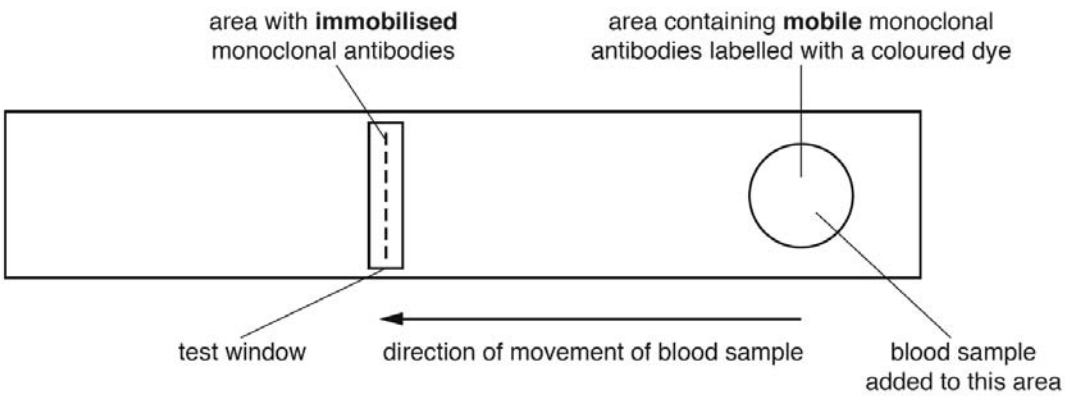

Fig. 2.1

The **immobilised** monoclonal antibodies in the test window are not visible.

If the blood sample contains a *Plasmodium* protein that can be detected by the RDT test stick:

- the **mobile** monoclonal antibodies bind to one part of the protein
- the **immobilised** monoclonal antibodies bind to another part of the protein
- a coloured line in the test window indicates a positive result for the protein.

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(a) **(i)** With reference to Table 2.1 and Fig. 2.1, explain why test stick 1 and test stick 2 will contain **different** mobile monoclonal antibodies.

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..... [2]

Two blood samples were removed from a person. One sample was added to test stick 1 and the other sample was added to test stick 2.

(ii) With reference to Table 2.1 and Fig. 2.1, explain what can be diagnosed for this person from a **positive** result for test stick 1 and a **negative** result for test stick 2.

.....

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.....

..... [2]

(b) Another team of researchers isolated particular *Plasmodium* proteins and tested these antigens' potential as vaccine targets. They introduced one of the antigens to human liver cells growing in a dish, then exposed the cells to rabbit antibodies that recognize and block the protein's activity.

Outline the process during B cell development that allows our immune system to produce antibodies that recognise a range of *Plasmodium* proteins.

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..... [4]

[Total: 8]

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QUESTION 3

(a) Grass crops such as maize, sorghum and sugarcane are C4 plants. They are common grass crops of tropical regions. They are termed 'C4' because the first product of photosynthesis is a four carbon compound. The first carbon dioxide acceptor is phosphoenolpyruvate (PEP).

Oats and wheat, commonly grown in temperate regions, are C3 plants. Most plants are C3 plants. They are termed 'C3' because the first product of photosynthesis is a three carbon compound.

The C4 pathway for fixing carbon dioxide was worked out in 1966 by Hatch and Slack. Some of the results from their investigation were recorded in Table 3.1. All rates were measured under high light intensities and at 30°C.

Table 3.1

grass crop	rate of fixation of carbon dioxide / arbitrary units	rate of activity of rubisco / arbitrary units	rate of activity of PEP carboxylase / arbitrary units
maize	3.5	0.62	17.50
sorghum	3.1	0.35	15.80
sugarcane	2.9	0.30	18.50
oats	1.6	4.50	0.33
wheat	1.7	4.70	0.29

(i) State the role of rubisco in the Calvin cycle.

.....

..... [1]

(ii) Compare the rates of fixation of carbon dioxide in C3 and C4 grasses.

.....

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.....

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..... [2]

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(iii) Suggest the advantages of PEP carboxylase in C4 plants.

.....

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.....

..... [2]

(b) Rainforests are carbon sinks that play a critical role in mitigating climate change.

Explain how forests can serve as carbon sinks.

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.....

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..... [3]

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(c) The impact of climate change is a major threat not only for mankind but also for life on earth as a whole.

Fig. 3.1 shows the distribution of the tundra biome and Fig. 3.2 the number of polar bears living in this biome.

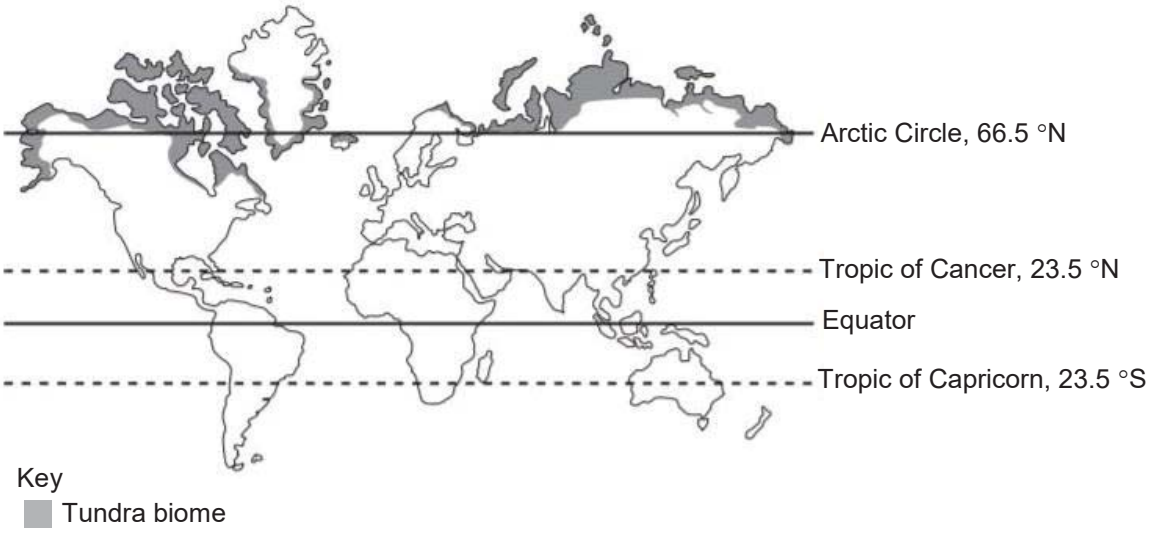

Fig. 3.1

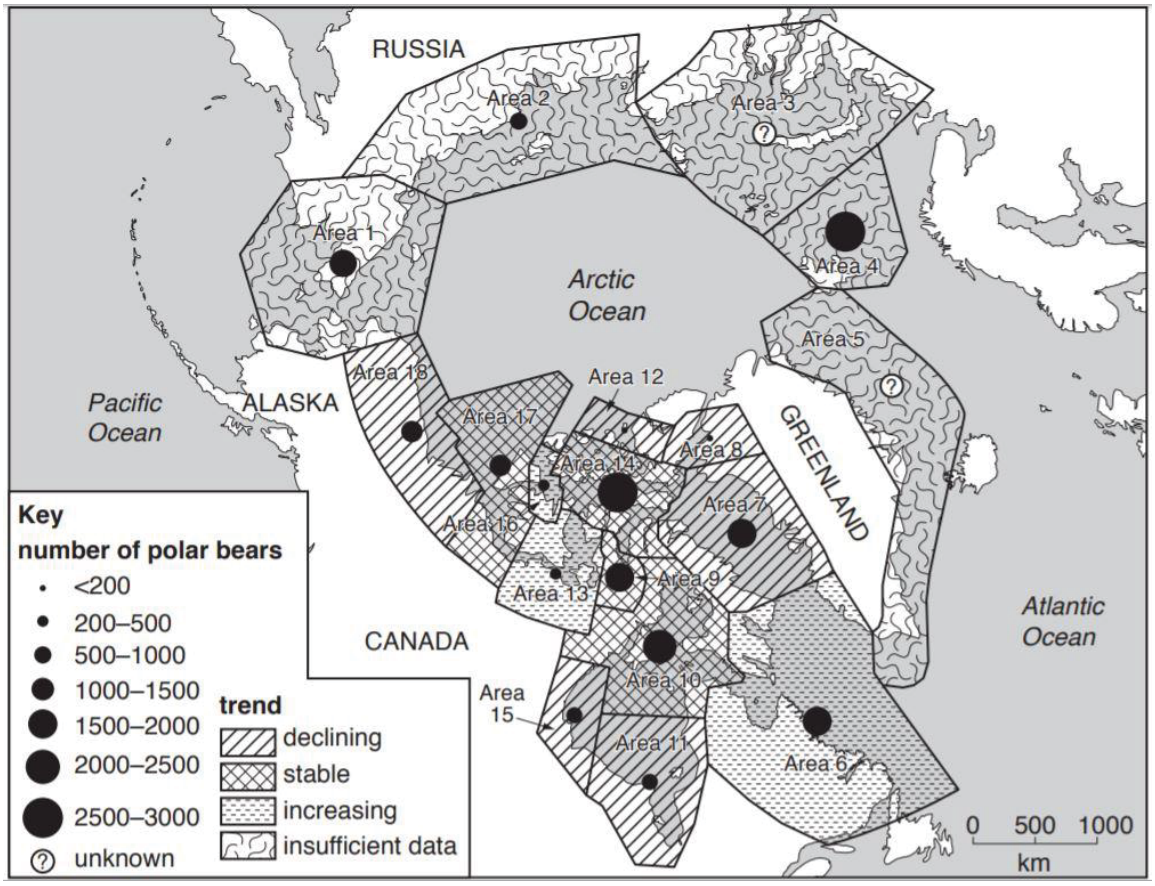

Fig. 3.2

With reference to Figs. 3.1 and 3.2, describe and explain the evidence which suggest that polar bears are at risk of extinction as a result of climate change.

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..... [4]

[Total: 12]

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SECTION B

Answer **one** question in this section.

Write your answers on the lined paper provided at the end of this Question Paper.

Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in parts **(a)** and **(b)**, as indicated in the question.

QUESTION 4

(a) A scientific theory is a way of interpreting the natural world. The cell theory, which is a single unified theory of cellular organisation, is an example where scientists have looked for trends and exceptions.

Using knowledge of the cell theory, describe the universal features of cells and suggest ways to test and challenge the cell theory. [15]

(b) Outline how genetic exchange in prokaryotes bring about variation and discuss the possible fate of the transferred DNA. [10]

[Total: 25]

QUESTION 5

(a) In the 1800s, Gregor Mendel formulated the Laws of Segregation and Independent Assortment based on his observations on pea plants.

Explain how the behaviour of chromosomes during meiosis supports Mendel's laws and suggest why it would be more difficult to investigate the patterns of inheritance in man than in peas. [15]

(b) Cell cycle checkpoints keep meiotic divisions faithful and accurate. Despite these checkpoints, errors in meiosis can still occur.

Outline the possible errors in meiosis and their impact on the evolutionary outcomes of a species. [10]

[Total: 25]

--- END OF PAPER---

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HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**18S7 __**
CENTRE NUMBER		**INDEX NUMBER**	

BIOLOGY 9744/04

Paper 4 Practical **3 September 2019**

No additional materials are required. **2 hours 30 minutes**

INSTRUCTIONS TO CANDIDATES

There are **three** question booklets (**I** to **III**) to this paper. Write your **name**, **CT group, Centre number** and **index number** in the spaces provided at the top of this cover page.

Answer **all** questions in the spaces provided on the question paper.

Shift
Laboratory

INFORMATION FOR CANDIDATES

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

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

You are reminded of the need for good English and clear presentation in your answers.

For Examiners' Use	
1	/ 23
2	/ 17
3	/ 15
Total	/ 55

This document consists of **18** printed pages.

QUESTION 1

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You are advised to read the whole of this question before starting the practical work, as you will need to make decisions about how to obtain high quality results using the apparatus and materials provided.

Browning in fruits, such as bananas, is the result of oxidation of colourless substances to a coloured substance. Fruits possess many polyphenol oxidase enzymes that catalyse the sequence of reactions involved. In banana, one of these enzymes is dopa oxidase.

The sequence of reactions is as follows:

$$\text{L-dopa} \xrightarrow{\text{dopa oxidase}} \text{dopaquinone} \xrightarrow{\text{spontaneous reaction}} \text{dopachrome}$$

You will investigate:

- the effect of a change in concentration of L-dopa on the **rate of the reaction** catalysed by dopa oxidase
- the effect of substance **X** on the **rate of the reaction** catalysed by dopa oxidase.

You are provided with:

- one piece of banana
- 50 mmol dm^{-3} L-dopa solution, in a vial labelled **L**
- distilled water, in a vial labelled **W**
- pH7 buffer, in a vial labelled **pH7 buffer**
- substance **X**, in a vial labelled **X**

(a) Sketch a graph in the space below to show the relationship between L-dopa concentration and rate of reaction catalysed by dopa oxidase.

On the same axes, sketch another graph to show the effect of substance **X** on the rate of reaction if substance **X** is a competitive inhibitor.

[2]

Proceed as follows.

1 You are required to make up a final volume of 20 cm^3 of five different concentrations (10, 20, 30, 40, 50 mmol dm^{-3}) of L-dopa solutions.

(b) Complete Table 1.1, to show how you will make up the L-dopa solutions using the 50 mmol dm^{-3} L-dopa solution, **L**, and distilled water, **W**.

Table 1.1

final concentration of L-dopa / mmol dm^{-3}	volume of **L** / cm^3	volume of **W** / cm^3	total volume / cm^3

[2]

2 Using the scalpel and white tile, cut 2 mm of the piece of banana provided from both ends to remove the tissues that were exposed to air. Discard these tissues. Remove the banana skin. Chop the remaining banana into small pieces on a white tile.

3 Place the chopped banana pieces into a mortar and add in 10 cm^3 of distilled water. Use the pestle to homogenise by crushing and grinding the banana to obtain a mash. Add in another 30 cm^3 of distilled water and stir well. Using the sieve, one layer of muslin cloth and a plastic vial, filter the banana mash. This will be the enzyme extract that contains dopa oxidase. Label the vial as **E**.

4 Label a test-tube **C**. The contents of this test-tube will be used as a colour comparator.

5 To test-tube **C**, add 2 cm^3 of 50 mmol dm^{-3} L-dopa solution and 1 cm^3 of **pH7** buffer. Do **not** add any **E** at this stage.

6 Label five test-tubes **P1** to **P5** and label another five test-tubes **X1** to **X5**.

7 Add 1 cm^3 of **pH7** buffer solution to all ten test-tubes (**P1** to **P5** and **X1** to **X5**).

8 Add 1 cm^3 of distilled water to test-tubes **P1** to **P5** and to test-tube **C**.

9 Add 1 cm^3 of the solution of substance **X** to test-tubes **X1** to **X5**.

10 Add 2 cm^3 of the 10 mmol dm^{-3} solution of L-dopa to test-tube **P1** and add 2 cm^3 of the 10 mmol dm^{-3} solution of L-dopa to test-tube **X1**.

11 Add 2 cm^3 of the 20 mmol dm^{-3} solution of L-dopa to test-tube **P2** and add 2 cm^3 of the 20 mmol dm^{-3} solution of L-dopa to test-tube **X2**.

12 Repeat step **11** with the remaining test-tubes, **P3** to **P5** and **X3** to **X5**, so that they have increasing concentrations of L-dopa (30 - 50 mmol dm^{-3}).

13 Add 1 cm^3 of the **E** to test-tube **C**. Do **not** shake or stir the test-tube. Leave the test-tube for **two minutes**.

14 Add 1 cm^3 of the **E** to each of the test-tubes **P5** and **X5**. Observe the lower half of each test-tube and record the time taken to reach the colour shown by the colour comparator (test-tube **C**). If this end point has not been reached after 10 minutes, record the time taken as 600 seconds.

15 Record your results in the space provided for **(c)(i)** on page 5.

16 Repeat step 14 for the remaining pairs of test-tubes, **P4** and **X4**, **P3** and **X3**, **P2** and **X2**, **P1** and **X1**.

17 Record your results in the space provided for **(c)(i)** on page 5.

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(c) **(i)** Calculate the rate of reaction for each of the reaction mixtures.

Calculate the rate as 1000/*t* where *t* = the time taken to reach the colour of the colour comparator (test-tube **C**).

Record all your results and calculations in a suitable form in the space below.

[6]

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(ii) Plot a graph to show the rate of reaction catalysed by dopa oxidase with and without substance **X** on the grid provided.

[5]

(d) It is suggested that substance **X** is a competitive inhibitor of dopa oxidase.

Discuss what the results from **(c)(ii)** suggest about the relationship predicted in part **(a)**.

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..... [3]

(e) Discuss **two** limitations of this investigation and the ways in which the procedure could be changed to improve the quality of the results.

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..... [4]

(f) In an actual experiment conducted, it was found that the V_{max} of the reaction is 50 s^{-1}.

Using your graph in **(c)(ii)**, determine the K_m for the reaction without the competitive inhibitor **X**.

K_m = ……..

[1]

[Total: 23]

QUESTION 2

Guard cells are part of the leaf epidermis and they flank the stomatal pores. They contain chloroplasts allowing for the process of photosynthesis to occur.

The opening and closing of stomata involves the movement of potassium ions into and out of guard cells. Opening and closing of stomata is influenced by a number of environmental factors, for example light and temperature.

A student investigated the effect of potassium chloride (KC*l*) on the opening of stomata.

The student was provided with:

- 500 cm^3 of 250 mmol dm^{-3} KC*l* solution
- freshly picked leaves from a plant that had been kept in the dark and a high concentration of carbon dioxide for an hour. This ensured that all the stomata were closed.

Strips of leaf tissue were obtained by cutting a leaf into sections as shown in Fig. 2.1.

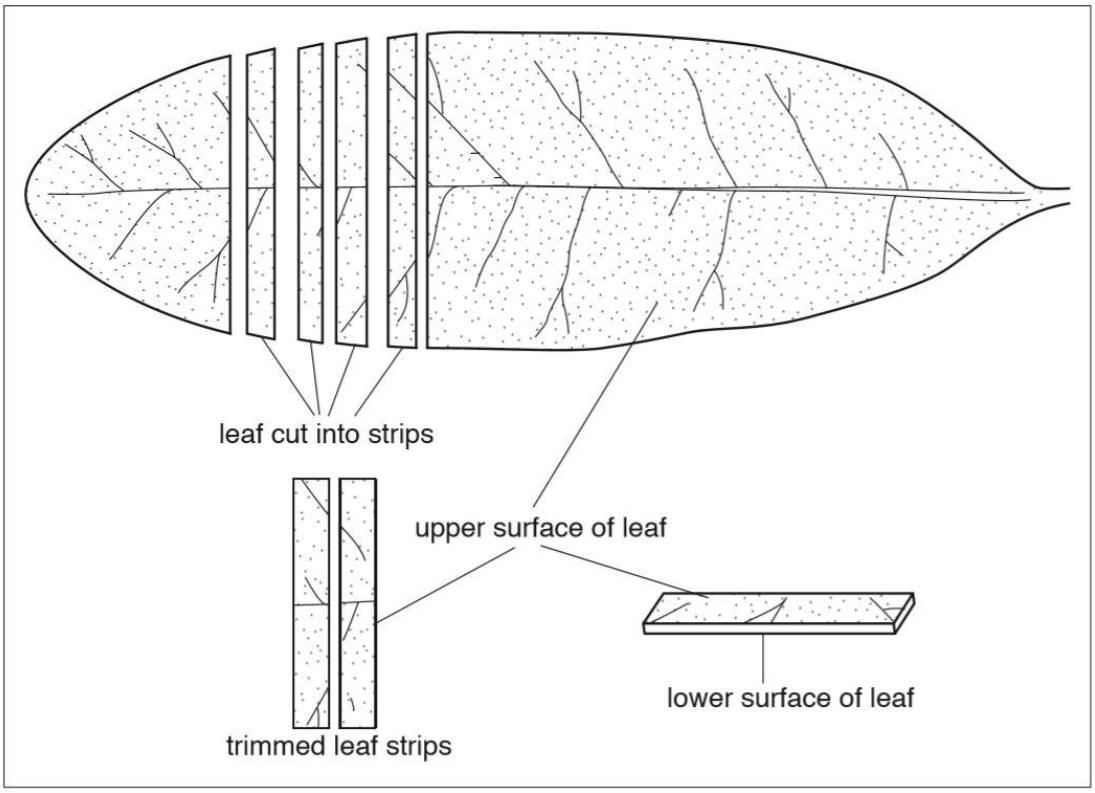

Fig. 2.1

The student floated three strips of leaf tissue in each of a range of buffered potassium chloride solutions for 2 hours and then recorded the number of open stomata.

(a) The student used the 250 mmol dm^{-3} KC*l* solution to make 100 cm^3 of four other concentrations by reducing the concentration by 50 mmol dm^{-3} each time.

Describe a procedure that the student could use to prepare these four concentrations.

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..... [3]

(b) **(i)** Suggest a hypothesis that the student could test about the effect of KC*l* on the opening and closing of stomata.

.....

.....

..... [1]

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(ii) Describe a method that the student could use to investigate the effect of different concentrations of KC*l* on the opening of stomata.

The description of your method should be detailed enough for another person to follow and should **not** repeat the details from **(a)** of how to dilute the 250 mmol dm^{-3} solution of KC*l*.

[5]

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(c) The student also tested the hypothesis:

The more light the wider the stomata open.

- Eight leaves from young plants that had been kept in the dark for 24 hours were covered by metal foil.
- A fluorescent lamp of fixed intensity was placed 10 cm from the plant. The metal foil was removed from the leaves.
- Two leaves were removed at the start of the experiment and three epidermal strips were made from each leaf. An epidermal strip is made by peeling the epidermis from a leaf as a single layer.
- The diameter of the stomatal aperture of five of the stomata with the widest aperture on each strip was measured.
- At one hour intervals two more leaves were removed and the same procedure repeated.

Fig. 2.2 shows stomata at different stages of opening.

Fig. 2.2

(i) Outline how the student could find the actual diameter of a stomatal aperture.

.....

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.....

.....

..... [2]

Table 2.1 shows the results of the student's experiment.

Table 2.1

time / min	diameter of stomatal aperture / μm														
0 (control)	0.5	0.1	0.2	0.3	0.4	0.1	0.5	0.2	0.3	0.3	0.1	0.2	0.2	0.2	0.4
60	0.9	1.1	1.0	1.3	1.2	1.8	1.5	0.8	0.2	1.3	1.1	0.8	1.0	1.9	0.9
120	1.9	2.4	2.6	2.6	2.5	2.2	2.8	2.4	2.4	3.9	2.6	2.3	2.5	2.2	2.7
180	4.1	4.8	4.2	4.0	5.7	4.7	3.9	4.1	5.5	4.5	4.3	4.0	3.1	4.1	4.3

(ii) On Table 2.1, draw circles around **two** values that are anomalous. [1]

(iii) The student calculated the mean diameter of the stomatal apertures and the rate at which the diameter of the stomatal apertures increased.

Table 2.2 shows some of these calculations.

Table 2.2

time / min	mean diameter of stomatal apertures / μm	rate of increase of diameter of stomatal apertures / μm min^{-1}
0	0.3	
60	1.2	0.015
120	2.5	0.022
180	4.6	

Complete Table 2.2 by calculating the rate of increase of the diameter of the stomatal apertures between 120 minutes and 180 minutes.

Space for working

[1]

(d) In a further investigation, the student used a colourimeter to find out the chlorophyll content of four different types of leaves as he hypothesised that chlorophyll content is another significant factor which affects the rate of photosynthesis.

Table 2.3 shows the students' results from the colourimeter measurements made on 10 samples of each of the four types of leaf.

Table 2.3

type of leaf	mean absorbance ± *s*
ivy	0.28 ± 0.08
geranium	0.32 ± 0.1
spiderwort	0.43 ± 0.18
sorghum	0.39 ± 0.21

The students decided to use the *t*-test to test the hypothesis that:

The difference in the chlorophyll concentration between spiderwort and each of the other plants is significant.

The formula for the *t*-test is shown in Fig. 2.3.

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}} \qquad v = n_1 + n_2 - 2$$

v = degrees of freedom
s = standard deviation
n = sample size
$\bar{x}$ = mean

Fig. 2.3

Comment on the use of the *t*-test by:

(i) stating how many values of *t* the student should calculate **and** explaining your answer

.....

.....

.....

..... [2]

(ii) explaining how the student would find out if the results of his *t*-tests were significant.

.....

.....

.....

..... [2]

[Total: 17]

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QUESTION 3

M1 is a slide of a stained transverse section through a plant leaf.

You are not expected to be familiar with this specimen.

Use a sharp pencil for drawing.

(a)(i) Draw a large plan diagram of the section of the leaf (midrib) shown by the shaded area in Fig. 3.1.

Fig. 3.1

You are expected to draw the correct shape and proportions of the different tissues.

[4]

(ii) Observe the upper epidermis of the leaf on **M1**. The upper epidermis has no guard cells.

Select **one** group of two adjacent, touching cells from the upper epidermis and one adjacent, touching cell from the palisade tissue below.

Each cell must touch at least one of the other cells.

Make a large drawing of this group of **three** cells.

Use **one** ruled label line and the label **P** to identify a structure that produces ATP.

[3]

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(b) Fig. 3.2 is a photomicrograph of a stained transverse section of part of a leaf from a different species. A grid has been placed over the photomicrograph to help you answer the question. Each square is 1 cm^2.

You are not expected to be familiar with this specimen.

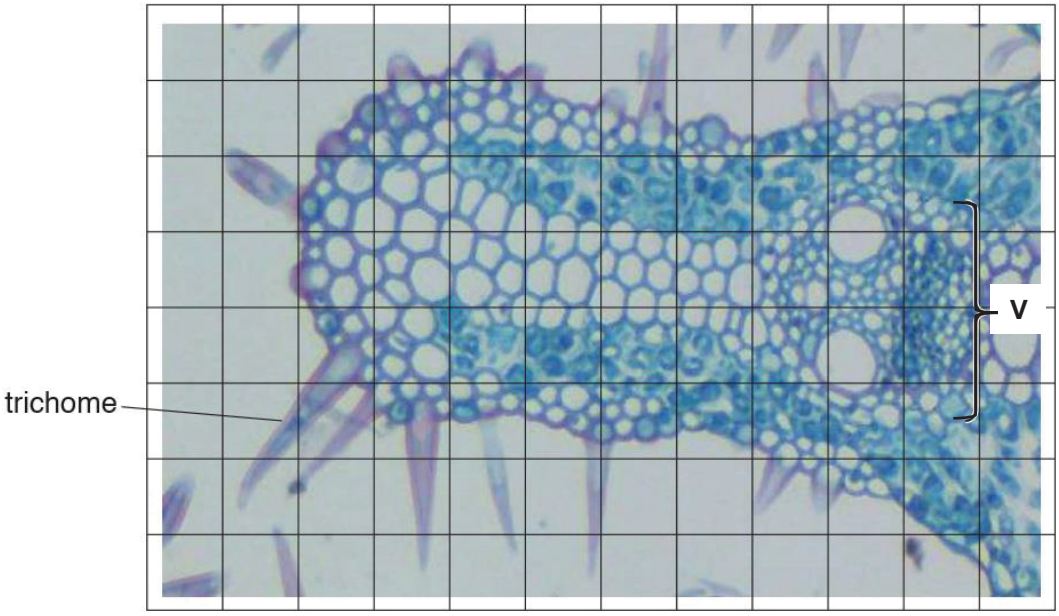

Fig. 3.2

(b)(i) Describe how you will use the grid to find the total area of the part of the leaf shown in Fig. 3.2. You do **not** need to include the trichomes.

.....

.....

..... [1]

(ii) Use the procedure you have described in **(b)(i)** to find:

the total area of the part of the leaf shown in Fig. 3.2 …….. cm^2

the area of the leaf section occupied by the vascular bundle, labelled **V**. …… cm^2

[2]

(iii) Calculate the percentage of the part of the leaf shown in Fig. 3.2 that is occupied by the vascular bundle, labelled **V**.

Show all the steps of your working.

..... % [2]

(iv) Suggest how you could modify the procedure you have used in **(b)(ii)** to give a more accurate estimate of the area of the leaf.

.....

..... [1]

(c) Observe the leaf on **M1** and the part of the leaf shown in Fig. 3.2 and identify the differences between them.

Record the observable differences in Table 3.1.

Table 3.1

feature	**M1**	Fig. 3.2

[2]

[Total:15]

--- END OF PAPER ---

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2019 JC2 9744 H2 BIOLOGY
PRELIMINARY EXAMINATIONS PAPER 1 MARK SCHEME

QUESTION	CORRECT ANSWER
1	C
2	A
3	B
4	B
5	D
6	A
7	B
8	B
9	A
10	B
11	D
12	D
13	D
14	C
15	A

QUESTION	CORRECT ANSWER
16	A
17	A
18	B
19	D
20	B
21	A
22	C
23	C
24	C
25	C
26	C
27	A
28	B
29	C
30	D

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QUESTION 1

(a) Describe the different levels of protein structure of CAP. [4]

- ref. to each polypeptide having sequence of 209 amino acids joined by peptide bonds
- ref. to α helices / β pleated sheets stabilised by hydrogen bonds
- ref. to specific 3D conformation by R group interactions
- ref. to two polypeptide chains

(b) **(i)** Describe how binding of cAMP to CAP activates transcription. [3]

- ref. to rotation of the helices in DBD
- ref. to helices in DBD moving closer
- ref. to change in specific 3D conformation of DBD
- ref. to correct orientation of the helices to interact with DNA
- ref. to facilitation of binding of RNA polymerase

(b) **(ii)** Identify the bond formed between CAP and DNA. [1]

ionic bond / hydrogen bond / hydrophobic interaction

(c) With reference to Fig. 1.1 and Fig. 1.2, suggest why CAP is capable of undergoing allosteric regulation. [2]

- CAP has two polypeptides
- ref. to CBD as the allosteric site
- ref. to CAP alternates between the active and inactive forms
- binding of cAMP to CBD increases the affinity of DBD to the DNA

[Total: 10]

QUESTION 2

(a) Compare the features of a cell derived from the zygote with that from the inner cell mass of a blastocyst. [3]

- ref. to both cells are capable of long term self-renewal / mitosis
- ref. to both cells are unspecialized
- ref. to both cells can be differentiated
- ref. to level of the different developmental potential of the cells
- ref. to the different levels of DNA methylation of the cells

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(b) Explain how the changes to DNA methylation from **R** to **S** bring about differentiation. [4]

- DNA methylation is decreased from R to S
- DNA is not attracted to histones/ DNA will not be tightly packed
- Accessible to transcription machinery / formation of transcription initiation complex
- expression of genes necessary for differentiation

(c) Control of the expression of the telomerase gene is crucial at different developmental stages of the mouse.

State and explain if the telomerase gene in cells is likely to be methylated from **T** to an adult mouse. [2]

- No because telomerase is required even in adult stem cell /
- Yes because telomerase is inactivated in terminally differentiated cells

[Total: 9]

QUESTION 3

(a) **(i)** Explain why this cell was undergoing mitosis. [2]

- Each chromosome is made up of two chromatids
- Ref to chromosomes not arranged in homologous pairs

(ii) Identify the stage of mitosis shown [1]

Prophase / metaphase

(b) Explain why the scientist was able to arrange the chromosomes in homologous pair as shown in Fig 3.2. [3]

- Pairs of homologous chromosomes are structurally similar
- ref. to similar size / shape
- ref. to similar centromere position

(c) Suggest ways the structure of the chromosome could differ along its length to result in the stain binding more in some areas. [2]

- ref. to differences in base sequences
- ref. to differences in histone proteins / interaction with histone proteins

(d)(i) Name the process of asexual reproduction shown. [1]

Binary fission

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(ii) Outline how the process of asexual reproduction in bacteria results in genetically identical daughter cells. [3]

- Bacteria chromosome is attached to the plasma membrane before DNA replication
- Semi-conservative DNA replication of the bacterial chromosome occurs
- ref to septum extends as the cell membrane invaginates / grows inwards and peptidoglycan / cell wall materials are added to it, dividing the bacterial cell into two daughter cells, each with one chromosome

[Total: 12]

QUESTION 4

(a)(i) Describe how smoking causes lung cancer. [2]

- Ref to polycyclic aromatic hydrocarbons
- forming adducts and damaging DNA
- causes mutations to cancer critical genes

(ii) Explain why lung cancer is described as a non-infectious disease. [2]

- ref to cancer being a genetic disease/ mutations to DNA
- ref to not caused by a pathogen
- ref caused by lifestyle choice
- ref cannot be passed onto another person / not transmissible / AW
- abnormal condition (affecting an organism) / condition that reduces the effectiveness of the functions of the organism / AW

(b)(i) Based on the information provided in Fig 4.1, explain if caspases 8 should be considered a proto-oncogene or a tumour suppressor gene. [3]

- tumour suppressor gene
- activates caspase 3 which cleaves PARP
- thus it is part of pathway resulting in apoptosis / prevent uncontrolled cell division

(ii) Explain why a mutation to *caspase 8* gene is insufficient to cause cancer in smokers. [4]

- Ref to multi-step model
- Accumulation of mutation/ same lineage of cell
- Ref to loss of single copy insufficient for disease

- Ref to gain of function mutation to proto oncogene to form oncogene
- ref to angiogenesis
- ref to metastasis
- ref to telomerase

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[Total: 11]

QUESTION 5

(a)(i) Define what is meant by a true-breeding mouse in this context. [1]

ref. to homozygous / have the same alleles, at both gene loci

(ii) Given that the genes for ear and tail types are located 6 cM apart on chromosome 3, complete Table 5.1 with the expected numbers for each of the following phenotypes from the test cross. [1]

Table 5.1

phenotypes	**expected numbers**
normal ears, flaky tail	47
droopy ears, normal tail	47
normal ears, normal tail	3
droopy ears, flaky tail	3

(b)(i) Using the symbols provided, draw a genetic diagram to clearly show the results of the test cross. [4]

F1 test cross normal ears, normal tail x droopy ears, flaky tail

$\frac{\mathbf{D\ f}}{\mathbf{d\ F}}$ x $\frac{\mathbf{d\ f}}{\mathbf{d\ f}}$

Gametes D f, d F, D F, d f d f

Random fertilization

		Female gametes			
		D f	d F	D F	d f
Male gametes	d f	$\frac{\mathbf{D\ f}}{\mathbf{d\ f}}$	$\frac{\mathbf{d\ F}}{\mathbf{d\ f}}$	$\frac{\mathbf{D\ F}}{\mathbf{d\ f}}$	$\frac{\mathbf{d\ f}}{\mathbf{d\ f}}$

offspring phenotypes	normal ears, flaky tail	droopy ears, normal tail	normal ears, normal tail	droopy ears, flaky tail
	parental		recombinants	

(ii) Explain your results to **(b)(i)**. [2]

- ref. to incomplete linkage
- ref. to crossing over between the 2 genes, resulting in majority of offspring with parental phenotypes and minority with recombinant phenotypes

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(c) Explain the conclusion that may be drawn from the calculated χ^2 value. [3]

- ref. to χ^2_{calc} smaller than χ^2_{crit}
- ref. to deviation between observed and expected results not significant
- ref. to results support conclusion that both genes located 6 cM apart / incompletely linked on chromosome 3

(d) Suggest why the researcher's claim is valid. [2]

- ref. to complete linkage

- ref. to crossing over between the 2 genes being rare

[Total: 13]

QUESTION 6

(a) Identify structures **X** and **Y**. In each case, relate one visible feature that allows the structure to perform its functions. [4]

- X: mitochondrion
- Highly folded inner membrane / cristae for embedding electron carriers

- Y: Golgi apparatus
- Stack of flattened, membrane-bound sacs / cisternae for modification / packaging of ER products / proteins

(b) Explain how the results from Table 6.1 support the chemiosmotic theory. [4]

- Ref to appropriate quote
- Aerobic respiration occurs allowing electron transfer coupled to generation of proton gradient for ATP synthesis in dish 1 and not in dish 2

- Generation of proton gradient in the intermembrane space
- Diffusion of protons from intermembrane space to matrix coupled to ATP synthesis in dish 4 and not in dish 3

(c) (i) Discuss the consequences to a mitochondrion if the water potential of the liquid in the dishes is less negative than the water potential of the mitochondrial matrix. [2]

- Water enters mitochondrial matrix by osmosis down the water potential gradient
- Membrane ruptures resulting in bursting of mitochondrion

(ii) Explain the role of the mitochondrial matrix in aerobic respiration. [3]

- Site of link reaction / Krebs cycle
- Link reaction: oxidative decarboxylation forming acetyl-coA / NADH
- Krebs cycle: completely oxidised glucose / AW

[Total: 13]

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QUESTION 7

(a) Outline the process of insulin-receptor interaction. [4]

- Ref to insulin binding to complementary site of RTK / signal reception
- Ref to dimerisation of two subunits of RTK / conformational change of RTK
- Ref to activation of tyrosine kinase
- Ref to autophosphorylation / cross phosphorylation of tyrosine residues by tyrosine kinase
- Ref to activation of RTK

(b) Describe the nature of IP_3 and explain its significance in insulin signalling. [3]

- Nature: Ref to small non-protein molecule / second messenger / relay molecule
- Significance: Ref to relay molecule that activates downstream protein Akt
- Significance: Ref to signal amplification / large scale response / fast response

(c) Explain how GLUT4 transporters regulate the concentration of blood glucose. [2]

- Ref to carrier function of GLUT4 to transport glucose from outside of cell to inside of cell
- ref to decrease of concentration of blood glucose

(d) Liver cells may over time, lose their responsiveness to insulin, even though the concentration of insulin remains unchanged. Suggest why this phenomenon may occur. [1]

- Ref to mutation in the gene coding for insulin receptor / GLUT4 transporters / PI 3- kinase / Akt
- Ref to, change in the shape / loss of function / reduction in number, of insulin receptor / GLUT4 transporters / PI 3- kinase / Akt as cell / tissue ages

[Total: 10]

QUESTION 8

(a) Describe how Fig. 8.1 can be interpreted as the current classification of chimpanzees and humans within the Family Hominidae. [2]

- Ref to idea of phylogeny, to show evolutionary relationships / AW
- Share a recent common ancestor

(b) Describe **two** differences between the two images that could have been used to classify humans and chimpanzees in separate families. [2]

Chimpanzee has (relatively)

- smaller / shorter / thinner , thumb
- longer / narrower, palm
- thicker / longer fingers
- wider wrists

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(c) (i) Calculate the rate of DNA change using the data in Fig. 8.3. [2]

- correct working shown
- answer given to 2 s.f. to 3 s.f.

(ii) The mutation rate in mammals can vary by as much as 20% between species.

Use **Fig. 9.3** to calculate the time since the phylogeny of humans diverged from chimpanzees, and the range over which this estimate may vary. [2]

time since divergence
5.0 – 5.5 million years

range
4.0 - 4.4 to 6.0 - 6.6 (million years)

(d) Evaluate their suggestion using evidence from **Figs. 8.1 to 8.3 and** your own knowledge of the scientific basis for the classification of organisms. [6]

Valid (V) because
the indicative point may be subsumed within reference to a supporting figure
- recent divergence, with relevant comparative figures to support from Fig 8.3
- ref to similarities in hand anatomy, as seen in Fig. 8.2
- occupy same branch on phylogenetic tree / AW, as seen in Fig 8.1

Invalid (I) because
the indicative point may be subsumed within reference to a supporting figure
- divergence less recent than chimpanzee and bonobo, with relevant comparative figures to support from Fig 8.3 / as seen in Fig. 8.1
- different anatomy, as seen in Fig 8.2

Principles of classification
- ref to phylogeny is basis of classification
- species that, diverged recently / share similar base sequence, occupy same group
- recognition that molecular sequences/ data is more accurate than comparative anatomy

(e) State a conclusion about the evolutionary relationship between humans and chimpanzees that can be drawn from this piece of evidence. [1]

- share a recent common ancestor
- close, evolutionary relationship

[Total: 15]

QUESTION 9

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(a)(i) Describe the relationship between the number of plant genera and the mean annual rainfall in these seven countries. [2]

- Ref to overall trend (i.e. positive correlation) / number of plant genera increases as mean annual rainfall increases
- Ref to paired figures (i.e. genera number and mean annual rainfall in 2 named countries showing the trend) correctly quoted with units
- Ref to China not fitting the trend

(ii) Discuss how changes in rainfall can affect plant biodiversity. [2]

- Ref to increase / decrease in rainfall / increased incidence of flooding / drought, shorter / longer rainy season
- Ref to relevant consequence on plants (e.g. plant wilting from loss of water / plant rotting from waterlogged roots / plants infected by pests and pathogens)
- Ref to idea of decrease / increase, in genetic diversity / species diversity

(b) Suggest the benefits to humans of conserving plant species. [3]

- may be of use in the future
- (may produce) medicines / AW
- resources (for humans)e.g. wood for building / fibres for clothes / fuel / food / agriculture
- maintain, gene pool / genetic diversity
- to maintain stability in ecosystems
- aesthetic reasons
- (eco)tourism

[Total: 7]

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SECTION A

QUESTION 1

(a) (i) Outline how the bacteriophage adsorbs to the host cell in step **1**. [2]

- Bacteria phage have tail fibres with a specific 3D conformation
- which bind / attach to, complementary cells surface receptors on bacteria

(ii) Identify the process shown by step **4** and explain how gRNA is formed. [4]

- ref to transcription
- RNA polymerase binds to promoter/ formation of transcription initiation complex
- ref to reading of template DNA strand in 3'-5'
- ref to complementary base pairing
- ref to formation of RNA in 5'-3'
- ref to formation of phosphodiester bond

(iii) Suggest why Cas9 binds to gRNA in step **5** and to phage DNA. [2]

- Cas9 binding site has a specific 3D conformation
- Which is complementary to gRNA only
- ref to RNA being single-stranded / different conformation from DNA

(iv) With reference to step **6**, explain how presence of the *Cas9* gene enhances the survival of the bacterial species. [4]

- ref to natural selection
- Selection pressure is the presence of phage that lyse cells
- Cells with *Cas9* gene have a selective advantage
- are not lysed
- since Cas9-gRNA complex can cleave specific phage DNA in subsequent infection
- *Cas9* gene is passed on to next generation
- Resulting in an increase in allelic frequency of *Cas9* in the gene pool / greater proportion of cells possessing *Cas9* gene

(b) Explain why the *GFP* gene was chosen for testing the new technique. [2]

- ref to marker
- no fluorescence, means GFP gene was deleted

(c) (i) Calculate the percentage of zygotes in the control group that were transgenic. Show your working. [1]

- 46/68 = 67.6 or 68

(ii) Name a statistical test that would allow you to test the significance of the difference between the percentage you calculated in **(i)** and the expected percentage. [1]

- higher
- Since 50% of offspring are expected to get GFP gene from heterozygous male

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(iii) Name a statistical test that would allow you to test the significance of the difference between the percentage you calculated in **(i)** and the expected percentage. [1]

- Chi-squared test

(iv) State the best concentration of Cas9-gRNA complex to use to cause a deletion in the GFP gene and give reasons for your choice. [3]

- 10 ng mm^{-3}
- more cells/ ORA
- less toxic /ORA
- No blastocysts seen under filter / (low concentration) as successful as higher concentrations / all blastocysts have deleted GFP

(d) (i) Outline the principles of gel electrophoresis. [3]

- Separate DNA fragment by size / length
- Negatively charged DNA will migrate to the positively charged anode when electric current is applied
- The agarose gel acts as a "molecular sieve" to impede the movement of DNA fragment OR smaller/ shorter DNA are less impeded/ move faster through the gel
- ref to DNA ladder to compare size

(ii) Explain what Fig. 1.2 indicates about the success of the new technique in causing a deletion in a gene in pigs so that they show resistance to PRRSV [4]

- lanes 1–4 show 4 kbp fragment
- so technique is 100% successful
- (6 kbp gene has) 2 kbp, deleted
- pigs 1–4 have no normal cell surface protein
- PRRSV, cannot infect the, cells / pigs (1–4)

(e) Discuss the ethical implications of genetically editing pig zygotes for experiments [2]

- ref to use of knowledge gained from experiments to maximise greater good
- ref to no need for human donor, sanctity/ respect for human life
- ref to pigs being used as food already
- ref to devaluing / lack of respect to the life of the pig
- ref to lack of respect for religious beliefs

[Total: 30]

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QUESTION 2

(a) **(i)** With reference to Table 2.1 and Fig. 2.2, explain why test stick 1 and test stick 2 will contain different mobile monoclonal antibodies. [2]

- testing for the presence of different, antigens / (*Plasmodium*) proteins / epitopes
- antibodies are, specific / have specific shape
- different monoclonal antibodies have, different, variable regions / antigen binding sites
- (pLDH / HRP-2 / Plasmodium) protein, binds to / complexes with, (monoclonal) antibody

(ii) With reference to Table 3.1 and Fig. 3.2, explain what can be diagnosed for this person from a positive result for test stick 1 and a negative result for test stick 2. [2]

- (positive result of test strip 1) pLDH present, (so) the person, has malaria / is infected by *Plasmodium*
- (negative result of test strip 2) HRP-2 not present, (so) the cause of malaria is not / the person is not infected by, *P. falciparum*
- (negative result of test strip 2) HRP-2 not present, (so) the person is infected by *Plasmodium* other than *P. falciparum*

(b) Outline the process during B-cell development that allows our immune system to produce antibodies that recognise a range of *Plasmodium* proteins. [4]

- ref. to somatic recombination
- ref. to V, D, J gene segments are, selected randomly during V(D)J rearrangement, to give many combinations of heavy chains / ref. to V, J gene segments are, selected randomly during V(D)J rearrangement, to give many combinations of light chains

- ref. to formation of junction between gene segments is not precise, creating different coding sequences at the joint
- ref. to random assortment / combinations of, light and heavy chains

[Total: 8]

QUESTION 3

(a) **(i)** State the role of rubisco in the Calvin cycle. [1]

- Rubisco catalyses the fixation of carbon (dioxide)
- It catalyses reaction between RuBP and CO_2

(ii) Compare the rates of fixation of carbon dioxide in C3 and C4 grasses. [2]

- Rate of fixation in C4 grasses higher than C3 grasses
- Mean rate in C4 is 3.17 a.u. and mean rate in C3 1.65 a.u.

(iii) Suggest the advantages of PEP carboxylase in C4 plants. [2]

- PEP does not react with oxygen, thus prevents photorespiration
- Conversion of malic and aspartic acids into CO_2 within bundle sheath cells acts to concentrate CO_2
- Thus, increases efficiency of the reaction between CO_2 and RuBP catalysed by rubisco / result in a higher maximum rate of photosynthesis

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(b) Explain how forests can serve as carbon sinks. [3]

- Plants / trees in forests undergo photosynthesis, where they take in CO_2 from the atmosphere and fix the CO_2 in the light-independent reaction / Calvin cycle
- Thus, carbon atoms being incorporated into sugar/organic molecules/glucose
- which are further polymerised to form macromolecules such as starch for storage / cellulose for structural growth of the plants / trees

(c) With reference to Figs. 3.1 and 3.2, describe the evidence which suggests that the polar bear is at risk of extinction as a result of climate change. [4]

- Climate change results in global warming / rising temperatures, which leads to earlier spring melting / shrinking of sea ice floating in the Arctic ocean and ice sheets on the island of Greenland OR increased risk of permafrost melting
- These contributes to habitat loss / fewer hunting grounds for polar bear

any two from:
- which is evident from the very low populations of polar bears in some areas, e.g. less than 200 in Area 12 and Area 8 (Lancaster Sound / Kane Basin)
- declining populations in 6 / 50% / of areas e.g. Area 7, 8, 11, 12, 15, 18
- a population range of less than 2000 in areas where the populations are declining e.g. Area 7, 8, 11, 12, 15, 18
- even in areas where the population is stable e.g. Area 9, 10, 14, 17, the range is only 1000–3000
- there are only a few, areas e.g. Area 6, 13, 15 where the population is currently increasing
- population change and population numbers are unknown for large areas e.g. Area 1, 2, 3, 4, 5

[Total: 12]

SECTION B

QUESTION 4

(a) A scientific theory is a way of interpreting the natural world. The cell theory, which is a single unified theory of cellular organisation, is an example where scientists have looked for trends and exceptions.

Using knowledge of the cell theory, describe the universal features of cells and suggest ways to test and challenge the cell theory. [15]

1. all known living organisms are made up of one or more cells
2. the cell is the fundamental unit of structure and function in living organisms
3. all living cells on Earth store hereditary information / genetic material
4. ref. to deoxyribonucleic acid / DNA
5. all living cells arise from pre-existing cells
6. ref. to cell division / mitosis / binary fission
7. all cells undergo DNA replication, to replicate / copy their hereditary information
8. DNA is passed from parent cell to daughter cell via cell division

9. using microscopes
10. ref to different types of microscopes serving different purposes in study of cells
11. estimating the size of cells
12. ref. to various experimental techniques to gain knowledge of DNA replication / cell metabolism / biochemical pathway etc

13. idea that viruses challenge the cell theory

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14. viruses are acellular and do not have protoplasm
15. lack the necessary molecular machinery to conduct many of the biochemical reactions a normal cell would need
16. cannot replicate unless they have entered a suitable host cell

(b) Outline how genetic exchange in prokaryotes bring about variation and discuss the possible fate of the transferred DNA. [10]

1. transformation, competent bacterial cells, takes up DNA fragments
2. transduction, accidental incorporation / packaging of random fragment of DNA, from donor bacterium into a phage capsid
3. transduction, excision of prophage is imprecise, taking with it a small region of bacterial DNA adjacent to prophage insertion site
4. conjugation, F plasmid is transferred from F^+ cell to F^- cell, via cytoplasmic mating bridge

5. homologous recombination of DNA fragment takes place, with a homologous section of the recipient cell's chromosome
6. resulting in different combinations of specific genes/ alleles, in prokaryotes

7. degraded / digested, by bacteria enzymes
8. ref. to recombined with bacterial chromosome
9. replicates by itself, if exist as plasmid / if phage genome possess own origin of replication / replicates with bacterial chromosome
10. expression of genes in DNA

[Total: 25]

QUESTION 5

(a) In the 1800s, Gregor Mendel formulated the Laws of Segregation and Independent Assortment based on his observations on pea plants.
Explain how the behaviour of chromosomes during meiosis supports Mendel's laws and suggest why it would be more difficult to investigate the patterns of inheritance in man than in peas. [15]

1. alleles occur in pairs
2. each allele is located on one of the pair of homologous chromosomes
3. when homologous chromosomes separate from each other during anaphase I, they take their alleles with them
4. each gamete receives only one of each type of chromosome
5. during the formation of gametes, the paired alleles separate randomly
6. each gamete receives one or the other allele with equal likelihood
7. two characters being controlled by two genes
8. which are located on two gene loci on two different chromosomes
9. independent assortment of homologous chromosomes occurs during metaphase I
10. resulting in random segregation of paternal and maternal chromosomes in gametes
11. for each pair whichever allele the gamete receives does not influence the outcome of segregation of any other pair
12. the segregation of one pair of alleles is independent of the segregation of other pairs
13. independent assortment stipulates that all four combinations will be formed with equal probabilities
14. some human characters displaying continuous variation
15. human having longer gestation / generation time than pea plants
16. human having a smaller number of offspring than pea plants
17. possibility of obtaining true breeding pea plants
18. bioethics, e.g. respect for human choice of partners as compared with pea plants

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(b) Cell cycle checkpoints keep meiotic divisions faithful and accurate. Despite these checkpoints, errors in meiosis can still occur.
Outline the possible errors in meiosis and discuss their impact on the evolutionary outcomes of a species. [10]

1. unequal crossing over
2. faulty attachment of kinetochore microtubules to centromeres
3. failure of the M checkpoint
4. non-disjunction
5. change in chromosome number
6. change in number of sets of chromosome
7. change in chromosome structure
8. variations in phenotypes ;;
9. natural selection
10. sympatric speciation
11. new species may become extinct
12. new species may coexist with parental species
13. new species may replace the parental species
14. adaptive radiation

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QUESTION 1

(a) In the space below, sketch a graph to show the relationship between L-dopa concentration and rate of reaction catalysed by dopa oxidase.

On the same axes, sketch another graph to show the effect of substance **X** on the rate of reaction if substance **X** is a competitive inhibitor. [2]

1. correct shape of graph without X
2. correct shape of graph with X

(b) Complete Table 2.1, to show how you will make up the L-dopa solutions using the 50 mmol dm^{-3} L-dopa solution, **L**, and distilled water, **W**. [2]

1. correct values for final concentration + total volume
2. correct values for volume of L + volume of W

(c)(i) Calculate the rate of reaction for each of the reaction mixtures.

Calculate the rate as 1000/*t* where *t* = the time taken to reach the colour of the colour comparator (test-tube **C**).

Record all your results and calculations in a suitable form in the space below. [6]

1. informative column headings
2. concentration of L-dopa shown in table
3. results for P agree with expected trend shown in (a)
4. results for substance X agree with expected trend shown in (a)
5. rates of reaction calculated correctly
6. time taken recorded to whole numbers + rates of reaction shown to consistent number of decimal places / significant figures

(c)(ii) Plot a graph to show the rate of reaction catalysed by dopa oxidase with and without substance **X** on the grid provided. [5]

1. axes with correct labels and units
2. use of sensible scale so that the graph occupy at least 50% of the grid in both the *x* and *y* directions
3. correct and accurate plotting of graphs to ± half a small square
4. point-to-point ruled lines
5. lines labelled / key given

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(d) It is suggested that substance **X** is a competitive inhibitor of dopa oxidase.
Discuss what the results from **(c)(ii)** suggest about the relationship predicted in part **(a)**. [3]

if results support relationship predicted,

1. comparative data quote to illustrate effect of X
2. (initial) rate increases with and without, X / inhibitor
3. rate of reaction is lower with, X / inhibitor / ORA
4. X binds to active site
5. at high concentrations L-dopa competes successfully with X / Vmax is *or* becomes the same as without X

if results don't support relationship predicted,

6. ref to possibility that X is a non-competitive inhibitor
7. ref. to the need to use higher concentrations of L-dopa / substrate to see if it is a competitive inhibitor

(e) Discuss **two** limitations of the investigation and the ways in which the procedure could be changed to improve the quality of the results. [4]

	limitation	improvement
1.	no, pilot / trial	experiment to practise determining the end point
2.	only one result for each concentration	perform replicates / repeat whole investigation at least twice
3.	not enough intermediate concentrations of, L-dopa / substrate	use higher concentration of, L-dopa / substrate, to find out if X is competitive or not use closer intervals of concentration of L-dopa
4.	*idea that* end point is, difficult to determine / subjective, so timings are, under / over, estimates or results are not a measure of the initial rate of the reaction / rate changes during the time taken to reach end point	use a colorimeter to determine rate of change in, absorbance / transmission use a colorimeter to determine when a particular absorbance is reached A: any method to quantify precipitate, e.g. filter / spin in a centrifuge, and measure
5.	temperature not controlled	use a thermostatically controlled water bath
6.	syringes are not very precise / large percentage error	use micropipette / use graduated pipette / use a mechanical pipette / use a burette A: use a syringe with more, calibrations / finer scale

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(f) In an actual experiment conducted, it was found that the V_{max} of the reaction is 50 s^{-1}.
Using your graph in **(c)(ii)**, determine the Km for the reaction without the competitive inhibitor **X**. [1]

K_m = correct value at ½ V_{max}

[Total: 23]

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QUESTION 2

(a) The student used the 250 mmol dm^{-3} KC*l* solution to make 100 cm^3 of four other concentrations by reducing the concentration by 50 mmol dm^{-3} each time.

Describe a procedure that the student could use to prepare these four concentrations. [3]

1. correct volumes of water and KC*l* solution for making <u>all</u> four dilutions with units
2. method of measuring volumes
3. *ref. to* stirring / mixing

(b)(i) Suggest a hypothesis that the student could test about the effect of KC*l* on the opening and closing of stomata. [1]

idea of:
the higher the concentration of KC*l* the greater / lower the number of stomata open / ora
or
the number of open stomata is directly proportional / inversely proportional to the concentration of potassium chloride / ora
R in terms of degree / speed of opening and closing of stomata e.g. more KC*l the stomata are wider*

(ii) Describe a method that the student could use to investigate the effect of different concentrations of KC*l* on the opening of stomata.

The description of your method should be detailed enough for another person to follow and should not repeat the details from **(a)** of how to dilute the 250 mmol dm^{-3} solution of KC*l*. [5]

1. *ref. to* putting the strips into solutions in appropriate containers
2. *ref. to* keeping in the dark
3. *ref. to* mounting on a slide and using a microscope
4. *ref. to* count / record the number of stomata that are open or closed
5. *ref. to* a method standardising the counting open / closed stomata
6. *ref. to* making several counts on each leaf strip and taking a mean / to identify anomalies
7. *ref. to* using suitable equipment for cutting and measuring strips
8. *ref. to* a method of maintaining a constant temperature
9. covering to prevent evaporation
10. *ref. to* low risk, examples of hazard and precaution

(c)(i) Outline how the student could find the actual diameter of a stomatal aperture. [2]

1. *ref. to* using graticule to measure
2. calibrating the graticule with a micrometer / AW
3. convert / calibrate the graticule units to μm / mm

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(ii) On Table 2.1, draw circles around **two** values that are anomalous. [1]

time / min	diameter of stomatal aperture / μm														
0 (control)	0.5	0.1	0.2	0.3	0.4	0.1	0.5	0.2	0.3	0.3	0.1	0.2	0.2	0.2	0.4
60	0.9	1.1	1.0	1.3	1.2	1.8	1.5	0.8	0.2	1.3	1.1	0.8	1.0	1.9	0.9
120	1.9	2.4	2.6	2.6	2.5	2.2	2.8	2.4	2.4	3.9	2.6	2.3	2.5	2.2	2.7
180	4.1	4.8	4.2	4.0	5.7	4.7	3.9	4.1	5.5	4.5	4.3	4.0	3.1	4.1	4.3

(iii) Complete Table 2.2 by calculating the rate of increase of the diameter of the stomatal apertures between 120 minutes and 180 minutes. [1]

Rate of increase of diameter of stomatal apertures = (4.6 – 2.5) μm / (180 – 120) min
= 0.035 μm min^{-1}

(d) Comment on the use of the *t*-test by:

(i) stating how many values of *t* the student should calculate **and** explaining your answer [2]

1. 3
2. *idea of* carrying out *t*-test on spiderwort and the other plants / AW

(ii) explaining how the student would find out if the results of his *t*-tests were significant. [2]

1. calculate / find / use, the degrees of freedom / *v*
2. *ref.* to critical / table, value at, 0.05 or 5%
3. if value of *t*, greater than / >, critical / table, value, the difference is significant / ORA

[Total:17]

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QUESTION 3

(a)(i) Draw a large plan diagram of the section of the leaf (midrib) shown by the shaded area in Fig. 3.1. [4]

1 correct size + no cells + no shading
2 correct arrangement + subdivision of vascular bundle
3 correct shape
4 correct proportion

(a)(ii) Make a large drawing of this group of **three** cells.
Use **one** ruled label line and the label **P** to identify a structure that produces ATP. [3]

1 correct size + cell wall shown as double lines + no shading
2 each cell touching at least one of the other cells in the group
3 label line + label P to identify chloroplast

(b)(i) Describe how you will use the grid to find the total area of the part of the leaf shown in Fig. 3.2. You do **not** need to include the trichomes. [1]

count the number of squares completely filled + count the number of squares more than half-filled

(b)(ii) Use the procedure you have described in **(b)(i)** to find:
the total area of the part of the leaf shown in Fig. 3.2,
the area of the leaf section occupied by the vascular bundle, labelled **V**. [2]

1 records the total area of the leaf showing in Fig. 3.2 to a whole number
2 records the area of the leaf section occupied by the vascular bundle V to a whole number

(b)(iii) Calculate the percentage of the part of the leaf shown in Fig. 3.2 that is occupied by the vascular bundle, labelled **V**.
Show all the steps of your working. [2]

1 shows the value for the area of V ÷ the value for the area of the leaf section × 100%
2 answer to the correct degree of accuracy

(b)(iv) Suggest how you could modify the procedure you have used in **(b)(ii)** to give a more accurate estimate of the area of the leaf. [1]

using a grid with smaller squares

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(c) Observe the leaf on **M1** and the part of the leaf shown in Fig. 3.2 and identify the differences between them.
Record the observable differences in Table 3.1. [2]

1 M1 few trichomes and Fig. 3.2 many trichomes
2 M1 many air spaces and Fig. 3.2 few air spaces
3 M1 palisade mesophyll cells present and Fig. 3.2 palisade mesophyll cells absent

[Total:15]

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