Civics Group	Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 PRELIMS

H2 BIOLOGY **9744/1**

Paper 1: Multiple Choice

Tuesday 18th Sept 2018 1 hour

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser (not supplied)
Soft pencil (type B or HB is recommended)

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name, civics group and index number on the multiple choice answer sheet in the spaces provided.

There are **30** questions in 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 multiple choice answer sheet.

INFORMATION TO CANDIDATES

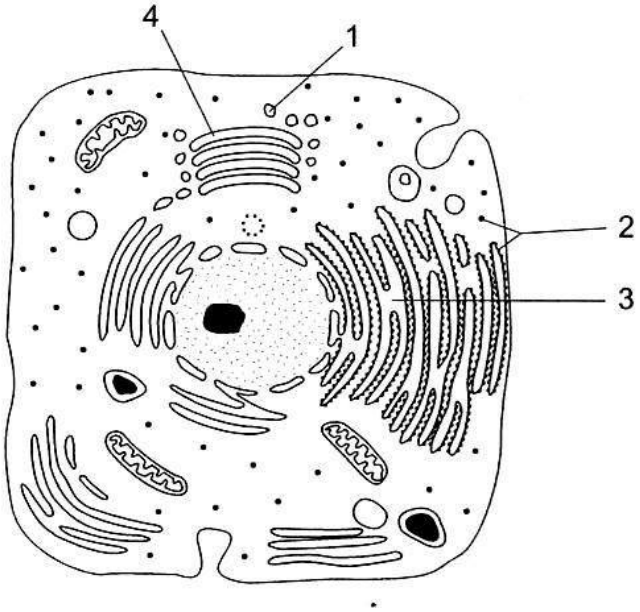
Each correct answer will score one mark. A mark will not be deducted for wrong answer. Any rough working should be done in this booklet.

At the end of the examination, submit both question paper and multiple choice answer sheet.

This document consists of **21** printed pages.

[Turn over

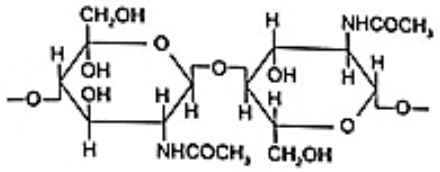
1 The figure below shows the structure of an animal cell.



Which of the following correctly identifies the functions of the labelled structures?

	Synthesising polypeptides from amino acids	Transporting proteins	Carrying out glycosylation	Secreting digestive enzymes
A	2	1	4	3
B	1	4	2	3
C	2	3	4	1
D	1	3	2	4

2 The diagrams show short sections of some common polysaccharides and modified polysaccharides.



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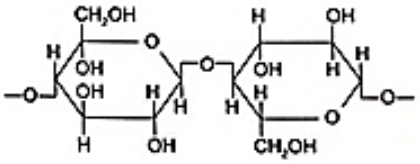

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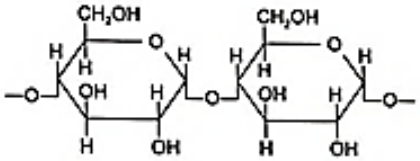

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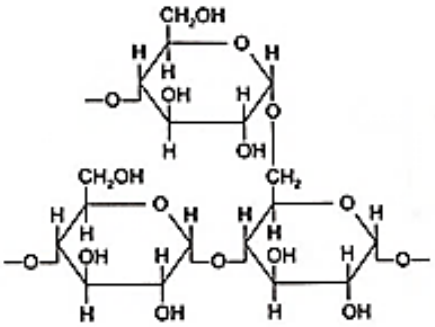

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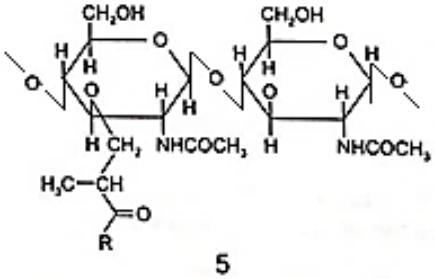


5

The polysaccharides can be described as below.

- Polysaccharide **F** is composed of β-glucose monomers with 1,4 glycosidic bonds.
- Polysaccharide **G** is composed of α-glucose monomers with 1,4 and 1,6 glycosidic bonds.
- Polysaccharide **H** is composed of N-acetylglucosamine and N-acetylmuramic acid monomers with β-1,4 glycosidic bonds.
- Polysaccharide **J** is composed of α-glucose monomers with 1,4 glycosidic bonds.
- Polysaccharide **K** is composed of N-acetylglucosamine monomers with β-1,4 glycosidic bonds.

Which shows the correct pairings of polysaccharide descriptions and diagrams?

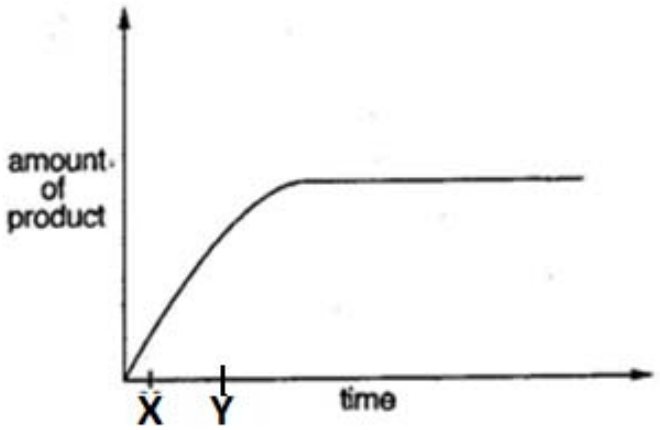
	Polysaccharide				
	F	**G**	**H**	**J**	**K**
A	2	4	5	3	1
B	2	5	4	1	3
C	3	4	1	2	5
D	3	5	4	1	2

3 With reference to carrier proteins, which of the following statements is/are true for all carrier proteins?

1 They contain binding sites for specific molecules or ions.
2 They directly require ATP to transport substances across the membrane.
3 They are soluble globular proteins.
4 They are embedded in membranes.

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

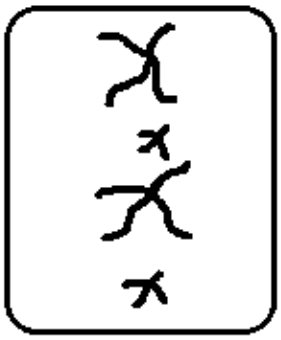
4 The graph below shows the amount of product formed in an enzyme-catalysed reaction over a certain period of time at 37° C.



What is true at time **X**?

A Most enzyme molecules will have free active sites.
B The number of unreacted substrate molecules is high.
C The number of enzyme-substrate complexes is low.
D The rate of enzymatic reaction is lower than at time **Y**.

5 The diagram below shows metaphase of mitosis in a cell of an organism.



Each homologous pair of chromosomes in this organism contains 4 gene loci. This organism was genotyped and found to be heterozygous at all gene loci. The organism reproduces sexually via the production of millions of gametes by meiosis.

What is the maximum possible number of genetically different gametes that can be produced by this organism, assuming crossing over does not occur during meiosis in all cells?

A 2
B 4
C 16
D 256

6 Hybrid species can be produced from cabbage and radish.
The table below shows the chromosome numbers in the parental species and the hybrids.

type of cell	number of chromosomes per cell
parental cabbage	18
parental radish	18
parental gametes	9
F1 hybrids	18
F1 gametes	9
F2 hybrids	18
F2 gametes	18
F3 hybrids	36

Chromosomal mutation occurred at one stage. At which stage did it occur?

A during the formation of the F1 gametes.
B during the formation of the F2 gametes.
C during the fusion of the parental gametes.
D during the fusion of the F1 gametes.

7 3 different polynucleotide molecules (X, Y and Z) were isolated from a eukaryotic cell. One of them is a double-stranded DNA gene, while the other two are the pre-mRNA and mature mRNA that the DNA gene codes for.

The adenine nucleotide content of all 3 molecules was examined and shown in the table below:

Molecule	Percentage of adenine nucleotides in the molecule / %
X	49
Y	52
Z	53

Based on the information given, which of the following conclusions is/are valid and true?

1 X is definitely the DNA gene.
2 Z is definitely the mature mRNA.
3 The pre-mRNA molecule has more uracil than guanine in it.
4 Y has more purine nucleotides than pyrimidine nucleotides in it.

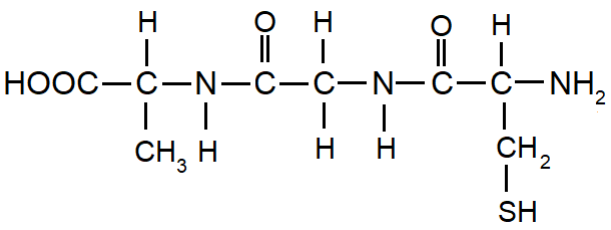
A 1 and 2
B 1, 2 and 4
C 1, 3 and 4
D 2, 3 and 4

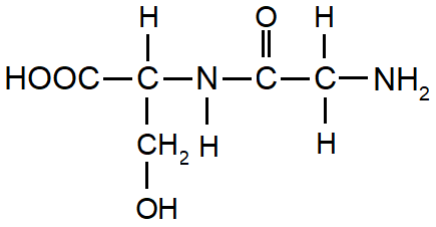
8 In an experiment, polypeptide A, which is coded for by a non-mutated version of a prokaryotic gene, was cleaved by a particular protease.

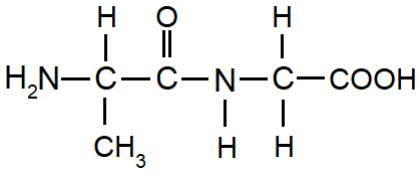
The cleavage produced 2 fragments, one of which contains the C-terminus of polypeptide A and is 5 amino acids long. This 5-amino-acid-long fragment, now called Peptide B, was then isolated for further investigation.

A solution containing many molecules of Peptide B was treated with another protease, called Protease X. The solution was analysed after the treatment and was found to contain various different fragments of different lengths and sequences.

The structures of 3 of these fragments are shown below:







It is known that Protease X is able to cleave any peptide bonds within the molecule of Peptide B. However, the cleavage of all peptide bonds within a single molecule is rare.

The mRNA codons involved in the synthesis of the Peptide B portion of Polypeptide A are shown below:

Amino acid	R group	mRNA codon
Glycine	H	5’ – GGC – 3’
Alanine	CH_3	5’ – GCC – 3’
Serine	CH_2OH	5’ – UCC – 3’
Cysteine	CH_2SH	5’ – UGU – 3’

Which of the following correctly shows a single point mutation in the portion of the template DNA sequence that codes for Peptide B, leading to a single amino acid substitution?

A 5’ – GCC GCC ACA GGA GCC – 3’
B 5’ – GCC GGA ACA GCC GCC – 3’
C 5’ – GGA GCC GCC GCC ACA – 3’
D 5’ – ACA GCC GCC GCC GGA – 3’

9 Arrange the following statements on the signal transduction pathway for insulin in order.

1 Auto-crossphosphorylation
2 Increase in uptake of glucose through facilitated diffusion
3 Relay proteins bind to specific activated tyrosine residues
4 Activated relay proteins activate their respective transduction pathways
5 Insulin binds to receptor tyrosine kinase (RTK) at the receptor site
6 Vesicles containing glucose transporters move to and fuse with the plasma membrane
7 Changes in the 3D conformation activates the tyrosine kinase domain of receptor

A 5, 1, 7, 3, 4, 6, 2
B 5, 7, 1, 3, 4, 6, 2
C 2, 5, 1, 7, 3, 4, 6
D 2, 5, 1, 7, 4, 3, 6

10 The Southern pine beetle is a pest native to pine forests in Central America and the southeastern U.S..

However recent observations show the latitude of this pest infestation creeping northward by about 40 miles a decade since 1980, and could damage 273,000 square miles of pine forests by 2080.

Which of the following explanations for the above observation are attributed to climate change?

1 Longer and more intense droughts weakening the defenses of trees, making them vulnerable to attack by the beetles.
2 Long-term suppression of forest fires leaving pine forests unnaturally dense and uniform, facilitating the beetles' spread from tree to tree.
3 Pines trees colonising new territories with cooler climates.
4 Increased temperatures in the winter allowing the beetles' lavae to survive.

A 1 and 4 only
B 2 and 3 only
C 1, 3 and 4 only
D All of the above

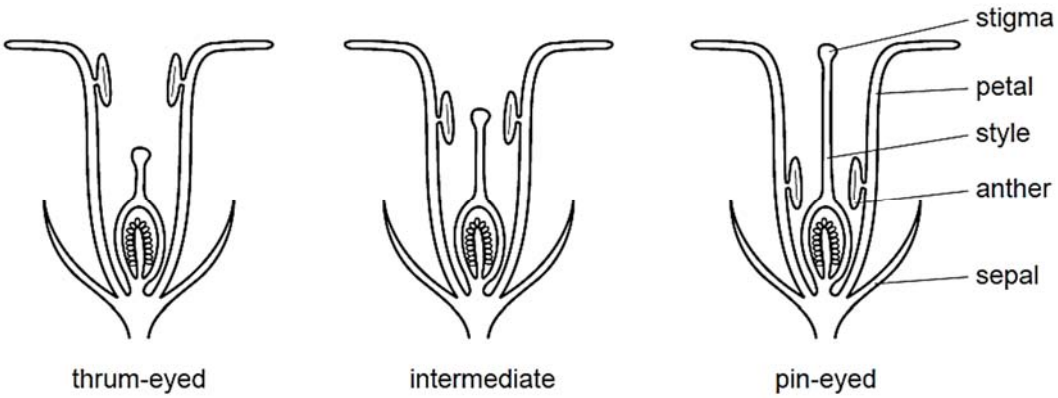
11 The primrose, *Primula vulgaris*, is a small herbaceous, yellow-flowered plant which is common in cooler areas of the Northern hemisphere including alpine and Arctic areas.

The flowers of the primrose have different flower shapes (polymorphic), which are adaptations for pollination. 'Thrum-eyed' primroses have a short style. 'Pin-eyed' primroses have much longer styles. The anther position also varies among the primrose.

Some populations of primrose consist almost entirely of plants with intermediate flowers. These populations are common where there are fewer winged insects.

Anthers produce pollen (male gametes) which land on the stigma, leading to fertilization.

The diagrams show polymorphic flowers of primroses.



Which statements are correct?

1 Cross-pollination will be favoured between pin-eyed and thrum-eyed primroses.
2 Primroses with pin-eyed flowers are likely to show more genetic diversity than primroses with intermediate flowers.
3 Primroses with thrum-eyed flowers are likely to be more able to adapt to changing environmental conditions than pin-eyed primroses.
4 Self-pollination is more likely to occur in primroses with intermediate flowers.

A 1 and 2
B 3 and 4
C 1, 2 and 4
D All of the above

12 On the tiny Lord Howe Island, 600 miles east of Australia, there are two species of palm which seem, from DNA analysis, to be descended from one original species. Factors involved in this speciation on this tiny island include:

1 linkage of genes for soil tolerance and flowering time
2 variation in flowering time
3 variation of soil tolerance
4 variation of soil types on the island

What is the correct sequence to explain this speciation?

A $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$
B $2 \rightarrow 1 \rightarrow 4 \rightarrow 3$
C $3 \rightarrow 4 \rightarrow 1 \rightarrow 2$
D $4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

13 Many types of evidence, can provide support for Darwin's theory of natural selection and descent with modification.

What statement provides support?

1 The allele for sickle cell haemoglobin that gives resistance to malaria is more frequent in malarial areas.
2 The distribution of the variants of the A blood group antigen reflects human migration patterns.
3 The homozygous condition of the sex-linked allele for a non-functional blood clotting protein is rare.
4 The molecular structure of ATP is almost identical in all eukaryotes.

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

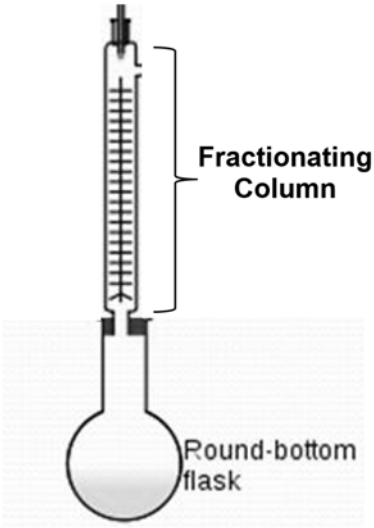
14 Which of the following statement(s) about chromosome structure is/are true?

1 Euchromatin is the more diffuse region of the interphase chromatin and is transcriptionally active.
2 Nucleosomes and linker DNA make up a 30nm chromatin fibre.
3 There are 8 nucleosomes in one turn of the helix of the 30nm chromatin fibre.
4 Further condensation of the 300nm chromatin fibre only takes place during mitosis/meiosis.

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

15 The active messenger RNAs (active mRNAs) in tissue cells can be isolated by passing the homogenised cell contents through a fractionating column (shown in diagram below). The column has short lengths of uracil nucleotides attached to a solid supporting material.

Most molecules of mRNA that pass through the column break up into small pieces and cannot be translated.



The active mRNAs that attach to the column can be separated by appropriate treatment.

Which statements correctly describe active mRNA?

1 Active mRNAs are held to the fractionating column by bonds between adenine and uracil bases.
2 Active mRNAs can be released from the fractionating column by breaking hydrogen bonds.
3 Only mRNAs with polyadenine tailing can be translated.

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

16 Four different genes are regulated in different ways.

Gene 1 undergoes tissue-specific patterns of alternative splicing.
Gene 2 is part of a group of structural genes controlled by the same regulatory sequences.
Gene 3 is in some circumstances subject to methylation.
Gene 4 codes for a repressor protein which acts at an operator site close by.

Which role of the table correctly identifies which genes are prokaryotic and which are eukaryotic?

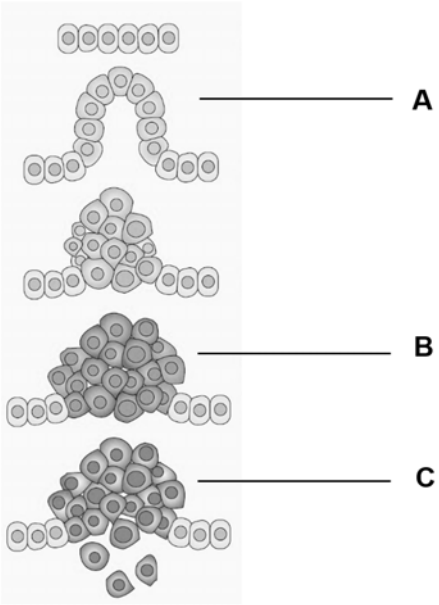
	prokaryotic	**eukaryotic**
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 4	1 and 3
D	2 and 3	1 and 4

17 Which of the following statements about the eukaryotic control elements are correct?

1 Attachment of the RNA polymerase II at the TATA box is achieved with the help of a series of specific transcription factors
2 A given gene may have multiple enhancers, each active at a different time or in a different cell type or location in the organism
3 Repressors bind to silencer regions of DNA far upstream of promoters to repress transcription

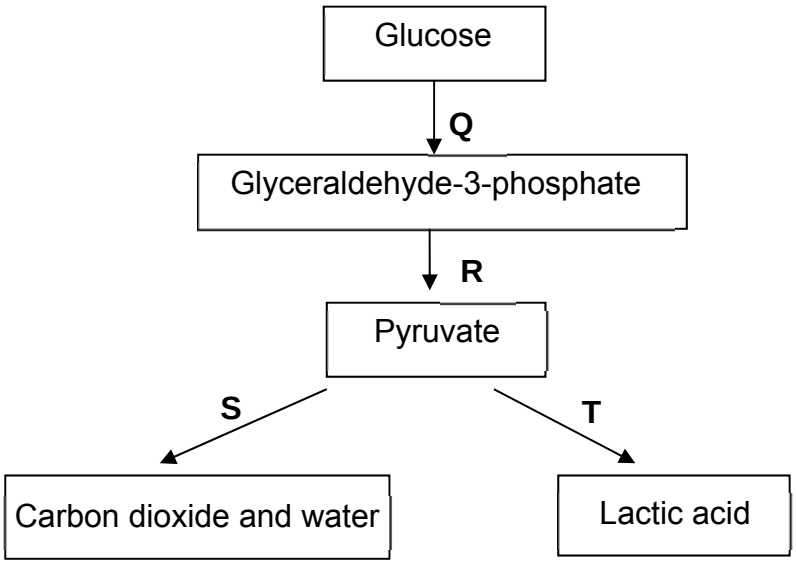
A 1 and 3
B 1 and 2
C 2 and 3
D 1, 2 and 3

18 The diagram below shows the mutli-step model of cancer development in colon cancer. Which of the following contains the most appropriate explanation for the different stages?



	A	B	C
A	Mutation in one copy of a tumor suppressor gene	Mutation in other genes such as telomerase gene	Loss of anchorage dependence
B	Mutation in one copy of a proto-oncogene	Loss of density dependence	Loss of anchorage dependence
C	Mutation in one copy of a proto-oncogene	Loss of anchorage dependence	Loss of density dependence
D	Mutation in promoter region upstream of a proto-oncogene	Mutation in one copy of a tumor suppressor gene	Loss of density dependence

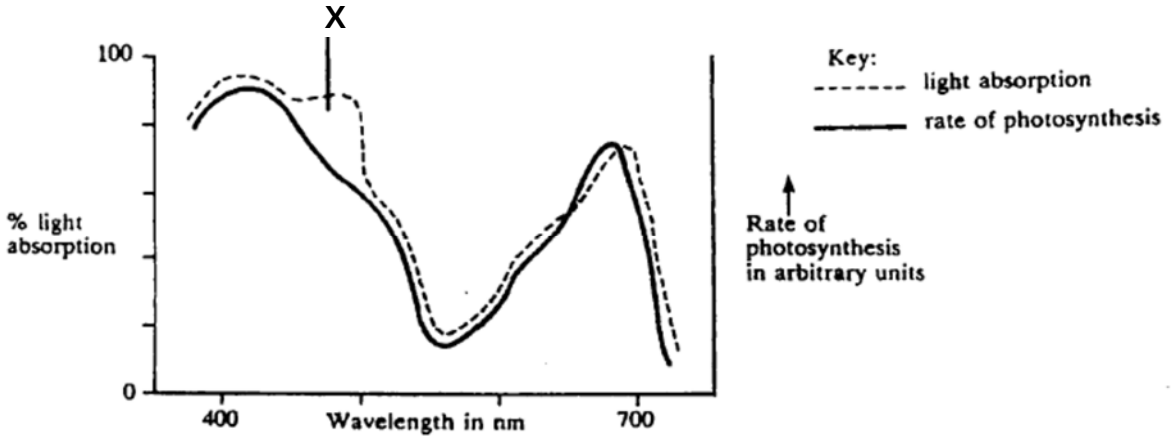
19 With reference to the diagram below, relate processes **Q, R, S, T** to statements **(1), (2)** and **(3).**



(1) NAD is regenerated without the use of the electron transport system
(2) ATP is synthesised via substrate level phosphorylation
(3) It can take place under anaerobic conditions.

	(1)	**(2)**	**(3)**
A	T only	R only	Q,R,T only
B	T only	R,S only	Q,R,T only
C	S,T only	R only	Q,R,S,T
D	S,T only	R,S only	Q,R,S,T

20 The graph below shows the effect of different wavelengths of light on the rate of photosynthesis and on the amount of light absorbed by the pigments in a green seaweed.



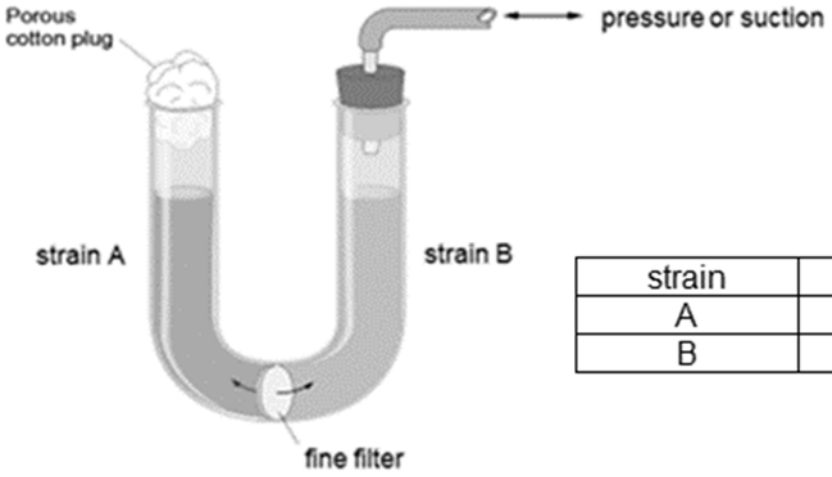
The difference between the two curves at X is due to

A inefficient trapping of light energy by the chlorophyll
B no ATP production at that wavelength
C oxygen given off during photosynthesis interferes with the absorption of light.
D carotenes absorbing light that is not used in photosynthesis.

21 A mutation that renders the product of a regulatory gene non-functional for an inducible operon will result in

A continuous transcription of the genes of the operon.
B irreversible binding of the repressor to the operon.
C complete blocking of the attachment of RNA polymerase to the promoter.
D continuous production of gene products that are anabolic in function

22 To investigate gene transfer between bacteria, two strains of the same bacterial species were each placed in one arm of a U-tube with a filter separating them.



strain	genotype
A	met^-
B	met^+

met $^+$ is a wild-type gene that codes for the ability to synthesise the essential amino acid, methionine.

met $^-$ indicates that the *met* $^+$ gene has been mutated.

Liquid may be transferred between the arms of the tube by the application of pressure or suction, but particles that are larger than the filter pore size would not be able to pass through the fine filter.

type of particle	size
bacteria	1 – 10μm
bacteriophages	0.025 – 0.2μm

After several hours of incubation, bacterial cells from the left arm of the tube are plated on minimal medium.

Which pair of experimental results best shows that transduction was most likely the process responsible for gene transfer between strains A and B?

	filter pore size	**growth of colonies on minimal medium**
A	5μm	no
	0.1μm	yes
B	5μm	no
	0.1μm	no
C	0.45μm	no
	0.02μm	yes
D	0.45μm	yes
	0.02μm	no

23 Probes are short, single-stranded DNA segments that are used to identify DNA fragments with a particular sequence. Which of the following statements about probes is false?

A They have the same sequence as the sequence to be identified.
B Probes may not adhere 100% to target sequences.
C A probe from one organism may be used to locate a homologous DNA segment from a different organism.
D In order to be useful, the probe must be labelled.

24 Which is a correct statement about obtaining human embryonic stem cells for research?

1 Removal of these cells is considered to be ethically acceptable as normal development of the embryo is not inhibited.
2 The cells must be removed at an early stage of development from a region of the blastocyst known as the inner cell mass.
3 The cells must be removed immediately following the successful fertilisation of the ovum by the sperm, and after checking for normal mitotic division.
4 The region of the blastocyst from where the cells are removed is an area that develops at a later stage into the placenta.

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

25 How do viruses cause diseases in animals?

1 They inhibit normal synthesis of host cell DNA, RNA, or protein.
2 They degrade the host cell's chromosomes.
3 They disrupt the oncogenes of the host cell causing uncontrolled cell division.
4 Their viral proteins and glycoproteins on the surface membrane of host cells cause them to be recognized and destroyed by the body's immune defences.

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

26 Which of the following statement(s) is/are true for tuberculosis?

1 The pathogen is from the genus *Orthopoxvirus*
2 Some individuals with the disease are not infectious
3 The disease can exist in the active or inactive state
4 Transmission of the disease increases with frequency of exposure to an infectious individual

A 4 only
B 1 and 3 only
C 2, 3 and 4 only
D All of the above

27 The length of the petiole (leaf stalk) in a type of flowering plant is controlled by two genes, A and B. These genes are found on different loci on non-homologous chromosomes.

Homozygous dominant plants have long petioles (30 cm), homozygous recessive plants have short petioles (10 cm). Each dominant allele contributes 5cm to the petiole length.

F_1 plants with medium length petioles (20 cm) were obtained when a plant with short petiole is crossed with a plant with long petiole. If the F1 generation plants were allowed to cross, what proportion of their offspring would be expected to have medium length (20 cm) petioles?

A 0.0625
B 0.25
C 0.375
D 0.5

28 Agouti mice have banded hairs, giving a grey colour. Black mice have unbanded hairs. White mice have no pigment. A cross between a homozygous black mouse and a white mouse produced offspring with agouti hair. Another cross between the (same) black mouse and another white mouse produced some offspring with agouti hair and some with black hair.

What explains these observations on the phenotype of hair of mice?

A There is a single gene with two codominant alleles, black and white.
B There is a single gene with three alleles in a dominance series, black → grey → white.
C There are two epistatic genes, one controlling pigment production and one controlling banding.
D There are two linked genes, one controlling pigment production and one controlling banding.

29 The Himalayan rabbits have white hair on the body and black hair on the extremities such as feet, tail, ears and face.

The allele for the Himalayan rabbit pigment pattern, c^h, is recessive to the alleles for normal colour (all hair agouti), C, as well as dark chinchilla (all hair dark grey), c^{chd}, and is dominant to the allele for albino (all hair white, no pigment production), c. All of the alleles of this gene produce different versions of the same enzyme involved in pigment production.

A patch of white fur was removed from a Himalayan rabbit and an ice pack secured to the skin. The fur that grew back on the patch was black.

Which is correct?

	Genotypes of Himalayan rabbits	**Explanation for pigment pattern in Himalayan rabbits**
A	c^hc^h only	The enzyme is denatured at the high skin temperatures found on the rabbit's bodies
B	c^hc^h only	The enzyme becomes inactive at the low skin temperatures found on the rabbit's feet, tail, ears and face.
C	c^hc^h and c^hc only	The enzyme is denatured at the high skin temperatures found on the rabbit's bodies
D	c^hc^h and c^hc only	The enzyme becomes inactive at the low skin temperatures found on the rabbit's feet, tail, ears and face.

30 Table 1 below shows the effect of a drug called P8 on the blood pressure of mice, 20 minutes after P8 was fed to the mice. 4 mice were administered P8, and another 4 mice were given placebo drug as control.

Table 1: Effect of P8 on the blood pressure of mice

	Systolic blood pressure /mmHg				
Condition	Reading 1	Reading 2	Reading 3	Reading 4	Average
Control	175	175.5	175	176	175.5
P8 added	140	140	141	140	140.25

The mathematical formulae for standard deviation and experimental t-value are provided below:

standard deviation $$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

Legend

$\sum$ is summation of

x is observed values

$\overline{x}$ is the mean

n is the sample size (number of observations per condition)

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$$

Where:

- **x1** is the mean of sample 1
- **s1** is the standard deviation of sample 1
- **n1** is the sample size of sample 1
- **x2** is the mean of sample 2
- **s2** is the standard deviation of sample 2
- **n2** is the sample size in sample 2

The table below shows the Student's t-test table of t critical values:

df	.10	.05
1	3.078	6.314
2	1.886	2.920
3	1.638	2.353
4	1.533	2.132
5	1.476	2.015
6	1.440	1.943
7	1.415	1.895
8	1.397	1.860
9	1.383	1.833
10	1.372	1.812
11	1.363	1.796
12	1.356	1.782
13	1.350	1.771
14	1.345	1.761
15	1.341	1.753

Which of the following is false?

A Degree of freedom is 1
B Standard deviation for control group is 0.577
C t-experimental value is 81.465
D There is significant difference between control mice and mice administered P8

END OF PAPER

Civics Group	Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 PRELIMS

H2 BIOLOGY **9744/1**

Paper 1: Multiple Choice (MARK SCHEME)

Tuesday 18th Sept 2018 1 hour

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser (not supplied)
Soft pencil (type B or HB is recommended)

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name, civics group and index number on the multiple choice answer sheet in the spaces provided.

There are **30** questions in 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 multiple choice answer sheet.

INFORMATION TO CANDIDATES

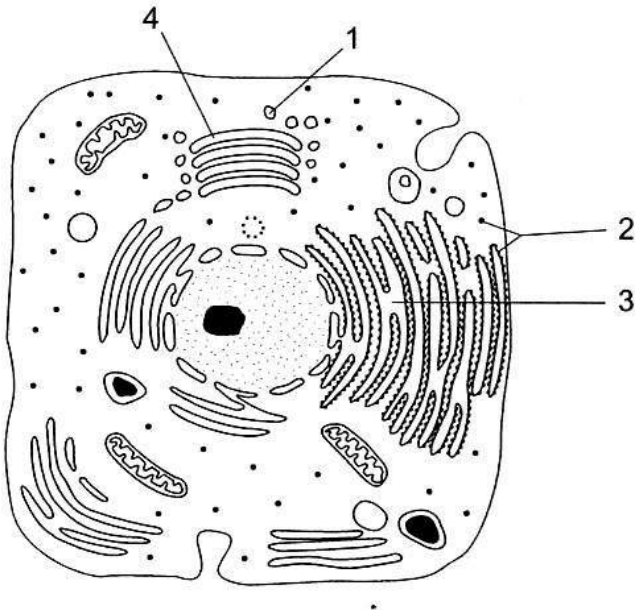
Each correct answer will score one mark. A mark will not be deducted for wrong answer. Any rough working should be done in this booklet.

At the end of the examination, submit both question paper and multiple choice answer sheet.

This document consists of **21** printed pages.

[Turn over

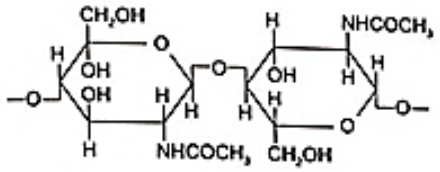
1 The figure below shows the structure of an animal cell.



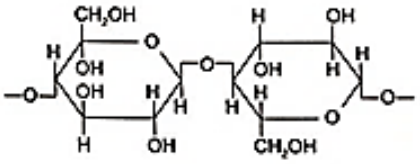
Which of the following correctly identifies the functions of the labelled structures?

	Synthesising polypeptides from amino acids	Transporting proteins	Carrying out glycosylation	Secreting digestive enzymes
A	2	1	4	3
B	1	4	2	3
C	2	3	4	1
D	1	3	2	4

2 The diagrams show short sections of some common polysaccharides and modified polysaccharides.



1



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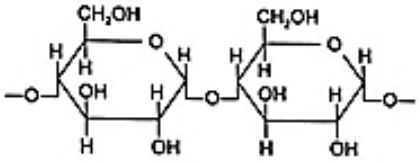

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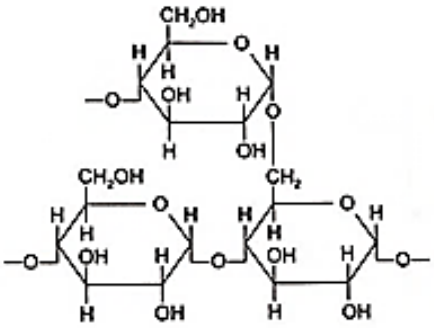

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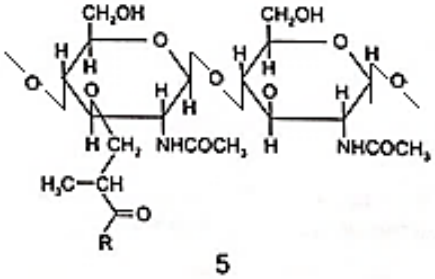


5

The polysaccharides can be described as below.

- Polysaccharide **F** is composed of β-glucose monomers with 1,4 glycosidic bonds.
- Polysaccharide **G** is composed of α-glucose monomers with 1,4 and 1,6 glycosidic bonds.
- Polysaccharide **H** is composed of N-acetylglucosamine and N-acetylmuramic acid monomers with β-1,4 glycosidic bonds.
- Polysaccharide **J** is composed of α-glucose monomers with 1,4 glycosidic bonds.
- Polysaccharide **K** is composed of N-acetylglucosamine monomers with β-1,4 glycosidic bonds.

Which shows the correct pairings of polysaccharide descriptions and diagrams?

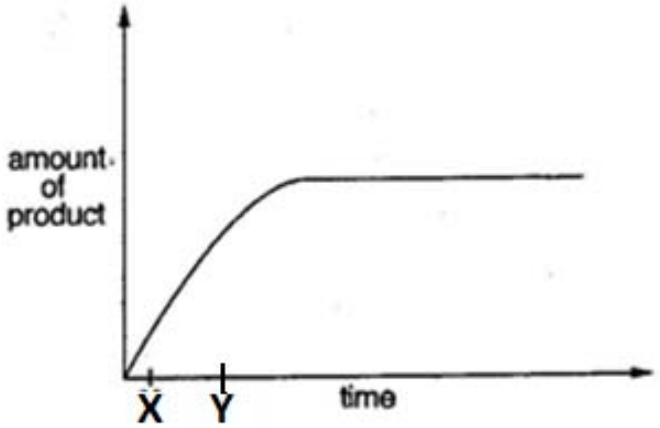
	Polysaccharide				
	F	**G**	**H**	**J**	**K**
A	2	4	5	3	1
B	2	5	4	1	3
C	3	4	1	2	5
D	3	5	4	1	2

3 With reference to carrier proteins, which of the following statements is/are true for all carrier proteins?

1 They contain binding sites for specific molecules or ions.
2 They directly require ATP to transport substances across the membrane.
3 They are soluble globular proteins.
4 They are embedded in membranes.

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

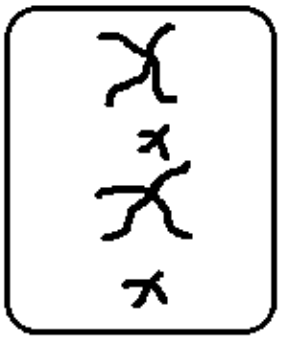
4 The graph below shows the amount of product formed in an enzyme-catalysed reaction over a certain period of time at 37° C.



What is true at time **X**?

A Most enzyme molecules will have free active sites.
B The number of unreacted substrate molecules is high.
C The number of enzyme-substrate complexes is low.
D The rate of enzymatic reaction is lower than at time **Y**.

5 The diagram below shows metaphase of mitosis in a cell of an organism.



Each homologous pair of chromosomes in this organism contains 4 gene loci. This organism was genotyped and found to be heterozygous at all gene loci. The organism reproduces sexually via the production of millions of gametes by meiosis.

What is the maximum possible number of genetically different gametes that can be produced by this organism, assuming crossing over does not occur during meiosis in all cells?

A 2
B 4
C 16
D 256

6 Hybrid species can be produced from cabbage and radish.
The table below shows the chromosome numbers in the parental species and the hybrids.

type of cell	number of chromosomes per cell
parental cabbage	18
parental radish	18
parental gametes	9
F1 hybrids	18
F1 gametes	9
F2 hybrids	18
F2 gametes	18
F3 hybrids	36

Chromosomal mutation occurred at one stage. At which stage did it occur?

A during the formation of the F1 gametes.
B during the formation of the F2 gametes.
C during the fusion of the parental gametes.
D during the fusion of the F1 gametes.

7 3 different polynucleotide molecules (X, Y and Z) were isolated from a eukaryotic cell. One of them is a double-stranded DNA gene, while the other two are the pre-mRNA and mature mRNA that the DNA gene codes for.

The adenine nucleotide content of all 3 molecules was examined and shown in the table below:

Molecule	Percentage of adenine nucleotides in the molecule / %
X	49
Y	52
Z	53

Based on the information given, which of the following conclusions is/are valid and true?

1 X is definitely the DNA gene.
2 Z is definitely the mature mRNA.
3 The pre-mRNA molecule has more uracil than guanine in it.
4 Y has more purine nucleotides than pyrimidine nucleotides in it.

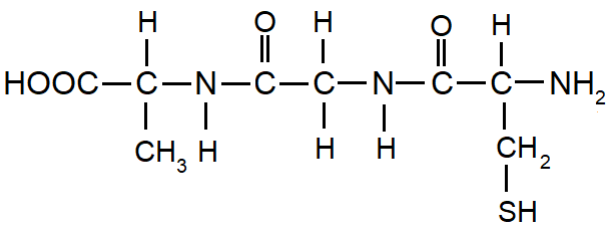
A 1 and 2
B 1, 2 and 4
C 1, 3 and 4
D 2, 3 and 4

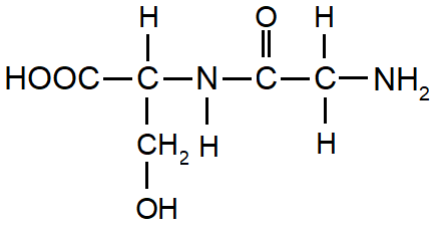
8 In an experiment, polypeptide A, which is coded for by a non-mutated version of a prokaryotic gene, was cleaved by a particular protease.

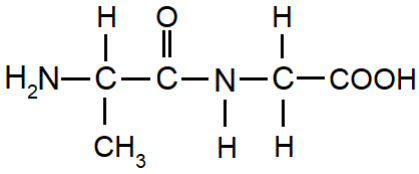
The cleavage produced 2 fragments, one of which contains the C-terminus of polypeptide A and is 5 amino acids long. This 5-amino-acid-long fragment, now called Peptide B, was then isolated for further investigation.

A solution containing many molecules of Peptide B was treated with another protease, called Protease X. The solution was analysed after the treatment and was found to contain various different fragments of different lengths and sequences.

The structures of 3 of these fragments are shown below:







It is known that Protease X is able to cleave any peptide bonds within the molecule of Peptide B. However, the cleavage of all peptide bonds within a single molecule is rare.

The mRNA codons involved in the synthesis of the Peptide B portion of Polypeptide A are shown below:

Amino acid	R group	mRNA codon
Glycine	H	5' – GGC – 3'
Alanine	CH_3	5' – GCC – 3'
Serine	CH_2OH	5' – UCC – 3'
Cysteine	CH_2SH	5' – UGU – 3'

Which of the following correctly shows a single point mutation in the portion of the template DNA sequence that codes for Peptide B, leading to a single amino acid substitution?

A 5' – GCC GCC ACA GGA GCC – 3'
B 5' – GCC GGA ACA GCC GCC – 3'
C 5' – GGA GCC GCC GCC ACA – 3'
D 5' – ACA GCC GCC GCC GGA – 3'

Examiner's comments:
C – Ala – Gly – Cys – N
C – Ser – Gly – N
N – Ala – Gly – C

Peptide B: N – Cys – Gly – Ala – Gly – Ser – C
mRNA sequence: 5' UGU GGC GCC GGC UCC 3'
Template DNA: 3' ACA CCG CGG CCG AGG 5'

Template DNA: 5' GGA GCC G**G**C GCC ACA 3'

9 Arrange the following statements on the signal transduction pathway for insulin in order.

1 Auto-crossphosphorylation
2 Increase in uptake of glucose through facilitated diffusion
3 Relay proteins bind to specific activated tyrosine residues
4 Activated relay proteins activate their respective transduction pathways
5 Insulin binds to receptor tyrosine kinase (RTK) at the receptor site
6 Vesicles containing glucose transporters move to and fuse with the plasma membrane
7 Changes in the 3D conformation activates the tyrosine kinase domain of receptor

A 5, 1, 7, 3, 4, 6, 2
B 5, 7, 1, 3, 4, 6, 2
C 2, 5, 1, 7, 3, 4, 6
D 2, 5, 1, 7, 4, 3, 6

10 The Southern pine beetle is a pest native to pine forests in Central America and the southeastern U.S..

However recent observations show the latitude of this pest infestation creeping northward by about 40 miles a decade since 1980, and could damage 273,000 square miles of pine forests by 2080.

Which of the following explanations for the above observation are attributed to climate change?

1 Longer and more intense droughts weakening the defenses of trees, making them vulnerable to attack by the beetles.
2 Long-term suppression of forest fires leaving pine forests unnaturally dense and uniform, facilitating the beetles' spread from tree to tree.
3 Pines trees colonising new territories with cooler climates.
4 Increased temperatures in the winter allowing the beetles' lavae to survive.

A 1 and 4 only
B 2 and 3 only
C 1, 3 and 4 only
D All of the above

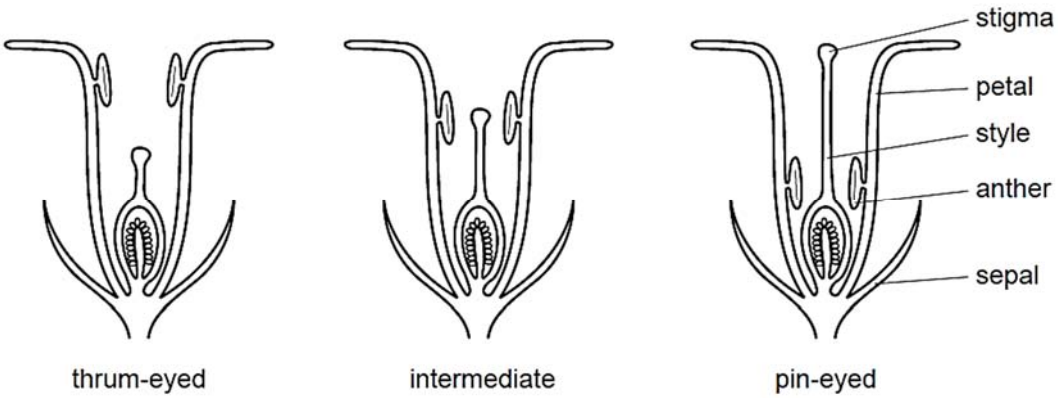
11 The primrose, *Primula vulgaris*, is a small herbaceous, yellow-flowered plant which is common in cooler areas of the Northern hemisphere including alpine and Arctic areas.

The flowers of the primrose have different flower shapes (polymorphic), which are adaptations for pollination. 'Thrum-eyed' primroses have a short style. 'Pin-eyed' primroses have much longer styles. The anther position also varies among the primrose.

Some populations of primrose consist almost entirely of plants with intermediate flowers. These populations are common where there are fewer winged insects.

Anthers produce pollen (male gametes) which land on the stigma, leading to fertilization.

The diagrams show polymorphic flowers of primroses.



Which statements are correct?

1 Cross-pollination will be favoured between pin-eyed and thrum-eyed primroses.
2 Primroses with pin-eyed flowers are likely to show more genetic diversity than primroses with intermediate flowers.
3 Primroses with thrum-eyed flowers are likely to be more able to adapt to changing environmental conditions than pin-eyed primroses.
4 Self-pollination is more likely to occur in primroses with intermediate flowers.

A 1 and 2
B 3 and 4
C 1, 2 and 4
D All of the above

12 On the tiny Lord Howe Island, 600 miles east of Australia, there are two species of palm which seem, from DNA analysis, to be descended from one original species. Factors involved in this speciation on this tiny island include:

1 linkage of genes for soil tolerance and flowering time
2 variation in flowering time
3 variation of soil tolerance
4 variation of soil types on the island

What is the correct sequence to explain this speciation?

A 1 → 2 → 3 → 4
B 2 → 1 → 4 → 3
C 3 → 4 → 1 → 2
D 4 → 3 → 2 → 1

Examiner's comments:
Statement 1: genes are inherited together, because plants will not be able to exchange alleles with the other variants.

13 Many types of evidence, can provide support for Darwin's theory of natural selection and descent with modification.

What statement provides support?

1 The allele for sickle cell haemoglobin that gives resistance to malaria is more frequent in malarial areas.
2 The distribution of the variants of the A blood group antigen reflects human migration patterns.
3 The homozygous condition of the sex-linked allele for a non-functional blood clotting protein is rare.
4 The molecular structure of ATP is almost identical in all eukaryotes.

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

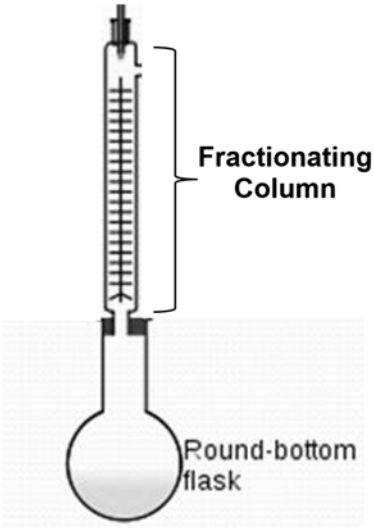
14 Which of the following statement(s) about chromosome structure is/are true?

1 Euchromatin is the more diffuse region of the interphase chromatin and is transcriptionally active.
2 Nucleosomes and linker DNA make up a 30nm chromatin fibre.
3 There are 8 nucleosomes in one turn of the helix of the 30nm chromatin fibre.
4 Further condensation of the 300nm chromatin fibre only takes place during mitosis/meiosis.

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

15 The active messenger RNAs (active mRNAs) in tissue cells can be isolated by passing the homogenised cell contents through a fractionating column (shown in diagram below). The column has short lengths of uracil nucleotides attached to a solid supporting material.

Most molecules of mRNA that pass through the column break up into small pieces and cannot be translated.



The active mRNAs that attach to the column can be separated by appropriate treatment.

Which statements correctly describe active mRNA?

1 Active mRNAs are held to the fractionating column by bonds between adenine and uracil bases.
2 Active mRNAs can be released from the fractionating column by breaking hydrogen bonds.
3 Only mRNAs with polyadenine tailing can be translated.

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

16 Four different genes are regulated in different ways.

Gene 1 undergoes tissue-specific patterns of alternative splicing.
Gene 2 is part of a group of structural genes controlled by the same regulatory sequences.
Gene 3 is in some circumstances subject to methylation.
Gene 4 codes for a repressor protein which acts at an operator site close by.

Which role of the table correctly identifies which genes are prokaryotic and which are eukaryotic?

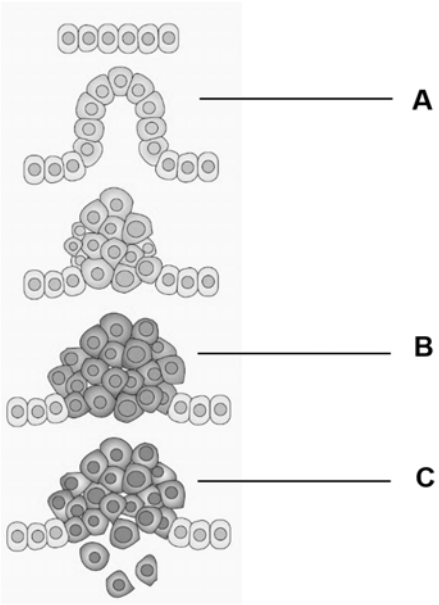
	prokaryotic	eukaryotic
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 4	1 and 3
D	2 and 3	1 and 4

17 Which of the following statements about the eukaryotic control elements are correct?

1 Attachment of the RNA polymerase II at the TATA box is achieved with the help of a series of specific transcription factors
2 A given gene may have multiple enhancers, each active at a different time or in a different cell type or location in the organism
3 Repressors bind to silencer regions of DNA far upstream of promoters to repress transcription

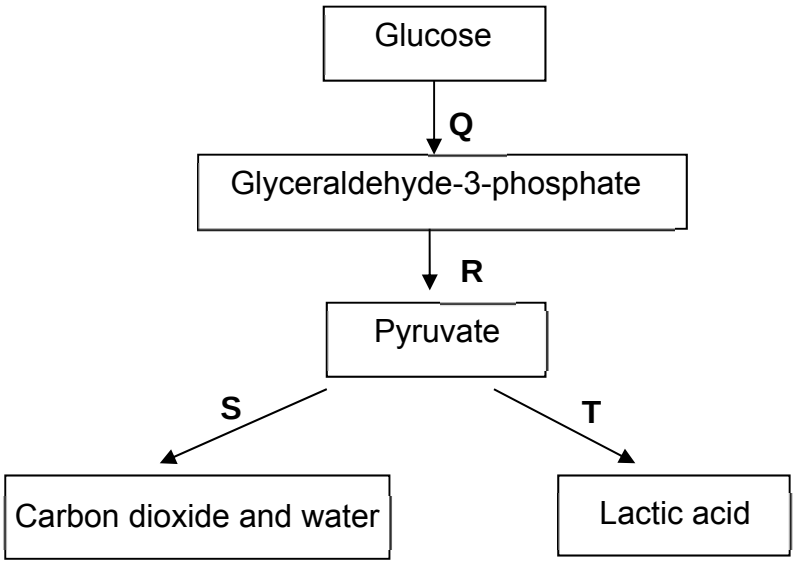
A 1 and 3
B 1 and 2
C 2 and 3
D 1, 2 and 3

18 The diagram below shows the mutli-step model of cancer development in colon cancer. Which of the following contains the most appropriate explanation for the different stages?



	A	B	C
A	Mutation in one copy of a tumor suppressor gene	Mutation in other genes such as telomerase gene	Loss of anchorage dependence
B	Mutation in one copy of a proto-oncogene	Loss of density dependence	Loss of anchorage dependence
C	Mutation in one copy of a proto-oncogene	Loss of anchorage dependence	Loss of density dependence
D	Mutation in promoter region upstream of a proto-oncogene	Mutation in one copy of a tumor suppressor gene	Loss of density dependence

19 With reference to the diagram below, relate processes **Q, R, S, T** to statements **(1), (2)** and **(3).**

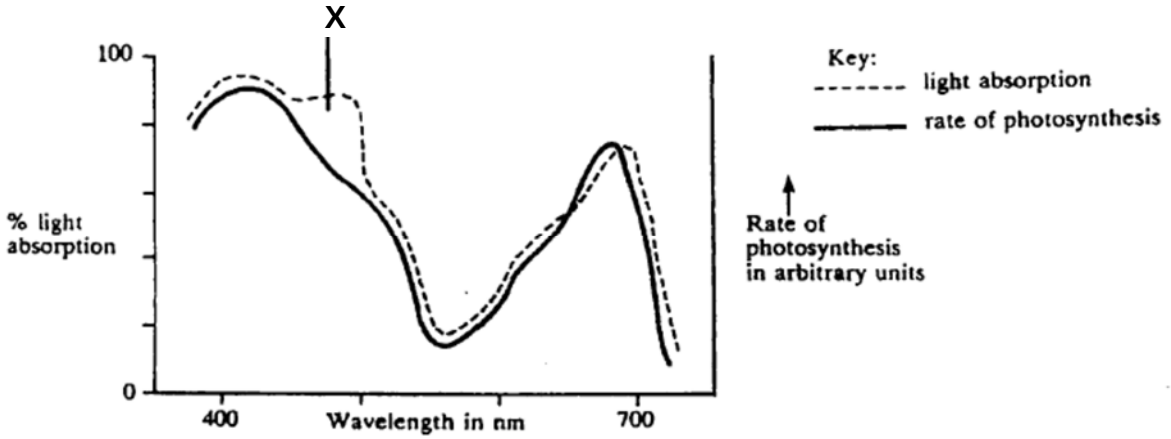


(1) NAD is regenerated without the use of the electron transport system
(2) ATP is synthesised via substrate level phosphorylation
(3) It can take place under anaerobic conditions.

	(1)	(2)	(3)
A	T only	R only	Q,R,T only
B	T only	R,S only	Q,R,T only
C	S,T only	R only	Q,R,S,T
D	S,T only	R,S only	Q,R,S,T

A: to catch students who forgot that Sustrate-Level Phosphorylation also occurs in S (link reaction, Krebs cycle, OP)
D: to catch students who thought S is fermentation of yeast/plants
C: to catch students who thought that S is fermentation AND also forgot SLP also occur in S

20 The graph below shows the effect of different wavelengths of light on the rate of photosynthesis and on the amount of light absorbed by the pigments in a green seaweed.



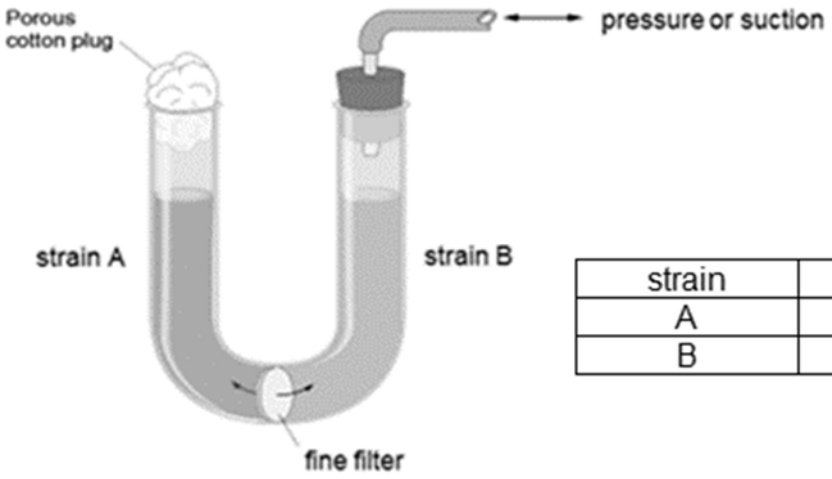
The difference between the two curves at X is due to

A inefficient trapping of light energy by the chlorophyll
B no ATP production at that wavelength
C oxygen given off during photosynthesis interferes with the absorption of light.
D carotenes absorbing light that is not used in photosynthesis.

21 A mutation that renders the product of a regulatory gene non-functional for an inducible operon will result in

A continuous transcription of the genes of the operon.
B irreversible binding of the repressor to the operon.
C complete blocking of the attachment of RNA polymerase to the promoter.
D continuous production of gene products that are anabolic in function

22 To investigate gene transfer between bacteria, two strains of the same bacterial species were each placed in one arm of a U-tube with a filter separating them.



strain	genotype
A	met$^-$
B	met$^+$

met $^+$ is a wild-type gene that codes for the ability to synthesise the essential amino acid, methionine.

met $^-$ indicates that the *met* $^+$ gene has been mutated.

Liquid may be transferred between the arms of the tube by the application of pressure or suction, but particles that are larger than the filter pore size would not be able to pass through the fine filter.

type of particle	size
bacteria	1 – 10μm
bacteriophages	0.025 – 0.2μm

After several hours of incubation, bacterial cells from the left arm of the tube are plated on minimal medium.

Which pair of experimental results best shows that transduction was most likely the process responsible for gene transfer between strains A and B?

	filter pore size	**growth of colonies on minimal medium**
A	5μm	no
	0.1μm	yes
B	5μm	no
	0.1μm	no
C	0.45μm	no
	0.02μm	yes
D	0.45μm	yes
	0.02μm	no

23 Probes are short, single-stranded DNA segments that are used to identify DNA fragments with a particular sequence. Which of the following statements about probes is false?

A They have the same sequence as the sequence to be identified.
B Probes may not adhere 100% to target sequences.
C A probe from one organism may be used to locate a homologous DNA segment from a different organism.
D In order to be useful, the probe must be labelled.

24 Which is a correct statement about obtaining human embryonic stem cells for research?

1 Removal of these cells is considered to be ethically acceptable as normal development of the embryo is not inhibited.
2 The cells must be removed at an early stage of development from a region of the blastocyst known as the inner cell mass.
3 The cells must be removed immediately following the successful fertilisation of the ovum by the sperm, and after checking for normal mitotic division.
4 The region of the blastocyst from where the cells are removed is an area that develops at a later stage into the placenta.

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

25 How do viruses cause diseases in animals?

1 They inhibit normal synthesis of host cell DNA, RNA, or protein.
2 They degrade the host cell's chromosomes.
3 They disrupt the oncogenes of the host cell causing uncontrolled cell division.
4 Their viral proteins and glycoproteins on the surface membrane of host cells cause them to be recognized and destroyed by the body's immune defences.

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

26 Which of the following statement(s) is/are true for tuberculosis?

1 The pathogen is from the genus *Orthopoxvirus*
2 Some individuals with the disease are not infectious
3 The disease can exist in the active or inactive state
4 Transmission of the disease increases with frequency of exposure to an infectious individual

A 4 only
B 1 and 3 only
C 2, 3 and 4 only
D All of the above

27 The length of the petiole (leaf stalk) in a type of flowering plant is controlled by two genes, A and B. These genes are found on different loci on non-homologous chromosomes.

Homozygous dominant plants have long petioles (30 cm), homozygous recessive plants have short petioles (10 cm). Each dominant allele contributes 5cm to the petiole length.

F_1 plants with medium length petioles (20 cm) were obtained when a plant with short petiole is crossed with a plant with long petiole. If the F1 generation plants were allowed to cross, what proportion of their offspring would be expected to have medium length (20 cm) petioles?

A 0.0625
B 0.25
C 0.375
D 0.5

Explanation: AaBb x AaBb ➔ Out of 16 possibilities, look for genotype with any 2 dominant alleles and any 2 recessive alleles. 6/16 = 0.375

28 Agouti mice have banded hairs, giving a grey colour. Black mice have unbanded hairs. White mice have no pigment. A cross between a homozygous black mouse and a white mouse produced offspring with agouti hair. Another cross between the (same) black mouse and another white mouse produced some offspring with agouti hair and some with black hair.

What explains these observations on the phenotype of hair of mice?

A There is a single gene with two codominant alleles, black and white.
B There is a single gene with three alleles in a dominance series, black → grey → white.
C There are two epistatic genes, one controlling pigment production and one controlling banding.
D There are two linked genes, one controlling pigment production and one controlling banding.

Explanation:
Scenario A: Cross 1 and 2: AA x aa ➔ Aa (all gray)
Scenario B: Cross 1and 2: A^BA^B x A^WA^W ➔ A^BA^W (agouti);
Scenario C: A_ pigment production; B_ banding: AAbb x aaBB ➔ AaBb all agouti;
AAbb x aaBb ➔ AaBb, Aabb agouti and black
Scenario D: Linkage + epistasis?

29 The Himalayan rabbits have white hair on the body and black hair on the extremities such as feet, tail, ears and face.

The allele for the Himalayan rabbit pigment pattern, c^h, is recessive to the alleles for normal colour (all hair agouti), C, as well as dark chinchilla (all hair dark grey), c^{chd}, and is dominant to the allele for albino (all hair white, no pigment production), c. All of the alleles of this gene produce different versions of the same enzyme involved in pigment production.

A patch of white fur was removed from a Himalayan rabbit and an ice pack secured to the skin. The fur that grew back on the patch was black.

Which is correct?

	Genotypes of Himalayan rabbits	**Explanation for pigment pattern in Himalayan rabbits**
A	c^hc^h only	The enzyme is denatured at the high skin temperatures found on the rabbit's bodies
B	c^hc^h only	The enzyme becomes inactive at the low skin temperatures found on the rabbit's feet, tail, ears and face.
C	c^hc^h and c^hc only	The enzyme is denatured at the high skin temperatures found on the rabbit's bodies
D	c^hc^h and c^hc only	The enzyme becomes inactive at the low skin temperatures found on the rabbit's feet, tail, ears and face.

30 Table 1 below shows the effect of a drug called P8 on the blood pressure of mice, 20 minutes after P8 was fed to the mice. 4 mice were administered P8, and another 4 mice were given placebo drug as control.

Table 1: Effect of P8 on the blood pressure of mice

	Systolic blood pressure /mmHg				
Condition	Reading 1	Reading 2	Reading 3	Reading 4	Average
Control	175	175.5	175	176	175.5
P8 added	140	140	141	140	140.25

The mathematical formulae for standard deviation and experimental t-value are provided below:

$$\text{standard deviation} \qquad s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

Legend

$\sum$ is summation of

x is observed values

$\overline{x}$ is the mean

n is the sample size (number of observations per condition)

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$$

Where:

- **x1** is the mean of sample 1
- **s1** is the standard deviation of sample 1
- **n1** is the sample size of sample 1
- **x2** is the mean of sample 2
- **s2** is the standard deviation of sample 2
- **n2** is the sample size in sample 2

The table below shows the Student's t-test table of t critical values:

df	.10	.05
1	3.078	6.314
2	1.886	2.920
3	1.638	2.353
4	1.533	2.132
5	1.476	2.015
6	1.440	1.943
7	1.415	1.895
8	1.397	1.860
9	1.383	1.833
10	1.372	1.812
11	1.363	1.796
12	1.356	1.782
13	1.350	1.771
14	1.345	1.761
15	1.341	1.753

Which of the following is false?

A Degree of freedom is 1
B Standard deviation for control group is 0.577
C t-experimental value is 81.465
D There is significant difference between control mice and mice administered P8

END OF PAPER

Civics Group	Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 PRELIM

H2 BIOLOGY **9744/2**

Paper 2

Monday 10th September 2018 2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A (Structured Questions)
Answer **all** questions.
Write your answers in the spaces provided on the question paper.

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

For Examiners' Use	
Section A	
1	/13
2	/13
3	/14
4	/14
5	/16
6	/10
7	/9
8	/5
9	/6
Total	**/100**

This document consists of **22** printed pages.

[Turn over

QUESTION 1

Fig 1.1 shows the structure of a G-protein-linked receptor (GPLR) from a cross-section of the plasma membrane.

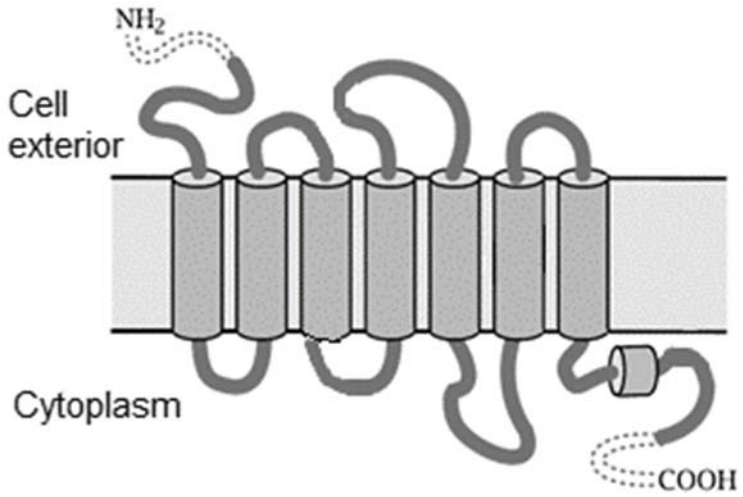


Fig 1.1

(a) With reference to **Fig 1.1**, describe the significance of R groups to the structure and function of a GPLR.

……

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…… [5]

(b) The GPLRs make up the largest family of cell surface receptors. Outline the route taken by the GPLR after its synthesis to its final location in the plasma membrane.

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…… [4]

GPLRs are found to be closely associated with a type of G protein called K-Ras in the cell signaling pathways.

Fig. 1.2 is a simplified diagram showing the normal roles of GPLR and K-Ras in the RAS/MARK signaling pathway.

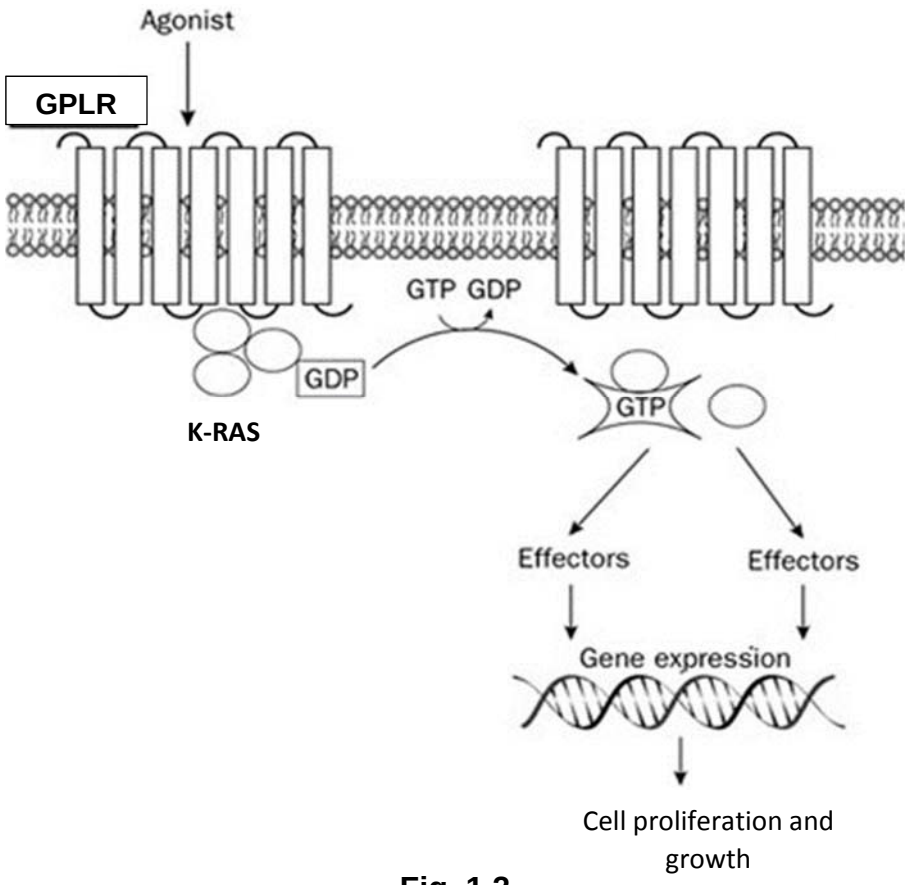

Fig. 1.2

(c) Assuming that the effectors (in **Fig. 1.2**) in the transduction pathways function normally, explain how a mutation can lead to the formation of tumours in cancer.

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…… [4]

[Total: 13m]

QUESTION 2

Fig. 2.1 shows Process X in an eukaryotic cell which produces ribosomal RNA (rRNA).

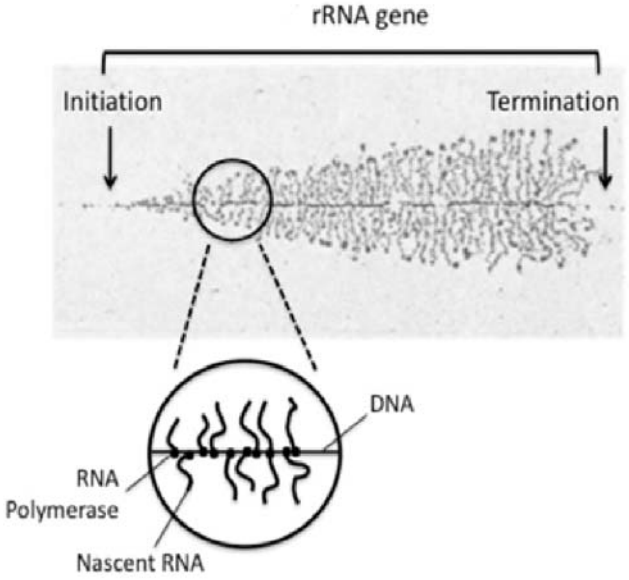

Fig. 2.1

(a)(i) Name the Process X occurring in **Fig. 2.1**.

…….[1]

(ii) List one molecule **not mentioned in Fig. 2.1** that is required for Process X.

…….[1]

(iii) Describe how RNA polymerase is able to recognise and bind to the promoter on DNA and not to other DNA regions.

……..

……..

……..

…….. [2]

(iv) Explain for the observed pattern of Process X in **Fig. 2.1**.

……..……..

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…..……..…….. [2]

(v) State the roles of rRNA in protein synthesis.

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…..……..…….. [2]

(b) During protein synthesis in cells of an embryo, all tRNA molecules with UAC anticodon sequence, are observed to be bound to arginine amino acid instead of methionine.

(i) Suggest how these tRNA molecules attached with the wrong amino acid might arise.

……..……..

……..……..

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…..…..…….. [2]

(ii) Suggest and explain the effect of this wrong pairing of amino acid to tRNA on the embryo.

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[Total: 13m]

QUESTION 3

In a dihybrid inheritance, gene B/b codes for flower colour while gene H/h codes for leaf shape of a plant.

The F1 progeny of a pure-bred plant with red flowers and oval leaves, and another pure-bred plant with yellow flowers and fan-shaped leaves, have red flowers and fan-shaped leaves.

F1 plants then undergo a test cross.

(a) Predict the expected phenotypic ratio in the F2 progeny.

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…..……..…….. [1]

(b) Explain how different characteristics can be inherited independently in dihybrid inheritance.

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…..……..…….. [2]

(c) Using the symbols for the alleles stated above, draw a genetic diagram to show the expected phenotypic ratios for the offspring of the test cross if inheritance is Mendelian.

……[3]

(d) You will now proceed to do a chi-square statistical test for the above cross.

(i) State the objective of performing a chi-squared statistical test.

……..……..

…..……..…….. [1]

The number and phenotypes of F2 plants are listed below:

F2 phenotypic classes	Observed numbers
Red flower, fan-shaped leaf	85
Red flower, oval leaf	70
Yellow flower, fan-shaped leaf	89
Yellow flower, oval leaf	78

Formula for χ^2 calculation

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \qquad v = c - 1$$

where Σ = 'sum of…' O = observed 'value'
v = degrees of freedom E = expected 'value'
c = number of classes

(ii) Calculate the chi-square value.

……[2]

Table 3.1

degrees of freedom	probability P				
	0.50	0.10	0.05	0.01	0.001
1	0.46	2.71	3.84	6.64	10.83
2	1.39	4.61	5.99	9.21	13.82
3	2.37	6.25	7.82	11.35	16.27
4	3.36	7.78	9.49	13.28	18.47

(iii) Using Table 3.1 and the calculated chi-square value, find the probability that observed and expected results differ by chance.

……[1]

(iv) State the conclusions for this test.

……..……..

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…..……..……..… [2]

(v) Plants are a good choice of experimental organisms for carrying out such crosses and for performing statistical tests.

Compared to plants, humans are less ideal and it is usually more difficult to arrive at reliable conclusions for observations involving humans. Suggest why.

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…..……..……..… [2]

[Total: 14m]

QUESTION 4

(a) In many ant species, polymorphism exists in the form of worker and queen ants. Some distinct differences between workers and queens are that workers are much smaller and cannot reproduce. Strict caste roles are also observed: queens lay eggs and workers take care of all other work, including offspring.

In a new study to identify the cause for these behavioural and physical differences, Rockefeller scientists report that a gene coding for an insulin-like peptide, ILP2, is instrumental in promoting and suppressing reproduction.

ILP2 is the ant version of insulin and, like human insulin, regulates metabolism by cellular uptake of glucose.
The table below summarises their results:

Expression of ILP2	**Type of ants**
High	Reproducing
Low	Non-reproducing

(i) Suggest a link between glucose uptake and reproduction.

……..……..

…..……..…….. [1]

(ii) The presence of larvae causes the activation of ovaries in worker ants. It was suggested that larvae release pheromones that control the expression of the ILP2 gene.

Explain how pheromones could have played a role at the transcriptional level of ILP2 expression in determining the caste roles of ants.

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…..……..…….. [4]

(iii) The expression of the ILP2 gene can be further controlled even after translation of the ILP2 mRNA. Describe 2 ways to control ILP2 expression at this level.

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…… [2]

(b) Double-stranded DNA of the ILP2 gene is denatured and allowed to hybridise through complementary base pairing with mature ILP2 mRNA isolated from queen ant cells. This is shown in **Fig. 4.1**.

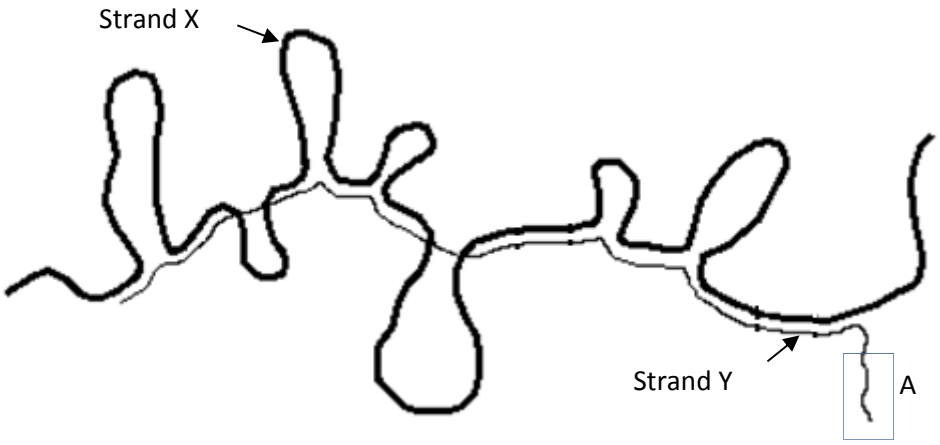

Fig 4.1

(i) State the identity of Strand X.

……[1]

(ii) Explain your answer in (i) using evidence from **Fig. 4.1**.

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…… [2]

(iii) Circle the locations of the promoter and termination regions of the ILP2 gene on **Fig. 4.1**. Label the regions accordingly. [2]

(iv) Suggest the identity of the unpaired segment (labelled A) on strand Y. Explain your answer.

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…… [2]

[Total: 14m]

QUESTION 5

(a) The following extract was summarised from an article published in Proceedings of the National Academy of Sciences journal.

The article proposes a method to overcome HIV pandemic using genetically modified rice.

Summary points of article:

- Scientists from the US, UK, and Spain have developed a new strain of genetically modified rice to manage HIV symptoms in countries where traditional medicines can be hard to access.

- The rice seeds produce three proteins – the antibody 2G12, and the lectins griffithsin and cyanovirin-N – which preliminary *in vitro* tests show bind to gp120 and *neutralize* HIV.

- These seeds can be ground up to form a paste that can then be applied as a topical cream, which counterbalances the virus in the exact same way as the anti-retroviral medication.

- There remains a few *hurdles* researchers will have to jump before the rice becomes widely available.

(i) Define the term "neutralise" in this context and explain how this process can halt the reproductive life cycle of HIV.

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(ii) Suggest one possible hurdle that researchers need to overcome for this treatment using GM rice.

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(b) Fig 5.1 shows a lentivirus, which can bind to cells lining the airways of the lungs. The lentivirus is a form of **retrovirus**. The **general structure** of this virus is similar to that of HIV.

The lentivirus is commonly used as a vector (vehicle to transport external copies of RNA coding for specific proteins into cells).

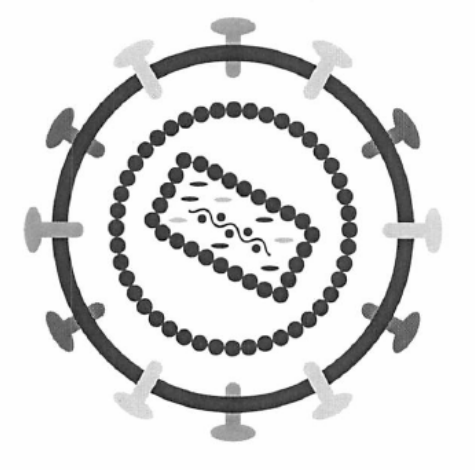

Fig. 5.1

(i) Using the letter **R**, label **Fig 5.1** to identify a feature that is protein in nature.

……[1]

(ii) Explain why external copies of RNA intended to be introduced into cells cannot pass through the membrane of cells directly.

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(iii) With reference to your knowledge on retroviruses, explain how **long-term** expression of an inserted RNA is brought about following infection of host cells with the lentiviral vector.

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(c) Plasmids are small, self-replicating circles of DNA.

During cloning, a target gene can be inserted into a plasmid, making the plasmid a **vector** that transports the target gene into cells.

It is hoped that the plasmid and the target gene gets replicated to multiple copies in the cell.

Based on its features, suggest why plasmids are good choices of cloning vectors.

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……..……..……[1]

(d) The F plasmid is a crucial plasmid found naturally in bacterial cells. It plays an integral role in the transfer of genes from one bacterial cell to another through processes such as conjugation.

Fig. 5.2 shows the process of conjugation.

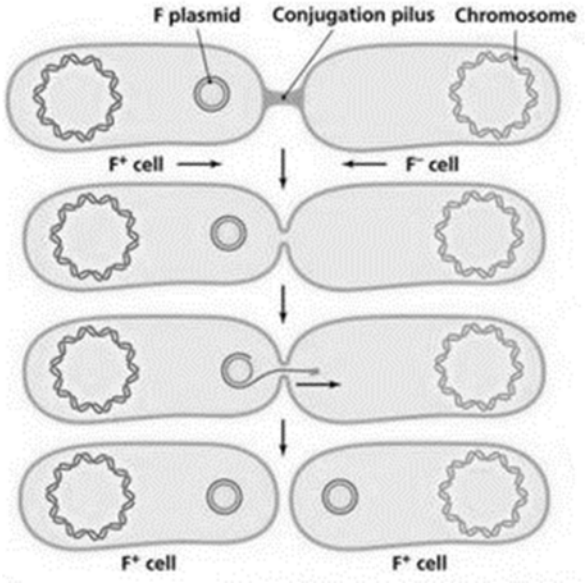

Fig. 5.2

During conjugation, the transferred F plasmid strand undergoes DNA replication similar to the synthesis of Okazaki fragments.

Explain why.

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(e) Scientists isolated one of the *lac permease* gene from the lac operon and proceeded to amplify the gene using an automated process of Polymerase Chain Reaction (PCR).

Fig. 5.3 shows the temperatures used at the different stages during PCR.

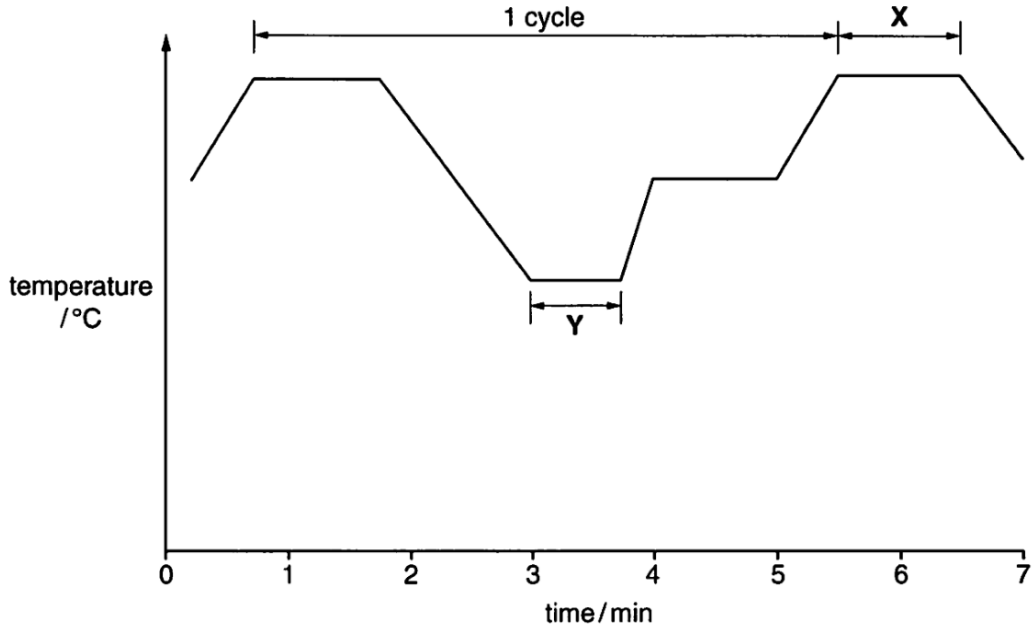

Fig. 5.3

(i) Describe what happens at stage Y.

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…..……..……. [2]

(ii) If stage X of PCR process persisted for more than two hours, suggest what you will expect to find in the PCR mixture during this period.

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[Total: 16m]

QUESTION 6

(a) The concentration of carbon dioxide in a sample of air was found to be 280 ppm (parts per million).

An experiment was designed to measure the concentration of carbon dioxide in the air after it had flowed over the leaves of a green plant. Measurements were taken at a range of light intensities.

The following results were obtained:

Light intensity (% of full sunlight)	**Concentration of carbon dioxide in air after flowing over leaves (ppm)**
75	253
50	252
25	254
10	280

(i) Predict the concentration of carbon dioxide in the air after flowing over the leaves when the plant was placed in the dark.

…….. [1]

(ii) Explain the experimental results obtained in relation to light intensity being a limiting factor of photosynthesis.

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(b) Discuss the validity of the statement "The synthesis of ATP during photophosphorylation depends on the **transport of protons** across membranes."

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(c) $NADP^+$ is an important electron carrier found in plants, but its level decreases sharply in the day. Suggest the significance of the decrease of $NADP^+$ during the day.

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[Total: 10m]

QUESTION 7

Ants and bees – which by all appearances seem so different – are found to be close relatives (refer to **Fig. 7.1**) in a new study which used cutting-edge DNA sequencing techniques to elucidate the taxonomic relationships among the different families of wasps, bees and ants.

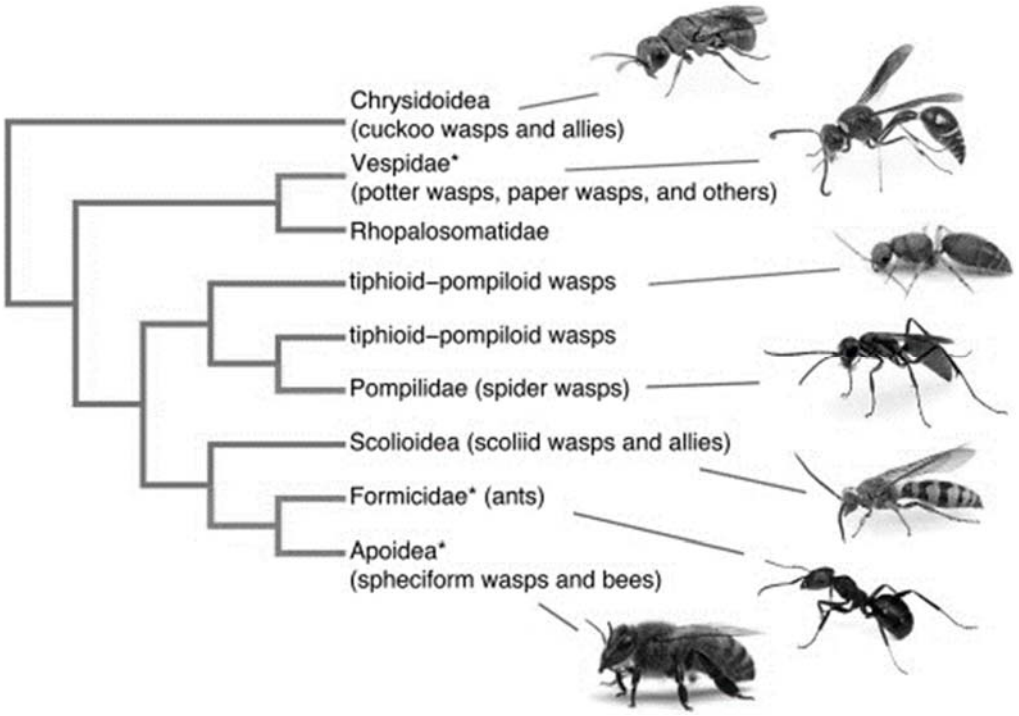

Fig. 7.1

(a) State **one** advantage of using DNA sequences to elucidate the evolutionary relationship between ants and wasps.

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…..…….. [1]

(b) Discuss how molecular homology was used in this study to derive the phylogram in **Fig. 7.1**.

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(c) Explain how biogeography can help to support the evolutionary deductions in this case study.

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(d) The same study also suggested that when the early bees switched from preying on other insects to pollen feeding, the number of bee species exploded compared with their hunting wasp sister group. The switch from predatory behavior in hunting wasps to pollen feeding in bees also saw a corresponding increase in diversification of the mouthparts and tongue lengths of the bees.

Suggest and explain how the increase in number of bee species is made possible with the switch to pollen feeding, as compared to speciation in hunting wasps.

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[Total: 9m]

QUESTION 8

(a) Explain how the structure of antibodies cause pathogens to be destroyed by macrophages.

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……[3]

(b) DNA coding for the light chain of an antibody is isolated from a **mature** B lymphocyte.

DNA coding for the light chain of an antibody is also isolated from a **developing** B lymphocyte (before maturation).

Gel electrophoresis was performed on both sources of DNA.

Fig 8.1 shows the gel diagram and the corresponding positive / negative electrode.

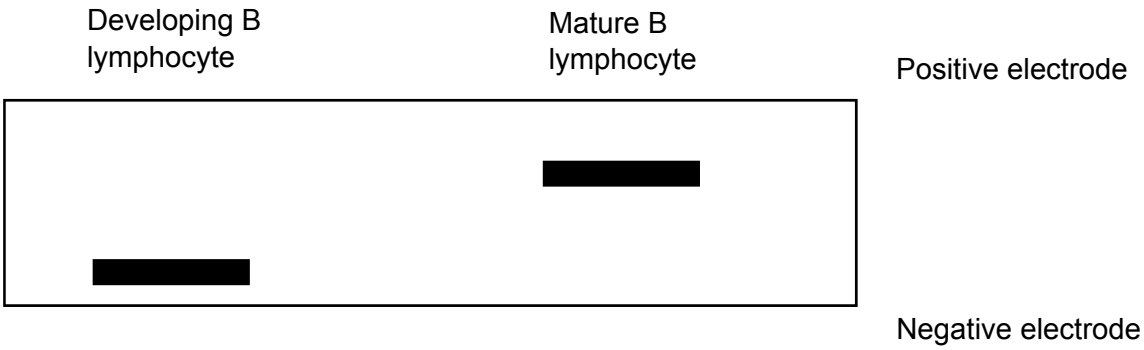

Fig. 8.1

Explain the difference in the results on the gel diagram.

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……..……..……[2]

[Total: 5m]

QUESTION 9

Carbon dioxide is one of the greenhouse gases that contribute to global warming and subsequently climate change.

A group of high school students decided to test whether varying temperatures would correspondingly affect mean carbon dioxide gas emission.

Table 9.1 shows the mean carbon dioxide gas emission after exposing a fixed number of mealworms to different temperatures. Carbon dioxide gas emission was measured before and after exposure to experimental temperature.

Table 9.1 showing effects of varying temperatures on mean carbon dioxide gas emission, measured in parts per million (ppm). Values represent mean ± standard deviation.

Temperature /°C	Mean Carbon dioxide gas emission /ppm	
	Before exposure to experimental temperature	**After** exposure to experimental temperature
30.0	445 ± 25	450 ± 17
40.0	450 ± 20	500 ± 30
50.0	460 ± 17	540 ± 18

(a)(i) Describe the patterns shown by the data in Table 9.1.

……

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……[2]

(ii) With reference to the mean carbon dioxide gas emission **before** exposure to 40 °C, suggest what standard deviation means.

……

……

……

……[2]

(b) Corals are affected by rising temperatures in ocean waters. Explain how.

……

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……[2]

[Total: 6m]

Civics Group	Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 PRELIM

H2 BIOLOGY **9744/2**

Paper 2

Monday 10th September 2018 2 hours

Additional Materials: Answer Paper

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Section A	
1	/13
2	/13
3	/14
4	/14
5	/16
6	/10
7	/9
8	/5
9	/6
Total	**/100**

This document consists of **22** printed pages.

[Turn over

QUESTION 1

Fig 1.1 shows the structure of a G-protein-linked receptor (GPLR) from a cross-section of the plasma membrane.

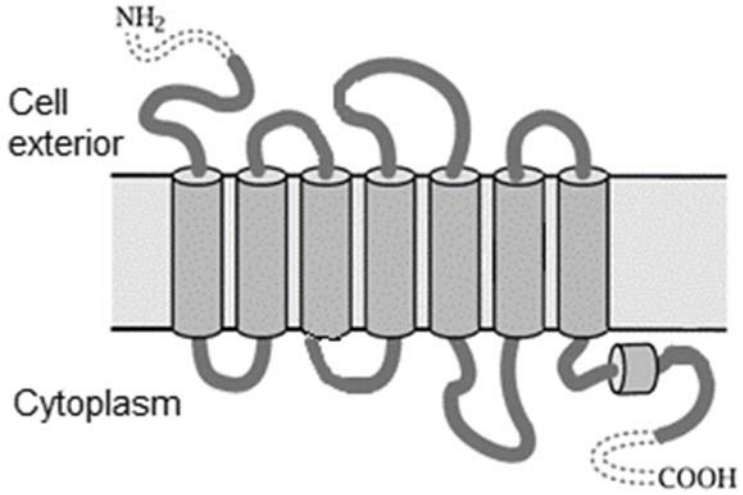

Fig 1.1

(a) With reference to **Fig 1.1**, describe the significance of R groups to the structure and function of a GPLR.

…….. [5]

1. Ref. seven **transmembrane domains/segments**, consisting of **amino acids with hydrophobic R groups**
2. that have <u>hydrophobic interactions</u> with **hydrophobic core** of plasma membrane;
3. **hydrophilic/polar** R groups of amino acids interacting with hydrophilic **phosphate heads** / **aqueous** medium;
4. ref. hydrogen bonds / ionic bonds (Note: hydrophilic interactions are vague)
5. ref. **extracellular** segment/domain/binding site which binds to **signal molecules /ligand**
6. ref. **intracellular/cytoplasmic** segment/domain/binding site which binds to <u>G-protein</u>
7. Ref. R groups of amino acids at binding site forming temporary interactions / providing complementary 3D conformation for signal molecules/G protein to bind

(b) The GPLRs make up the largest family of cell surface receptors. Outline the route taken by the GPLR after its synthesis to its final location in the plasma membrane.

…….. [4]

1. Newly synthesised polypeptide enters the rough endoplasmic reticulum (rER**)** and **folds into its native / 3-dimensional conformation**
2. Protein undergoes **chemical / post-translational modification** (where short carbohydrate chains are added to these proteins (glycosylation))
3. ref. GPLR being packaged into **transport vesicles** which **buds off the rER** and **fuse with** cis **face of the Golgi body**
4. where **further chemical / post-translational modification** of the protein occurs.
5. Modified proteins packaged into **secretory vesicles** which **bud off the** trans **face** of the Golgi body.
6. Secretory vesicles move to and **fuse with the cell surface membrane** / plasma membrane, GPLR embedded within plasma membrane;
7. Ref. movement of vesicles on cytoskeleton / microtubules involving ATP hydrolysis

GPLRs are found to be closely associated with a type of G protein called K-Ras in the cell signaling pathways.

Fig. 1.2 is a simplified diagram showing the normal roles of GPLR and K-Ras in the RAS/MARK signaling pathway.

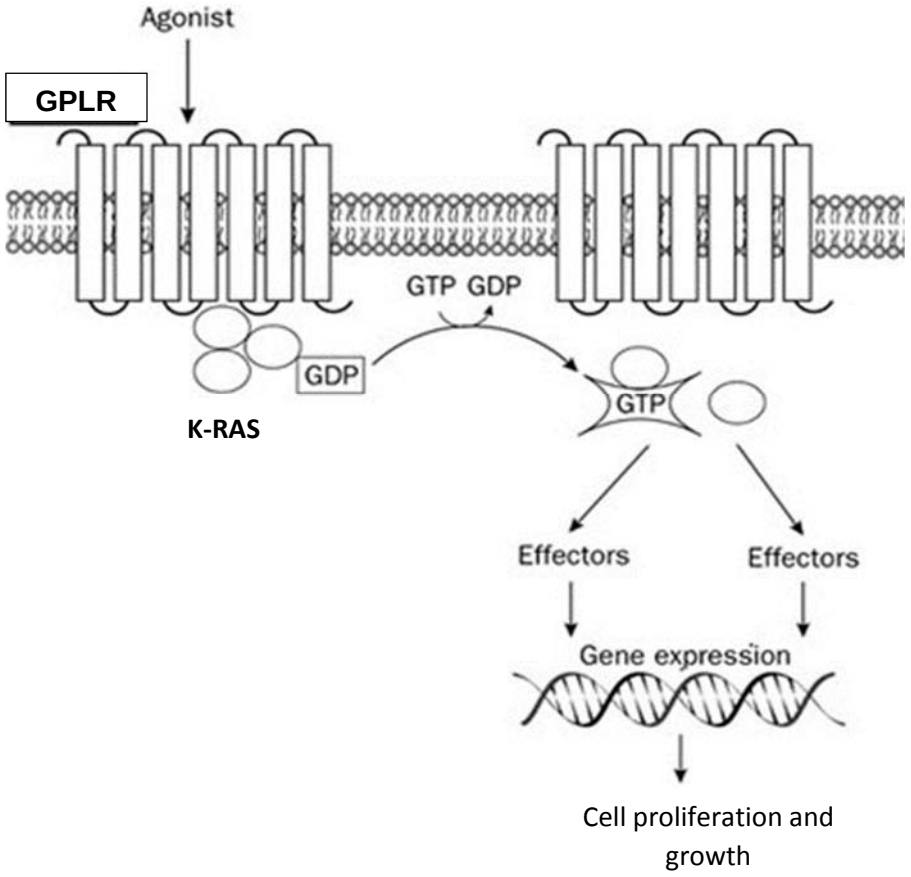

Fig. 1.2

(c) Assuming that the effectors (in **Fig. 1.2**) in the transduction pathways function normally, explain how a mutation can lead to the formation of tumours in cancer.

…….. [4]

1. (gain of function) Mutation in the K-Ras gene
2. ref. K-Ras protein functions as a GTPase enzyme;
3. Mutated K-Ras protein unable to hydrolyse/convert GTP to GDP / mutated K-Ras continuously/constitutively bound to GTP; ref. mutated K-Ras protein constitutively activated/switched on
4. activating/switching on downstream **transduction** pathways / ref. expression of genes; that lead to continuous cell growth and division;
5. Ref. accumulations of other mutations / 1 example e.g. tumour suppressor genes / other proto-oncogene mutations

Or

1. Mutation in the GPLR gene
2. Mutated GPLR unable to hydrolyse ligand / ligand continuously bound to mutated GPLR / doesn't require ligand for activation;
3. GPLR continuously activated to (expose K-Ras binding domain to) bind to G-protein; K-Ras protein continuously activated/switched on
4. activating/switching on downstream **transduction** pathways / ref. expression of genes that lead to continuous **cell growth and division;**
5. Ref. accumulations of other mutations + 1 example e.g. tumour suppressor genes / other proto-oncogene mutations

QUESTION 2

Fig. 2.1 shows Process X in an eukaryotic cell which produces ribosomal RNA (rRNA).

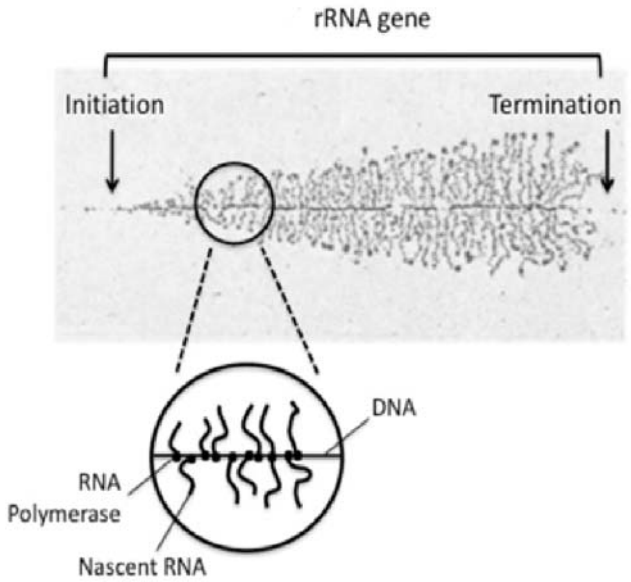

Fig. 2.1

(a)(i) Name the Process X occurring in **Fig. 2.1**.
……[1]

1. Transcription

(ii) List one molecule **not mentioned in Fig. 2.1** that is required for Process X.
……[1]

1. General Transcription factor (Reject: Specific transcription factor due to it not a real requirement for transcription)
   / ribonucleotides
   / transcription initiation factors;

(iii) Describe how RNA polymerase is able to recognise and bind to the promoter on DNA and not to other DNA regions.
……[2]

1. Ref. RNA polymerase has a domain complementary in shape to general transcription factors which bind to TATA box of promoter
2. General Transcription factors contain a **DNA-binding domain** [Reject: active site] which recognize and bind to specific DNA sequence in the **promoter** ;
3. Ref. **Nucleotide sequence** / length / major and minor grooves of promoter offers a **complementary shape** to DNA-binding domain of RNA polymerase ;

[Reject: complementary base pairing]

(iv) Explain for the observed pattern of Process X in **Fig. 2.1**.

……[2]

1. **Shorter** RNA transcripts seen at the **beginning** of the DNA template strand, which get **longer** till the **end** of the transcription unit, (where the transcripts detach from the DNA template after transcription termination)
2. Due to simultaneous transcription of rRNA gene **by multiple RNA polymerases**, (causing RNA transcripts to extend perpendicularly from DNA template strand) ;

(v) State the roles of rRNA in protein synthesis.

……[2]

1. The rRNA in ribosomes holds the tRNA and mRNA together in **close proximity**, via **complementary base pairing / hydrogen bonds**
2. positions the new amino acid for addition to the carboxyl end of the growing polypeptide
3. rRNA peptidyl transferase activity catalyzes formation of a peptide bond between the new amino acid and the polypeptide chain
4. Ref. rRNA associate with proteins to form ribosomal subunits / ribosomes (which synthesizes proteins)

(b) During protein synthesis in cells of an embryo, all tRNA molecules with UAC anticodon sequence, are observed to be bound to arginine amino acid instead of methionine.

(i) Suggest how these tRNA molecules attached with the wrong amino acid might arise.

……[2]

1. Ref. possible mutation in the **gene** sequence for the aminoacyl tRNA synthetases,
2. resulting in **altered 3D conformation** of active site
   which is **complementary** (in shape) to the amino acid arginine and the corresponding tRNA with anticodon UAC

(ii) Suggest and explain the effect of this wrong pairing of amino acid to tRNA on the embryo.

……[3]

1. ref. altered **primary sequence** of polypeptides (all methionine replaced by arginine) and folding of polypeptides to **tertiary structure** / 3D conformation is affected;
2. ref. **non-functional proteins** made in cells
3. ref. possible disruption of metabolic processes in the **cell** / cells might die easily, **embryo cannot further develop** into a fetus

[Total: 13m]

QUESTION 3

In a dihybrid inheritance, gene B/b codes for flower colour while gene H/h codes for leaf shape of a plant.

The F1 progeny of a pure-bred plant with red flowers and oval leaves, and another pure-bred plant with yellow flowers and fan-shaped leaves, have red flowers and fan-shaped leaves.

F1 plants then undergo a test cross.

(a) Predict the expected phenotypic ratio in the F2 progeny.

……[1]

1. 1 Red flower, fan-shaped leaf : 1 Red flower, oval leaf : 1 Yellow flower, fan-shaped leaf: 1 Yellow flower, oval leaf
   [Reject: 1:1:1:1 with no phenotypes]

(b) Explain how different characteristics can be inherited independently in dihybrid inheritance.

……[2]

1. The **2 genes** (encoding for flower colour and leaf shape) are found on **different** pairs of homologous **chromosomes** / are **unlinked** genes ;
2. Ref. **independent assortment** occurs (Reject: random assortment)
   / allows for random **arrangement** of the alleles of one gene pair at **metaphase plate** during metaphase I and II is independent of the alleles of the other gene pair ;
   Subsequent segregation of alleles of one gene pair is independent of the alleles of the other gene pair during anaphase I and II;
   (allows the production of gametes with different combinations of alleles)

(c) Using the symbols for the alleles stated above, draw a genetic diagram to show the expected phenotypic ratios for the offspring of the test cross if inheritance is Mendelian.

……[3]

F_1 phenotypes:	Red flower, Fan-shaped leaf	x	Yellow flower, Oval leaf
F_1 genotype:	BbHh		bbhh
F_1 gametes	(BH) (Bh) (bH) (bh)		(bh)

F_2 genotypes:
Punnett square:

	BH	Bh	bH	bh
bh	BbHh (Red flower, Fan-shaped leaf)	Bbhh (Red flower, Oval leaf)	bbHh (Yellow flower, Fan-shaped leaf)	bbhh (Yellow flower, oval leaf)

F_2 / Progeny phenotypes:	Red flower, Fan-shaped leaf	Red flower, Oval leaf	Yellow flower, Fan-shaped leaf	Yellow flower, oval leaf
F_2 / Progeny phenotypic ratio:	1	1	1	1

Mark scheme:
1. F_1 phenotype and genotypes
2. Parental gametes – (Gametes **must** be circled)
3. F_2 genotypes correspond to phenotypes

(d) You will now proceed to do a chi-square statistical test for the above cross.

(i) State the objective of performing a chi-squared statistical test.

……[1]

1. To test if there is **significant difference** between **observed and expected** numbers / results (Reject: ratio)

The number and phenotypes of F2 plants are listed below:

F2 phenotypic classes	Observed numbers
Red flower, fan-shaped leaf	85
Red flower, oval leaf	70
Yellow flower, fan-shaped leaf	89
Yellow flower, oval leaf	78

Formula for χ^2 calculation

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \qquad v = c - 1$$

where Σ = 'sum of…' O = observed 'value'
v = degrees of freedom E = expected 'value'
c = number of classes

(ii) Calculate the chi-square value.

……[2]

1. 2.60 (2 dp according to chi-square table);
2. 1 mark for clear working

Table 3.1

degrees of freedom	probability P				
	0.50	0.10	0.05	0.01	0.001
1	0.46	2.71	3.84	6.64	10.83
2	1.39	4.61	5.99	9.21	13.82
3	2.37	6.25	7.82	11.35	16.27
4	3.36	7.78	9.49	13.28	18.47

(iii) Using Table 3.1 and the calculated chi-square value, find the probability that observed and expected results differ by chance.

……[1]

1. Probability is between 0.10 and 0.50 (Reject: between 0.50 and 0.10) / between 10% and 50%

(iv) State the conclusions for this test.

……[2]

1. There is **no significant difference** between observed and expected values/results, **any difference is due to chance**
2. The Mendelian ratio of 1:1:1:1 is correct

(v) Plants are a good choice of experimental organisms for carrying out such crosses and for performing statistical tests.

Compared to plants, humans are less ideal and it is usually more difficult to arrive at reliable conclusions for observations involving humans. Suggest why.

……[2]

1. Humans produce **limited offspring**. (This makes statistical tests difficult)
2. Humans have a long life span and **some traits only appear at a later stage in life**

[Total: 14m]

QUESTION 4

(a) In many ant species, polymorphism exists in the form of worker and queen ants. Some distinct differences between workers and queens are that workers are much smaller and cannot reproduce. Strict caste roles are also observed: queens lay eggs and workers take care of all other work, including offspring.

In a new study to identify the cause for these behavioural and physical differences, Rockefeller scientists report that a gene coding for an insulin-like peptide, ILP2, is instrumental in promoting and suppressing reproduction.

ILP2 is the ant version of insulin and, like human insulin, regulates metabolism by cellular uptake of glucose.
The table below summarises their results:

Expression of ILP2	**Type of ants**
High	Reproducing
Low	Non-reproducing

(i) Suggest a link between glucose uptake and reproduction.

…… [1]

1. ref. link between **nutritional state/ATP synthesis** and production of viable/fertile/healthy offspring;

(ii) The presence of larvae causes the activation of ovaries in worker ants. It was suggested that larvae release pheromones that control the expression of the ILP2 gene.

Explain how pheromones could have played a role at the transcriptional level of ILP2 expression in determining the caste roles of ants.

…… [4]

1. Pheromones act as activator/specific transcription factor; (Reject: general transcription factor due to the word "control" of expression)
2. **Binding** of activator / specific transcription factors to <u>enhancer</u>
3. Faciltates the <u>efficient positioning of RNA polymerase</u> at promoter / stabilizes the <u>transcription initiation complex</u> (to increase the rate of transcription)
4. Increased expression of ILP2 gene that lead to **activation of ovaries** => **queen ants**

(iii) The expression of the ILP2 gene can be further controlled even after translation of the ILP2 mRNA. Describe 2 ways to control ILP2 expression at this level.

……[2]

1. Transport of ILP2 protein to target destinations;
2. Chemical modification / attaching other biochemical functional groups / any 1 example i.e. phosphorylation, acetylation, glycosylation and the formation of disulfide bonds;
3. <u>Ubiquitin</u> are covalently attached to ILP2 proteins which are **degraded** by proteasomes;
4. **Proteolysis / hydrolytic processing/cleavage** of polypeptide into smaller, functional protein molecules;

(b) Double-stranded DNA of the ILP2 gene is denatured and allowed to hybridise through complementary base pairing with mature ILP2 mRNA isolated from queen ant cells. This is shown in **Fig. 4.1**.

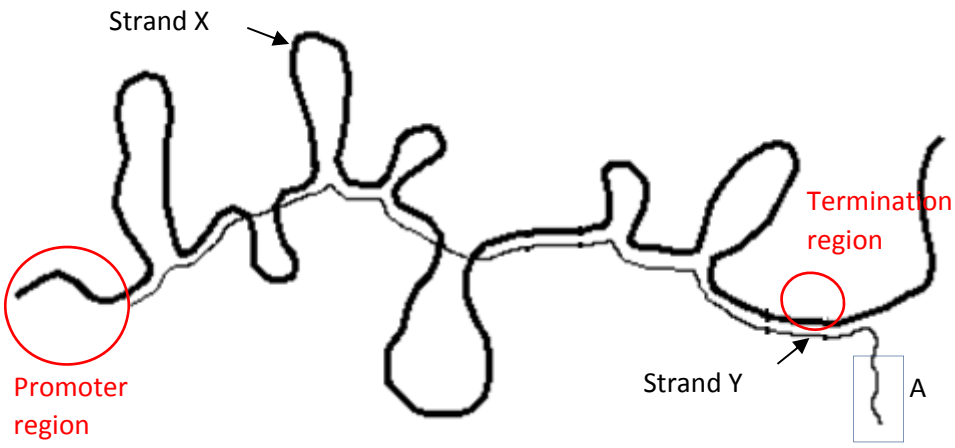

Fig 4.1

(i) State the identity of Strand X.

……[1]

1. Template DNA strand / single-stranded DNA (of ILP2 gene)

REJECT: DNA (which is double-stranded)

(ii) Explain your answer in (i) using evidence from Fig. 4.1.

……[2]

1. Strand X longer
2. due to introns / promoter / terminator

OR

1. Strand Y shorter
2. due to introns being excised (to form the mature mRNA) / as promoter / terminator not transcribed

OR

1. Strand X contains **looped** portions that consist of **introns**
2. No complementary sequence on Strand Y (mature mRNA) for complementary base pairing with non-coding sequences in Strand X

(iii) Circle the locations of the promoter and termination regions of the ILP2 gene on **Fig. 4.1**. Label the regions accordingly. Ans in RED. [2]

(iv) Suggest the identity of the unpaired segment (labelled A) on strand Y. Explain your answer.

……[2]

1. Poly (A) tail
2. Poly (A) tail is added to strand Y post-transcriptionally /Template DNA does not code for the poly (A) tail

[Total: 14m]

QUESTION 5

(a) The following extract was summarised from an article published in Proceedings of the National Academy of Sciences journal.

The article proposes a method to overcome HIV pandemic using genetically modified rice.

Summary points of article:

- Scientists from the US, UK, and Spain have developed a new strain of genetically modified rice to manage HIV symptoms in countries where traditional medicines can be hard to access.

- The rice seeds produce three proteins – the antibody 2G12, and the lectins griffithsin and cyanovirin-N – which preliminary *in vitro* tests show bind to gp120 and *neutralize* HIV.

- These seeds can be ground up to form a paste that can then be applied as a topical cream, which counterbalances the virus in the exact same way as the anti-retroviral medication.

- There remains a few *hurdles* researchers will have to jump before the rice becomes widely available.

(i) Define the term "neutralise" in this context and explain how this process can halt the reproductive life cycle of HIV.

……[3]

1. Ref. antibody 2G12, / lectins griffithsin / cyanovirin-N **bind to/surround** gp120 of HIV
2. Gp120 **cannot** recognise and bind/adsorb to CD4 receptor of T helper cells/macrophages;
3. Ref. fusion between viral envelope and host cell plasma membrane **cannot** occur

(ii) Suggest one possible hurdle that researchers need to overcome for this treatment using GM rice.

……[1]

1 Ref. unknown long term health consequences

2 Ref. acceptance to tampering of nature

3 Ref. GM rice disrupting eco-system

4 AVP e.g. rapid changing antigenic surface of gp120

[Any 1]

(b) Fig 5.1 shows a lentivirus, which can bind to cells lining the airways of the lungs. The lentivirus is a form of **retrovirus**. The **general structure** of this virus is similar to that of HIV.

The lentivirus is commonly used as a vector (vehicle to transport external copies of RNA coding for specific proteins into cells).

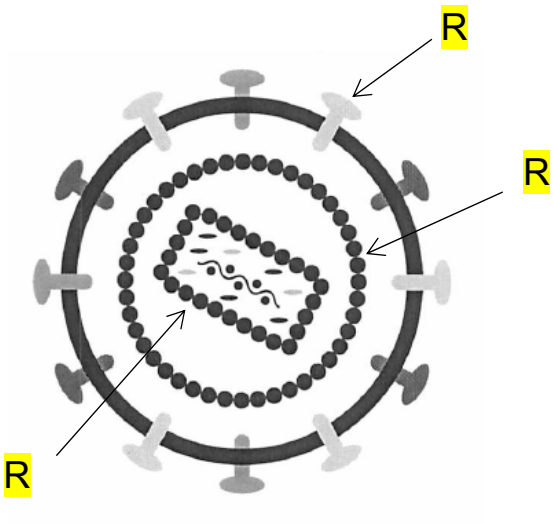

Fig. 5.1

(i) Using the letter **R**, label **Fig 5.1** to identify a feature that is protein in nature.

……[1]

1. Glycoprotein
2. Matrix
3. Capsid
4. Viral enzyme(s)

[Any 1]

(ii) Explain why external copies of RNA intended to be introduced into cells cannot pass through the membrane of cells directly.

……[2]

1. RNA is <u>charged</u> (due to phosphate backbone) (Reject: large size)
2. Cannot pass through hydrophobic core of fatty acid tail / phospholipid bilayer.

(iii) With reference to your knowledge on retroviruses, explain how **long-term** expression of an inserted RNA is brought about following infection of host cells with the lentiviral vector.

……[3]

1. Inserted RNA (and viral RNA genome) is **reverse transcribed** into cDNA using viral <u>reverse transcriptase</u>
2. the resulting cDNA is then **integrated** into host cell DNA using viral <u>integrase</u>
3. cDNA (of inserted RNA) is **expressed** using host cell machinery e<u>.g. RNA polymerase and host ribsomes</u>

(c) Plasmids are small, self-replicating circles of DNA.

During cloning, a target gene can be inserted into a plasmid, making the plasmid a **vector** that transports the target gene into cells.

It is hoped that the plasmid and the target gene gets replicated to multiple copies in the cell.

Based on its features, suggest why plasmids are good choices of cloning vectors.
……[1]

1 Small **size** plasmid allows **insertion of target genes of larger sizes / ease of being taken up by cells;**
2 Ref. **Origin of replication** allows for plasmid to **replicate independently**, (results in multiple copies of the plasmid and inserted foreign gene within one bacterium)
3 **Double stranded** DNA nature similar to the target gene allows for **integration**
[Any 1]

Reject: points on conjugation as question is on cloning in the lab.

(d) The F plasmid is a crucial plasmid found naturally in bacterial cells. It plays an integral role in the transfer of genes from one bacterial cell to another through processes such as conjugation.

Fig. 5.2 shows the process of conjugation.

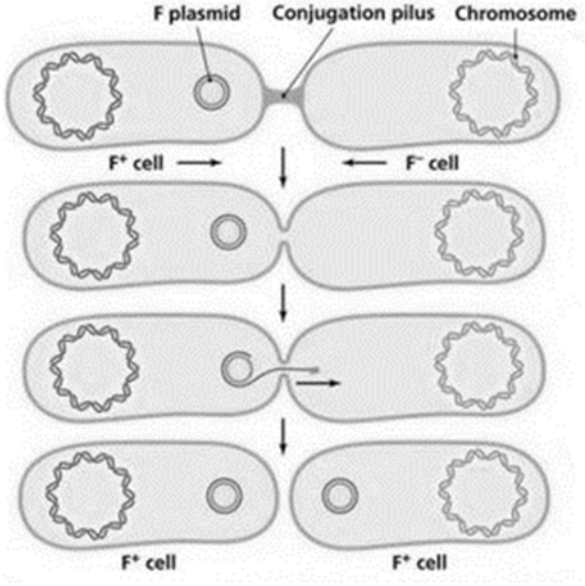

Fig. 5.2

During conjugation, the transferred F plasmid strand undergoes DNA replication similar to the synthesis of Okazaki fragments.

Explain why.

……[2]

1. DNA polymerase can only add new nucleotides to the **available** 3'-OH end of a pre-existing polynucleotide chain;;
2. DNA strands are antiparallel
   /DNA strands run in the 5'→ 3' and 3'→ 5' directions ;;

(e) Scientists isolated one of the *lac permease* gene from the lac operon and proceeded to amplify the gene using an automated process of Polymerase Chain Reaction (PCR).

Fig. 5.3 shows the temperatures used at the different stages during PCR.

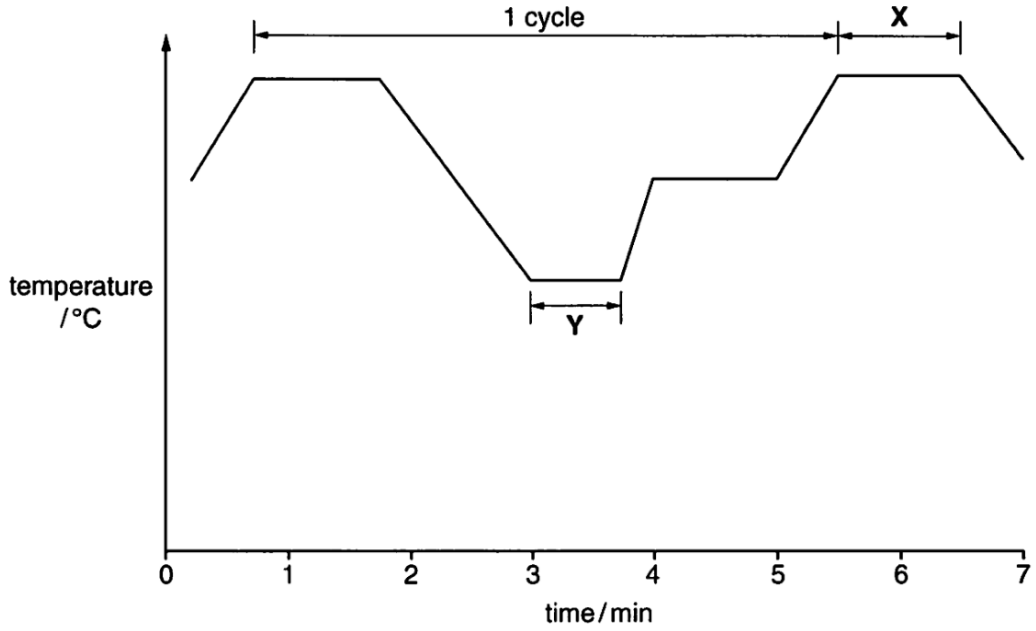

Fig. 5.3

(i) Describe what happens at stage Y.

……[2]

1. Annealing stage at temperatures between 50 – 65^{0}C ;
2. **Forward and reverse primers** bind to <u>complementary sequences</u> **flanking** the target sequence to be amplified at the <u>3' ends</u> of <u>single</u> (DNA) strands ;

(ii) If stage X of PCR process persisted for more than two hours, suggest what you will expect to find in the PCR mixture during this period.

……[1]

1. Free/unused DNA nucleotides / DNA primers ;
2. Some Taq DNA polymerases are denatured, (hence they are unable to bind to and elongate DNA) ;
3. **Single-stranded** DNA templates (with no new daughter molecules)

[Total: 16m]

QUESTION 6

(a) The concentration of carbon dioxide in a sample of air was found to be 280 ppm (parts per million).

An experiment was designed to measure the concentration of carbon dioxide in the air after it had flowed over the leaves of a green plant. Measurements were taken at a range of light intensities.

The following results were obtained:

Light intensity (% of full sunlight)	**Concentration of carbon dioxide in air after flowing over leaves (ppm)**
75	253
50	252
25	254
10	280

(i) Predict the concentration of carbon dioxide in the air after flowing over the leaves when the plant was placed in the dark.

…….. [1]

1. 280ppm or more;

(ii) Explain the experimental results obtained in relation to light intensity being a limiting factor of photosynthesis.

…….. [3]

1. ref. light intensity being a limiting factor of photosynthesis at values **lower than 25% or 50%**;
2. As light intensity increases from 10% to 25% or 50%, concentration of carbon dioxide in air after flowing over leaves **decreases from 280ppm to 254ppm (or 252ppm for 50%);**
3. At higher light intensities tested (i.e. 25% or 50% and above), the rate of photosynthesis is affected by **factors other than light**;
   / light intensity is no longer a limiting factor;
4. Concentration of carbon dioxide in air after flowing over leaves **remains constant around 252ppm-254ppm**, due to the rate of photosynthesis being constant;
5. Ref. light intensity leads to higher electron flow down ETC and higher production of **ATP and NADPH**, leading to **higher rate of Calvin cycle** where CO2 fixation occurs

(b) Discuss the validity of the statement "The synthesis of ATP during photophosphorylation depends on the **transport of protons** across membranes."

…….. [4]

1. Statement is valid;
2. Energy released by the transfer of electrons down the ETC used to **pump** H^+ ions / protons **from stroma into thylakoid space**;
3. Higher concentration of H^+ ions in thylakoid space than in stroma / proton gradient established across thylakoid membrane;
4. **Diffusion** / **facilitated diffusion** of H^+ ions / protons (down concentration gradient) through ATP synthase
5. Potential energy coupled to ATP synthase to produce ATP from ADP and Pi;

(c) $NADP^+$ is an important electron carrier found in plants, but its level decreases sharply in the day. Suggest the significance of the decrease of $NADP^+$ during the day.

…….. [2]

(ref. light-dependent reactions during day
/ photoexcited electrons (from PS I and II)being passed down ETC)

1. $NADP^+$ acts as the **final electron acceptor**, forming NADPH;
/ $NADP^+$ **accepts electrons and H^+ ions** to form NADPH;
2. NADPH (and ATP) used in **Calvin cycle** / light independent reactions to reduce PGA to PGAL **to synthesis of glucose;**

[**Total: 10m]**

QUESTION 7

Ants and bees – which by all appearances seem so different – are found to be close relatives (refer to **Fig. 7.1**) in a new study which used cutting-edge DNA sequencing techniques to elucidate the taxonomic relationships among the different families of wasps, bees and ants.

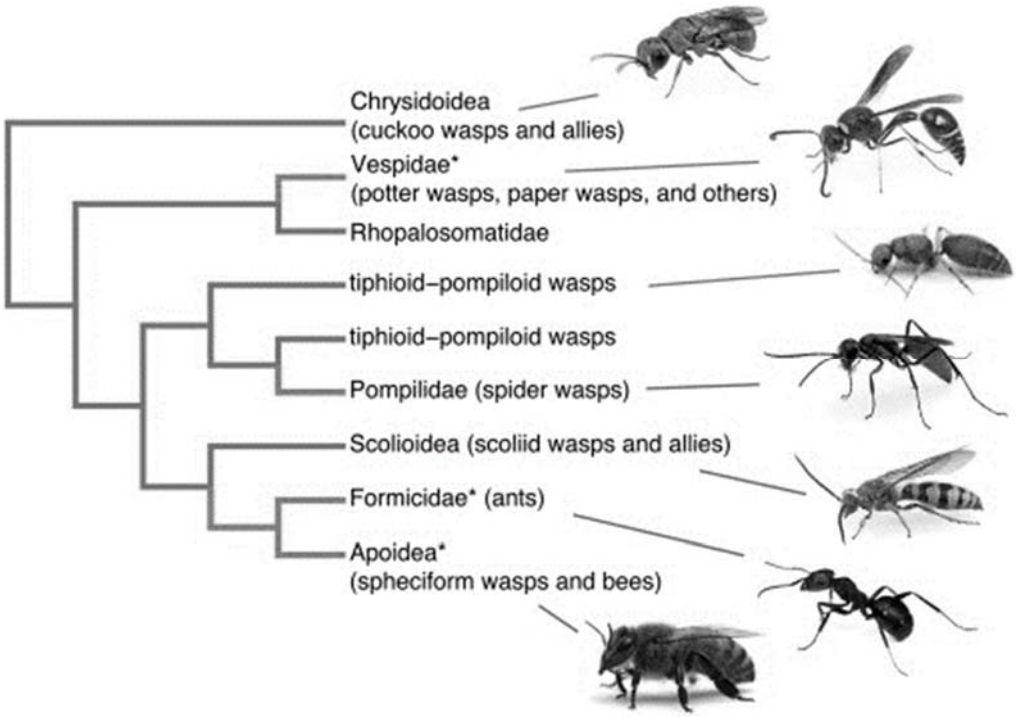

Fig. 7.1

(a) State **one** advantage of using DNA sequences to elucidate the evolutionary relationship between ants and wasps.

…….. [1]

1. Quantifiable / open to statistical analysis;
2. Unambiguous and **objective**;
3. Not affected by convergent evolution;
4. Based strictly on heritable material;
5. Greater number of organisms can be compared;
6. Greater number of characters can be compared;
7. Ref. abundance in DNA samples

(b) Discuss how molecular homology was used in this study to derive the phylogram in **Fig. 7.1**.

…….. [2]

1 Comparison of DNA sequences of a **common gene** from the different families;

2 High homology indicates that they are more closely related / share a more recent common ancestor (vice versa);

(c) Explain how biogeography can help to support the evolutionary deductions in this case study.

…….. [2]

1. ref. biogeography being the study of the geographic distribution of species;
2. Species of bees and ants that are **closely related /recently evolved from a common ancestor** are **found close together**,;
   /species that are not closely related are found in environments far away due to geographical barriers;

(d) The same study also suggested that when the early bees switched from preying on other insects to pollen feeding, the number of bee species exploded compared with their hunting wasp sister group. The switch from predatory behavior in hunting wasps to pollen feeding in bees also saw a corresponding increase in diversification of the mouthparts and tongue lengths of the bees.

Suggest and explain how the increase in number of bee species is made possible with the switch to pollen feeding, as compared to speciation in hunting wasps.

…….. [4]

1. More types of flowers available as compared to types of insects/prey;
2. **Variation** in the mouthparts and tongue length of early bees due to **mutation**;
3. Different selection pressures + different types of food available;
4. Individuals with a selective advantage in the particular environment **survive** till **reproductive** age; and pass on their alleles to their offspring; (Reject: traits)
5. ref. reproductive barriers/isolation / preventing gene flow between different populations of bees (leading to each population accumulating own genetic differences);
6. ref. **long period of time** before different species evolved;
7. ref. adaptive radiation / divergent evolution;

[Total: 9m]

QUESTION 8

(a) Explain how the structure of antibodies cause pathogens to be destroyed by macrophages.

……[3]

1. **Variable / antigen-binding sites** of antibodies allow for (recognition and) **binding to pathogens**
2. **Constant region** (of heavy chains) allow (recognition and) **binding** (of antibodies) **to** (Fc) <u>receptors</u> on **macrophages**
3. Ref. **complementary shape recognition** between antigen-binding site and pathogen / between constant region of antibody with macrophages (followed by subsequent phagocytosis of pathogens by macrophages)

(b) DNA coding for the light chain of an antibody is isolated from a **mature** B lymphocyte.

DNA coding for the light chain of an antibody is also isolated from a **developing** B lymphocyte (before maturation).

Gel electrophoresis was performed on both sources of DNA.

Fig 8.1 shows the gel diagram and the corresponding positive / negative electrode.

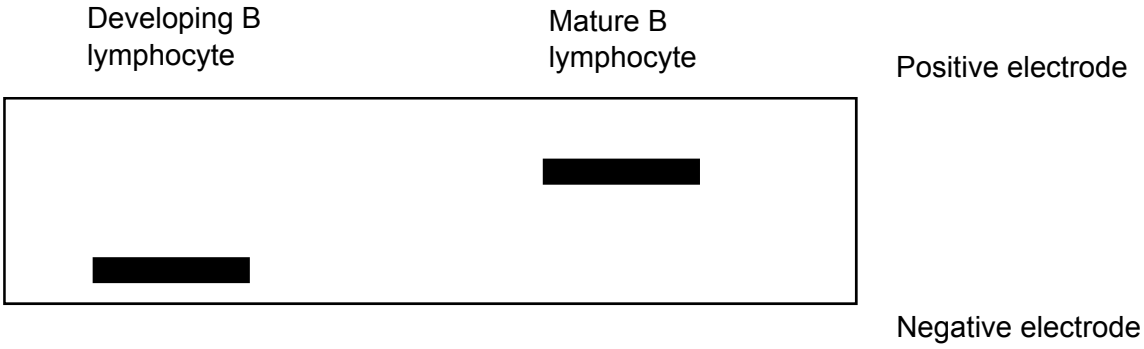

Fig. 8.1

Explain the difference in the results on the gel diagram.

……[2]

1. DNA fragment from mature B lymphocyte travels <u>faster</u> (Reject: further) than that of the developing B lymphocyte / DNA fragment from mature B lymphocyte is short**er** in length (Accept: vice versa)
2. Ref. <u>somatic recombination</u> has **already** occurred in mature B lymphocytes / certain V,J,C segments were chosen and the **rest of the segments removed** (thus, DNA is shorter) (Accept: vice versa)

[Total: 5m]

QUESTION 9

Carbon dioxide is one of the greenhouse gases that contribute to global warming and subsequently climate change.

A group of high school students decided to test whether varying temperatures would correspondingly affect mean carbon dioxide gas emission.

Table 9.1 shows the mean carbon dioxide gas emission after exposing a fixed number of mealworms to different temperatures. Carbon dioxide gas emission was measured before and after exposure to experimental temperature.

Table 9.1 showing effects of varying temperatures on mean carbon dioxide gas emission, measured in parts per million (ppm). Values represent mean ± standard deviation.

Temperature /°C	Mean Carbon dioxide gas emission /ppm	
	Before exposure to experimental temperature	**After** exposure to experimental temperature
30.0	445 ± 25	450 ± 17
40.0	450 ± 20	500 ± 30
50.0	460 ± 17	540 ± 18

(a)(i) Describe the patterns shown by the data in Table 9.1.

……..……..[2]

1. The mean carbon dioxide gas emission increases as temperature increases;
2. As temperature increases from 30.0°C to 50.0°C, emission increases from 450ppm to 540ppm.

   OR

1. **Increase** in carbon dioxide gas emission **after exposure** to experimental temperatures **compared to before** exposure, gets bigger as temperature increases
2. As temperature increases from 30.0°C to 50.0°C, increase in emission increases from 5ppm to 80ppm

(ii) With reference to the mean carbon dioxide gas emission **before** exposure to 40 °C, suggest what standard deviation means.

……..……..[2]

1. Standard deviation is the **deviation from the mean** carbon dioxide gas and determines the range of the carbon dioxide gas emission observed
2. the mean carbon dioxide gas emission ranges from 430ppm (450-20) to 470ppm (450+20)

(b) Corals are affected by rising temperatures in ocean waters. Explain how.

……..…….[2]

1. Ref. Absorption of **more carbon dioxide which dissolves** when ocean waters get warmer; **ocean pH decreases** / ocean acidification occurs
2. Hard **corals cannot absorb calcium carbonate** they need to maintain their **skeletons**, stony skeletons that support corals will dissolve and corals destroyed / Coral polyp metabolism is affected and **corals expels the zooxanthellae**, (leaving the coral skeleton bleached), and eventual **death of corals due to lack of nutrients (provided by zooxanthellae)**

OR

1. **Photosynthesis in zooxanthellae is disrupted** at higher than usual temperatures, thus producing an excess of **products that are toxic**
2. Coral polyp metabolism is affected and **corals expels the zooxanthellae**, (leaving the coral skeleton bleached), and eventual **death of corals due to lack of nutrients (provided by zooxanthellae)**

[Total: 6m]

Civics Group	Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 Prelim

H2 BIOLOGY **9744/03**

Paper 3

Monday 17th September 2018 2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A (Structured Questions)
Answer **all** questions.
Write your answers in the spaces provided on the question paper.

Section B (Essay Question)
Answer **one** essay question.
Write your answers in the spaces provided on the question paper.
All working for numerical answers must be shown.

For Examiners' Use	
Section A	
1	/35
2	/7
3	/8
Section B	
4 or 5	/25
Total	**/75**

This document consists of **20** printed pages.

[Turn over

Section A

Answer **all** *questions*.

QUESTION 1

(a) Potential cancer cells experience a series of alterations during oncogenic transformation that confers them new features. These features are both genetic and phenotypic in nature. One prominent feature is the reprogramming of their energy metabolism. This phenomenon has been termed 'The Warburg Effect'.

The Warburg Effect describes the observation that cancer cells exhibit an enhanced glycolysis without undergoing oxidative phosphorylation, even when oxygen is abundant. This leads to another prominent feature of cancer – the acidification of the extracelluar environment of tumours due to the secretion of an overproduced molecule by cancer cells as a result of enhanced glycolysis.

Since the observation, many journal reports have surfaced to provide explanations to the Warburg Effect. Some of these include various mutations, upregulation or downregulation of expression of various genes involved in respiration, for example, those that code for the enzyme ATP synthase.

(i) Outline the 'series of alterations' that could occur in the potential cancer cells.

……

……

……

……

……

……

……

……

……

……..[5]

(ii) Explain how an enhanced glycolysis can lead to the acidification of the tumours' extracellular environment.

……

……

……

……[2]

The fact that most cancer cells exhibit the Warburg Effect has been used clinically as a basis for cancer diagnosis in patients. This method of diagnosis is known as PET scanning as outlined below:

- Patient is first injected with ^{18}F-fluorodeoxyglucose, a radioactive glucose analogue
- ^{18}F-fluorodeoxyglucose can be taken up by respiring cells
- In the cytoplasm, ^{18}F-fluorodeoxyglucose can be phosphorylated by hexokinase but cannot be metabolised further in glycolysis
- Presence of radioactivity is determined in the various sites of the body

(iii) Predict the observation in PET scanning on cancer cells compared to non-cancer cells.

……

……[1]

(iv) Explain the prediction made in **(iii)**.

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……[2]

(v) Suggest why cancer cells require more glucose than non-cancer cells to meet energy demands.

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……[1]

(b) Central to the energy metabolism of aerobically respiring cells is the enzyme ATP synthase. It consists of multiple subunits, coded for by several genes.

The enzyme is located on the inner mitochondrial membrane and catalyses the reversible reaction of ATP synthesis from ADP in intact mitochondria. Here, the **proton motive force** is required to drive the ATP synthesis.

(i) Explain how the structure, including protein components, of the inner mitochondrial membrane is significant in driving the reaction of ATP synthase towards ATP synthesis during aerobic respiration.

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……[4]

In a cell-free or mitochondrial-free system, the same enzyme can also catalyse ATP hydrolysis when ATP is present. This reaction can be exploited for the investigation of ATP synthase activity.

To examine the enzymatic activity of ATP synthase, the indirect method of measuring the relative NADH concentration in the solution can be utilised as shown below in **Fig. 1.1**.

ATP produced when phosphoenolpyruvate is converted to pyruvate by pyruvate kinase, is acted upon by ATP synthase to form ADP.

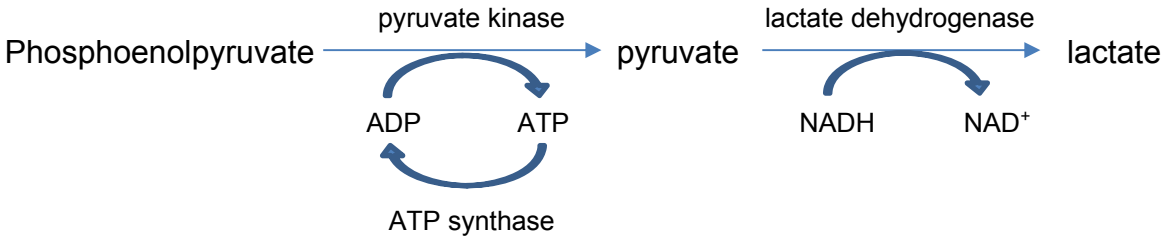

Fig. 1.1

The relative concentration of NADH can be tracked with a spectrophotometer as NADH absorbs light at 340nM while NAD^+ and other molecules in the system do not.

(ii) In examining the activity of ATP synthase using the reactions in **Fig. 1.1**, explain why phosphoenolpyruvate, ATP and NADH need to be in high concentrations.

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……[2]

The reactions in **Fig. 1.1** can also be used to determine the effect of a particular drug on ATP synthase. Curcumin, a phytochemical isolated from the rhizome of turmeric, has been shown to affect the activity of ATP synthase. However, its effect varies according to the source of ATP synthase.

Fig. 1.2 and **Fig. 1.3** show the effect of curcumin on ATP synthase molecules isolated from the liver mitochondria and brain mitochondria of the same rat respectively.

% control refers to ATP synthase activity with reference to activity at 0 μM curcumin.

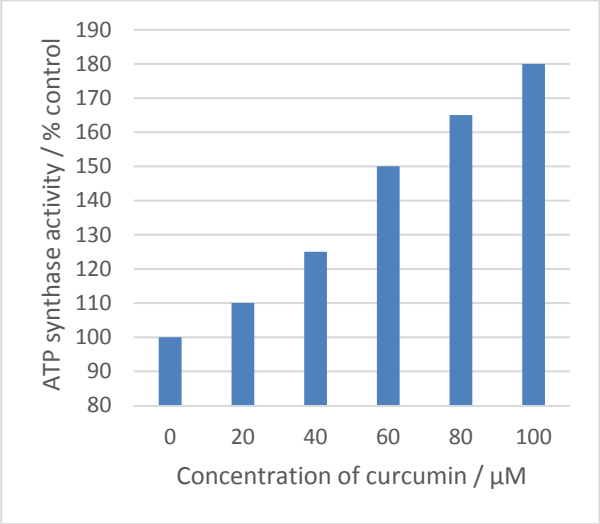

Fig. 1.2: Effect of curcumin on ATP synthase isolated from rat liver mitochondria

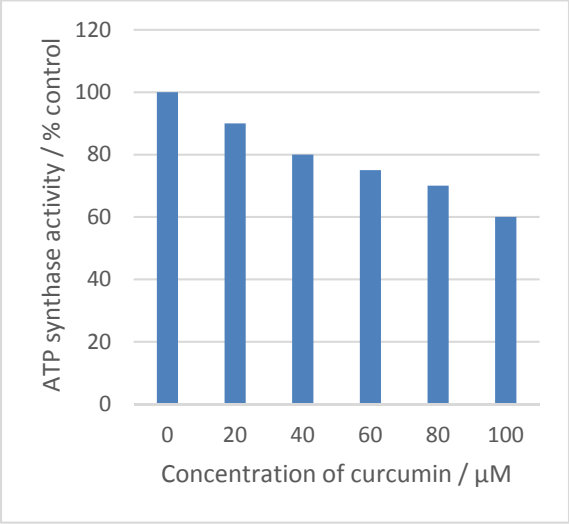

Fig. 1.3: Effect of curcumin on ATP synthase isolated from rat brain mitochondria

(iii) With reference to **Fig. 1.2**, describe the effect of curcumin on rat liver mitochondrial ATP synthase.

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(iv) Suggest one process that can occur within cells, and explain how it can lead to the differential effects of curcumin on ATP synthase molecules isolated from liver and brain mitochondria of the same rat.

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In many prokaryotes, the multi-subunit ATP synthase expression is under the control of a single operon.

(v) Suggest how the ATP synthase operon is organised.

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……..[2]

(c) ATP synthase deficiency is a disorder in which individuals are deficient in the enzyme, leading to a wide variety of signs and symptoms affecting many organs and systems of the body. The disorder can range from being mild to life-threatening.

Different mutations in different nuclear genes can result in the deficiency. These can generally be grouped into 2 categories. The first being mutations at gene loci coding for an ATP synthase subunit, for example, *ATP5E*.

The second being mutations at gene loci coding for a protein that is required for the proper assembly of the ATP synthase subunits to form the functional enzyme, for example, *TMEM70*.

(i) Justify the claim that the severity of the disorder in an individual depends on his/her genetic makeup.

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……[3]

ATP synthase deficiency cases have been reported frequently in the Roma population, an ethnic group living mostly in Europe. Various journal articles have collectively reported the following:

- *TMEM70* gene defect was identified as a novel cause of autosomal recessive ATP synthase deficiency in 2009
- Most of the patients with *TMEM70* gene mutations share a common Roma descent
- In all genotyped cases for the patients of Roma origin, an adenine to guanine substitution was found, located in the splicing site of intron 2, which leads to aberrant splicing and thus preventing synthesis of the functional protein
- If the disorder is present as a result of this substitution mutation, a fatal outcome or life-threatening symptoms are expected

References:

1) Anne K. Braczynski, Stefan Vlaho, Klaus Müller, et al. (2015). ATP Synthase Deficiency due to TMEM70 Mutation Leads to Ultrastructural Mitochondrial Degeneration and Is Amenable to Treatment. BioMed Research International, vol. 2015, Article ID 462592, 10 pages. https://doi.org/10.1155/2015/462592.
2) Josef Houštěk et al. (2009). TMEM70 protein — A novel ancillary factor of mammalian ATP synthase. *Biochimica et Biophysica Acta – Bioenergetics*. 1787(5): 529-532.
3) Spiegel R et al. (2011). TMEM70 mutations are a common cause of nuclear encoded ATP synthase assembly defect: further delineation of a new syndrome. *J Med Genet.* 48(3):177-82.

(ii) It can thus be deduced that a particular mutation is associated with people of Roma origin that can result in ATP synthase deficiency.

With reference to the information given, suggest how the mutation could have been preserved in present day people of Roma descent despite leading to fatal outcomes.

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ATP synthase deficiency can also result from mutations in the mitochondrial genes, for example, *ATP6*. The *ATP6* gene codes for a subunit of ATP synthase.

Fig. 1.4 shows a pedigree chart where individual 2, who is female, carries a mutation in the *ATP6* gene and thus suffer from the disorder. Individual 1 does not carry any mutations in the *ATP6* gene. Both individuals 1 and 2 do not carry any other mutations that can result in the disorder.

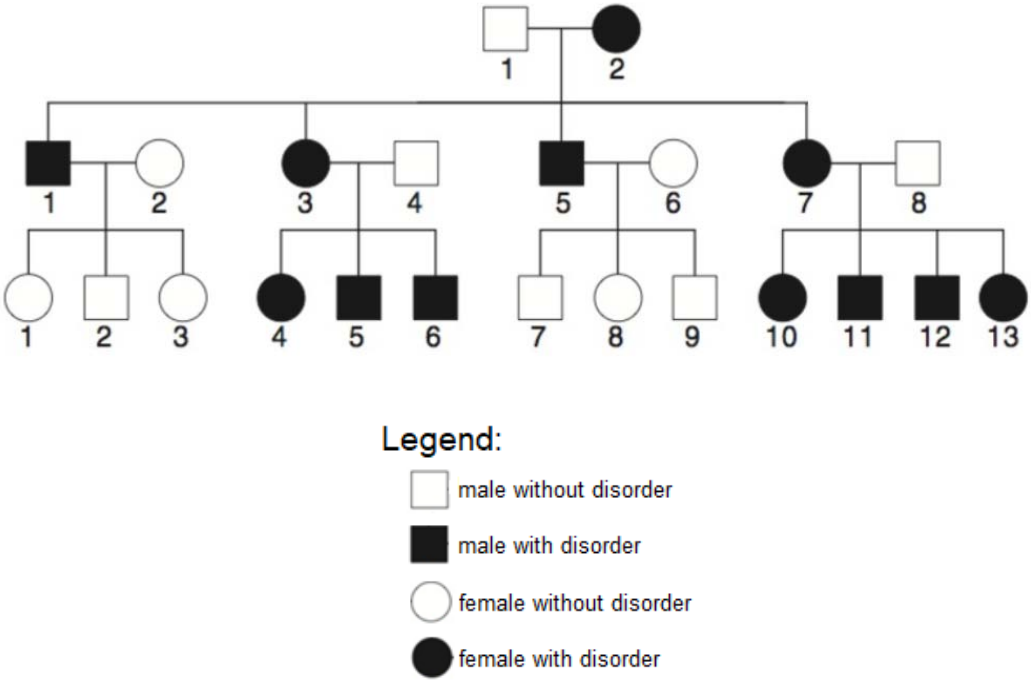

Fig. 1.4

(iii) With reference to **Fig. 1.4**, explain how the disorder is inherited.

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……..[4]

[Total: 35]

QUESTION 2

Climate change, in the form of global warming, is expected to have an impact on various organisms. This impact however, varies geographically, particularly for insects. **Fig. 2.1** and **Fig. 2.2** below show the fitness curves of representative insects from a temperate and a tropical location respectively.

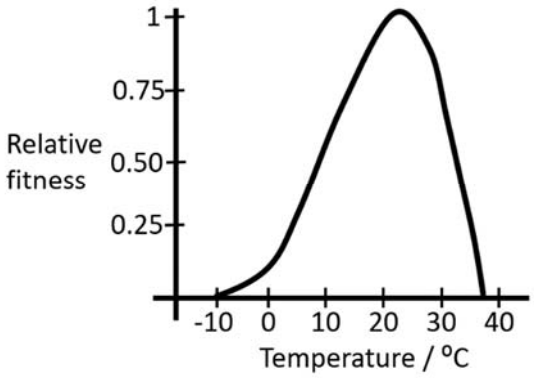

Fig. 2.1: Fitness curve of representative insect from temperate location

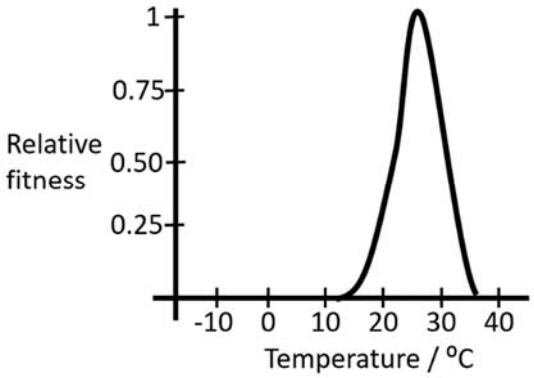

Fig. 2.2: Fitness curve of representative insect from tropical location

The mean annual temperature of the temperate location is 11 □C, with a typical temperature range from 1 to 20□C. On the other hand, the mean annual temperature of the tropical location is 27□C, with a typical temperature range from 21 to 31□C.

(a) Suggest what is meant by the term relative fitness in **Fig. 2.1** and **Fig. 2.2**.

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……[2]

(b) With reference to **Fig. 2.1** and **Fig. 2.2** and the information given, predict and explain which insects, from the temperate or tropical location, would face a greater extinction risk as a result of global warming, assuming the warming elevates temperatures equally at both locations.

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(c) Suggest one strategy that the insects in **(b)** can employ to reduce the impact of global warming on themselves.

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……..[1]

[Total: 7]

QUESTION 3

Proper activation of CD4 T cells is essential for an effective humoral immune response. This activation requires the involvement of antigen presenting cells, such as dendritic cells, that provide signals for the activation.

One such important signal is the presence of co-stimulatory molecules, such as CD80 or CD86, on the dendritic cell surface. These molecules are expressed and upregulated in dendritic cells via the Toll-like receptor signalling pathway. Toll-like receptors belong to a group of receptors known as Pattern Recognition Receptors that recognise typical surface molecules of pathogens as ligands.

CD4 T cell activation can occur via the natural route during infection or artificially via vaccination. Vaccines, when formulated effectively, could provide long term protection against a particular disease. Modern day vaccines that utilise only purified antigens generally do not evoke a strong immune response as compared to older style vaccines utilising live or killed whole bacteria.

(a) Outline how activation of CD4 T cells is important for an effective humoral immune response.

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……[4]

(b) Explain how vaccines can provide a long term protection against a disease.

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……[2]

(c) For vaccines utilising purified antigens to be as effective as older style vaccines utilising live or killed whole bacteria, adjuvants need to be added to these vaccines.

Based on the information given, suggest what can be used as an adjuvant and explain how it contributes to the vaccine's effectiveness.

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……[2]

[Total: 8]

Section B

Answer **one** *question only*.

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) Cellulose is the most abundant biopolymer on earth. It forms a significant proportion of the dry mass of plants.

Describe the Calvin cycle and explain the origin of the carbon atoms in cellulose, taking into consideration the number of molecules involved. [12]

(b) In a particular plant species, which could produce offsprings in the hundreds, its height and flower colour are each controlled by a single gene locus. The two gene loci are located on different chromosomes. It is known that the alleles for tallness (T) and red flower (R) are dominant to the alleles for shortness (t) and white flower (r) respectively.

Using one molecular method and one genetic cross method, explain how the genotype of a tall, red-flowered plant of this species can be determined. [13]

[Total: 25]

QUESTION 5

(a) The Centers for Disease Control and Prevention in the United States of America recommends an annual influenza vaccination for everyone 6 months and older with rare exceptions, for example, those with life-threatening allergies to the vaccine. Each annual vaccine is different and contains three influenza strains.

Explain the need for a person to receive influenza vaccinations annually for protection against the disease and suggest why a person may still get the disease even after receiving his/her annual dose of vaccine. [12]

(b) Free nucleotides are present in various locations in a eukaryotic cell. They can exist both in the more commonly known non-cylic form or in the cyclic form.

Describe the general structure of a non-cyclic form of nucleotide and with named examples, outline the roles of free nucleotides, cyclic or non-cyclic, at particular locations in a human cell. [13]

[Total: 25]

Civics Group	Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 Prelim

H2 BIOLOGY **9744/3**

Paper 3 (Mark Scheme)

Monday 17th September 2018 2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A (Structured Questions)
Answer **all** questions.
Write your answers in the spaces provided on the question paper.

Section B (Essay Question)
Answer **one** essay question.
Write your answers on the separate answer paper provided.
All working for numerical answers must be shown.

For Examiners' Use	
Section A	
1	/35
2	/7
3	/8
Section B	
4 or 5	/25
Total	**/75**

This document consists of **23** printed pages.

[Turn over

Section A

Answer **all** *questions*.

QUESTION 1

(a) Potential cancer cells experience a series of alterations during oncogenic transformation that confers them new features. These features are both genetic and phenotypic in nature. One prominent feature is the reprogramming of their energy metabolism. This phenomenon has been termed 'The Warburg Effect'.

The Warburg Effect describes the observation that cancer cells exhibit an enhanced glycolysis without undergoing oxidative phosphorylation, even when oxygen is abundant. This leads to another prominent feature of cancer – the acidification of the extracelluar environment of tumours due to the secretion of an overproduced molecule by cancer cells as a result of enhanced glycolysis.

Since the observation, many journal reports have surfaced to provide explanations to the Warburg Effect. Some of these include various mutations, upregulation or downregulation of expression of various genes involved in respiration, for example, those that code for the enzyme ATP synthase.

(i) Outline the 'series of alterations' that could occur in the potential cancer cells.

……[5]

1 results in loss of <u>arrest</u> of cell division + loss of ability for <u>DNA repair</u> + loss of <u>apoptosis</u>;
2 <u>Gain of function</u> mutation of <u>proto-oncogene</u>;
3 lead to over-stimulation of the cell cycle / cell keeps dividing;

(max 2 AVP: ref. gene amplification of proto-oncogene; ref. translocation of proto-oncogene to be under control of more active promoter / translocation of active promoter to upstream of proto-oncogene;)

(max 3)
(This allows for subsequent <u>accumulation</u> of many other mutations)
4 Some mutations may cause <u>activation of telomerase gene</u>; (Reject: mutation of telomerase gene)
5 Some mutations cause a <u>loss of ability to differentiate</u>;
6 Some mutations cause cells to <u>no longer exhibit anchorage dependence</u> / loss of cell adhesion;
7 Some mutations cause a <u>loss of contact inhibition</u> / density-dependence (and cells do not stop dividing);
8 Mutations can also lead to <u>angiogenesis</u> / formation of new network of blood vessels to the cancer cells;
9 Some mutations allow <u>metastasis</u> to occur/ cancer cells are able to break loose and travel in the bloodstream and invade other tissues to form secondary tumors;
10 AVP; (e.g. elaboration of preamble without direct copying e.g. mutations in / upregulation / downregulation of genes involved in **respiration**) (Reject: ATP synthase as it is in the preamble)

(ii) Explain how an enhanced glycolysis can lead to the acidification of the tumours' extracellular environment.

……..[2]

1 **Lactate / lactic acid** produced from lactate fermentation;
2 to **regenerate NAD^+** from NADH for aerobic glycolysis to continue;
3 ref. secreted out of cell into extracellular environment; (Reject: diffusion) (Accept: H^+ ion being pumped out)

The fact that most cancer cells exhibit the Warburg Effect has been used clinically as a basis for cancer diagnosis in patients. This method of diagnosis is known as PET scanning as outlined below:

- Patient is first injected with ^{18}F-fluorodeoxyglucose, a radioactive glucose analogue
- ^{18}F-fluorodeoxyglucose can be taken up by respiring cells
- In the cytoplasm, ^{18}F-fluorodeoxyglucose can be phosphorylated by hexokinase but cannot be metabolised further in glycolysis
- Presence of radioactivity is determined in the various sites of the body

(iii) Predict the observation in PET scanning on cancer cells compared to non-cancer cells.

……[1]

1 Ref. **higher radioactivity** in cancer cells compared to non-cancer cells; (Reject: presence of radioactivity as there must be a comparison)

(iv) Explain the prediction made in **(iii)**.

……[2]

1 Cancer cells exhibit **enhanced glycolysis** / undergo glycolysis without oxidative phosphorylation;
2 Leads to **higher uptake/accumulation** of **^{18}F-fluorodeoxyglucose**; (and hence radioactivity in cancer cells as ^{18}F-fluorodeoxyglucose is not metabolised further)

(v) Suggest why cancer cells require more glucose than non-cancer cells to meet energy demands.

……[1]

1 As (enhanced) glycolysis synthesises only **net 2 ATP** molecules as compared to oxidative phosphorylation that synthesises **32 / 38 ATP** molecules **per glucose** molecule;
2 Ref. cancer cells may also need more **ATP** molecules as it is **dividing uncontrollably**;

(b) Central to the energy metabolism of aerobically respiring cells is the enzyme ATP synthase. It consists of multiple subunits, coded for by several genes.

The enzyme is located on the inner mitochondrial membrane and catalyses the reversible reaction of ATP synthesis from ADP in intact mitochondria. Here, the **proton motive force** is required to drive the ATP synthesis.

(i) Explain how the structure, including protein components, of the inner mitochondrial membrane is significant in driving the reaction of ATP synthase towards ATP synthesis during aerobic respiration.

……[4]

[Important structure – hydrophobic fatty acid tails]

1 **Hydrophobic** fatty acid tails / hydrocarbon chains / hydrophobic core of inner mitochondrial membrane **repels / does not allow hydrophilic / charged** H^+ ions to pass through membrane;

2 Allows **proton gradient / proton motive force** to be established;

[Important composition – series of electron carriers]

3 Electrons passed down a series of **electron carriers / ETC** present on membrane with increasing electronegativity and in order of **decreasing energy levels**; (until they reach final electron acceptor – oxygen)

4 Energy released during transfer of electrons along series of electron carriers used to **pump H^+ ions from mitochondrial matrix into intermembrane space**;

[Important composition – ATP synthase]

5 **ATP synthase** embedded in an orientation that allows facilitated **diffusion of H^+ ions from intermembrane space to mitochondrial matrix** to be coupled with ATP synthesis;

In a cell-free or mitochondrial-free system, the same enzyme can also catalyse ATP hydrolysis when ATP is present. This reaction can be exploited for the investigation of ATP synthase activity.

To examine the enzymatic activity of ATP synthase, the indirect method of measuring the relative NADH concentration in the solution can be utilised as shown below in **Fig. 1.1**.

ATP produced when phosphoenolpyruvate is converted to pyruvate by pyruvate kinase, is acted upon by ATP synthase to form ADP.

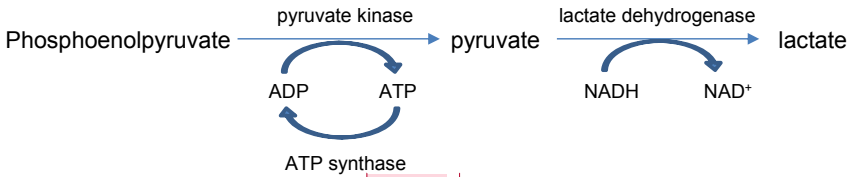

Fig. 1.1

Commented [TYMY1]: Change diagram labels to Fig 1.1 Fig 1.2 .....

The relative concentration of NADH can be tracked with a spectrophotometer as NADH absorbs light at 340nM while NAD^+ and other molecules in the system do not.

(ii) In examining the activity of ATP synthase using the reactions in **Fig. 1.1**, explain why phosphoenolpyruvate, ATP and NADH need to be in high concentrations.

……[2]

1 So that phosphoenolpyruvate, ATP and NADH are **not limiting** factors in the overall reaction;
2 Ref. to allow reaction to proceed forward;
3 Allows rate of **depletion of NADH / decrease in absorbance** to reflect / to be the same as **ATP synthase activity**;

The reactions in **Fig. 1.1** can also be used to determine the effect of a particular drug on ATP synthase. Curcumin, a phytochemical isolated from the rhizome of turmeric, has been shown to affect the activity of ATP synthase. However, its effect varies according to the source of ATP synthase.

Fig. 1.2 and **Fig. 1.3** show the effect of curcumin on ATP synthase molecules isolated from the liver mitochondria and brain mitochondria of the same rat respectively.

% control refers to ATP synthase activity with reference to activity at 0 μM curcumin.

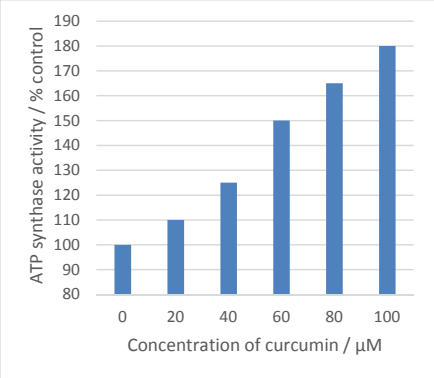

Fig. 1.2: Effect of curcumin on ATP synthase isolated from rat liver mitochondria

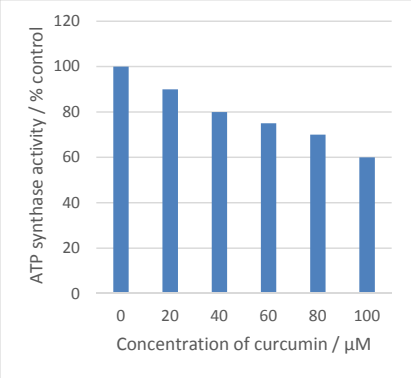

Fig. 1.3: Effect of curcumin on ATP synthase isolated from rat brain mitochondria

(iii) With reference to **Fig. 1.2**, describe the effect of curcumin on rat liver mitochondrial ATP synthase.

……[2]

1 **[Curcumin effect in general]** Curcumin **activates / increases activity** of ATP synthase;
2 **[Quote data]** ATP synthase activity is above 100% control for all concentrations of curcumin OR quote for any single curcumin concentration;
OR
3 **[Trend]** As curcumin concentration increases, ATP synthase activity increases;
4 **[Quote data]** e.g. as curcumin concentration increases from 0/20μM to 100μM, ATP synthase activity increases from 100/110% control to 180% control;

(iv) Suggest one process that can occur within cells, and explain how it can lead to the differential effects of curcumin on ATP synthase molecules isolated from liver and brain mitochondria of the same rat.

……[4]

1 **[Process 1] Different genes** that code for the subunits are **expressed** in liver and brain cells;
2 Ref. each subunit has a different **3D conformation / tertiary structure**;
3 Ref. ATP synthase in liver and brain mitochondria consisting of **different subunits** and **quarternary structure**
4 Both ATP synthase still complementary to curcumin, but curcumin **binds differently** to both, leading to differential effect; (Reject: curcumin binding to active site)

OR

1 **[Process 2]** **Alternative splicing** of ATP synthase subunit pre-**mRNA** from a particular gene (in liver and brain cells);
2 Leading to subunits with different **3D conformation / tertiary structure**;
3 Thus, ATP synthase in liver and brain mitochondria will have different **quarternary structure**;
4 Both ATP synthase still complementary to curcumin, but curcumin **binds differently** to both, leading to differential effect; (Reject: curcumin binding to active site)

OR

1 **[Process 3] Different post-translational modification** of ATP synthase subunit in liver and brain cells;
2 Leading to subunits with different **3D conformation**;
3 Thus, ATP synthase in liver and brain mitochondria will have different **quarternary structure**;
4 Both ATP synthase still complementary to curcumin, but curcumin **binds differently** to both, leading to differential effect; (Reject: curcumin binding to active site)

OR

1 **[Process 4] Mutation(s) in any genes** that code for the subunits in liver or brain cells;
2 Ref. the **corresponding subunits** in liver or brain cells having different primary structure and hence **3D conformation / tertiary structure**;
3 Thus, ATP synthase in liver and brain mitochondria will have different **quarternary structure**;
4 Both ATP synthase still complementary to curcumin, but curcumin **binds differently** to both, leading to differential effect; (Reject: curcumin binding to active site)

In many prokaryotes, the multi-subunit ATP synthase expression is under the control of a single operon.

(v) Suggest how the ATP synthase operon is organised.

……[2]

1 **Structural genes** that code for the **ATP synthase subunits** clustered together;
2 Under the control of a single **promoter**;

(c) ATP synthase deficiency is a disorder in which individuals are deficient in the enzyme, leading to a wide variety of signs and symptoms affecting many organs and systems of the body. The disorder can range from being mild to life-threatening.

Different mutations in different nuclear genes can result in the deficiency. These can generally be grouped into 2 categories. The first being mutations at gene loci coding for an ATP synthase subunit, for example, *ATP5E*.

The second being mutations at gene loci coding for a protein that is required for the proper assembly of the ATP synthase subunits to form the functional enzyme, for example, *TMEM70*.

(i) Justify the claim that the severity of the disorder in an individual depends on his/her genetic makeup.

.....[3]

1 **Different mutations** in a gene coding for an ATP synthase subunit / e.g. *ATP5E* lead to **different efficiency of ATP synthase**;
2 **Different mutations** in a gene coding for a protein that is required for the proper assembly of the ATP synthase subunits to form the functional enzyme / e.g. *TMEM70* lead to **different efficiency of ATP synthase / different proportion of functional ATP synthase**;
3 Ref. different effects of gene mutations (e.g. insertion/deletion not in multiples of 3 leading to frameshift vs substitution leading to silent/neutral mutation);

4 Ref. **different combinations** of mutations at different loci;
5 Ref**. additive effect** of mutations at multiple loci;
6 Lead to **different ATP synthesis efficiency / ability** in different patients and hence different severity of the disorder;

ATP synthase deficiency cases have been reported frequently in the Roma population, an ethnic group living mostly in Europe. Various journal articles have collectively reported the following:

- *TMEM70* gene defect was identified as a novel cause of autosomal recessive ATP synthase deficiency in 2009
- Most of the patients with *TMEM70* gene mutations share a common Roma descent
- In all genotyped cases for patients of Roma origin, an adenine to guanine substitution was found, located in the splicing site of intron 2, which leads to aberrant splicing and thus preventing synthesis of the functional protein
- If the disorder is present as a result of this substitution mutation, a fatal outcome or life-threatening symptoms are expected

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3) Spiegel R et al. (2011). TMEM70 mutations are a common cause of nuclear encoded ATP synthase assembly defect: further delineation of a new syndrome. *J Med Genet.* 48(3):177-82.

(ii) It can thus be deduced that a particular mutation is associated with people of Roma origin that can result in ATP synthase deficiency.

With reference to the information given, suggest how the mutation could have been preserved in present day people of Roma descent despite leading to fatal outcomes.

……[3]

1 Mutation is **recessive**;
2 Ref. effect of mutation can be **masked** by a dominant allele coding for a **functional TMEM70 protein**;
3 **Heterozygous** individuals with the recessive mutation able to **survive and reproduce**, thus, the recessive allele can be passed down to the offspring, and can be preserved in the population;

ATP synthase deficiency can also result from mutations in the mitochondrial genes, for example, *ATP6*. The *ATP6* gene codes for a subunit of ATP synthase.

Fig. 1.4 shows a pedigree chart where individual 2, who is female, carries a mutation in the *ATP6* gene and thus suffer from the disorder. Individual 1 does not carry any mutations in the *ATP6* gene. Both individuals 1 and 2 do not carry any other mutations that can result in the disorder.

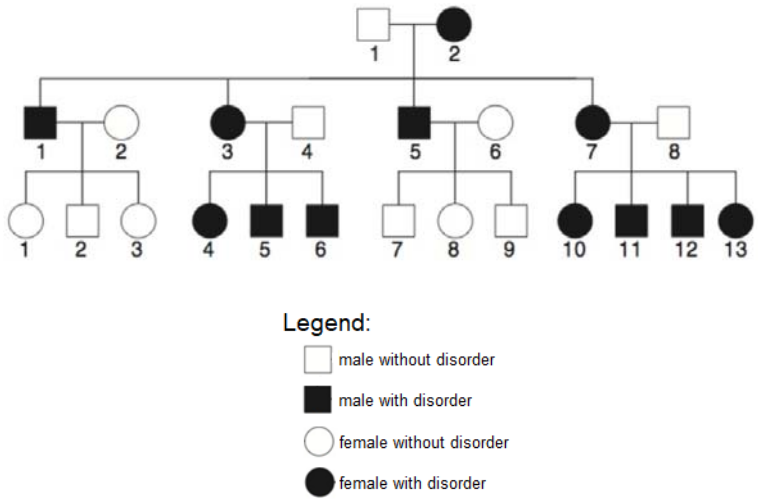

Fig. 1.4

(iii) With reference to **Fig. 1.4**, explain how the disorder is inherited.

……[4]

1 Inheritance is via **maternal line** / mothers;
2 **All children**, male or female, will inherit the disorder from the **mother**;
3 **[Quote data]** e.g. All children individuals 4, 5 and 6 (generation 3) of individual 3 will have the disorder OR All children individuals 10, 11, 12 and 13 (generation 3) of individual 7 will have the disorder OR All children individuals 1, 3, 5 and 7 (generation 2) of individual 2 will have the disorder

4 Zygote obtains all **mitochondria** from **mother** and none from father;
5 *ATP6* gene present only in mitochondrial DNA and **not present in nuclear DNA/chromosomes**;

QUESTION 2

Climate change, in the form of global warming, is expected to have an impact on various organisms. This impact however, varies geographically, particularly for insects. **Fig. 2.1** and **Fig. 2.2** below show the fitness curves of representative insects from temperate and tropical locations respectively.

Commented [TYMY2]: Change diagram labels to Fig. 2.1, Fig 2.2 etc

Same for Q1 Diagrams

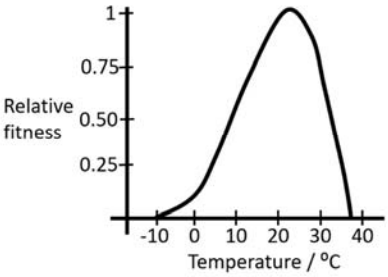

Fig. 2.1: Fitness curve of representative insect from temperate location

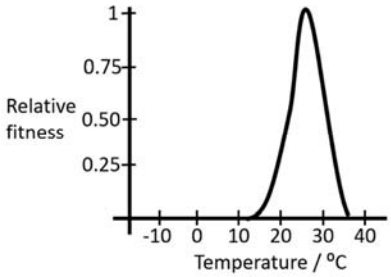

Fig. 2.2: Fitness curve of representative insect from tropical location

The mean annual temperature of the temperate location is 11 °C, with a typical temperature range from 1 to 20 °C. On the other hand, the mean annual temperature of the tropical location is 27 °C, with a typical temperature range from 21 to 31 °C.

(a) Suggest what is meant by the term relative fitness in **Fig. 2.1** and **Fig. 2.2**.

Commented [TYMY3]: change

.....[2]

1 a measure of evolutionary success as indicated by the number of surviving offspring left to produce the next generation;

2 **[**reference to / as compared to **fitness at optimum temperature** (relative fitness of 1);

(b) With reference to **Fig. 2.1** and **Fig. 2.2** and the information given, predict and explain which insects, from the temperate or tropical location, would face a greater extinction risk as a result of global warming, assuming the warming elevates temperatures equally at both locations.

Commented [TYMY4]: change

……..[4]

1 Insects from the **tropical location**;

2 As these insects are already living **close to / just under / around /** (sometimes) **beyond** their **optimum temperature** for maximum relative fitness of 1 / these insects have a **narrower temperature tolerance**;

3 [Quote] Optimum temperature = 26 - 28□C (Accept: any figure within range) + mean annual temperature of the tropical location is 27□C OR typical temperature range from 21 to 31□C;

4 Ref. temperature predicted to increase by 2 – 3 □C as a result of global warming;

5 Ref. lower relative fitness beyond optimum temperature / Ref. temperature increase likely to lower relative fitness, thus, increasing extinction risk;

6 Ref. temperature increase likely to increase relative fitness of insects from temperate location instead, reducing extinction risk;

(c) Suggest one strategy that the insects in **(b)** can employ to reduce the impact of global warming on themselves.

……..[1]

1 Migration to cooler climate / regions / habitats / higher altitude / latitude;

QUESTION 3

(a) Proper activation of CD4 T cells is essential for an effective humoral immune response. This activation requires the involvement of antigen presenting cells, such as dendritic cells, that provide signals for the activation.

One such important signal is the presence of co-stimulatory molecules, such as CD80 or CD86, on the dendritic cell surface. These molecules are expressed and upregulated in dendritic cells via the Toll-like receptor signalling pathway. Toll-like receptors belong to a group of receptors known as Pattern Recognition Receptors that recognise typical surface molecules of pathogens as ligands.

CD4 T cell activation can occur via the natural route during infection or artificially via vaccination. Vaccines, when formulated effectively, could provide long term protection against a particular disease. Modern day vaccines that utilise only purified antigens generally do not evoke a strong immune response as compared to older style vaccines utilising live or killed whole bacteria.

(i) Outline how activation of CD4 T cells is important for an effective humoral immune response.

……[4]

1 Activated CD4 T cells give rise to many clones of activated **T helper cells** that are required for the activation of B cells;
2 Activated **T helper cells** have receptors that bind to (complementary / specific) **antigen** fragment displayed on a **class II MHC molecule** on the **B cell**;
3 Activated **T helper cells** release **cytokines**;
4 Activated B cells then **proliferate** and **differentiate** into **plasma cells** and memory B cells / undergoes **clonal selection** and **clonal expansion** to form **plasma cells**;
5 Plasma cells secrete **antibodies**;

(ii) Explain how vaccines can provide a long term protection against a disease.

……[2]

1 Ref. vaccines consist of antigen + example purified antigens / live or killed whole bacteria (preamble)
2 Ref. to immunological **memory** (e.g. Once activated, B and T cells undergo multiple cell divisions to produce a population of cells identical to the original cell where some cells in the clone become **memory cells**);
3 Memory cells are **long-lived cells** that can give rise to **effector cells** if the same antigen is encountered later in life / Encounter with the same pathogen again from which the vaccine was derived, during a real infection, triggers a **rapid** and strong **secondary immune response**;

(iii) For vaccines utilising purified antigens to be as effective as older style vaccines utilising live or killed whole bacteria, adjuvants need to be added to these vaccines.

Based on the information given, suggest what can be used as an adjuvant and explain how it contributes to the vaccine's effectiveness.

……..[2]

1 Bacterial cell wall (components) / flagella / Lipopolysaccharides / any named surface component of bacteria / **ligands** that bind to Toll-like receptor;

max 1

2 Leads to **expression / upregulation** of **co-stimulatory molecules / CD80 / CD86** on the **dendritic cell / APC surface**;

3 for **proper activation of CD4 T cells**;

Section B

Answer **one** *question only*.

QUESTION 4

(a) Cellulose is the most abundant biopolymer on earth. It forms a significant proportion of the dry mass of plants.

Describe the Calvin cycle and explain the origin of the carbon atoms in cellulose, taking into consideration the number of molecules involved. [12]

Phase 1: Carbon dioxide fixation

1. **CO_2** (1-carbon molecule) **enters** the Calvin cycle, and is **fixed by combining** with a 5C compound called **ribulose-1,5-bisphosphate / RuBP**;
2. catalysed by the enzyme **rubisco / RuBP carboxylase**,
3. to form an **unstable intermediate 6C compound**;
4. The unstable 6C compound immediately splits into half to form **2 molecules** of a 3C compound called **glycerate-3-phosphate / GP / PGA**;

Phase 2: glycerate-3-phosphaste (GP) reduction

5. **GP / PGA** is reduced to **triose phosphate / glyceraldehyde-3-phosphate / TP / PGAL / G3P**;
6. The electrons (hydrogen) for this **reduction** come from **NADPH**;
7. and the **energy** for this step comes from **ATP**;
8. ref. NADPH and ATP produced from the **light-dependent reactions**
9. For every ***3*** molecules of **CO_2**, there are ***6*** molecules of **triose phosphate / glyceraldehyde-3-phosphate / TP / PGAL / G3P**;
10. but only **1** molecule of **triose phosphate / glyceraldehyde-3-phosphate / TP / PGAL / G3P** (3C) **exits** the cycle, and will be used by the plant cell to synthesise carbohydrate like glucose (sugar);

Phase 3: Ribulose bisphosphate (RuBP) regeneration

11. The other **5** molecules of **triose phosphate / glyceraldehyde-3-phosphate / TP / PGAL / G3P** must be **recycled** to **regenerate 3** molecules of **RuBP**;
12. 3 more molecules of **ATP** from light dependent reaction used;

Max 8 pts

[explain origin of carbon atoms in cellulose]

13. Origin: **Carbon dioxide**;
14. Cellulose is a polymer of **β-glucose**;
15. Each β-glucose comes from 2 molecules of **triose phosphate / glyceraldehyde-3-phosphate / TP / PGAL / G3P**;
16. **6** carbon dioxide molecules required for synthesis of **1** molecule of β-glucose;
17. **6n** molecules of carbon dioxide required for **1** molecule of cellulose where n is number of β-glucose in the molecule;

Max 3 pts

QwC: [1mark] Clear, organised flow without ambiguity for Calvin cycle description and to include **at least 1 description for at least 2 phases in the Calvin cycle** + **at least 1 mark for origin**.

(b) In a particular plant species, which could produce offsprings in the hundreds, its height and flower colour are each controlled by a single gene locus. The two gene loci are located on different chromosomes. It is known that the alleles for tallness (T) and red flower (R) are dominant to the alleles for shortness (t) and white flower (r) respectively.

Using one molecular method and one genetic cross method, explain how the genotype of a tall, red-flowered plant of this species can be determined. [13]

Molecular method:

1. Ref **extraction** of genomic **DNA** from sample;
2. Forward and Reverse **primers** designed for **alleles t** and **r**; (A: primers for alleles T and R)
3. **Polymerase Chain Reaction** conducted using the designed primers **separately**;
4. Using thermostable DNA polymerase / Taq DNA polymerase;
5. **Ref. Denaturing** involving **heating** to **95°C**;
6. **Ref. Annealing** involving **cooling** to **55°C** (**A: 50 – 65°C)**;
7. **Ref. Elongation** involving **heating** to **72°C**;
8. Ref. cycle **repeated** 30-40 times for PCR;
9. **Gel electrophoresis** conducted;
10. Blotting process: DNA fragments (in the gel) are transferred onto nitrocellulose paper/membrane;
11. ref. nucleic acid hybridization - treatment with a **single-stranded radioactive DNA probe** which **binds/anneals to alleles t and r** via complementary base pairing;
12. Bands are visualized on X-ray film / autoradiography.
13. Presence of band for allele t indicates Tt genotype / heterozygous for gene locus for plant height while presence of band for allele r indicates Rr genotype / heterozygous for gene locus for flower colour;
14. absence of bands indicates plant is homozygous dominant at that gene locus;

OR

13. Presence of thicker bands for T allele indicates homozygosity (TT) + thicker bands for R allele indicates homozygosity (RR) / thinner bands indicates heterozygosity;

Max 8 for method + Max 2 for pt 13/14

Genetic cross method:

1. Perform a **test cross**;
2. If offsprings are all tall, plant is homozygous dominant at gene locus for height / ref. correct determination of TT genotype;
3. If offsprings are all red flowered, plant is homozygous dominant at gene locus for flower colour / ref. correct determination of RR genotype;
4. If short offspring present, indicates Tt genotype / heterozygous for gene locus for plant height;
5. if white flower offspring present, indicates Rr genotype / heterozygous for gene locus for flower colour;

(Accept: genetic cross diagrams for TTRR, TtRr, TTRr and TtRR for pt 16-19)

Max 5

QwC: [1mark] Clear, organised flow without ambiguity and to include 1 mark each for both methods and determination of results.

QUESTION 5

(a) The Centers for Disease Control and Prevention in the United States of America recommends an annual influenza vaccination for everyone 6 months and older with rare exceptions, for example, those with life-threatening allergies to the vaccine. Each annual vaccine is different and contains three influenza strains.

Explain the need for a person to receive influenza vaccinations annually for protection against the disease and suggest why a person may still get the disease even after receiving his/her annual dose of vaccine. [12]

[need for vaccinations annually]

1. Ref. Different strains exist;
(New influenza virus strain can emerge via Antigenic drift and Antigenic shift)

[Antigenic drift]

2. Ref to **antigenic drift +** Spontaneous mutations in the viral genome coding for antigens haemagglutinin and neuraminidase,
3. due to a lack of proof reading of viral RNA-dependent RNA polymerase,
4. causing minor changes in the 3D conformation of haemagglutinin or neuraminidase;
5. **Ref. changes may accumulate to become a new strain;**

[Antigenic shift]

6. Ref to antigenic shift + Two (or more) different strains of the influenza virus infects the **same host cell**;
7. There is reassortment of the **viral RNA segments**,
8. giving rise to a new combinations of RNA segments in new viral particles, hence **new combinations** of **surface antigens haemagglutinin and neuraminidase arises**, a **new virus strain** results;

9. Annual vaccines contain only **3 strains** that are **common** for that **year / season** / Ref annual vaccine does not provide protection for all strains;

[suggest]

[infection by one strain only]

10. exposed to an influenza virus **shortly before getting vaccinated** OR **during the period that it takes the body to gain protection after getting vaccinated**. This exposure may result in the person becoming ill with influenza before the vaccine begins to protect the person;

[infection by other strains]

11. ref. exposed to a flu virus that is not included in the seasonal flu vaccine;
12. Ref. influenza vaccine is made to protect against the three strains that research **suggests** will be most common / likelihood that prediction for 3 most common strain not being accurate;
13. Ref existing memory cells / antibodies do not recognise antigens on new strain;

14. Ref. Protection provided by vaccination can vary widely, based in part on health and age factors of the person getting vaccinated / ref. may not provide protection in people with **immune system that are not fully functioning or developed**;

QwC: [1mark] Clear, organised flow without ambiguity and to include at least 1 mark for each section.

(b) Free nucleotides are present in various locations in a eukaryotic cell. They can exist both in the more commonly known non-cylic form or in the cyclic form.

Describe the general structure of a non-cyclic form of nucleotide and with named examples, outline the role of free nucleotides, cyclic or non-cyclic, at particular locations in a human cell. [13]

[Describe structure of nucleotide]

1. A nucleotide consists of 3 components covalently bonded together: a **nitrogenous base**, **a pentose sugar / 5-carbon sugar** and a **phosphate group**;

[Nitrogenous base]

2. Adenine (A), **Thymine** (T), Cytosine (C), Guanine (G) in **DNA nucleotides** and Adenine (A), **Uracil (**U), Cytosine (C), Guanine (G) in **RNA nucleotides**;
3. Ring structure of each base can either be **purine** or **pyrimidine**;

[Pentose sugar]

4. Ref. deoxyribose in DNA nucleotide and ribose in RNA nucleotide / OH group on carbon-2 in ribose is replaced by hydrogen atom in deoxyribose;

[Phosphate group]

5. Ref. possibility of **monophosphate**, **diphosphate** and **triphosphate**;

6. The **base** is joined to **C-1** of pentose, the **phosphate group** is joined to **C-5** of pentose; (Accept: drawing showing the joining)

[role of free nucleotides]

7. **Deoxyribonucleotides/ DNA nucleotides** in **nucleus** used as raw materials for **DNA replication** to synthesise DNA molecules;

8. **Ribonucleotides / RNA nucleotides** in **nucleus** used as raw materials for **transcription** to synthesise rRNA, tRNA and mRNA;

9. **cAMP** generated from ATP in **cytosol/cytoplasm** in a reaction catalyzed by the active form of a membrane-bound enzyme known as adenyl cyclase acts as **second messenger**;
10. ref. **signal amplication** during **signal transduction** in cell signalling;

11. **GTP** in **cytoplasm/cytosol**, when bound to G protein, **activates G protein** / ref. inactivation when GDP is bound;
12. Ref. allows **switching on and off** of the **transduction pathway** during cell signalling;

13. **ATP / GTP** in a **named location** + **hydrolysed** to provide energy in a **named metabolic process**;

14. **ADP** in **mitochondrial matrix** used for **ATP synthesis** by ATP synthase OR **ADP** in **cytoplasm / mitochondrial matrix** used for **ATP synthesis** in **substrate level phosphorylation**;

15. AVP; (eg. Distribution of various nucleotides across a membrane affects electrical gradient due to negative charges of phosphate groups)

16. AVP; (e.g. addition of 5' guanosine cap in the nucleus during post-transcriptional modification)

QwC: [1mark] Clear, organised flow without ambiguity and 1 point for nucleotide structure + 1 point for role of nucleotides

Civics Group		Name (use BLOCK LETTERS)

H2

Centre number / Index Number	

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 PRELIMS

H2 BIOLOGY **9744/4**

Paper 4: Practical Exam

Friday 24th August 2018 2 hours 30 minutes

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Give details of the practical shift and laboratory, where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a HB pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

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

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.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

IMPORTANT INFORMATION TO CANDIDATES:

Candidates with access to microscope at the start of the paper are given the **first 1h 15 min** to use them. Please answer **QUESTION 2** within this time frame.

Candidates with no access to microscope at the start of the paper will be given access **1h 15min after the start of the paper**. You may proceed with **QUESTION 1** first.

Shift
Lab

For Examiner's Use	
Section A	
1	/ 20
2	/20
3	/15
Total	**/55**

This document consists of **17** printed pages including **1** blank page

QUESTION 1

Investigation of glucose concentration in fruit juice.

You are advised to:

- *Read through the entire question and prepare a table to record your results in **(b)(ii)**;*
- *Prepare a boiling water bath;*

  ***before** starting the investigation.*

You are required to estimate the concentration of reducing sugar in a fruit juice, labelled **F1**, by comparison with that in a range of glucose solutions.

You are provided with a 0.8% solution of glucose, labelled **F2**, Benedict's solution, distilled water and five test-tubes.

(a) Carry out the Benedict's test on fruit juice **F1**. Describe the procedure. Record your results in your table in **(b)(ii).**

……..

……[1]

(b) You are now going to test a range of glucose solutions that you will prepare yourself using **F2** and distilled water.

Carefully follow the instructions below. You should present and record your observations and data in the space provided. You will need to:

- read through the instructions carefully
- prepare the space on the next page so that it is ready for you to record the readings
- prepare a range of glucose of varying concentrations by **serial dilution**
- carry out the tests so that you can compare your results with the result for the fruit juice **F1**.
- rinse your syringes if necessary.

(i) You will now perform **serial dilution** using **F2** (0.80% glucose) as stock solution according to the steps below.

You will use **F2** (0.80% stock solution) to prepare 8.0 cm^3 of glucose solution of **half** the concentration i.e. 0.40%.

Using this newly prepared 0.40% solution, prepare another 8.0 cm^3 solution of **half** the concentration i.e. 0.20%.

Continue using this method until you have a total of 5 glucose solutions of varying concentrations.

Complete the table below.

……[2]

concentration of glucose / %	0.80 (F2)				
volume of the glucose solution to be diluted / cm^3					
volume of distilled water / cm^3					

(ii) Using a **table**, record the results for Benedict's test of F1 and the range of glucose standards in the space below.

……[3]

(iii) Estimate the concentration of reducing sugar in the fruit juice **F1**. You may use a range for your estimation or the nearest glucose standard concentration.

…….. [1]

(c) The volume of reactants can affect the results that you obtain.

(i) State how you controlled this variable in your investigation.

……..

……[1]

(ii) Identify two other significant sources of error in this experiment.

1 .....

……..

2 .....

.....[2]

(d) Suggest how the student could improve this experiment.

……..

……..

……..

……..

……..

……[3]

(e) A student used another carbohydrate, starch, to investigate the effect of pH on the activity of the enzyme amylase.

The data in Table 1.1 were obtained.

Table 1.1

pH	time taken for complete hydrolysis / min			mean time / min
	first run	second run	third run	
5	9	10	8	9.0
6	7	6	8	7.0
7	3	4	3	3.3
8	4	5	6	5.0
9	10	9	11	10.0

(i) When the student first performed this investigation, the time taken for complete hydrolysis at pH 7 was 17 minutes.

Explain why the student discarded this result and repeated the experiment with freshly made solutions.

.....

.....[1]

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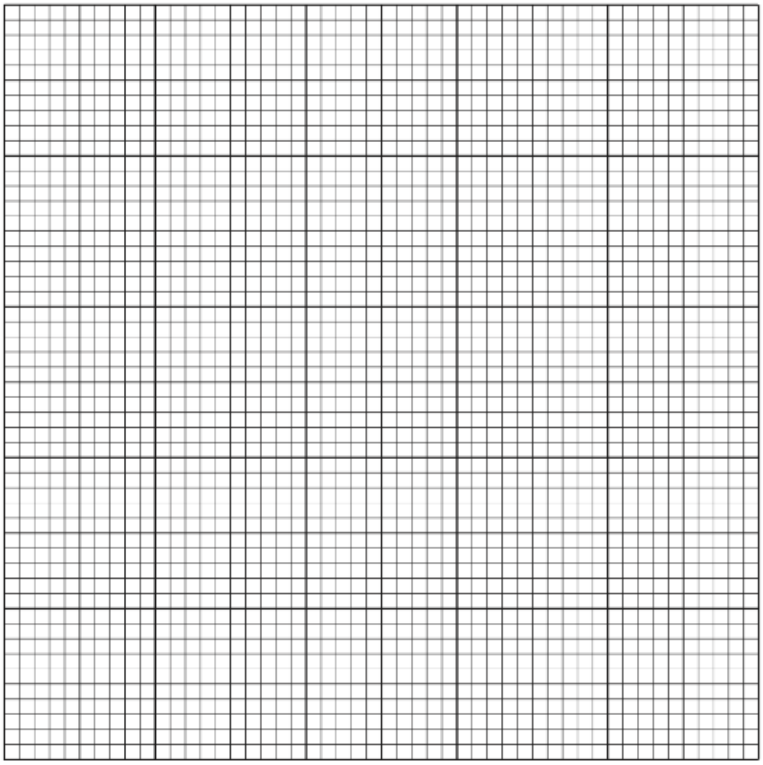
(ii) Plot a graph to show the effect of pH on the time taken for complete hydrolysis of starch by amylase.



[3]

(f) The student's hypothesis was:

- the activity of the enzyme would increase with increasing pH.

Discuss the student's hypothesis in relation to the results obtained.

……..

……..

……..

……..

……..

……[3]

[Total : 20]

QUESTION 2

You will need access to a microscope and stage micrometer for this question.

Betalains are water-soluble red pigments found in some fungi and flowering plants, including rhubarb and beetroot.

The red colour of the rhubarb stem is a result of betalains, present in the cytoplasm of the rhubarb cells. This gives the cytoplasm a reddish colour, enabling the cell membrane to be distinguished.

You are required to investigate the effect of a solution, **labelled K**, on the epidermal cells of the rhubarb.

You are provided with a petri dish containing two segments of the rhubarb stem.

- Use a pair of forceps to carefully peel a piece of the epidermis (coloured) from one of the rhubarb stems.
- With the scalpel, cut a small piece (e.g. 0.5cm X 0.5cm) from this epidermal tissue.
- Mount the square on a microscope slide in **distilled water** and cover it with a cover slip.

You are also provided with an eyepiece graticule that has been fitted to the eyepiece of your microscope and a stage micrometer.

The 1cm stage micrometer is divided into 100 divisions.

(a) Observe your slide under the low-power and then high-power objective lens (40X) of your microscope.

(i) Use the space below to make a high-power drawing of **3** adjoining epidermal cells. Label your drawing.

……[5]

(ii) Count the number of divisions of the eyepiece graticule across any 1 of the 3 cells using the 40X objective lens.

Number of divisions …….

Remove the slide and replace it with the stage micrometer. Using the same magnification, adjust the focus until you can see the eyepiece graticule on top of the stage micrometer.

(iii) Count the number of eyepiece graticule divisions that match an exact number of stage micrometer divisions.

Number of eyepiece graticule divisions ……..

Number of stage micrometer divisions ……

Use this information to calculate the actual diameter of the cell.
Show your working.

Actual diameter of cell …….. [2]

(iv) Suggest how an error in measuring the lengths could occur.

.....

.....[1]

(b) Fig. 2.1 shows a photomicrograph of rhubarb cells after being immersed in **Solution K** for a few minutes.

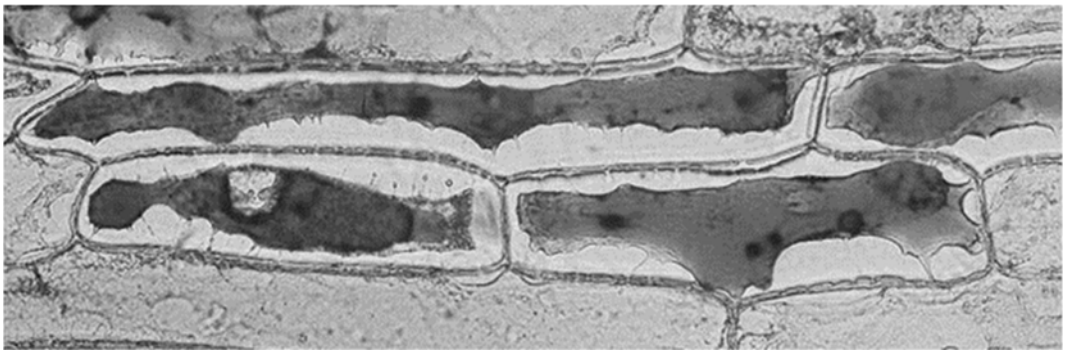


Fig. 2.1

(i) Prepare the space below so that it is suitable for you to record the observable differences between the rhubarb cells you have seen in **2(a)** and the cells in **Fig. 2.1.**

Record these differences in the space you have prepared.

……[2]

(ii) Explain the observation of the cells in **Fig. 2.1** and suggest a property of **Solution K**.

……

……

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……

……[4]

(iii) With atmospheric temperature set to increase due to climate change, predict how the constituents of the plasma membranes of plants will change.

Explain why.

……

……

……

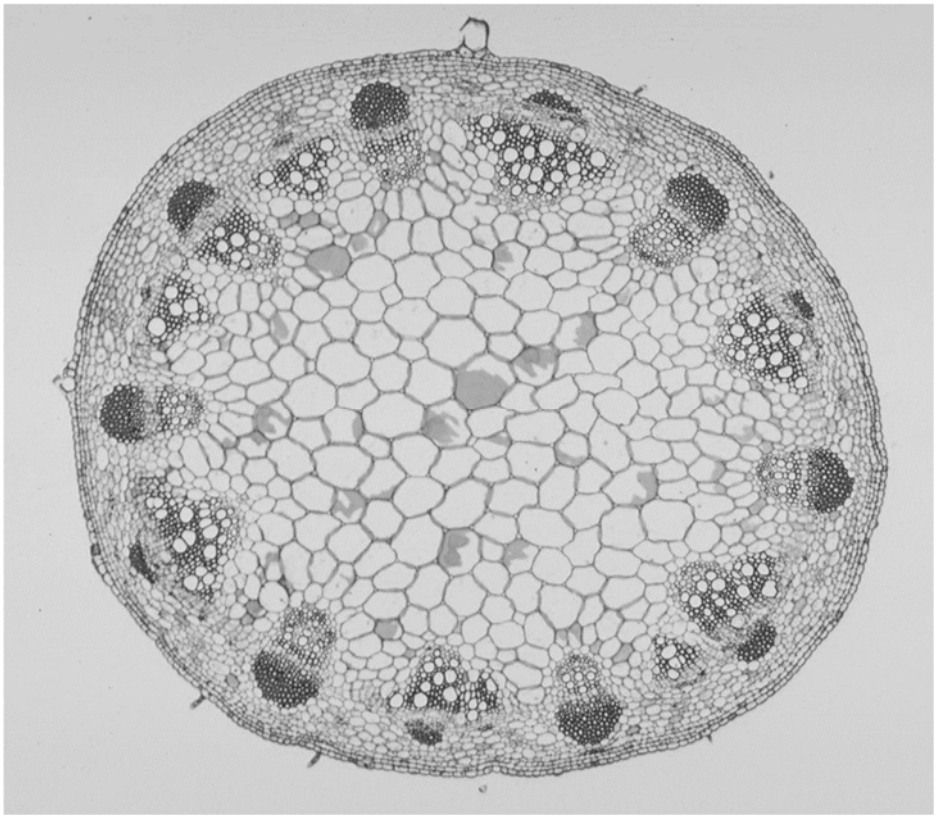
……

……

……[3]

(c) Fig. 2.2 is a photomicrograph of a stained transverse section through an organ of a different type of plant.

You are not expected to be familiar with this specimen.



(Adapted from www.carolina.com)

Fig. 2.2

Make a low-power plan drawing of **Fig. 2.2**.

……[3]

[TOTAL : 20]

QUESTION 3: PLANNING QUESTION

Effect of alcohol on membrane permeability of beetroot tissue.

Beetroot cells store molecules of betalain in their vacuoles. The membrane surrounding vacuoles in plant cells is the tonoplast, which has a similar structure to other cell membranes. Various factors such as alcohol influence the permeability of membranes.

Using this information and your own knowledge, design an experiment to determine the effect of different concentrations of alcohol on the membrane permeability of beetroot cells.

The following equipment may be used in your plan or not as you wish.
You should **not** use any additional reagents/equipment.

- beetroot root tissue
- distilled water
- a supply of hot water
- Clingwrap
- 100% alcohol containing a mixture of ethanol and methanol
- thermometer
- thermostatically controlled water bath
- colourimeter & cuvettes
- stopwatch
- core borer
- ruler
- scalpel
- syringes
- normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods, etc.,

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimize any risks associated with the proposed experiment.

[Total: 15]

……

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……

PREPARATION LIST FOR QUESTIONS 1 AND 2

Item / preparations	Quantity
QUESTION 1	
0.2% glucose solution, **coloured yellow** with 1 drop of food dye, **labelled F1.** This should be prepared by **dissolving 0.2 g of glucose in 80 cm^3 of distilled water, adding 1 drop of yellow food colouring**, then making up to **100 cm^3**. This can be made up the day before the examination.	5 cm^3 / pax in a container
0.8% glucose solution, **labelled F2.** This should be prepared by **dissolving 0.8 g of glucose in 80 cm^3 of distilled water** and then **making up to 100 cm^3.** This can be made up the day before the examination.	50 cm^3 / pax in a container
Benedict's solution, labelled **Benedict's solution.** The usual formulation used in the centre for reducing sugar testing will be suitable. This can be made up well in advance of the examination.	20 cm^3 / pax in a container
Distilled water, labelled **distilled water**	50 cm^3/ pax in a container
10 cm^3 syringe	2
Small 100ml beaker labelled **for rinsing**	1
Test-tube rack	1
Test-tubes	6
500ml Beaker for Benedict's test (boiling)	1
Bunsen burner	1
tripod and gauze	1
Glass marker pen	1
Stop-watch	1
Plastic containers	5
QUESTION 2	
Microscope (shared apparatus) with eyepiece graticule	1 (shared apparatus; 2 students share 1)
Stage micrometer (10mm)	1 (shared apparatus; 2 students share 1)
Cover slip	1
Glass slide	1
Dissecting / Mounted needle	1
Forceps	1
scalpel	1
Pasteur pipette	1
Rubra plant	2 stalks of purple stem wrapped in wet tissue

Civics Group		Name (use BLOCK LETTERS)

H2

Centre number / Index Number	

ST. ANDREW'S JUNIOR COLLEGE
2018 JC2 PRELIMS

H2 BIOLOGY **9744/4**

Paper 4: Practical Exam (Mark Scheme)

Friday 24th August 2018 2 hours 30 minutes

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Give details of the practical shift and laboratory, where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a HB pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

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

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.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

IMPORTANT INFORMATION TO CANDIDATES:

Candidates with access to microscope at the start of the paper are given the **first 1h 15 min** to use them. Please answer **QUESTION 2** within this time frame.

Candidates with no access to microscope at the start of the paper will be given access **1h 15min after the start of the paper**. You may proceed with **QUESTION 1** first.

Shift
Lab

For Examiner's Use	
Section A	
1	/ 20
2	/20
3	/15
Total	**/55**

QUESTION 1

Investigation of glucose concentration in fruit juice.

You are advised to:

- *Read through the entire question and prepare a table to record your results in **(b)(ii)**;*
- *Prepare a boiling water bath;*

  ***before** starting the investigation.*

You are required to estimate the concentration of reducing sugar in a fruit juice, labelled **F1**, by comparison with that in a range of glucose solutions.

You are provided with a 0.8% solution of glucose, labelled **F2**, Benedict's solution, distilled water and five test-tubes.

(a) Carry out the Benedict's test on fruit juice **F1**. Describe the procedure. Record your results in your table in **(b)(ii).**

……[1]

1. Description of Benedict's test that works: add an appropriate **equal volume** (e.g. 2.0 cm^3) of **sample** and **Benedict's solution** put in **boiling** water bath for appropriate duration (list a duration e.g. 10min)

(b) You are now going to test a range of glucose solutions that you will prepare yourself using **F2** and distilled water.

Carefully follow the instructions below. You should present and record your observations and data in the space provided. You will need to:

- read through the instructions carefully
- prepare the space on the next page so that it is ready for you to record the readings
- prepare a range of glucose of varying concentrations by **serial dilution**
- carry out the tests so that you can compare your results with the result for the fruit juice **F1**.
- rinse your syringes if necessary.

(i) You will now perform **serial dilution** using **F2** (0.80% glucose) as stock solution according to the steps below.

You will use **F2** (0.80% stock solution) to prepare 8.0 cm^3 of glucose solution of **half** the concentration i.e. 0.40%.

Using this newly prepared 0.40% solution, prepare another 8.0 cm^3 solution of **half** the concentration i.e. 0.20%.

Continue using this method until you have a total of 5 glucose solutions of varying concentrations.

Complete the table below.

concentration of glucose / %	0.80 (F2)	0.40	0.20	0.10	0.05
volume of the glucose solution to be diluted / cm^3		4.0	4.0	4.0	4.0
Volume of distilled water / cm^3		4.0	4.0	4.0	4.0

……[2]

1. Accuracy of volume to 1 d.p. for cm^3 and concentration to 2 d.p.
2. Correct concentrations of glucose AND appropriate volumes of glucose to be diluted and distilled water

(ii) Using a **table**, record the results for Benedict's test of F1 and the range of glucose standards in the space below.

……[3]

1. independent variable in leftmost column
2. heading column headings include concentration with units in % and colour; [trend of color going from brick red ppt, to orange, to yellow, to blue-green, to blue

Concentration <u>of glucose</u> / %	Initial color <u>of Benedict's solution</u>	Final color <u>of Benedict's solution</u>
0.05	Blue solution	Blue solution /Green ppt in blue solution
0.10	Blue solution	Red ppt in blue solution
0.20	Blue solution	Reddish brown ppt
0.40	Blue solution	Orange ppt
0.80	Blue solution	Dark brown ppt
F1 (unknown)	Blue solution	Reddish brown ppt

(iii) Estimate the concentration of reducing sugar in the fruit juice **F1**. You may use a range for your estimation or the nearest glucose standard concentration.

…… [1]

1. correct value/range for fruit juice concentration i.e. >0.10**%** and < 0.40**%**; Reject: 0.10%; 0.40% [ecf: dp]

(c) The volume of reactant**s** can affect the results that you obtain.

(i) State how you controlled this variable in your investigation.
..... [1]
1. Keep volume of **glucose** solutions measured constant for each test + list a **volume** e.g. 2.0cm^3

AND

keeping the volume of **Benedict's** solution constant for each test + list a **volume** e.g. 2.0cm^3

AND

Listing of 10.0cm^3 <u>syringe</u> (**apparatus**)

(ii) Identify two other significant sources of error in this experiment. [2]

1. Difficulty in judging colour / colour identification is subjective
2. Insufficient concentrations tested in glucose standards (thus, difficult to estimate F1 concentration accurately)
3. Lack of replicates performed lead to lack of reliability / lack of repeats performed to ensure reproducibility of results
4. Lack of (negative) control performed

[Any 2]

(d) Suggest how the student could improve this experiment.
.....[3]
[Difficulty in judging color]
1. use more accurate measuring device e.g. colorimeter/compare colour chart/spectrophotometer;

[Difficulty in estimating concentration of F1 using the 5 glucose standards]
2. use wider range of solutions at different concentrations / prepare more concentrations of glucose

[Lack of replicates / repeats]
3. perform replicates/repeat at each concentration of glucose;

[Lack of control]
4. replace glucose solution with equal volume of distilled water

(e) A student used another carbohydrate, starch, to investigate the effect of pH on the activity of the enzyme amylase.

The data in Table 1.1 were obtained.

Table 1.1

pH	time taken for complete hydrolysis / min			mean time / min
	first run	second run	third run	
5	9	10	8	9.0
6	7	6	8	7.0
7	3	4	3	3.3
8	4	5	6	5.0
9	10	9	11	10.0

(i) When the student first performed this investigation, the time taken for complete hydrolysis at pH 7 was 17 minutes.

Explain why the student discarded this result and repeated the experiment with freshly made solutions.

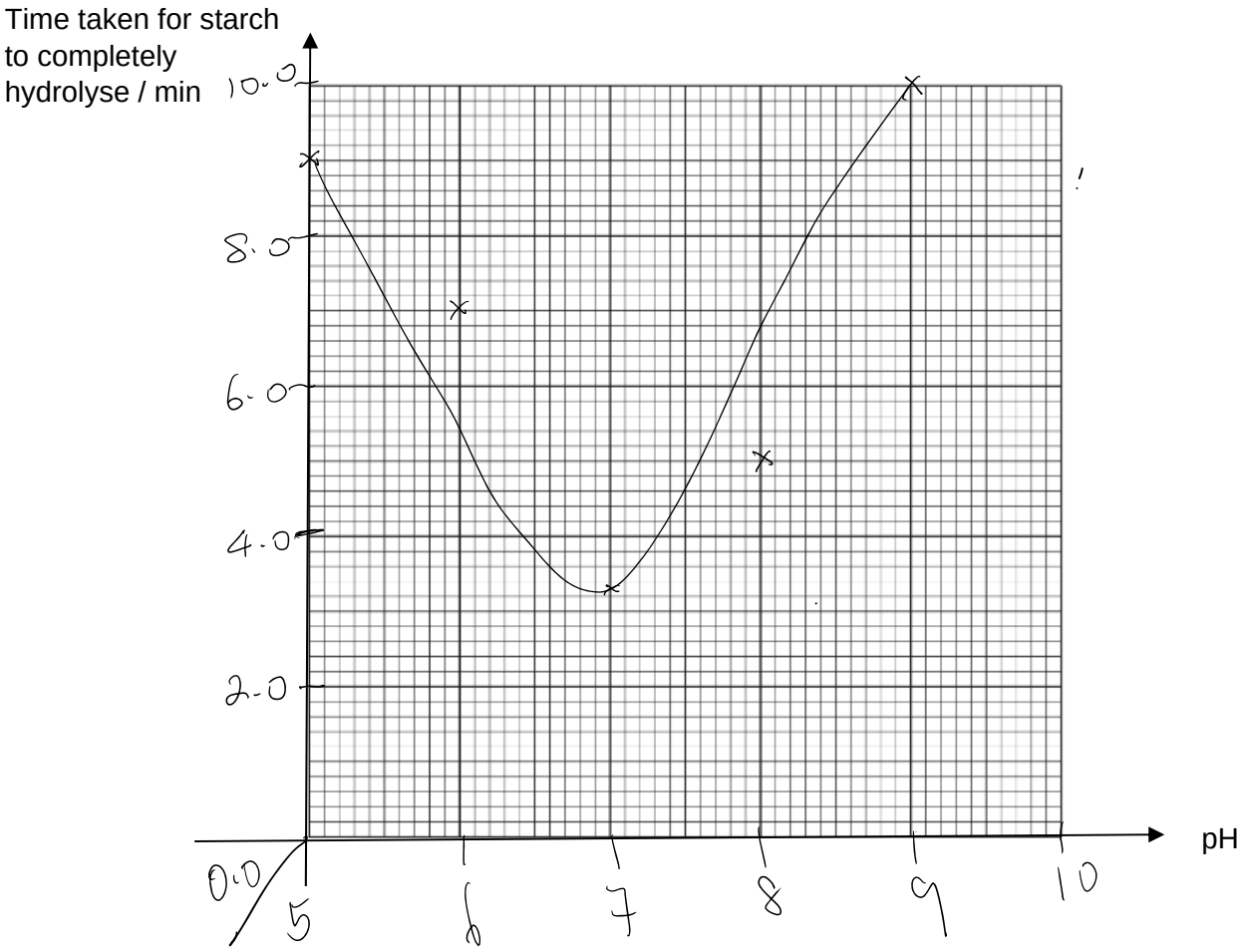
.....[1]

1. time for that pH should be much quicker/AVP (accept: reading anomalous/not reliable)

(ii) Plot a graph to show the effect of pH on the time taken for complete hydrolysis of starch by amylase.

Graph showing effects of pH on time taken for starch to completely hydrolyse

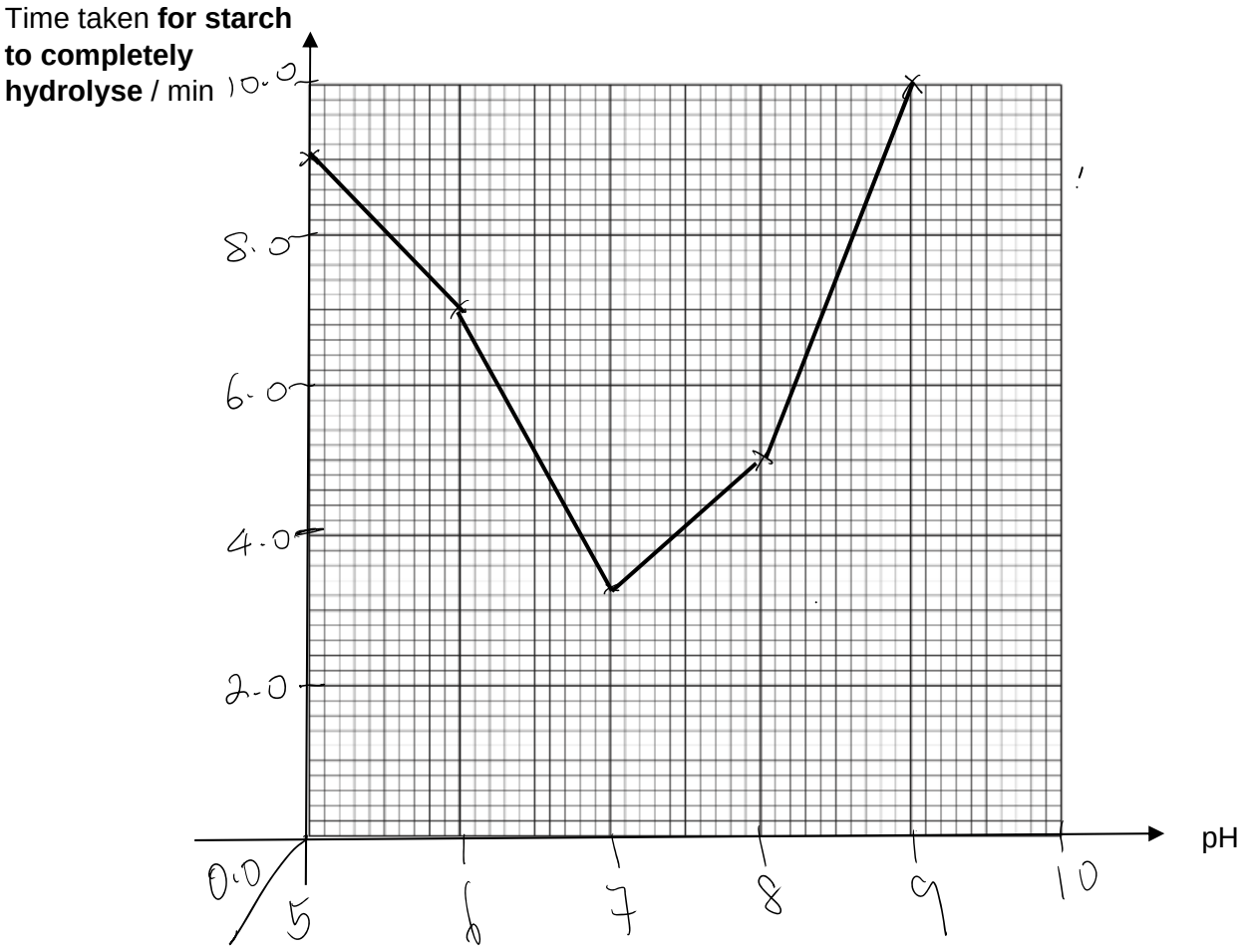
/min



1. [**axes**] independent variable (pH) on x-axis, dependent variable (mean time/min) on y-axis AND axis **labels** appropriate (accept ecf from table if already penalised in (b) (i));
2. [**scale**] scale should be chosen so that data spans **at least half** of the width and height of the grid AND **scale appropriate** such as 1:10, 1:5 or 1:2 (Reject: awkward scales such as 3:10, 7:10, 8:10) (scale does not need to start at 0);
3. [**plot**] data plotted accurately to within 1mm, using crosses or circle-with-dot AND points joined with **straight ruled lines (dot to dot plot)** OR **fine curve (best fit line)** drawn through the data points, **not extrapolated** beyond the first or last point;

OR

Graph showing effects of pH on time taken for starch to completely hydrolyse /min



1. [**axes**] independent variable (pH) on x-axis, dependent variable (mean time/min) on y-axis AND axis **labels** appropriate (accept ecf from table if already penalised in (b) (i));
2. [**scale**] scale should be chosen so that data spans **at least half** of the width and height of the grid AND **scale appropriate** such as 1:10, 1:5 or 1:2 (Reject: awkward scales such as 3:10, 7:10, 8:10) (scale does not need to start at 0);
3. [**plot**] data plotted accurately to within 1mm, using crosses or circle-with-dot AND points joined with **straight ruled lines (dot to dot plot)** OR **fine curve (best fit line)** drawn through the data points, **not extrapolated** beyond the first or last point;

(f) The student's hypothesis was:

- the activity of the enzyme would increase with increasing pH.

Discuss the student's hypothesis in relation to the results obtained.

.....[3]

1. Quote + Ref. results agree with hypothesis from **pH 5 to pH 7/optimum pH**
2. Quote + Ref. results do not agree with hypothesis from **pH 7/optimum pH to pH 9**
3. [compulsory] Ref. enzyme gradually denatures at **low** and **high** pH;

[Total : 20]

QUESTION 2

You will need access to a microscope and stage micrometer for this question.

Betalains are water-soluble red pigments found in some fungi and flowering plants, including rhubarb and beetroot.

The red colour of the rhubarb stem is a result of betalains, present in the cytoplasm of the rhubarb cells. This gives the cytoplasm a reddish colour, enabling the cell membrane to be distinguished.

You are required to investigate the effect of a solution, **labelled K**, on the epidermal cells of the rhubarb.

You are provided with a petri dish containing two segments of the rhubarb stem.

- Use a pair of forceps to carefully peel a piece of the epidermis (coloured) from one of the rhubarb stems.
- With the scalpel, cut a small piece (e.g. 0.5cm X 0.5cm) from this epidermal tissue.
- Mount the square on a microscope slide in **distilled water** and cover it with a cover slip.

You are also provided with an eyepiece graticule that has been fitted to the eyepiece of your microscope and a stage micrometer.

The 1cm stage micrometer is divided into 100 divisions.

(a) Observe your slide under the low-power and then high-power objective lens (40X) of your microscope.

(i) Use the space below to make a high-power drawing of **3** adjoining epidermal cells. Label your drawing.

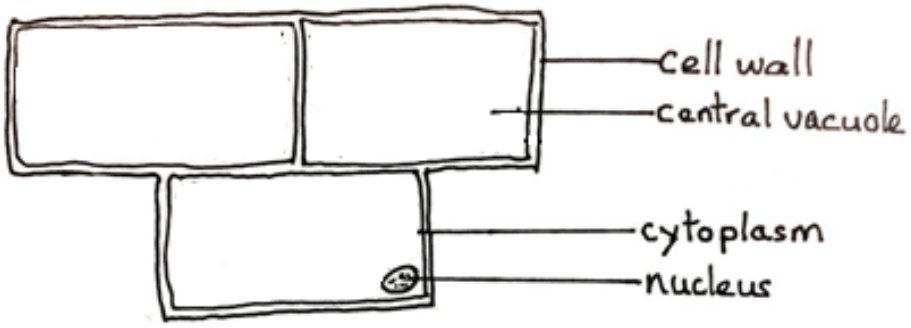
……[5]

Mark scheme:

1. **3** adjoining cells drawn;
2. Cells drawn with **clear, continuous lines**;
3. **Labels**: Cell wall, plasma membrane/ cell **surface** membrane, cytoplasm,(nucleus);
4. Appropriate **thickness** of cell wall
5. Presence of **shared cell wall**

Reminder: draw inner layer separately, then outline the exterior for cell wall

High power drawing of rhubarb epidermal cells (400X)



(ii) Count the number of divisions of the eyepiece graticule across any 1 of the 3 cells using the 40X objective lens.

Number of divisions …….

Range: 10 - 90 divisions

Remove the slide and replace it with the stage micrometer. Using the same magnification, adjust the focus until you can see the eyepiece graticule on top of the stage micrometer.

(iii) Count the number of eyepiece graticule divisions that match an exact number of stage micrometer divisions.

Number of eyepiece graticule divisions ……..
Ans: 40 graticule divisions

Number of stage micrometer divisions …….
Ans: 1

Use this information to calculate the actual diameter of the cell.
Show your working.

Actual diameter of cell ……..…….. [2]

Mark scheme:

1. Working shown (i.e. 10-90 divisions **X 2.5um**) [ecf: wrong number of divisions]
2. Actual diameter = 25um – 225um

(iv) Suggest how an error in measuring the lengths could occur.

……,,…….[1]

1. Thickness of scale lines / difficulty in matching the scales;

Reject: ref. any operator's error. i.e. parallax error in reading the number of divisions

(b) Fig. 2.1 shows a photomicrograph of rhubarb cells after being immersed in **Solution K** for a few minutes.

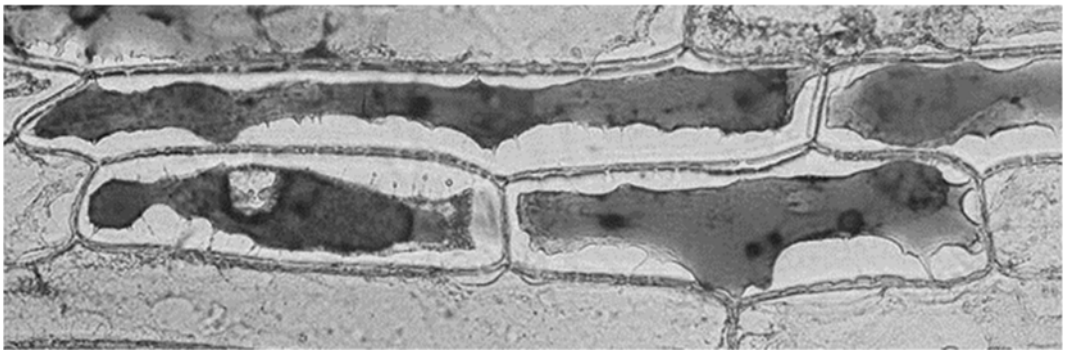


Fig. 2.1

(i) Prepare the space below so that it is suitable for you to record the observable differences between the rhubarb cells you have seen in **2(a)** and the cells in **Fig. 2.1.**

Record these differences in the space you have prepared.

……[2]

	Rhubarb cells in 2(a)	**Rhubarb cells in Fig 2.1**
1	No pulling away of cell surface membrane from cell wall;	Cell surface membrane pulls away from cell wall / shrinkage of cytoplasm;
2	No empty spaces within cell;	Empty spaces within the cell;
3	Cells are turgid/swollen;	Cells are flaccid/shrunken/not turgid/swollen;

NB: Must have table drawn with lines

Examiner's comments: If coloured diagram is given, can consider colour intensity as a difference (higher concentration of betalain pigments found in plasmolysed cells due to water moving out of cells)

Reject: vacuoles shrink after plasmolysis (as preamble in page 8 states that pigment is within cytoplasm)

(ii) Explain the observation of the cells in **Fig. 2.1** and suggest a property of **Solution K**.

……[4]

1. Cells are **plasmolysed**;
2. ref. movement of water out of cells by **<u>osmosis</u>** i.e. water leaving the rhubarb cells;
3. from region of high water potential to region of lower water potential through a selectively/partially [Reject: semi] permeable / cell surface membrane
4. [property of Solution K] Solution K is a hypertonic / concentrated solution

(iii) With atmospheric temperature set to increase due to climate change, predict how the constituents of the plasma membranes of plants will change.

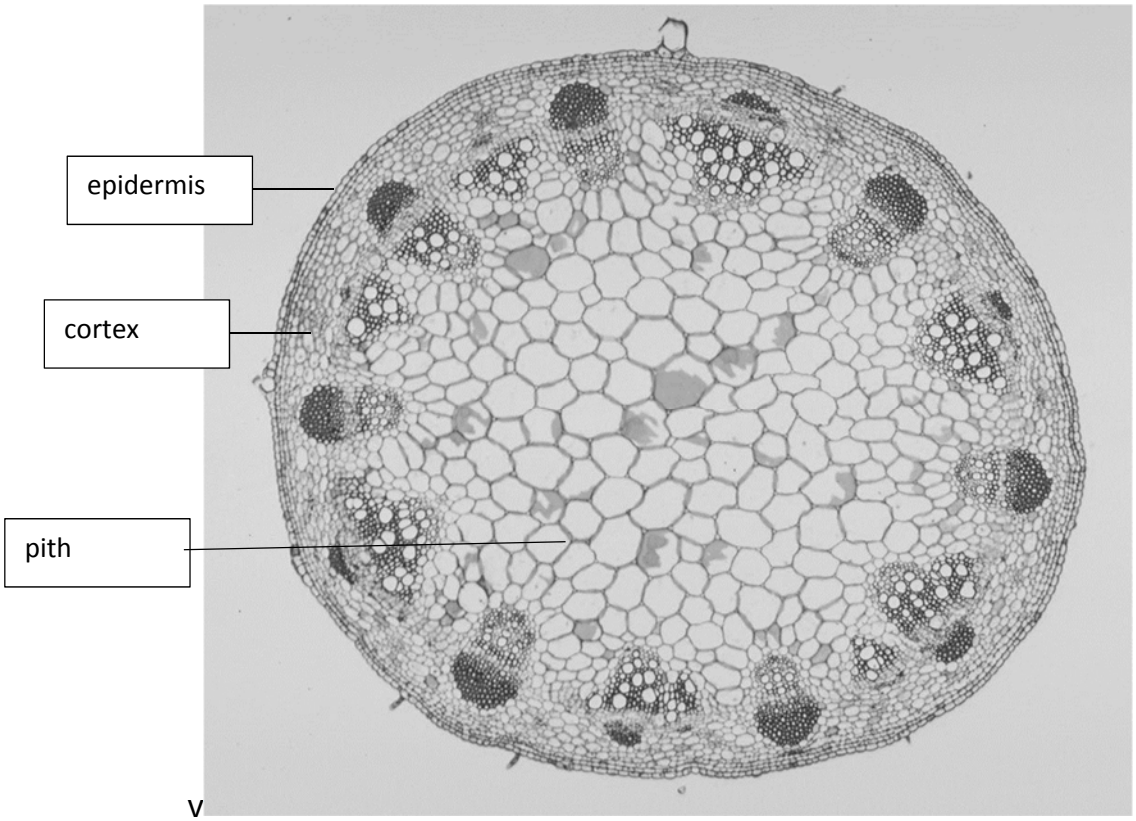
Explain why.

……[3]

1. More cholesterol found in cell membrane;
2. Higher ratio of saturated fatty acids:unsaturated fatty acids / more saturated fatty acids / less unsaturated fatty acids / less C=C double bonds
3. ref. decrease fluidity of cell membrane / maintain integrity of membrane at a higher temperature;

(c) Fig. 2.2 is a photomicrograph of a stained transverse section through an organ of a different type of plant.

You are not expected to be familiar with this specimen.



(Adapted from www.carolina.com)

Fig. 2.2

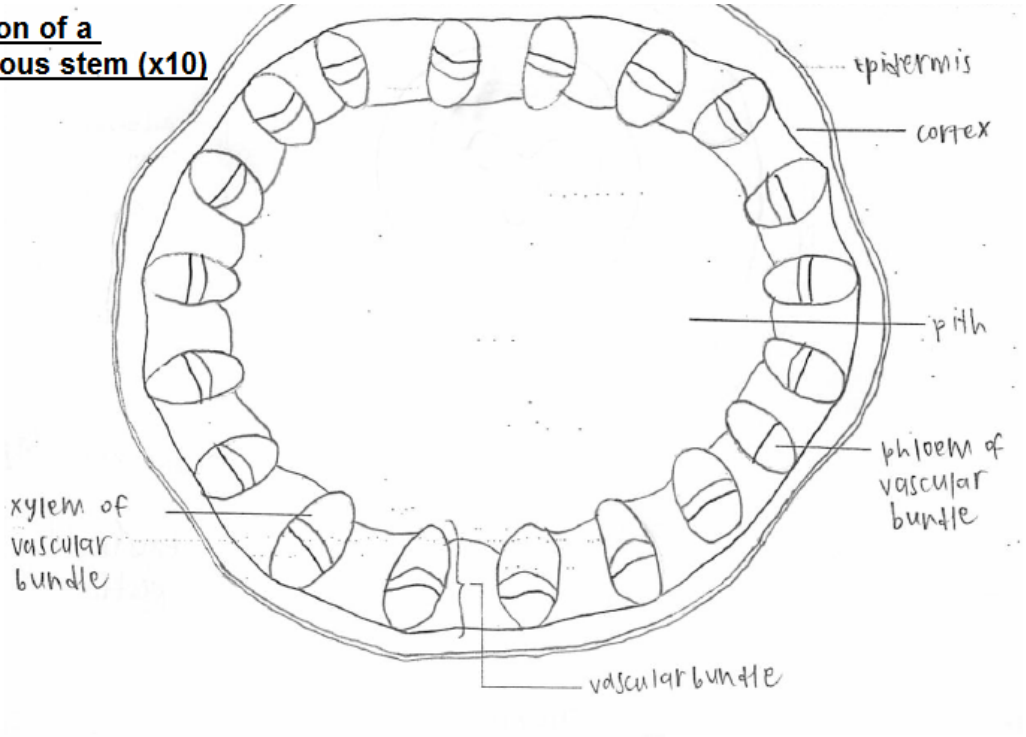
Make a low-power plan drawing of **Fig. 2.2**.

……[3]

Mark scheme:

1. at least 3 layers shown, with appropriate thickness, e.g. epidermis, cortex, pith; (ignore: layer joining the cambium)
2. at least 3 layers for vascular bundles e.g. xylem, phloem, cambium;
3. plan drawing with clear, continuous lines, no cells drawn and no shading;

Cross section of a dicotyledonous stem (x10)



[TOTAL : 20]

QUESTION 3: PLANNING QUESTION

Effect of alcohol on membrane permeability of beetroot tissue.

Beetroot cells store molecules of betalain in their vacuoles. The membrane surrounding vacuoles in plant cells is the tonoplast, which has a similar structure to other cell membranes. Various factors such as alcohol influence the permeability of membranes.

Using this information and your own knowledge, design an experiment to determine the effect of different concentrations of alcohol on the membrane permeability of beetroot cells.

The following equipment may be used in your plan or not as you wish.
You should **not** use any additional reagents/equipment.

- beetroot root tissue
- distilled water
- a supply of hot water
- Clingwrap
- 100% alcohol containing a mixture of ethanol and methanol
- thermometer
- thermostatically controlled water bath
- colourimeter & cuvettes
- stopwatch
- core borer
- ruler
- scalpel
- syringes
- normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods, etc.,

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimize any risks associated with the proposed experiment.

[Total: 15]

MARK SCHEME

INTRODUCTION

A: <u>BACKGROUND KNOWLEDGE / RATIONALE</u>

[1m for 2 points = 2m]

1. ref. plasma membrane / tonoplast membrane as a **phospholipid bilayer**, (with hydrophilic phosphate heads facing outwards and hydrophobic fatty acid tails facing inwards);
2. hydrophobic core / fatty acid tails are impermeable to charged/polar substances /allow non-polar substances to pass through;
3. Alcohol disrupts the physical structure of membranes / ref. denaturation of proteins embedded in membrane
4. ref. leakage of betalain molecules out of cytoplasm/vacuole/cell into surrounding medium

[Hypothesis] – 1m

5. As the <u>alcohol concentration increases</u>, the membrane permeability increases (followed by plateau)

[Rationale] – 1m

6. Membrane permeability is indicated by the extent of leakage of pigments which is **measured using a colourimeter to give an absorbance value.**

B: <u>VARIABLES AND CONTROLLED VARIABLES</u>

[*State the independent and dependent variables*] – 1m for #1,2

1. The independent variable is **<u>alcohol concentration</u>** / % ; 10%, 30%, 50%,70%, 90%. [At least 5 readings, regular intervals; maximum 100%]

2. The dependent variable is **membrane permeability**, measured by the absorbance of the surrounding medium.

[*Other variables to keep constant: Can be written in detail in Procedure Section*] – 1m for 2 points, max 1m

1. **Surface area/dimensions** and <u>number</u> of discs of beetroot tissue used
   - Use a <u>core borer</u> to ensure cylinders of beetroot tissue are of the same dimensions/size, and cut into discs of the **<u>same thickness</u>** e.g. **0.5cm using scalpel and ruler**

2. <u>Volume of alcohol solution</u>
   - Use a <u>syringe</u> to add the **<u>same volume</u>** e.g. 10cm^3 (state volume here or in procedure) of fresh alcohol solution from the same stock (stirred well before use) to keep the initial concentration of alcohol constant.

3. <u>Temperature</u>
   - The temperature, **e.g. 35°C**, is kept constant by using a <u>thermostatically controlled water bath</u>/ thermometer and hot and cold water

4. pH
   - Keep pH constant with a pH buffer of same volume ($2cm^3$)

5. Duration of reactions
   - A digital stopwatch is used to ensure duration of reactions is kept constant **e.g. 5 min.**

[Control] -1m

1. A control is set up with **10.0 cm^3** of distilled water instead of alcohol solution, but with all other experimental conditions remaining constant.

   Purpose: to show any change in absorbance of solution is due to the disruption of the membranes by alcohol.

2. A control is set up using the same dimensions/size/number of **plastic discs** (or other inert material), subjected to the same concentrations of alcohol and experimental conditions.

   Purpose: To show that any change in absorbance of solution is due to the leakage of betalain pigments from the beetroot tissue.

[Diagram] -1m

Labelled with:

Beaker of water as conventional water bath with thermometer / thermostatically controlled water bath, test tube with discs

C: <u>DETAILED PROCEDURE – total 7m</u>

<u>Part 1: Preparation of the different alcohol concentrations</u>

1. Label 5 boiling tubes – 10%, 30%, 50%, 70%, 90%. (minimum 5 tubes)

2. Prepare 30.0 cm^3 of various concentrations of alcohol solutions as shown in the table below. <u>10.0 cm^3 syringes</u> are used to add the stock alcohol solution and distilled water into the respective boiling tubes.

1m

Concentration of alcohol solution to be prepared /%	**Volume of 100% alcohol solution / cm^3**	**Volume of distilled water / cm^3**
10	3.0	27.0
30	9.0	21.0
50	15.0	15.0
70	21.0	9.0
90	27.0	3.0

OR

Concentration of alcohol solution to be prepared /%	**Volume of 100% alcohol solution / cm^3**	**Volume of distilled water / cm^3**
20	4.0	16.0
40	8.0	12.0
60	12.0	8.0
80	16.0	4.0
100	20.0	0.0

<u>Part 2:</u>

3. Use a core borer to obtain 2-3 cylinders from the beetroot tissue.

4. Use a ruler and scalpel to measure and cut the cylinder into 5.0cm discs.

5. Wash the discs under running water to remove any pigments released from the cells during cutting.

6. Using a syringe, measure 10cm^3 of 10% alcohol solution into a beaker.

1m

7. Cover the beaker with **Clingwrap to prevent evaporation** of alcohol.

1m

8. Incubate the beaker containing the alcohol solution in a thermostatically controlled water bath at **35ºC. Allow 5 minutes** for the alcohol solution to **equilibrate**.

9. Place 2 beetroot discs into the beaker containing 10% alcohol solution.

10. Ensure that the discs are completely soaked in the alcohol solution.

11. Using a stopwatch, incubate the beaker containing the beetroot discs in the thermostatically controlled water bath for 15 minutes. Ensure that beaker is covered to prevent evaporation of alcohol.

12. After 15 minutes, remove the beetroot discs from the solution.

13. Pour 2.0cm^3 of the alcohol solution into a cuvette. Shake the solution gently to ensure that the pigment is well mixed into the water before pouring into the cuvette.

1m

14. Measure the absorbance of the solution using a colourimeter. Record the absorbance into a suitable table.

15. Repeat steps 5 to 11 using the different concentrations of alcohol solutions.

[Replicates and Repeats] – 1m

16. To ensure reliability of results, repeat steps 3 to 14 to obtain a total of three readings at each alcohol concentration, and calculate the average.
17. To ensure reproducibility of data, repeat the entire experiment twice using freshly prepared reagents and solutions and beetroot root tissue.

D: DATA MANIPULATION AND EXPECTED RESULTS

1. [*Draw Table of results*] -1m

Table showing the absorbance /A at different concentrations of alcohol /%

For control using 0% alcohol

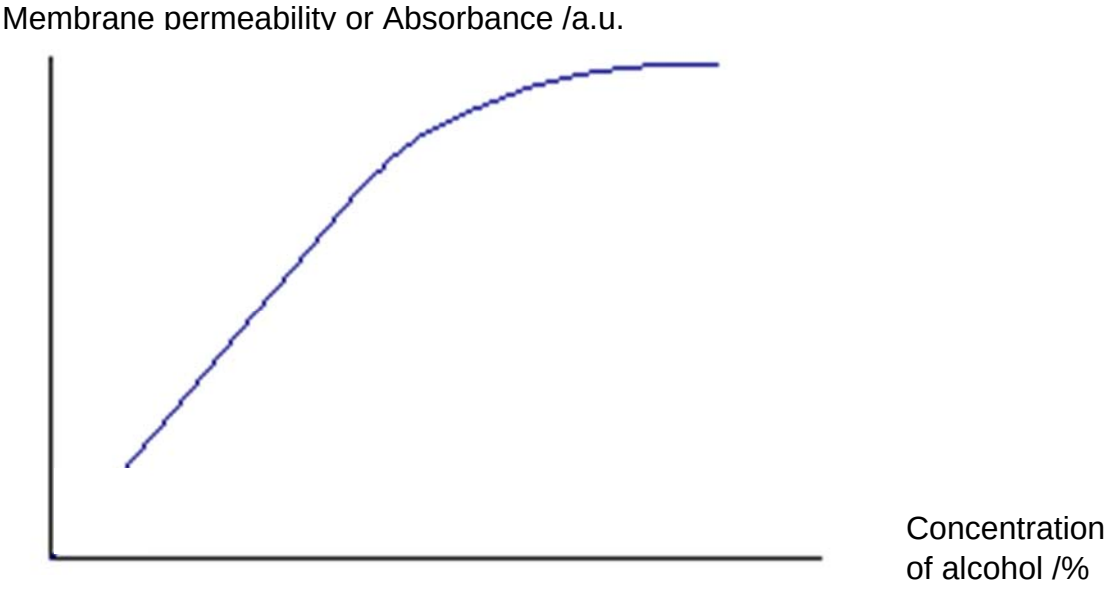
Concentration of alcohol /%	Absorbance of solution /A			
	Reading 1	Reading 2	Reading 3	Average
0				
10				
30				
50				
70				
90				

For control using inert plastic discs:

Concentration of alcohol /%	Absorbance of solution /A						
	Reading 1	Control	Reading 2	Control	Reading 3	Control	Average
0							
10							
30							
50							
70							
90							

2. [*Draw a graph to show expected trends and/or results*] -1m

Graph of absorbance /A against concentration of alcohol /%



SAFETY PRECAUTIONS -1m for 2 sets

	Risk	**Precaution**
1	Alcohol is flammable.	Ensure that there is no naked/open flame nearby.
2a	Scalpel is sharp and cause injuries	Place the sharp objects away from the main work area after use / handle with caution
2b	Core borer is sharp and cause cuts	Handle with caution
3	Alcohol is an irritant/toxic.	Wear safety goggles and gloves when handling alcohol.
4	AVP	

[Total: 15]