H

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME			
BIOLOGY CLASS	2bi2 __ / 2IPbi2 __	REGISTRATION NUMBER	

BIOLOGY 9744/01

Paper 1 Multiple Choice

13 September 2017

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Biology class and registration number above and on the Answer Sheet provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

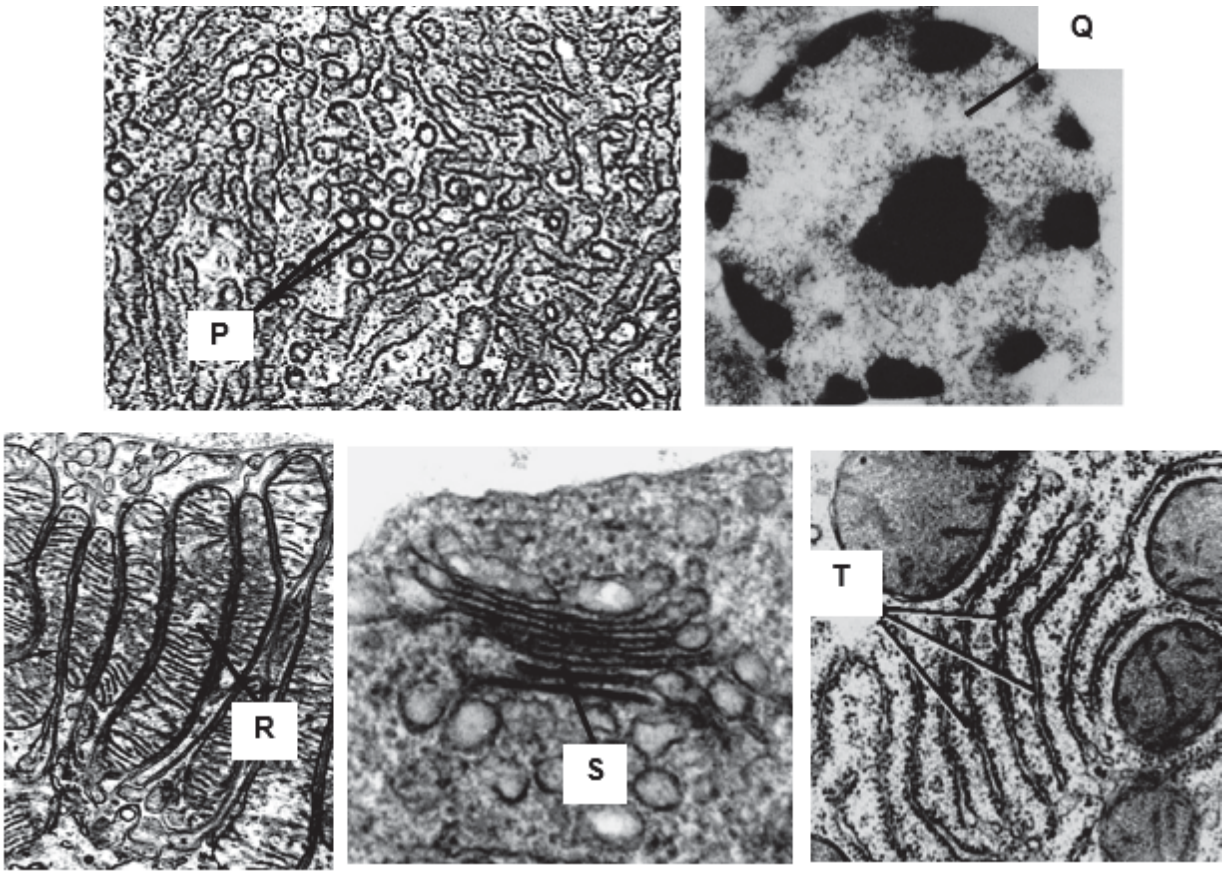
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **16** printed pages.

[Turn over

1 The electron micrographs show various organelles labelled P to T in a liver cell.



Radioactive amino acids are supplied to the liver cell to synthesise insulin receptors.

Which sequence shows the correct order in which these amino acids would be detected in the organelles during the synthesis of insulin receptors?

A Q → T → P → S

B Q → T → R → P → S

C T → P → S → R

D T → S → P

2 Which statements about the cell theory are correct?

1 All cells contain nucleus.

2 All cells divide from pre-existing cells.

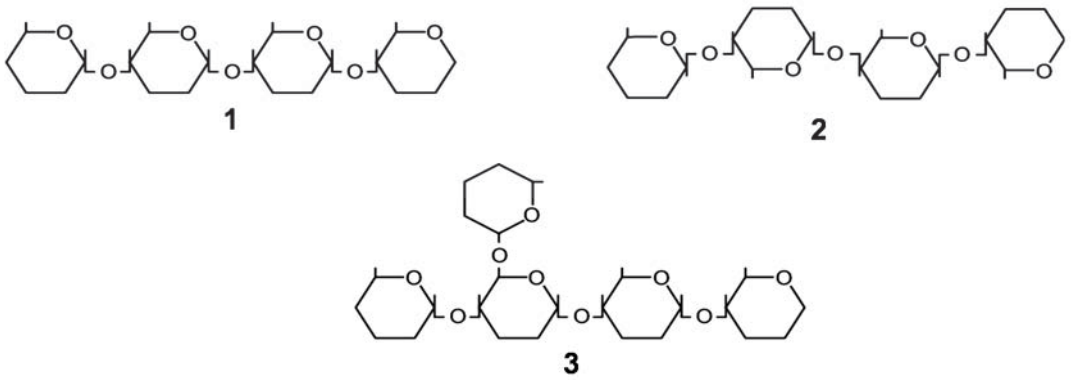
3 All cells divide to form new daughter cells.

4 Cells are the smallest unit of life.

5 Living organisms are composed of cells.

A 1, 2 and 3
B 1, 2 and 4
C 2, 4 and 5
D 3, 4 and 5

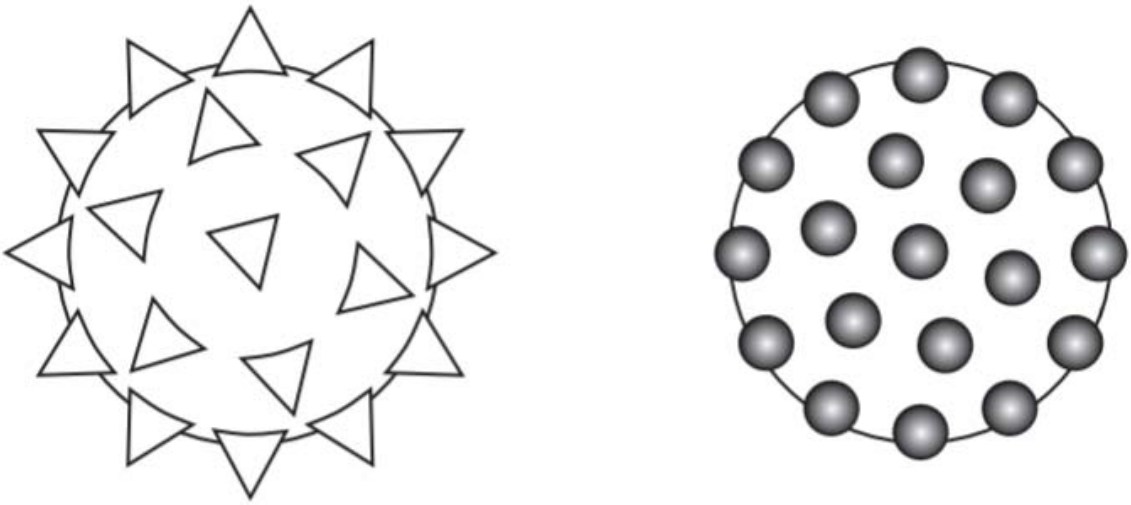
3 The diagram shows the structural formulae of three polysaccharides.



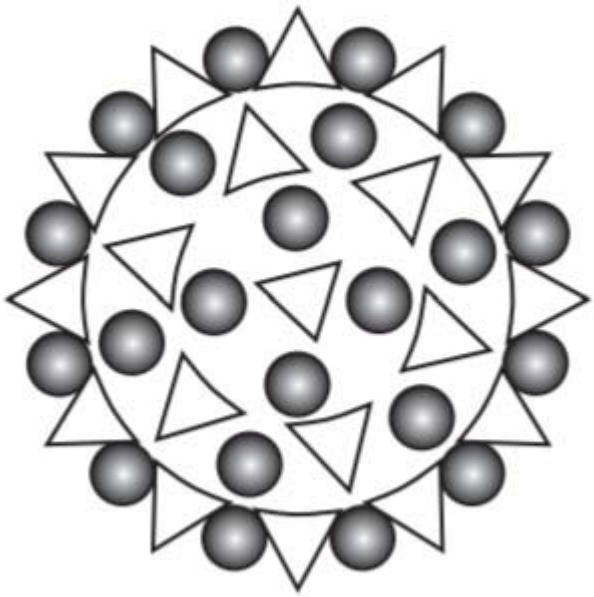
Which row is correct?

	1	2	3
A	amylose	cellulose	glycogen
B	amylose	amylopectin	cellulose
C	cellulose	amylose	amylopectin
D	glycogen	cellulose	amylose

4 Many eukaryotic cells have proteins as part of their plasma membranes. An experiment was performed on two different animal cells. The diagram shows the positions and shapes of two proteins on the plasma membranes of the two different cells.



These cells were then fused. After one hour, the plasma membrane of the resulting living cell was observed. The diagram shows the changed positions of the proteins.



What best explains the redistribution of proteins on the plasma membrane?

A the amphipathic nature of the phospholipid bilayer

B the fluidity of the phospholipid bilayer

C the presence of cholesterol at high temperature in the plasma membrane

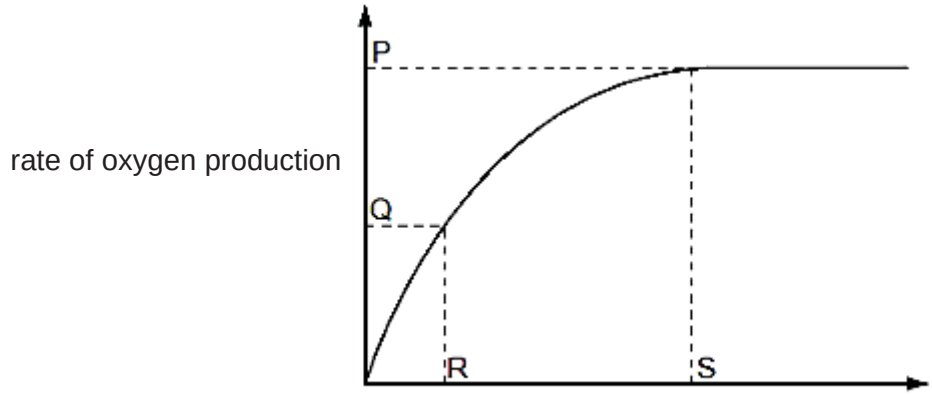
D the presence of saturated fatty acid chains of phospholipids in the plasma membrane

5 The diagram shows the action of a liver enzyme called catalase, which breaks down hydrogen peroxide into water and oxygen.

$$2\,H_2O_2 \xrightarrow{\text{catalase}} 2\,H_2O + O_2$$

The rate of this reaction can be determined by measuring the volume of oxygen produced in a given length of time. Students added small cubes of fresh liver tissue to hydrogen peroxide solution of varying concentrations and measured the volume of oxygen produced.

The graph shows how the concentration of hydrogen peroxide affected the rate of oxygen production.



Which statements are correct?

1 At P, the rate of reaction is limited by the concentration of enzyme.

2 At Q, all of the enzyme active sites are occupied by substrate molecules.

3 At Q, the rate of reaction is limited by the concentration of the substrate.

4 At S, all of the enzyme active sites are occupied by substrate molecules.

A 1 and 4

B 2 and 4

C 1, 2 and 3

D 1, 3 and 4

6 Ethylene glycol is a chemical used to prevent water from freezing. If ethylene glycol is swallowed accidentally, it is metabolised by an enzyme found in liver cells to produce a toxic product.

The enzyme normally catalyses the oxidation of ethanol to a harmless product.

People who have swallowed ethylene glycol are treated with large doses of ethanol. This prevents formation of a toxic product and allows the body to excrete the ethylene glycol.

Which statement describes why this treatment works?

A Ethanol binds near the active site on the enzyme, altering its shape.

B Ethanol binds permanently to the active site of the enzyme, blocking it.

C Ethanol changes the tertiary structure of the enzyme, denaturing it.

D Ethanol is more likely to bind to the active site on the enzyme.

7 Mesenchymal stem cells can differentiate into several types of cells belonging to our skeletal tissue, such as cartilage, bone and fat.

Which statement correctly describes mesenchymal stem cells?

A They are specialised cells that can give rise to a variety of cell types.

B They can be stimulated by chemical signals to express certain genes.

C They lose genetic information as they differentiate.

D They occur in large numbers in the bone marrow.

8 What is an accurate description of the coding of protein structure by DNA?

A 64 different complementary codons used in transcription to make the three-dimensional shape of the tertiary structure

B a code, with several triplets for each amino acid, determining the shape of the α-helix for the secondary structure

C a degenerate, non-overlapping code for the primary structure, determining the location of the folding sites involved in tertiary structure

D amino acids coded for by three consecutive bases, used with tRNA anticodons in translation to determine the quarternary structure

9 An mRNA codon for the amino acid arginine is CGG.

How many arginine molecules are present in part of the polypeptide, containing eight amino acids, coded for by the following DNA template?

TCGGCCTACCGGGCCCATGCCAAT

A 0

B 1

C 2

D 3

10 What increases the possibility of antigenic shift in influenza virus?

A infection of multiple individuals with the same strain of influenza virus

B lack of proofreading ability in viral RNA polymerase

C presence of herd immunity

D simultaneous infection of one individual with two different strains of influenza virus

11 Which event is most likely due to bacterial conjugation?

A A gene encoding resistance to gentamicin in the *Escherichia coli* chromosome appears in the genome of a bacteriophage that has infected *Escherichia coli*.

B A strain of *Corynebacterium diphtheriae* produces a toxin encoded by a prophage.

C A strain of *Pseudomonas aeruginosa* produces β-lactamase encoded by a plasmid similar to a plasmid of another Gram-negative bacterium.

D An encapsulated strain of *Streptococcus pneumoniae* acquires the gene for capsule formation from an extract of DNA from another encapsulated strain.

12 Which rows correctly compare generalised and specialised transduction?

	generalised transduction	specialised transduction
1	Any donor gene can be transferred by the phage.	Only certain donor genes can be transferred by the phage.
2	The transducing phage contains a hybrid chromosome in its capsid.	The transducing phage contains only bacterial chromosome in its capsid.
3	Phage genome is transcribed.	Phage genome is not transcribed.
4	The donor cell lyses, releasing the phages.	The donor cell lyses, releasing the phages.

A 1 and 3

B 1 and 4

C 2 and 3

D 2 and 4

13 Which statement correctly describes the control of transcription of the genes involved in the breakdown of lactose in *Escherichia coli*?

A A repressor protein binds to the operator and the genes are switched on.

B A repressor protein binds to the operator and the genes are switched off.

C A transcription factor binds to the promoter and the genes are switched on.

D A transcription factor binds to the promoter and the genes are switched off.

14 A region of eukaryotic DNA consists of over fifty tandem repeats of the same sequence of twelve bases.

Where is this repetitive region **least** likely to be found?

A an exon

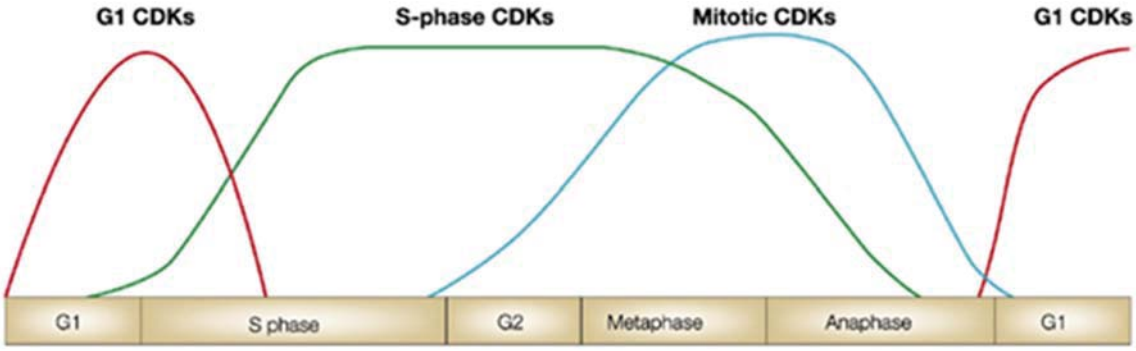
B an intron

C centromere

D promoter

15 Cyclins are regulatory proteins that associate with cyclin-dependent kinases (CDKs) to control the different stages of the cell cycle. The right type and amount of cyclins and CDKs must be present at the different stages to ensure regulation of the cell cycle.

The diagram shows the concentrations of the different CDKs.



How could the levels of the different CDKs be regulated during these stages?

1 binding of repressor to operator

2 formation of heterochromatin

3 length of mRNA poly(A) tail

4 ubiquitination of CDKs

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

16 Which group of genes are common tumour suppressor genes?

A genes involved in DNA synthesis
B genes involved in maintenance of cell cycle checkpoints
C genes involved in signal transduction
D genes involved in stimulation of cell division

17 Chromosomal mutations were induced to produce a fertile hybrid species from cabbage and radish.

The table 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
F_1 hybrids	18
F_1 gametes	9
F_2 hybrids	18
F_2 gametes	18
F_3 hybrids	36

At which stage did the chromosomal mutation 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

18 Which observation would rule out an X-linked trait in an extended family pedigree?

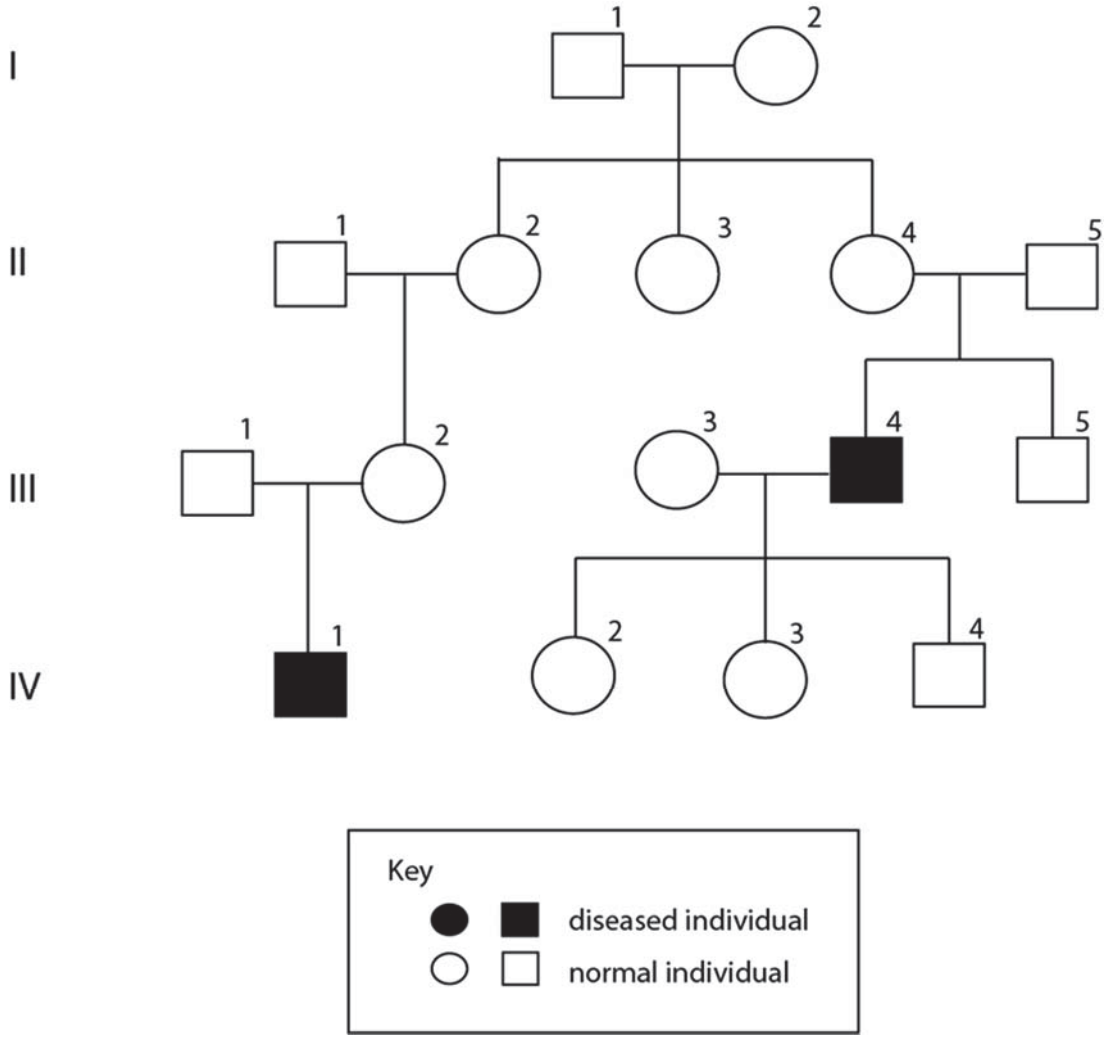
A females expressing the disease

B female-to-male transmission

C males expressing the disease

D male-to-male transmission

19 The pedigree shows the inheritance of a disease in a family for four generations.



What is the probability that individual IV-3 is a carrier of the disease?

A 0%

B 50%

C 75%

D 100%

20 A student measured the biomass that was produced by bacterium A and bacterium B in shake flasks containing glucose as substrate. For each type of bacterium, there were four replicate flasks.

The mean biomass that was produced by bacterium A and bacterium B is 487.5 mg and 257.5 mg respectively. The standard deviations of the biomass that was produced by bacterium A and bacterium B are 27.5 mg and 22.2 mg respectively.

The student then performed a t-test with the null hypothesis that there is no significant difference between the biomass that was produced by bacterium A and bacterium B.

The following formula was used to calculate the *t* statistic.

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

Keys to symbols:
s = standard deviation $\bar{x}$ = mean n = sample size
x = observation v = degree of freedom

Part of the *t* table is shown below.

***t* Table**

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587

Which conclusion is correct?

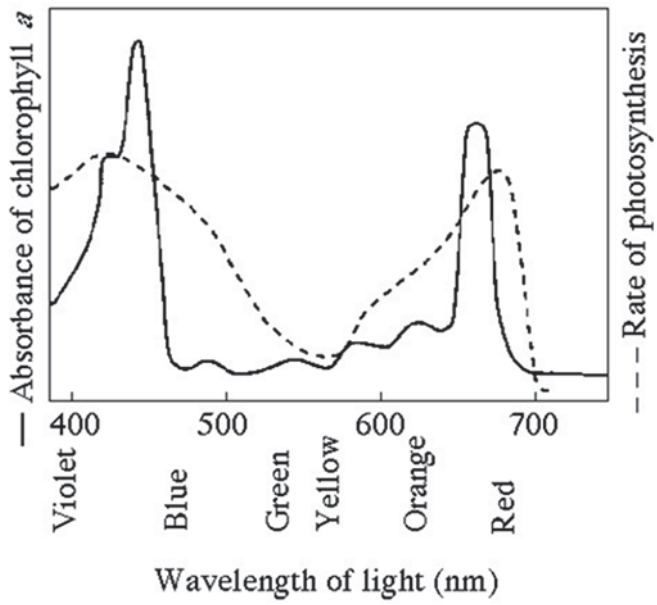
A $t_{\text{calculated}}$ is much higher than t_{critical} so it is not statistically significant. Hence, we accept the null hypothesis.

B $t_{\text{calculated}}$ is much higher than t_{critical} so it is statistically significant. Hence, we reject the null hypothesis.

C $t_{\text{calculated}}$ is much lower than t_{critical} so it is not statistically significant. Hence, we accept the null hypothesis.

D $t_{\text{calculated}}$ is much lower than t_{critical} so it is statistically significant. Hence, we reject the null hypothesis.

21 The graph shows the absorption spectrum for chlorophyll *a* and the photosynthetic action spectrum of a plant.



Why are they different?

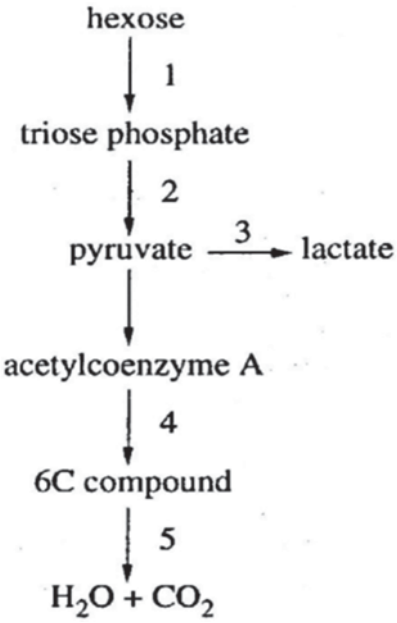
A Chlorophyll *a* absorbs different wavelengths of light to different extents.

B Chlorophyll *a* is not present in the plant.

C Chlorophyll *a* is not the only pigment in the plant that absorbs light.

D Chlorophyll *a* is the main pigment responsible for photosynthesis in the plant.

22 The diagram summarises the pathway of glucose breakdown.



Which two steps result in a net increase of ATP?

A 1 and 4

B 2 and 4

C 2 and 5

D 3 and 5

23 What is the main purpose of the second messengers in signal transduction pathways?

A allow for long distance signalling between cells

B amplify the signal by phosphorylating proteins

C relay a signal from the outside to the inside of the cell

D relay a signal from the plasma membrane to the cytoplasm

24 Why has evolution resulted in the appearance of antibiotic resistant bacteria?

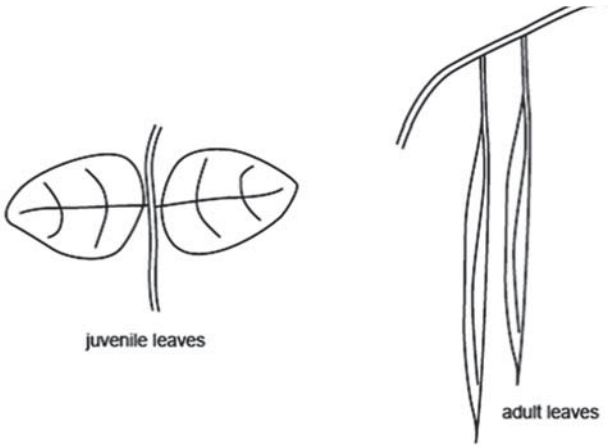
A Bacteria develop resistance due to the incomplete course of antibiotic.

B Bacteria learn the ability to neutralise the effect of antibiotic and they pass on this characteristic to their next generation.

C Bacteria modify their metabolism to cope with the presence of antibiotics.

D Bacteria that are resistant to the antibiotic survive and pass on this characteristic to their next generation.

25 Australian *Eucalyptus* trees characteristically have two types of leaves, a juvenile (young) form and an adult form. As shown in the diagram, the juvenile leaves are held horizontally and are relatively large and broad, while the adult leaves hang vertically and are long and narrow.



What is a selection pressure that is likely to have the greatest influence on the evolution of the juvenile leaf shape and position?

A competition for light

B consumption by herbivores

C high ambient temperatures

D nutrient availability

26 The various taxonomic levels of the hierarchical classification system differ from each other.

How are they different?

A inclusiveness of the different taxonomic levels

B morphological characters that are applicable to all organisms

C relative distribution of organisms throughout the environment

D relative genome sizes of the organisms

27 A park ranger was injected with antivenom immunoglobulins to treat a snake bite. The treating doctor explained that the injection would not protect him against future snake bites.

What type of immunity does the antivenom immunoglobulin confer?

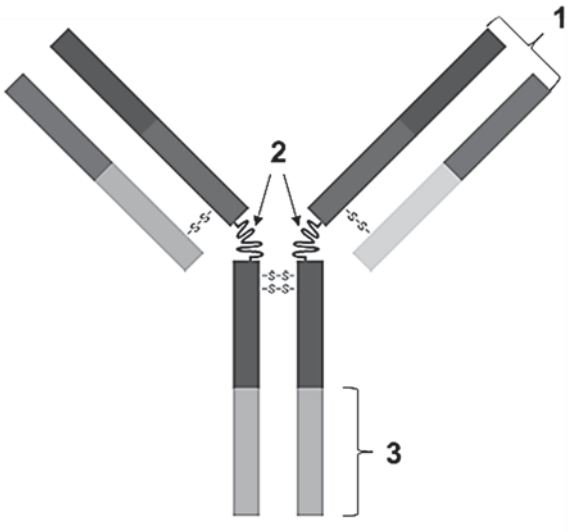
A active and artificial immunity

B active and natural immunity

C passive and artificial immunity

D passive and natural immunity

28 The diagram shows the structure of an antibody IgG.



Which statement about the structures labelled 1 to 3 is incorrect?

A Structure 1 differs in the different classes of antibodies produced by the same cell.

B Structure 1 is highly variable and specific to the epitope of the antigen that it binds to.

C Structure 2 allows flexible movement of the two arms of the antibody for binding to antigens.

D Structure 3 is important for interaction with effector cells and molecules.

29 Which statement about climate change is true?

A As average global temperature rises, average precipitation increases.

B Melting sea ice has a greater effect on global sea level rise than melting land ice.

C Shrinking sea ice in the Artic is fully offset by growing sea ice in the Antarctic.

D Water vapour, carbon dioxide, methane and nitrogen are greenhouse gases.

30 Levels of carbon dioxide in the atmosphere fall during summer in the northern hemisphere.

What best explains this trend?

A seasonal decrease in the use of fossil fuel and wood for heating

B seasonal increase in the amount of carbon dioxide dissolved in the oceans

C seasonal increase in the rate of decay of organic matter

D seasonal increase in the rate of photosynthesis in the northern hemisphere

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BIOLOGY 9744/02

Paper 2 Structured Questions

25 August 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Biology class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid

Answer **all** questions 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 the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/12**
2	**/12**
3	**/8**
Section B	
4	**/12**
5	**/12**
6	**/10**
7	**/10**
Section C	
8	**/13**
9	**/11**
Total	**/100**

This document consists of **26** printed pages.

Section A

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

1 Fig. 1.1 shows the process of collagen synthesis in a fibroblast cell.

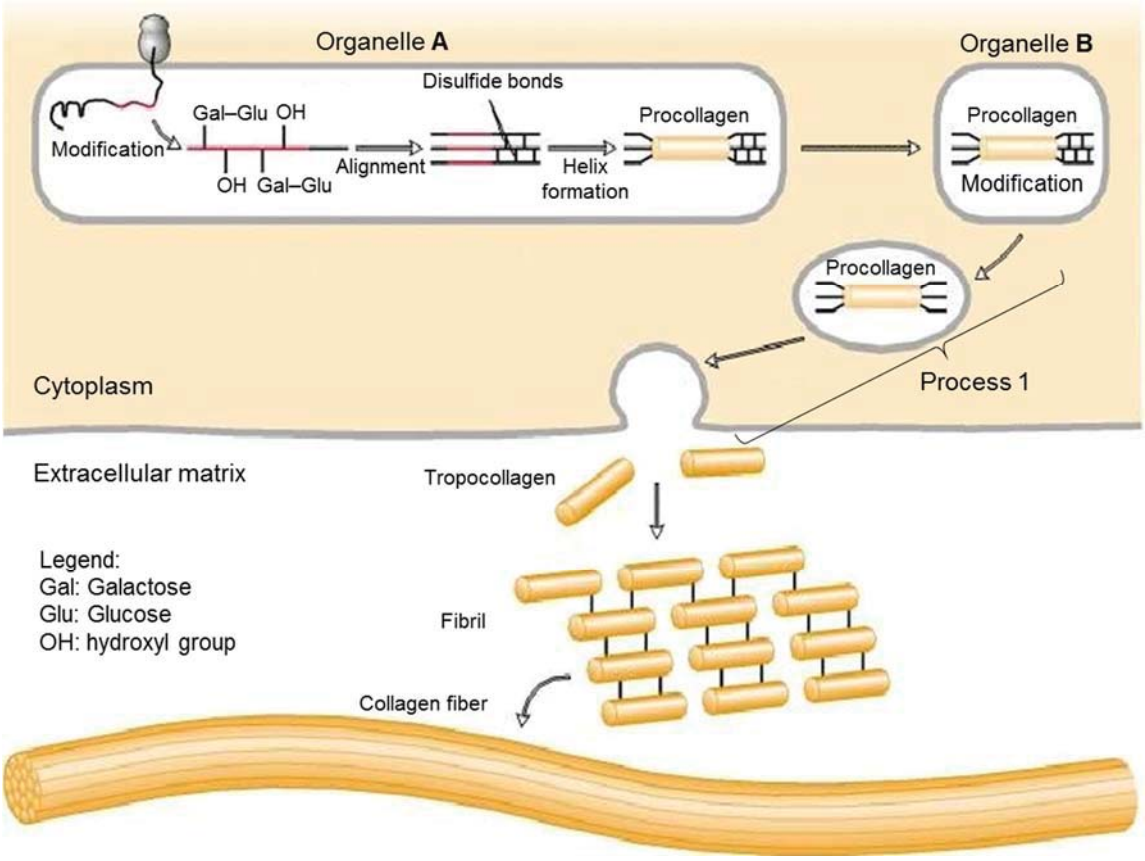

Fig. 1.1

(a) Identify organelles **A** and **B** in Fig. 1.1.

Organelle **A**: .....

Organelle **B**: ..... [1]

(b) Collagen has hydroxylproline and hydroxylysine, which are not present in many other proteins. Based on Fig. 1.1, deduce how these modified amino acids are incorporated into collagen.

.....

.....

.....

..... [2]

(c) Describe the bonds formed between the polypeptide chains of procollagen.

[2]

(d) Procollagen needs to be transported out of the cell via process 1.

(i) Describe process 1.

[3]

(ii) Suggest why it must be transported out of the cell via process 1 and cannot be transported across the membranes out of the cell directly.

[2]

(e) With reference to Fig. 1.1, suggest why tropocollagen is less soluble than procollagen.

[2]

[Total: 12]

2 Mutations can be inherited or acquired in a person's lifetime. Inherited mutations must be present in the parent's germ cells in order to be passed on to the child. On the other hand, acquired mutations arise due to environmental factors or errors in the cell cycle.

(a) Identify three specific phases in the cell cycle where different types of mutations are likely to happen.

[1]

(b) Explain how mutations occur in the phases identified in **(a)**.

[3]

(c) In some cases, a mutation in the coding sequence of a gene does not change the amino acid sequence of the protein.

Explain why such a mutation has no effect on the amino acid sequence of the protein.

[3]

(d) Distinguish between gene mutation and chromosome structural mutation.

[3]

(e) The accumulation of mutations may increase the chances of cancer. One of the causative factors of cancer is loss of immunity.

Explain the role of the immune system in preventing cancer.

[2]

[Total: 12]

3 Fig. 3.1 shows the development of B cells and the fate of a specific B cell after encountering an antigen.

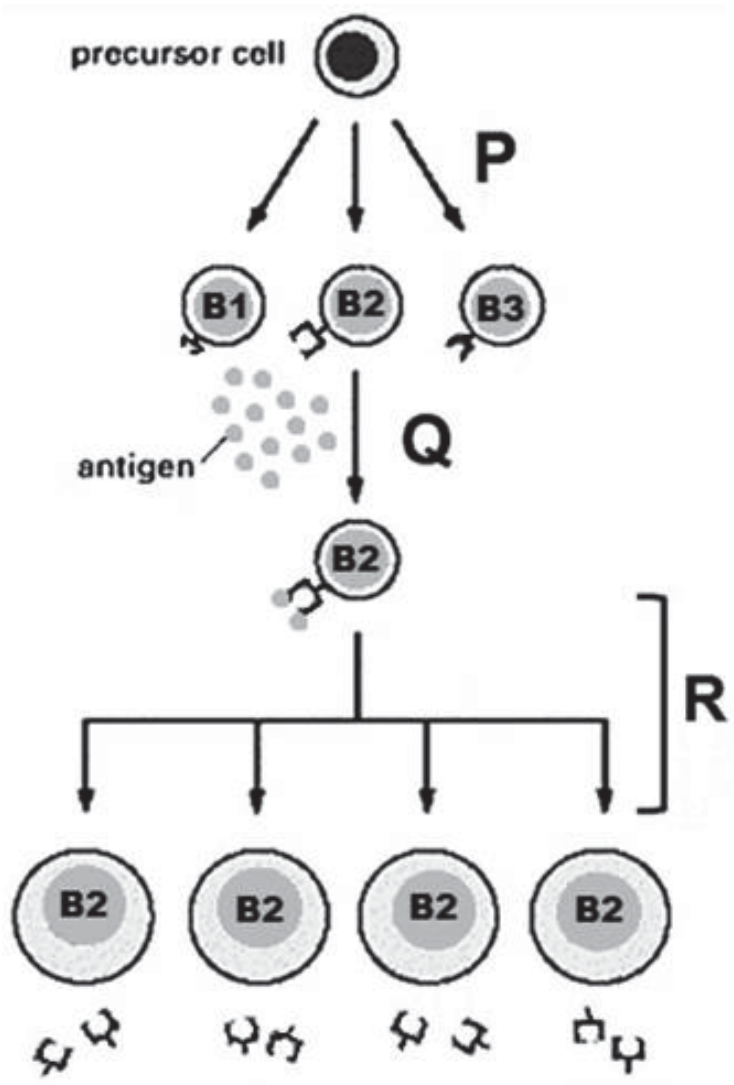

Fig. 3.1

(a) With reference to Fig. 3.1,

(i) describe the genetic mechanism that occurs during process **P**, and explain its biological significance,

.....

.....

.....

.....

.....

..... [3]

(ii) explain how process **Q** leads to process **R**.

[3]

(b) After eliminating the antigens, the plasma cells would undergo apoptosis. Only a small number of memory B cells would persist in the blood for a long period of time after the infection.

Memory B cells have similar properties to haematopoietic stem cells. Compare memory B cells and haematopoietic stem cells.

[2]

[Total: 8]

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Section B

For Examiner's Use	
Section B	
4	**/12**
5	**/12**
6	**/10**
7	**/10**

Section B

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

4 The rate of respiration in cells can be controlled by regulating the activity of various enzymes involved in respiration.

Phosphofructokinase (PFK), an important enzyme in glycolysis, can be regulated by adenosine triphosphate (ATP) and adenosine monophosphate (AMP). It catalyses the phosphorylation of fructose-6-phosphate (F-6-P) to fructose-1,6-bisphosphate.

Fig. 4.1 shows the T and R states of PFK under high and low concentrations of ATP respectively.

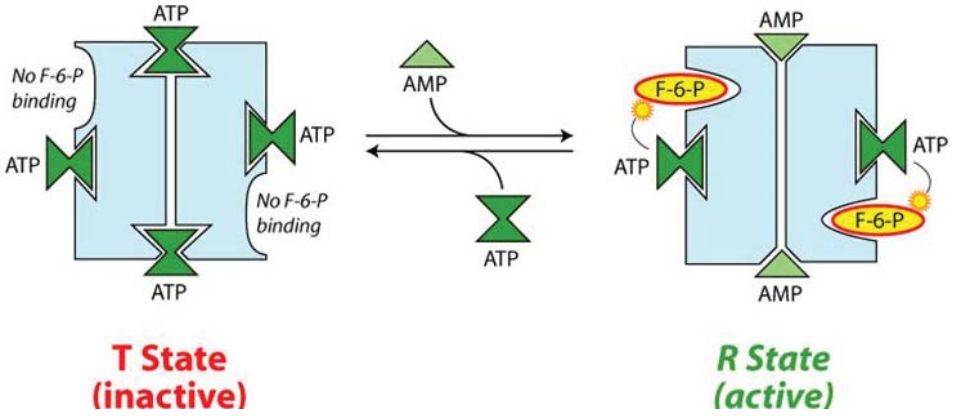

Fig. 4.1

(a) With reference to Fig. 4.1,

(i) describe two roles of ATP in the PFK-catalysed reaction,

[2]

(ii) explain the effect of AMP on the rate of glycolysis.

[4]

Fig. 4.2 shows the results of an experiment investigating the effect of temperature on a reaction catalysed by PFK. The same starting concentration of substrate and the same starting concentration of enzyme were used for each temperature tested. Reactions were kept at different temperatures for periods of one, two and five hours, after which the quantities of product formed were determined.

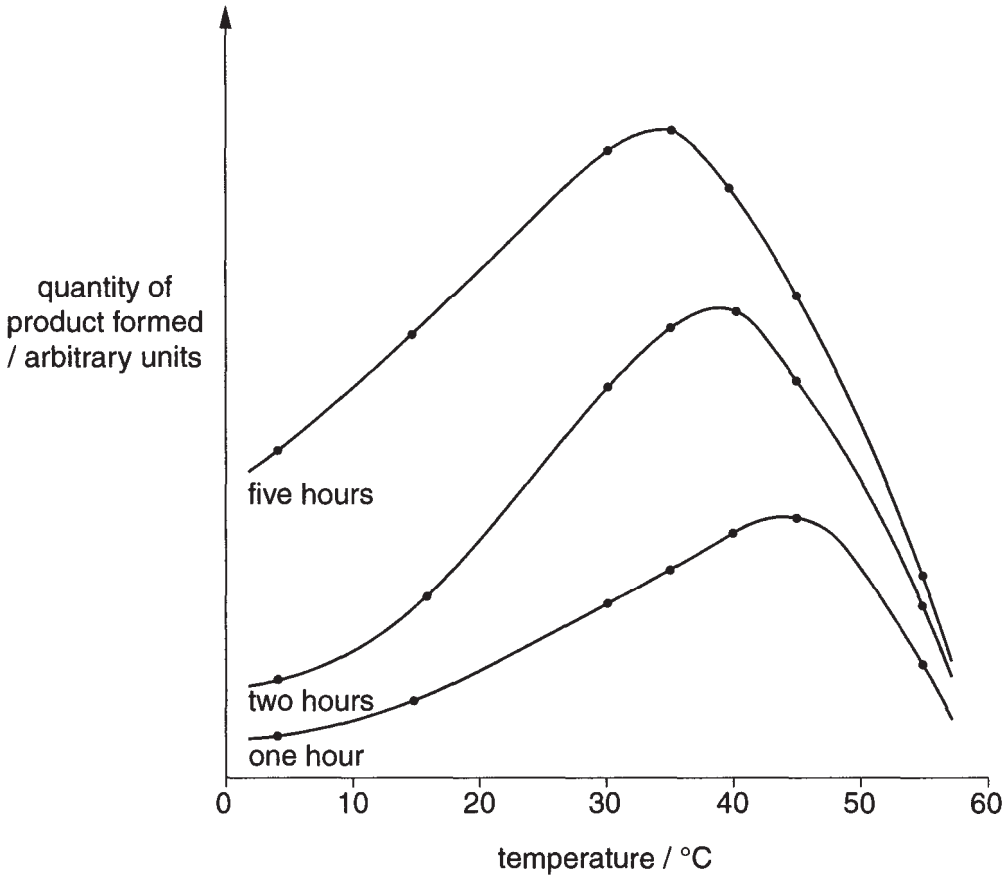

Fig. 4.2

(b) Explain the effect of increasing temperature on the quantity of product formed from the reactions kept at different temperatures for one hour.

[4]

(c) Explain the difference in the optimum temperature for the reactions after one, two and five hours.

[2]

[Total: 12]

5 In cats, coat colour is determined by the X-linked, codominant alleles: black (B) and orange (O). A calico female, which is the homogametic sex, is bred many times with a black male. They produced the following offspring:

black female 27

calico female 20

black male 31

orange male 18

(a) Explain the meaning of the terms:

(i) *X-linked*,

.....

..... [1]

(ii) *codominant*.

.....

..... [1]

(b) Draw a genetic diagram in the space below to show the expected phenotypic ratio of the offspring from the cross described.

[5]

(c) Carry out a chi-squared (χ^2) test to determine whether the observed data fits the expected phenotypic ratio of the offspring from the cross described.

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

v = degree of freedom, c = number of classes, O = observed value, E = expected value

Table 5.1 shows part of the table of probabilities for the chi-squared test.

Table 5.1

degrees of freedom	probability, p				
	0.10	*0.05*	*0.02*	*0.01*	*0.001*
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

Show your working clearly and state your conclusion in the space below.

Conclusion:

[5]

[Total: 12]

6 During photosynthesis, carbon dioxide reacts with ribulose bisphosphate (RuBP) to form two molecules of glycerate 3-phosphate (GP). This reaction is catalysed by the enzyme Rubisco.

Rubisco can also catalyse a reaction between RuBP and oxygen to form one molecule of GP and one molecule of phosphoglycolate. However, phosphoglycolate cannot be used in the light-independent reaction of photosynthesis.

Fig. 6.1 shows both the reactions catalysed by Rubisco.

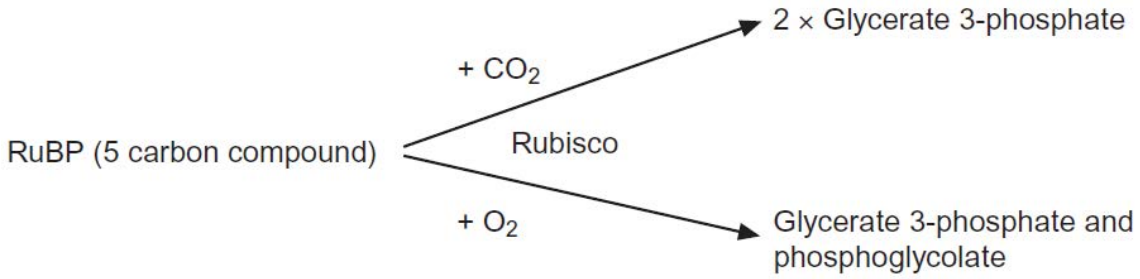

Fig. 6.1

(a) (i) State exactly in a cell where the enzyme Rubisco is found

.....

[1]

(ii) Use the information provided to give the number of carbon atoms in one molecule of phosphoglycolate.

.....

[1]

(b) A scientist investigated the effect of different concentrations of oxygen on the rate of absorption of carbon dioxide by leaves of soya bean plants. His results are shown in Fig. 6.2.

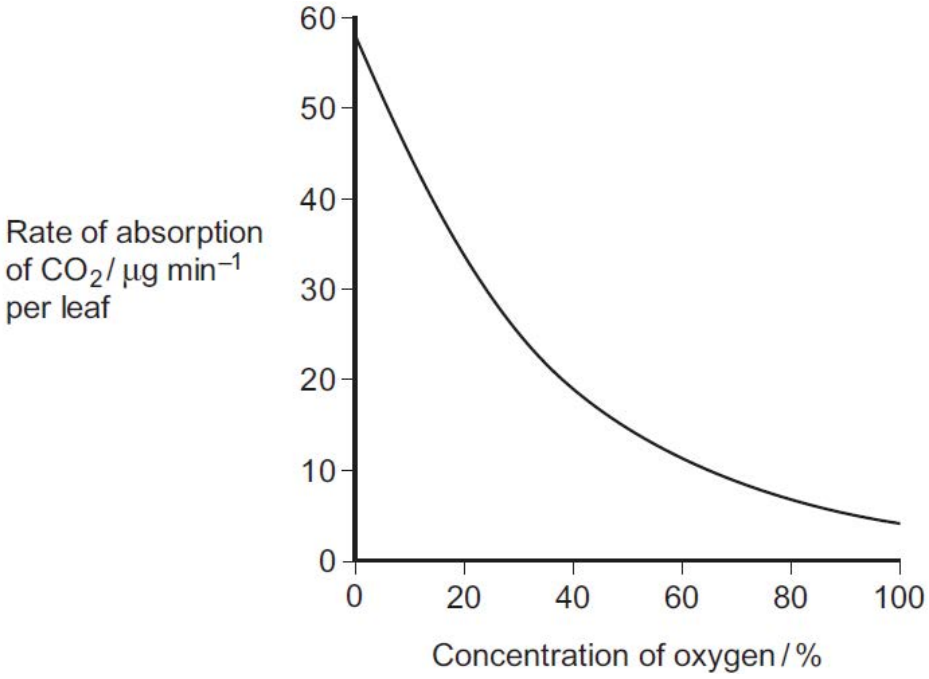

Fig. 6.2

(i) Use Fig. 6.1 to explain the results shown in Fig. 6.2.

[2]

(ii) Using the information provided and your knowledge of the light-independent reaction, explain why the glucose yield from soya bean plants is decreased at higher concentrations of oxygen.

[3]

(c) Another scientist investigated the uptake of radioactively labelled carbon dioxide in chloroplasts. She used three tubes, each containing different components of chloroplasts.

Table 6.1 shows the uptake of radioactively labelled carbon dioxide in each tube.

Table 6.1

Tube	Contents of tube	Uptake of radioactively labelled CO_2 / counts per minute
A	Stroma and grana	96 000
B	Stroma, ATP and reduced NADP	97 000
C	Stroma	4 000

(i) Explain why the result in tube **B** is similar to that in tube **A**.

.....

..... [1]

(ii) Use the information in Table 6.1 to predict the uptake of radioactively labelled carbon dioxide if tube **A** was placed in the dark. Explain your answer.

.....

.....

.....

..... [2]

[Total: 10]

7 A student investigated respiration in a population of yeast growing in a sealed container.

Fig. 7.1 shows the results of his investigation.

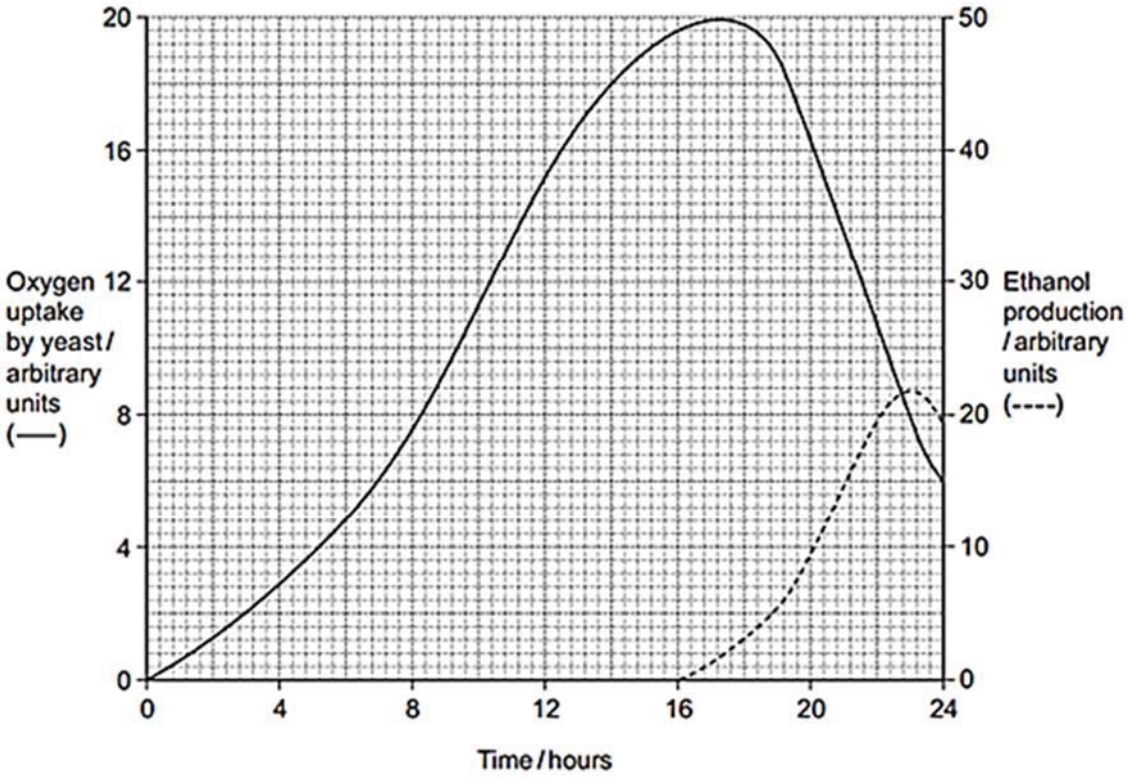

Fig. 7.1

(a) Calculate the rate of oxygen uptake in arbitrary units per hour between 2 and 4 hours.

[1]

(b) With reference to Fig. 7.1, explain the changes in oxygen uptake and ethanol production by yeast during this investigation.

[6]

(c) Sodium azide is a substance that inhibits the electron transport chain in respiration. The student repeated the investigation but added sodium azide after 4 hours.

Suggest and explain how the addition of sodium azide would affect oxygen uptake and ethanol production by yeast.

[3]

[Total: 10]

CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

Section C

For Examiner's Use	
Section C	
8	**/13**
9	**/11**

Section C

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

8 The endocrine system facilitates the communication between different cells through the release of hormones into the bloodstream. Binding of hormones to receptors on or within target cells initiates signal transduction, which may result in a change in gene expression.

(a) Fig. 8.1 shows the signalling pathway of glucocorticoid receptor (GR) mediated gene expression. GR is activated when it is bound to glucocorticoids (S), which is a of steroid hormone. Activated GR binds to glucocorticoid response elements (GREs) within the promoter of target genes. This results in the recruitment of the chromatin remodelling complex, BRG1 complex.

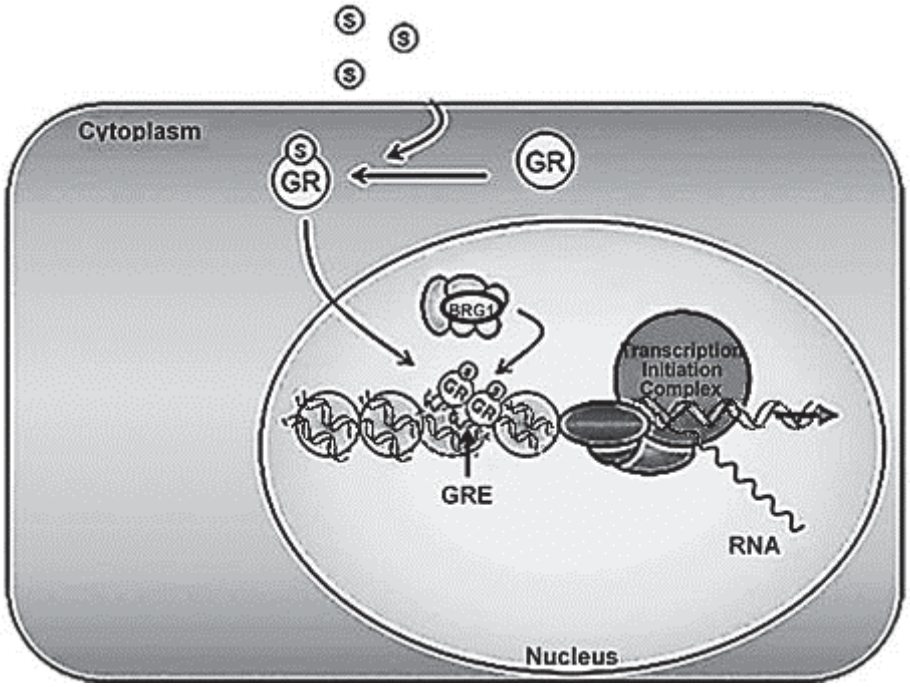

Fig. 8.1

(i) GRs are known to have highly conserved regions that are structurally important for its function.

With reference to Fig. 8.1, describe two structural features of GR that allows it to carry out its role.

[4]

Fig. 8.2 shows the effect of BRG1 complex binding to the promoter of a target gene.

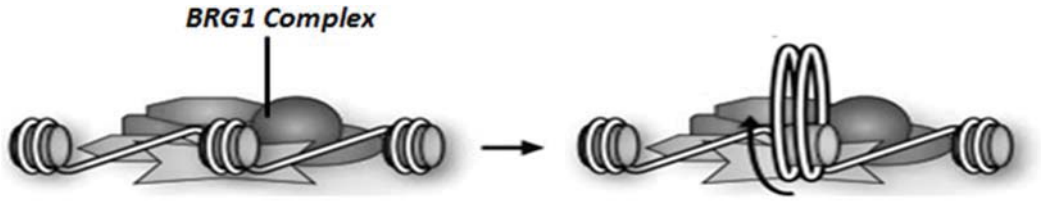

Fig. 8.2

(ii) With reference to Fig. 8.2, describe the effect of BRG1 complex binding to the promoter on gene expression.

.....

.....

.....

..... [2]

(iii) Briefly describe one other mechanism that may bring about a similar effect on gene expression as described in **(ii)**.

.....

..... [1]

(b) The signal transduction pathway in Fig. 8.3 is initiated by the binding of the growth factor (GF) to the receptor tyrosine kinase (RTK). This pathway controls the fundamental cellular processes such as growth, proliferation and differentiation.

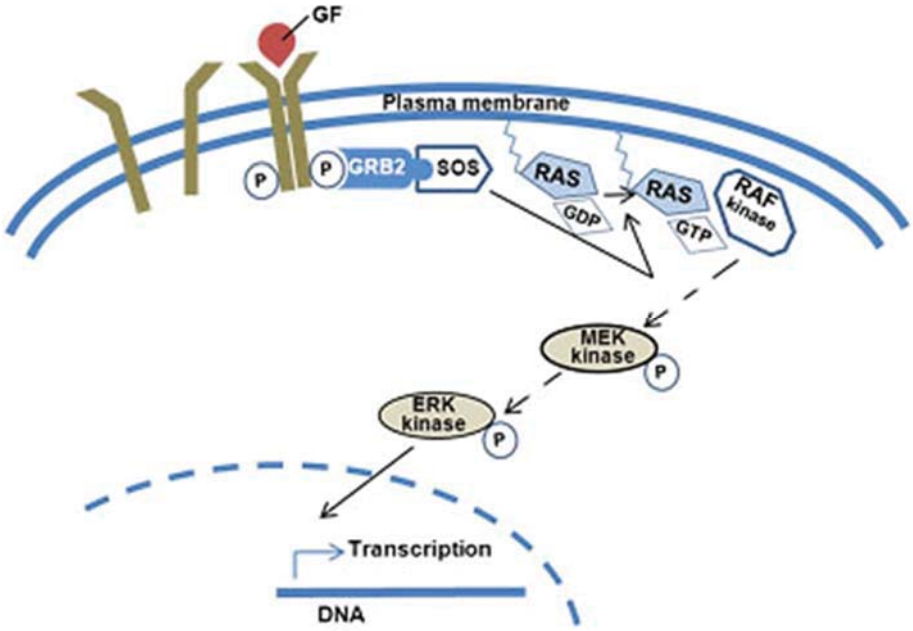

Fig. 8.3

With reference to Fig. 8.3,

(i) describe how RAS, a G protein, is activated by GF,

[4]

(ii) explain one significance of the series of events that occur after the activation of RAS.

[2]

[Total: 13]

9 Reef-building corals are marine invertebrates found in shallow, clear, tropical oceans. The corals secrete an exoskeleton of calcium carbonate that becomes the underlying structure of the coral reef ecosystem.

Zooxanthellae are a group of unicellular algae from the genus *Symbiodinium* that live within the cells of reef-building corals. The relationship has been described as mutualistic since it is beneficial to both the corals and the zooxanthellae.

(a) Evidence shows that the mutualistic relationship between reef-building corals and zooxanthellae has evolved from free-living algae invading corals that initially did not contain algae.

(i) Corals are usually found in shallow areas at depth of less than 40 metres. However, some coral reefs extend even deeper, up to about 130 metres.

Explain why this is possible for deep-sea corals.

[2]

(ii) Suggest the benefits to the zooxanthellae of their association with the corals.

[2]

(iii) During stressful conditions, coral bleaching may occur where zooxanthellae are expelled from coral. Coral bleaching can lead to death of the coral.

Suggest one reason why permanent loss of zooxanthellae can lead to death of the coral.

[1]

(b) The temperature range for healthy survival of reef-building coral is 25 °C – 29 °C. Increased sea temperature associated with global climate change is known to be an environmental stress that can cause coral bleaching.

(i) Suggest why the areas of sea containing coral reefs are susceptible to increased temperature resulting from global climate change.

[1]

(ii) Raw sewage released into the oceans may contain bacteria that cause disease in corals.

Suggest how global warming increases the rate of coral bleaching caused by bacterial disease.

[1]

(c) Recently, the International Union for Conservation of Nature (IUCN) has assessed over 47% of reef-building coral species as threatened, or near-threatened, with a global risk of extinction.

Explain how the loss of reef-building corals reduces biodiversity at different levels.

[4]

[Total: 11]

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

BIOLOGY 9744/03

Paper 3 Long Structured and Free-response Questions — 29 August 2017

Additional Materials: Answer Paper — 2 hours

READ THESE INSTRUCTIONS FIRST

Write your Biology class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid

Sections A and B
Answer **all** questions in the spaces provided on the question paper.

Section C
Answer any **one** question on the answer paper provided.

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 the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/25**
Section B	
2	**/25**
Section C	
3 / 4	**/25**
Total	**/75**

This document consists of **15** printed pages.

Section A

Answer the question in this section.

1 Fig. 1.1 shows two electron micrographs of cells **A** and **B**, both of which are not shown to scale.

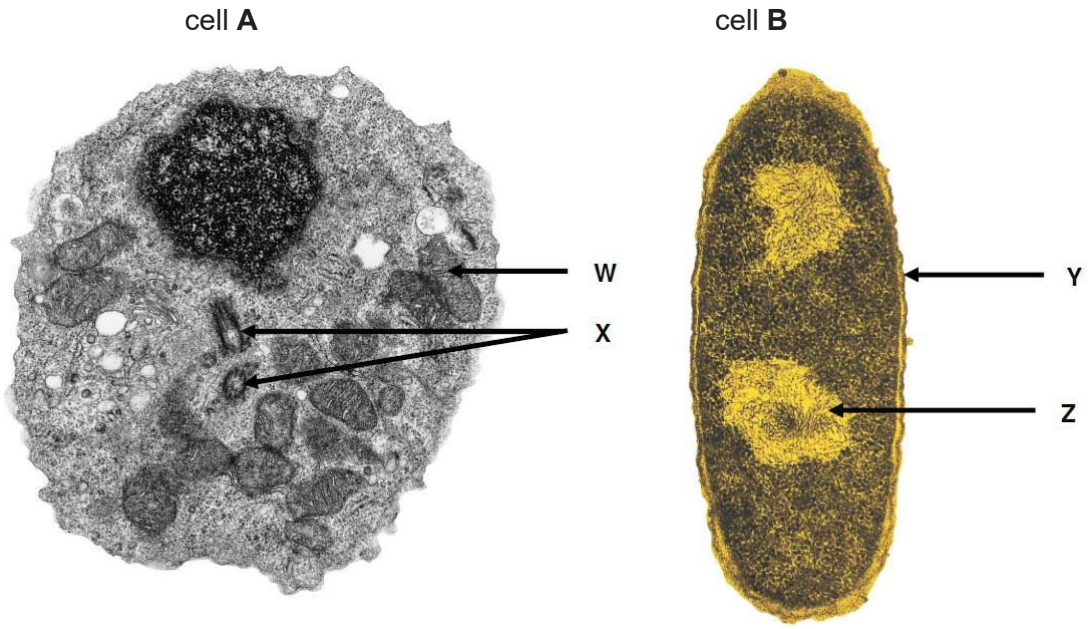

Fig. 1.1

(a) Name the structures labelled **W** to **Z** in Fig. 1.1.

W .....

X .....

Y .....

Z .....

[2]

(b) Some scientists support the theory that structure **W** in cell **A** originated from cell **B**.

(i) Give two pieces of evidence that support this theory.

[2]

(ii) Explain why it is advantageous for cell **A** to have many copies of structure **W**.

[2]

(c) Outline the process in which cell **B** divides into two cells.

[3]

(d) A scientist investigated the effect of a specific drug on two strains of the same species of cell **B**.

- One strain, SR, shows a **stringent response** in the presence of this drug. Part of the response involves stopping cell division. This gives this strain a greater resistance to the effect of this drug.

- The other strain, non-SR, cannot carry out a stringent response.

The scientist grew cultures of the SR strain and the non-SR strain containing the same number of cells. He then stopped each strain from dividing and exposed them to different concentrations of the drug. After a fixed time, he estimated the number of living cells remaining in the cultures.

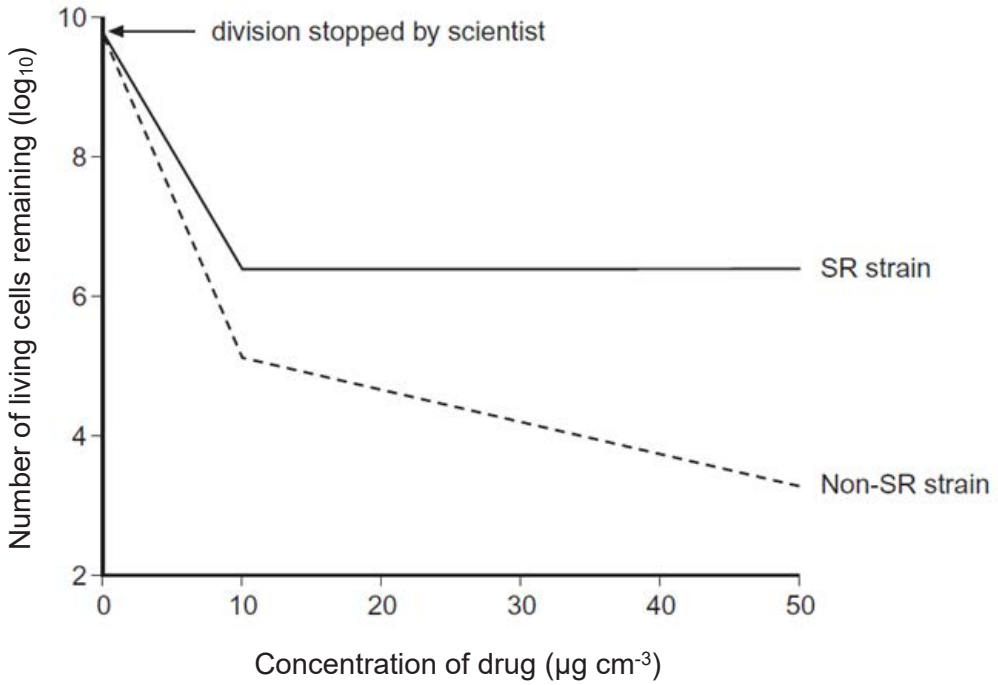

Fig. 1.2

(i) With reference to Fig. 1.2, describe the differences in the effect of increasing the concentration of drug on the SR strain and the non-SR strain.

.....

.....

.....

.....

.....

..... [3]

(ii) The scientist concluded that stopping cell division is not the only way in which the stringent response gives resistance to this drug.

Explain how Fig. 1.2 supports this conclusion.

.....

..... [1]

(e) Another scientist attempted to sequence the genome of cell **A**. Due to the sheer size of the genome, the chromosomes could not be sequenced directly. Each chromosome must first be digested by a restriction enzyme into smaller fragments. Each purified restriction fragment is then sequenced – a process that involves two procedures.

Fig. 1.3 shows the first procedure of the sequencing process, which is a modified Polymerase Chain Reaction (PCR). The DNA sample is divided into four separate sequencing reactions, each containing all four of the standard deoxynucleotides and the DNA polymerase. Only one of the four dideoxynucleotides (ddG, ddA, ddT, or ddC) is added to each reaction.

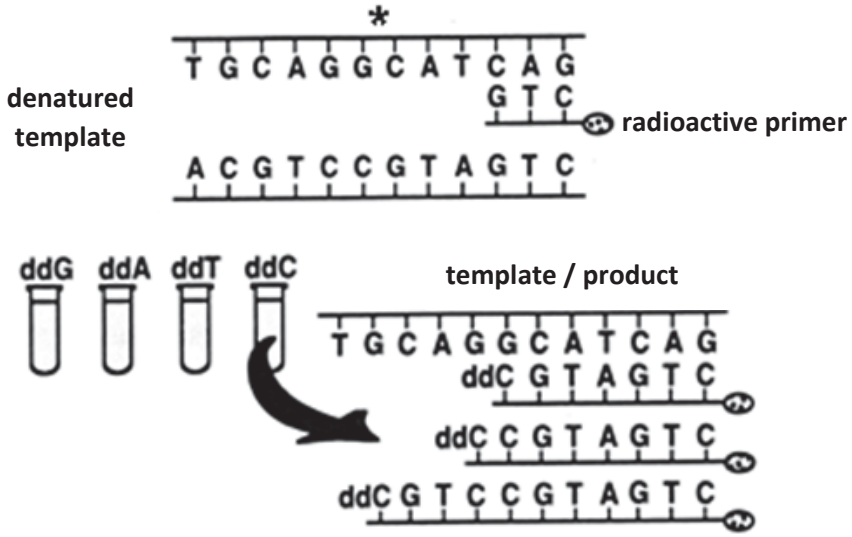

Fig. 1.3

Fig. 1.4 shows the structure of a dideoxyribonucleotide.

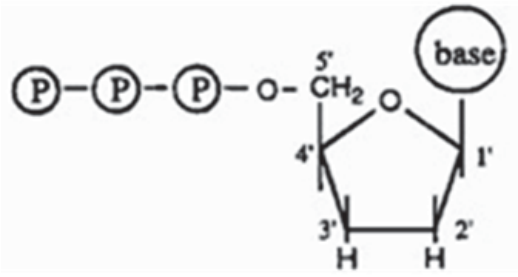

Fig. 1.4

The second procedure of the sequencing process produces a result shown in Fig. 1.5, from which the DNA sequence can be read.

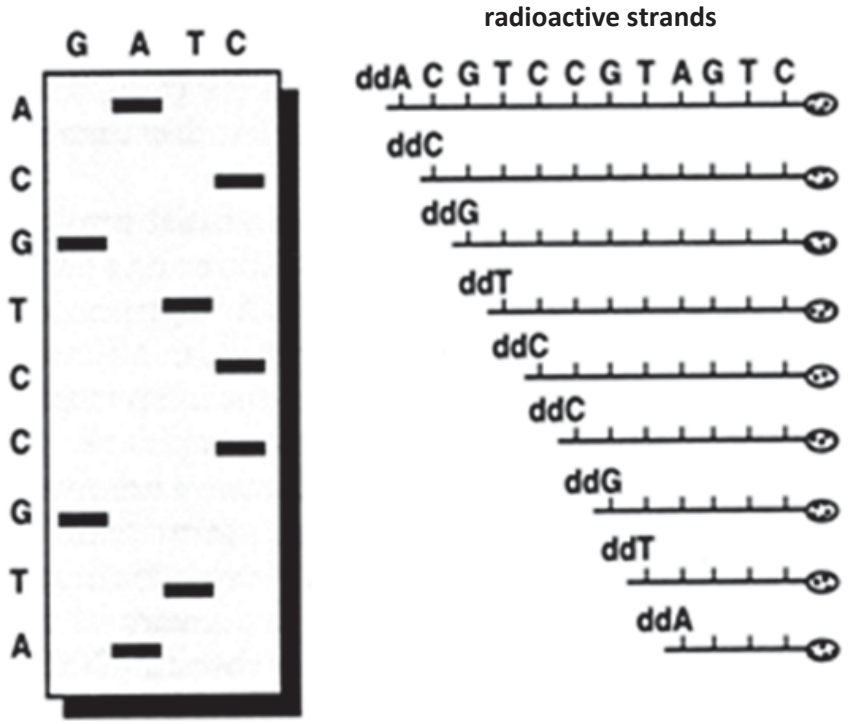

Fig. 1.5

(i) On Fig. 1.3, label the 5' and 3' ends of the DNA marked with an asterisk (*). [1]

(ii) Describe four features that distinguish the process in Fig. 1.3 from that of *in vivo* DNA replication.

[4]

(iii) With reference to Fig. 1.4, explain the need to use dideoxyribonucleotides in the sequencing process.

[2]

(iv) Describe the procedure that would give rise to the result shown in Fig. 1.5.

[5]

[Total: 25]

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CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

Section B

For Examiner's Use	
Section B	
2	/25

Section B

Answer the question in this section.

2 (a) First seen as poisons, then as life-forms, then biological chemicals, viruses today are thought of as being in a grey area between living and nonliving.

State three characteristics of life and for each, explain how dengue virus (DENV) challenges the concept of what is considered living.

[4]

(b) DENV infects its host cell through interaction with specific receptors. Human monocytes and mouse neural cells are main targets of DENV infection.

Fig. 2.1 shows the reproductive cycle of DENV, a single-stranded positive-sense RNA virus.

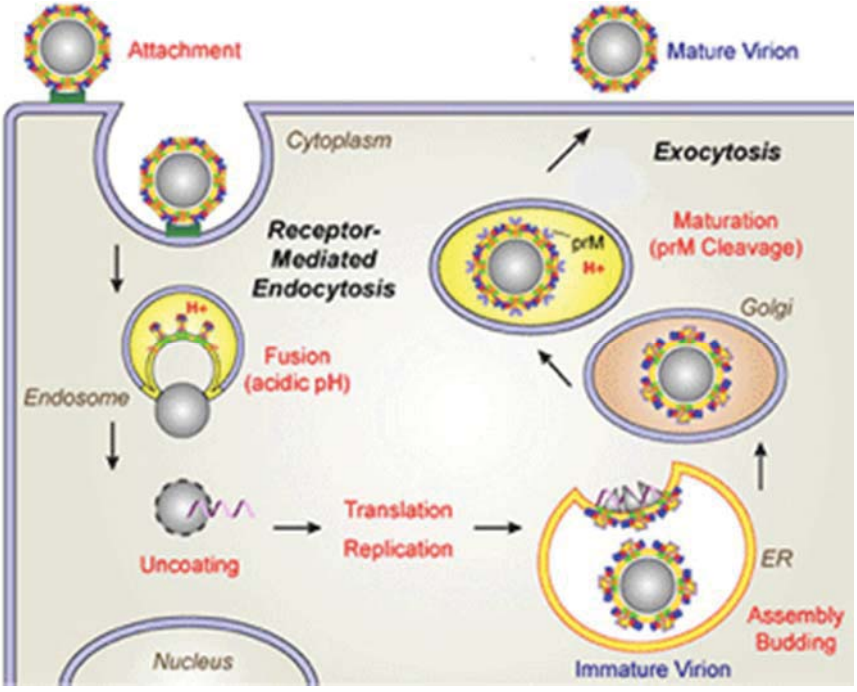


Fig. 2.1

With reference to Fig. 2.1, describe the differences between the reproductive cycles of DENV and human immunodeficiency virus (HIV).

[3]

(c) When a pathogen like DENV invades the human body, the main defence against such pathogen is the immune system.

Briefly explain one advantage and one disadvantage of the innate and adaptive immune responses against invading DENV.

[4]

(d) DENV is a member of the genus *Flavivirus*, which contains a number of important human pathogens, usually vector-borne. DENV is particularly notable in that it exists as four antigenically distinct serotypes (denoted as DENV-1 to DENV-4), within which there is considerable genetic variation in the guise of phylogenetically defined "genotypes".

Fig 2.2 shows a phylogenetic tree of DENV serotypes based on the analysis of non-structural-5 (*NS-5*) gene from DENV using molecular methods.

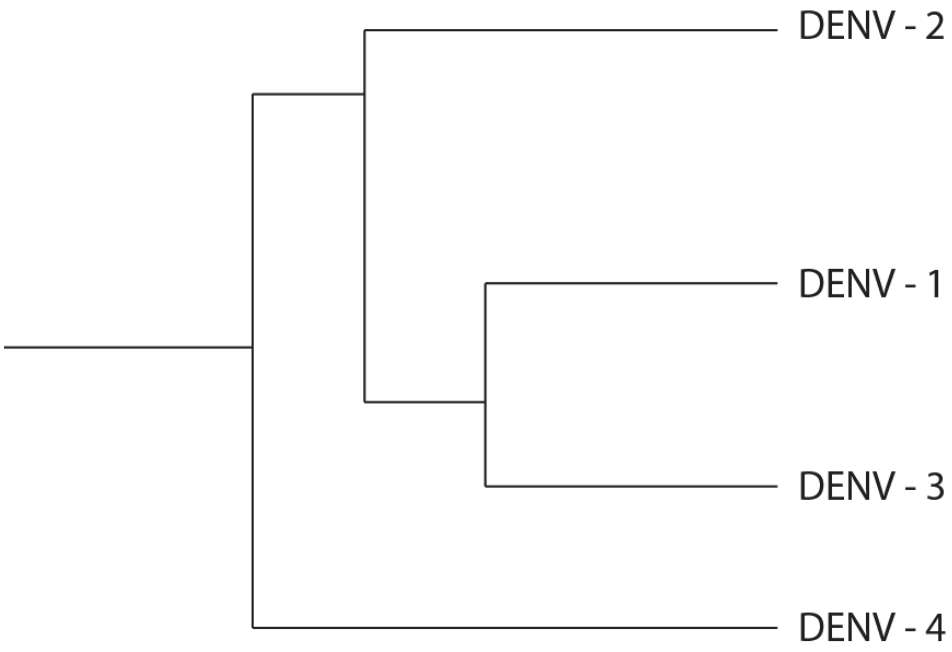


Fig. 2.2

(i) Explain the advantages of using molecular methods in classifying viruses.

[3]

(ii) Describe the phylogenetic tree of DENV serotypes shown in Fig. 2.2.

.....

.....

.....

.....

.....

..... [3]

(iii) A different research group published another version of phylogenetic tree of DENV serotypes.

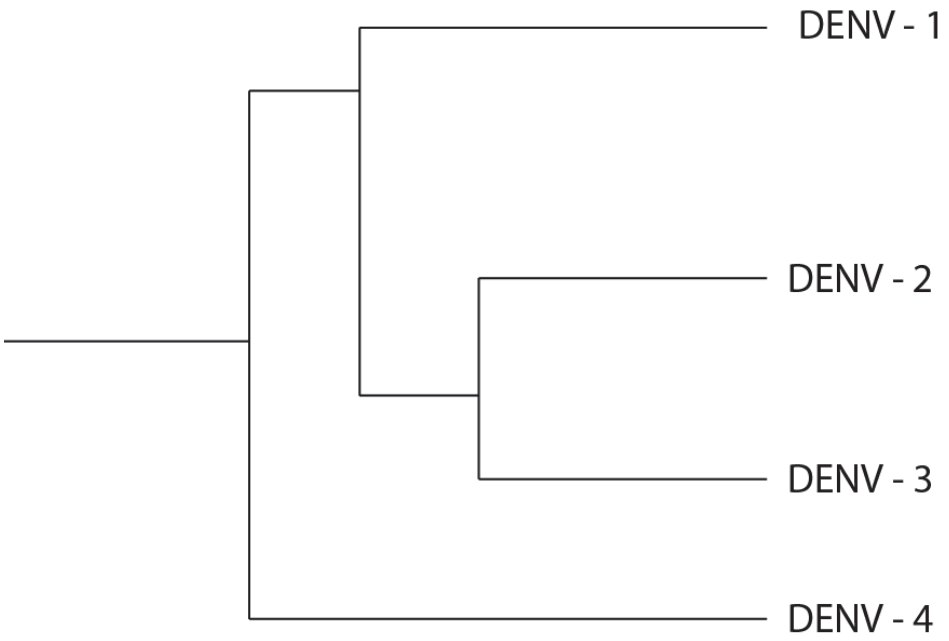


Fig. 2.3

Suggest one reason why the phylogenetic tree in Fig. 2.3 is different from that in Fig. 2.2.

.....

..... [1]

(iv) One question on the origin of DENV is why it exists as four distinct serotypes. This can be explained in two ways:

- through geographical partitioning in different primate populations
- evolution in sympatry (within a single population)

Using your knowledge in evolution, explain how DENV has evolved into four distinct serotypes through geographical partitioning.

[4]

(v) Suggest how evolution into the four DENV serotypes can take place through sympatry.

[1]

(vi) Suggest and explain one possible selection pressure for the evolution into the four DENV serotypes.

[2]

[Total: 25]

Section C

Answer **one** question in this section.

Write your answers on the separate answer paper provided.

Your answers 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 section (a), (b) etc., as indicated in the question.

3 **(a)** With reference to named examples, explain how the gene expression in prokaryotes can be regulated using inducible and repressible systems. [13]

(b) Explain the advantages of regulating gene expression at different levels in eukaryotes and suggest why prokaryotes have fewer levels of gene regulation. [12]

[Total: 25]

4 **(a)** Explain the need for a large amount of non-coding sequences in eukaryotes. [13]

(b) Explain the normal functions of embryonic stem cells (ESCs), distinguish between ESCs and induced pluripotent stem cells (iPSCs), and compare the pros and cons of their use in research and medical applications. [12]

[Total: 25]

H

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Practical Examination
Higher 2

CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

Biology 9744/04

Paper 4 Practical

15 August 2017

2 hours 30 minutes

READ THESE INSTRUCTIONS FIRST

Write your name and Biology class on all the work you hand in.
Circle your practical shift and laboratory in the boxes.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions 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 workings 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 the brackets [ ] at the end of each question or part of question.

Shift		
1	2	3
Laboratory		
BI23	BI24	CM44

For Examiner's Use	
1	/21
2	/20
3	/14
Total	/55

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

1 In this question, you will investigate the effect of the colour of light on the rate of photosynthesis.

The light-dependent reaction of photosynthesis can be examined by the reduction of an artificial electron acceptor, 2,6-dichlorophenolindophenol (DCPIP). DCPIP is blue when oxidised, and turns colourless when reduced.

oxidised DCPIP (blue) → reduced DCPIP (colourless)

In this experiment, chloroplast suspension will be mixed with oxidised DCPIP solution, which will give a blue-green solution.

chloroplast + oxidised DCPIP (blue-green) → chloroplast + reduced DCPIP (green)

You are provided with:

- chilled chloroplast suspension in a brown vial with lid
- oxidised DCPIP solution
- 5 cm^2 cellophane papers of two different colours (red and green)
- access to spectrophotometer (wavelength set at 620 nm)

*Read through steps **1** to **11** and prepare a table to record your results in **(a)**, before starting the investigation.*

Proceed as follows:

1 Wrap the bottom part of a test tube with a red cellophane paper and secure it with a rubber band near the top edge of the cellophane paper.

2 Repeat step **1** with a green cellophane paper.

3 Prepare a chloroplast-DCPIP mixture by adding 2 cm^3 of DCPIP solution to 18 cm^3 of chloroplast suspension in a 50 ml beaker. Gently swirl the beaker to ensure homogeneity. The mixture should appear blue-green. If the mixture appears light green, add another 1 cm^3 of DCPIP solution.

4 Wrap the 50 ml beaker containing the chloroplast-DCPIP mixture with aluminium foil to prevent exposure to light.

5 Add 3 cm^3 of chloroplast-DCPIP mixture into each of the two test tubes prepared in steps **1** and **2**, and another test tube not wrapped with coloured cellophane paper.

6 Place all three test tubes at a distance of 10 cm from the lamp and switch on the lamp for five minutes.

7 After five minutes, decant the solution in each test tube to a plastic cuvette.

8 Blank a spectrophotometer with about 3 cm^3 of chloroplast suspension (without DCPIP) at 620 nm, and then measure the absorbance of the solution in each cuvette.

9 Repeat steps **5** to **8** with clean test tubes to obtain a second set of readings.

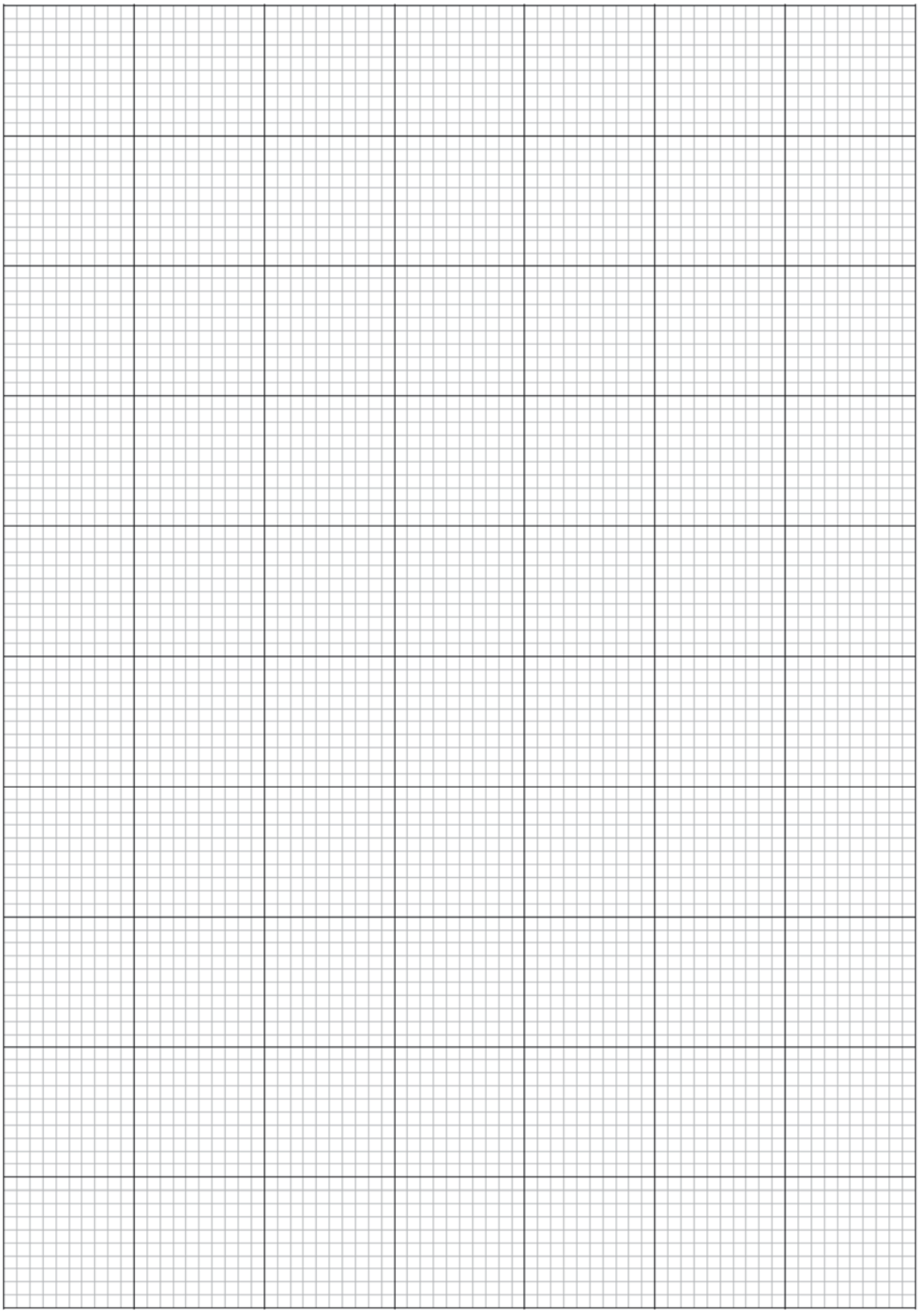
10 Prepare a boiling water bath. Add 18 cm^3 of chloroplast suspension to a boiling tube and boil it for about three minutes. Allow the chloroplast suspension to cool to room temperature.

11 Repeat steps **3** to **9** with the boiled chloroplast suspension.

(a) Record your results in a suitable form in the space below.

[5]

(b) Use the grid below to display your results from **(a)**.



[4]

(c) Describe the purpose of having a test tube not wrapped with coloured cellophane paper in the given procedure.

[1]

(d) Discuss the need for step 11.

[3]

(e) Discuss what your results from **(a)** suggest about the effect of the colour of light on the rate of photosynthesis.

[2]

(f) **(i)** Identify one significant source of error in the given procedure.

[1]

(ii) Suggest one modification to the given procedure to reduce the errors identified in **(f) (i)**.

[1]

(g) One student did a similar experiment with eight replicates to determine the effect of red light and blue light on the rate of photosynthesis.

Table 1.1 shows the results obtained by the student.

Table 1.1

absorbance of the solution at 620 nm / Abs	
red light	blue light
0.047	0.040
0.055	0.044
0.049	0.032
0.045	0.045
0.050	0.039
0.044	0.042
0.060	0.050
0.052	0.036

Carry out a t-test to determine if red light and blue light have the same effect on the rate of photosynthesis at 5% level of significance, assuming a normal distribution and equal variance.

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

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

Keys to symbols:
s = standard deviation $\bar{x}$ = mean n = sample size
x = observation v = degree of freedom

(Please refer to the t-table given to you separately.)

You may continue your workings in the space on the next page.

[4]

[Total: 21]

2 In this question, you will investigate the water potential of potato tissue and onion epidermis.

You are provided with known concentrations of sucrose and distilled water as shown in Table 2.1.

Table 2.1

solution	concentration of sucrose solution / mol dm^{-3}
W	0.0
S1	0.3
S2	0.6
S3	1.0

You are also provided with:

- potato cylinders
- methylene blue solution
- onion scale leaf incubated in solution **S3**

*Read through steps **1** to **9** and prepare a table to record your results in **(a)**, before starting the investigation.*

Proceed as follows:

1 Add 6 cm^3 of distilled water into a test tube and label it "**W**". Place another 3 cm^3 of distilled water into a vial and label it "**W-blue**". Add one drop of methylene blue into the vial **W-blue** and mix well. This would colour the distilled water blue without significant alteration of the water potential.

2 Repeat step 1 to dispense sucrose solution **S1**, **S2** and **S3** into appropriately labelled test tubes and vials.

3 Using a scalpel, ensure that any potato skin present is trimmed off. Cut the potato cylinders into 5 mm thick discs

4 Place 10 potato discs into the test tube **W** and leave it to incubate for 25 minutes. Ensure that the discs are completely soaked in the solution. During this time, you may proceed on to part **(f)** or other parts of the Question Paper.

5 After 25 minutes, decant the liquid in test tube **W** into a suitably labelled clean test tubes.

6 With a Pasteur pipette, collect a small amount of the coloured solution in the vial **W-blue**.

7 Very gently, by squeezing on the Pasteur pipette, introduce one drop of the coloured liquid into the centre of the decanted liquid from **W** as shown in Fig. 2.1. Be careful not to disperse the coloured liquid with any sudden squeezing of the Pasteur pipette. Withdraw the pipette slowly.

Fig. 2.1

8 Observe whether the drop of coloured liquid remains in the same position, floats or sinks, and how fast it occurred. Release another drop of coloured liquid and continue until you are certain you have made the correct observation about the behaviour of the drop of coloured liquid.

9 Using clean pipettes, vials and test tubes, repeat steps 4 to 8 with solution **S1**, **S2**, and **S3** in turn. In a similar manner, introduce one drop of coloured liquid from **S1-blue**, **S2-blue**, and **S3-blue** into the decanted liquids of **S1**, **S2**, and **S3** respectively, after incubating the potato discs for 25 minutes.

(a) . Record your observations in the space below.

[4]

(b) If the coloured drop sinks, it implies that the coloured drop is denser than the decanted liquid. Suggest why the decanted liquid becomes less dense after the incubation with potato discs.

---

[2]

(c) Explain the behaviour of the coloured drop in the liquid decanted from tube S1 in terms of movement of water molecules and water potential of the potato tissue.

[4]

(d) A student wanted a more accurate estimation of the range of sucrose concentration of the potato tissue.

Describe two modifications to the method that can increase the accuracy of the estimated range of sucrose concentration found in the potato cells.

[2]

(e) Another student conducted a similar experiment to investigate the effect of placing pieces of potato tissue in varying concentrations of sucrose solution by measuring the change in mass of the potato tissue after incubation.

At the start, each potato tissue was weighed to obtain the initial mass. Each sample of potato tissue was then incubated in a different concentration of sucrose solution for a set time. After the incubation time, the potato tissue was removed and the final mass of the potato tissue was recorded.

The results of his investigation were tabulated and a graph was drawn as shown in Fig. 2.2.

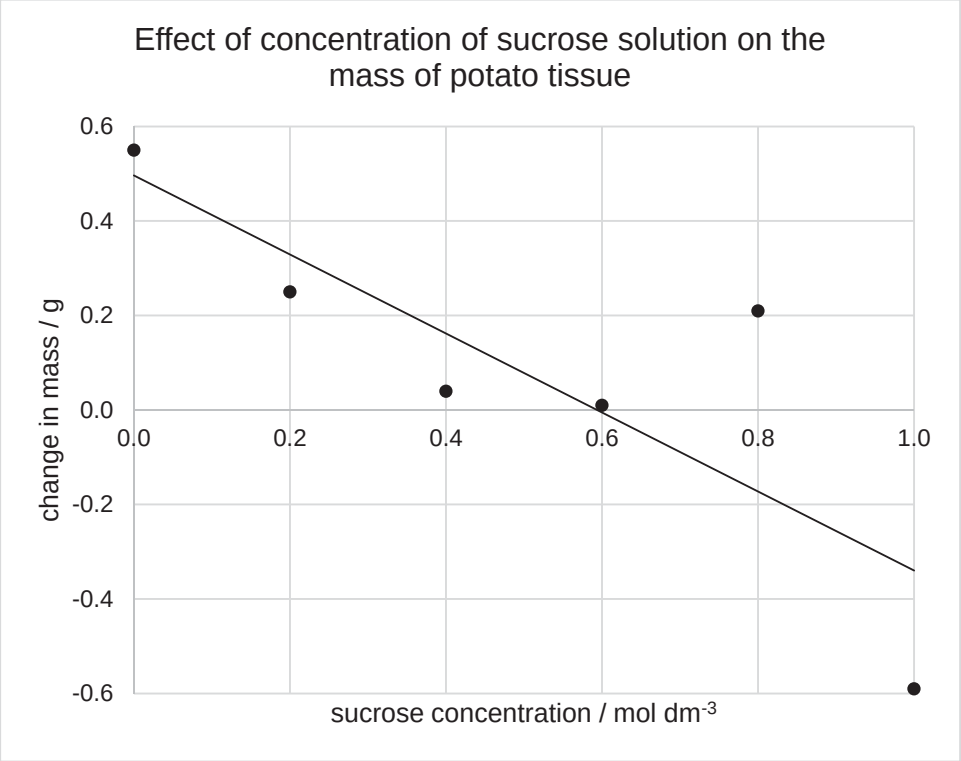


Fig. 2.2

(i) Circle the data point that is likely to be an anomaly. [1]

(ii) Based on your understanding of water potential, state and explain why this data point was chosen to be an anomaly.

.....

.....

.....

..... [2]

(f) You are required to observe the effects of treating onion epidermal cells with sucrose solution. You are provided with a scale leaf from the bulb of a red onion that has been incubated in solution **S3**.

10 Make a shallow cut on the outer surface of the scale leaf. Using a pair of forceps, peel off a thin sheet of epidermis.

11 Place the epidermal peel on a microscope slide with a drop of solution **S3** that was used to keep the onion leaf moist in the petri dish. Using forceps and mounting needle, spread out the epidermis flatly without tearing the peel. Cover with a cover slip.

12 Observe the onion epidermal cells under an appropriate objective lens of the microscope.

In the space below, make an accurate and labelled drawing of three adjacent pigmented cells that are clearly visible in the field of view. Calculate the magnification of your drawings.

[5]

[Total: 20]

3 Human activities over the past centuries have led to increased emission of carbon dioxide, resulting in rising atmospheric carbon dioxide concentration. Since carbon dioxide is the raw material for photosynthesis in green plants, it is important to understand how elevated carbon dioxide concentration would affect the rate of photosynthesis.

There are three types of photosynthetic mechanisms in green plants: C3, C4, and CAM. Most agricultural crop plants either use the C3 or C4 mechanism.

The C3 pathway involves the use and subsequent regeneration of ribulose 1,5-biophosphate (RuBP) in a cyclic series of reactions called the Calvin cycle. The first product of photo-assimilation of carbon dioxide is 3-phosphoglycerate, a three-carbon sugar, hence the term C3 pathway of photosynthesis.

The C4 plants begin their carbon dioxide uptake in mesophyll cells of leaves, forming a four-carbon molecule, oxaloacetate. This four-carbon molecule is changed into aspartic acid or malic acid, which is then transported immediately to bundle sheath cells. Here, the carbon dioxide is released and utilised in the C3 biochemical pathway. Thus, the C4 plant mechanism first traps carbon dioxide in the mesophyll cells, and then transports and concentrates the carbon dioxide in the bundle sheath cells, where it is utilised in the C3 pathway. Since C4 plants have a mechanism for concentrating carbon dioxide in the bundle sheath cells of leaves, it is hypothesised that their photosynthetic rates will not respond to rising carbon dioxide concentration to the same extent as C3 plants.

Using this information and your own knowledge, design an experiment to determine the effect of different concentrations of carbon dioxide on the rate of photosynthesis of C3 and C4 plants.

Comparison of the results would then allow the testing of the hypothesis that elevated carbon dioxide concentration has a greater effect on C3 plants than on C4 plants.

You must use:

- fresh green leaves from C3 and C4 plants
- plastic straw (for cutting out leaf discs)
- 0.1% sodium hydrogen carbonate solution (you need to remove the gas from the air spaces in the leaf discs so that they will sink in sodium hydrogen carbonate solution)

You may select from the following apparatus and use appropriate additional apparatus:

- normal laboratory glassware, e.g. test-tubes, boiling tubes, beakers, measuring cylinders, syringes, glass rods, white tile, etc.
- bench lamp
- stopwatch

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 diagram(s), if necessary, to show, for example, the arrangement of the apparatus used
- 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 repeatable as possible
- include layout of results tables and graphs with clear headings and labels
- use the correct technical and scientific terms
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 14]

H

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME			
BIOLOGY CLASS	2bi2 __ / 2IPbi2 __	REGISTRATION NUMBER	

BIOLOGY 9744/01

Paper 1 Multiple Choice

13 September 2017

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Biology class and registration number above and on the Answer Sheet provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

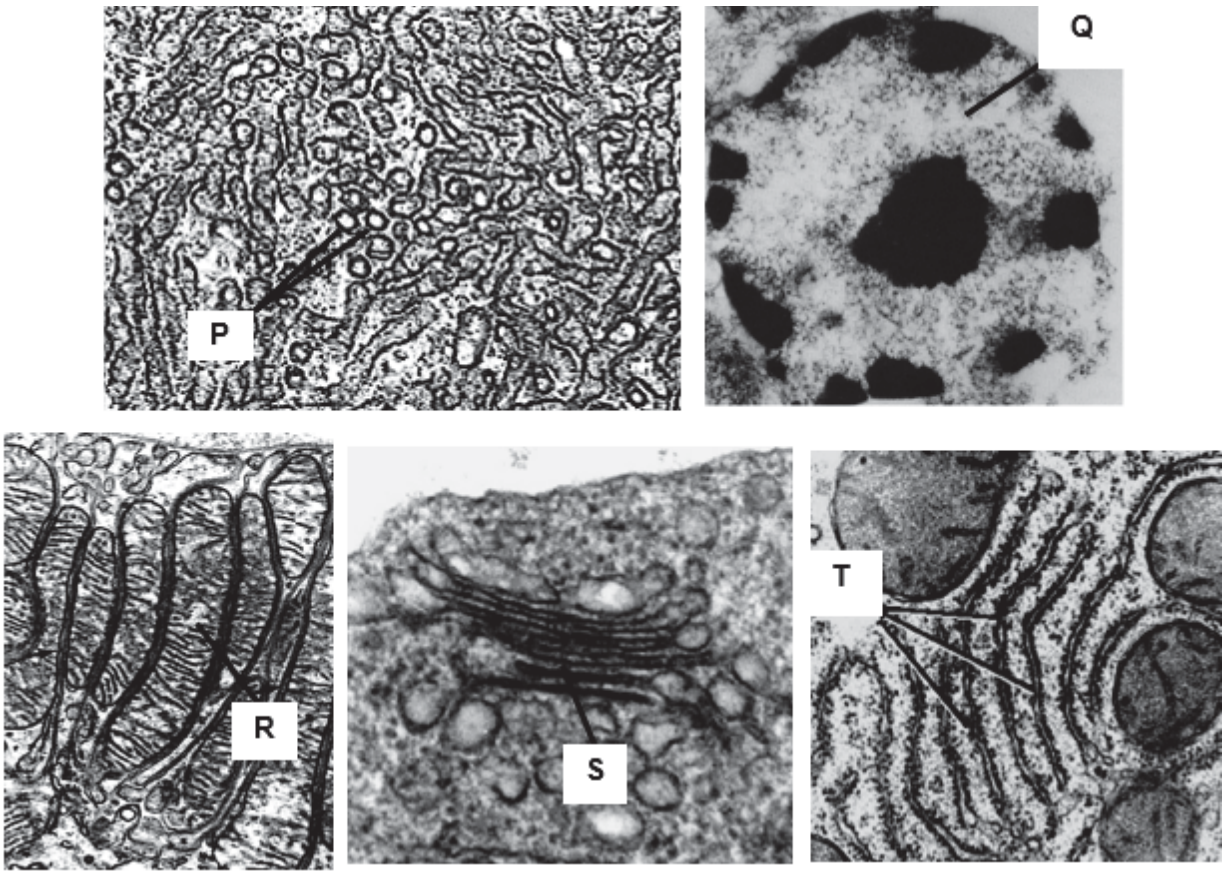
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **16** printed pages.

[Turn over

1 The electron micrographs show various organelles labelled P to T in a liver cell.



Radioactive amino acids are supplied to the liver cell to synthesise insulin receptors.

Which sequence shows the correct order in which these amino acids would be detected in the organelles during the synthesis of insulin receptors?

A Q → T → P → S

B Q → T → R → P → S

C T → P → S → R

D T → S → P

2 Which statements about the cell theory are correct?

1 All cells contain nucleus.

2 All cells divide from pre-existing cells.

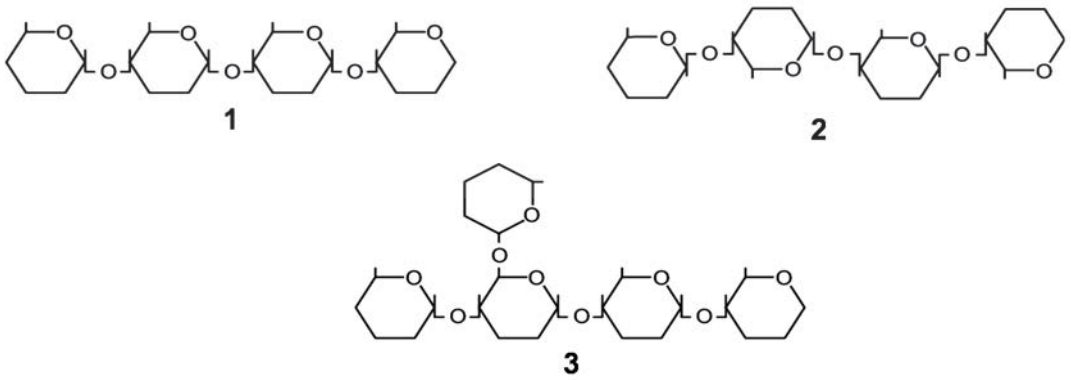
3 All cells divide to form new daughter cells.

4 Cells are the smallest unit of life.

5 Living organisms are composed of cells.

A 1, 2 and 3
B 1, 2 and 4
C 2, 4 and 5
D 3, 4 and 5

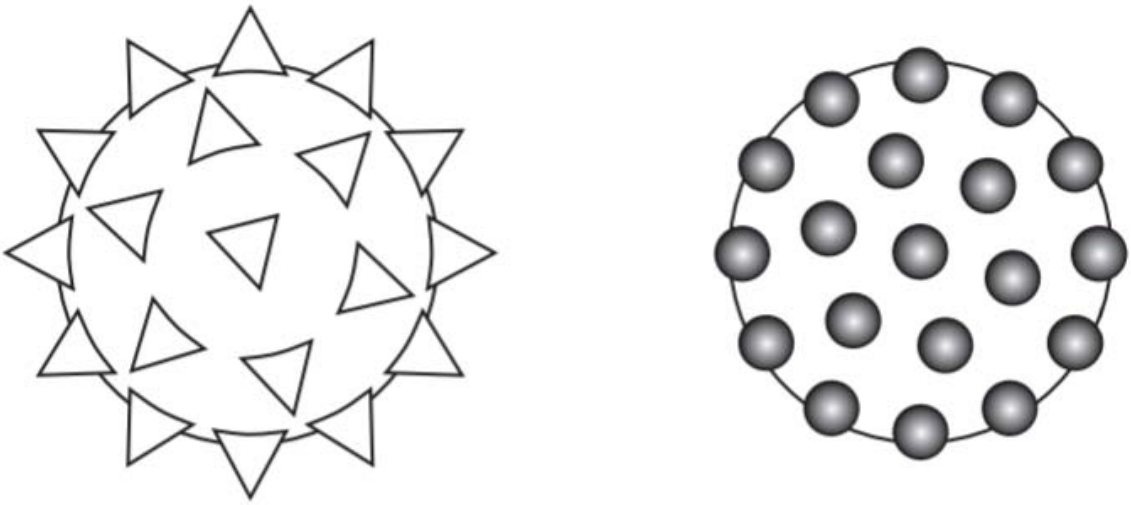
3 The diagram shows the structural formulae of three polysaccharides.



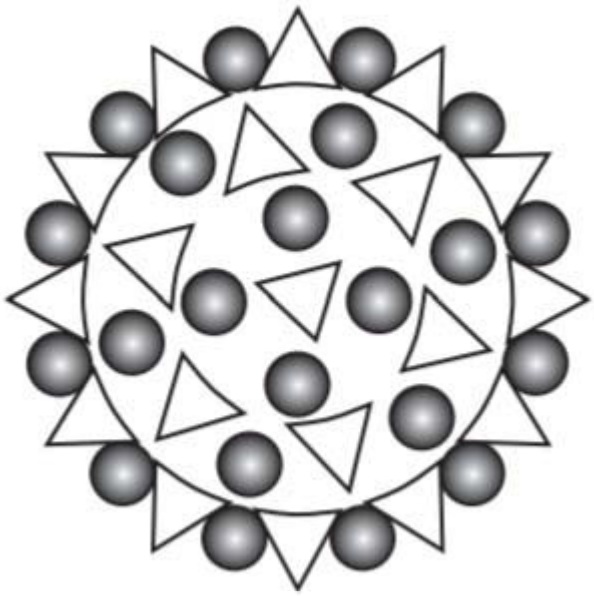
Which row is correct?

	1	2	3
A	amylose	cellulose	glycogen
B	amylose	amylopectin	cellulose
C	cellulose	amylose	amylopectin
D	glycogen	cellulose	amylose

4 Many eukaryotic cells have proteins as part of their plasma membranes. An experiment was performed on two different animal cells. The diagram shows the positions and shapes of two proteins on the plasma membranes of the two different cells.



These cells were then fused. After one hour, the plasma membrane of the resulting living cell was observed. The diagram shows the changed positions of the proteins.



What best explains the redistribution of proteins on the plasma membrane?

A the amphipathic nature of the phospholipid bilayer

B the fluidity of the phospholipid bilayer

C the presence of cholesterol at high temperature in the plasma membrane

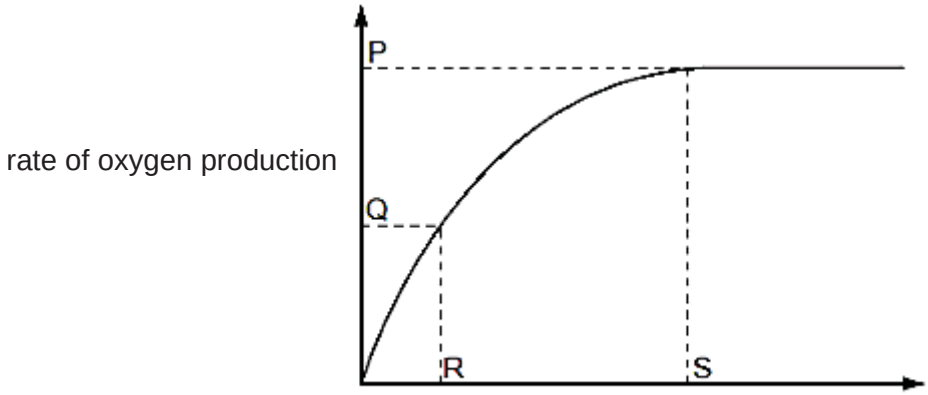
D the presence of saturated fatty acid chains of phospholipids in the plasma membrane

5 The diagram shows the action of a liver enzyme called catalase, which breaks down hydrogen peroxide into water and oxygen.

$$2\,H_2O_2 \xrightarrow{\text{catalase}} 2\,H_2O + O_2$$

The rate of this reaction can be determined by measuring the volume of oxygen produced in a given length of time. Students added small cubes of fresh liver tissue to hydrogen peroxide solution of varying concentrations and measured the volume of oxygen produced.

The graph shows how the concentration of hydrogen peroxide affected the rate of oxygen production.



Which statements are correct?

1 At P, the rate of reaction is limited by the concentration of enzyme.

2 At Q, all of the enzyme active sites are occupied by substrate molecules.

3 At Q, the rate of reaction is limited by the concentration of the substrate.

4 At S, all of the enzyme active sites are occupied by substrate molecules.

A 1 and 4

B 2 and 4

C 1, 2 and 3

D 1, 3 and 4

6 Ethylene glycol is a chemical used to prevent water from freezing. If ethylene glycol is swallowed accidentally, it is metabolised by an enzyme found in liver cells to produce a toxic product.

The enzyme normally catalyses the oxidation of ethanol to a harmless product.

People who have swallowed ethylene glycol are treated with large doses of ethanol. This prevents formation of a toxic product and allows the body to excrete the ethylene glycol.

Which statement describes why this treatment works?

A Ethanol binds near the active site on the enzyme, altering its shape.

B Ethanol binds permanently to the active site of the enzyme, blocking it.

C Ethanol changes the tertiary structure of the enzyme, denaturing it.

D Ethanol is more likely to bind to the active site on the enzyme.

7 Mesenchymal stem cells can differentiate into several types of cells belonging to our skeletal tissue, such as cartilage, bone and fat.

Which statement correctly describes mesenchymal stem cells?

A They are specialised cells that can give rise to a variety of cell types.

B They can be stimulated by chemical signals to express certain genes.

C They lose genetic information as they differentiate.

D They occur in large numbers in the bone marrow.

8 What is an accurate description of the coding of protein structure by DNA?

A 64 different complementary codons used in transcription to make the three-dimensional shape of the tertiary structure

B a code, with several triplets for each amino acid, determining the shape of the α-helix for the secondary structure

C a degenerate, non-overlapping code for the primary structure, determining the location of the folding sites involved in tertiary structure

D amino acids coded for by three consecutive bases, used with tRNA anticodons in translation to determine the quarternary structure

9 An mRNA codon for the amino acid arginine is CGG.

How many arginine molecules are present in part of the polypeptide, containing eight amino acids, coded for by the following DNA template?

TCGGCCTACCGGGCCCATGCCAAT

A 0

B 1

C 2

D 3

10 What increases the possibility of antigenic shift in influenza virus?

A infection of multiple individuals with the same strain of influenza virus

B lack of proofreading ability in viral RNA polymerase

C presence of herd immunity

D simultaneous infection of one individual with two different strains of influenza virus

11 Which event is most likely due to bacterial conjugation?

A A gene encoding resistance to gentamicin in the *Escherichia coli* chromosome appears in the genome of a bacteriophage that has infected *Escherichia coli*.

B A strain of *Corynebacterium diphtheriae* produces a toxin encoded by a prophage.

C A strain of *Pseudomonas aeruginosa* produces β-lactamase encoded by a plasmid similar to a plasmid of another Gram-negative bacterium.

D An encapsulated strain of *Streptococcus pneumoniae* acquires the gene for capsule formation from an extract of DNA from another encapsulated strain.

12 Which rows correctly compare generalised and specialised transduction?

	generalised transduction	specialised transduction
1	Any donor gene can be transferred by the phage.	Only certain donor genes can be transferred by the phage.
2	The transducing phage contains a hybrid chromosome in its capsid.	The transducing phage contains only bacterial chromosome in its capsid.
3	Phage genome is transcribed.	Phage genome is not transcribed.
4	The donor cell lyses, releasing the phages.	The donor cell lyses, releasing the phages.

A 1 and 3

B 1 and 4

C 2 and 3

D 2 and 4

13 Which statement correctly describes the control of transcription of the genes involved in the breakdown of lactose in *Escherichia coli*?

A A repressor protein binds to the operator and the genes are switched on.

B A repressor protein binds to the operator and the genes are switched off.

C A transcription factor binds to the promoter and the genes are switched on.

D A transcription factor binds to the promoter and the genes are switched off.

14 A region of eukaryotic DNA consists of over fifty tandem repeats of the same sequence of twelve bases.

Where is this repetitive region **least** likely to be found?

A an exon

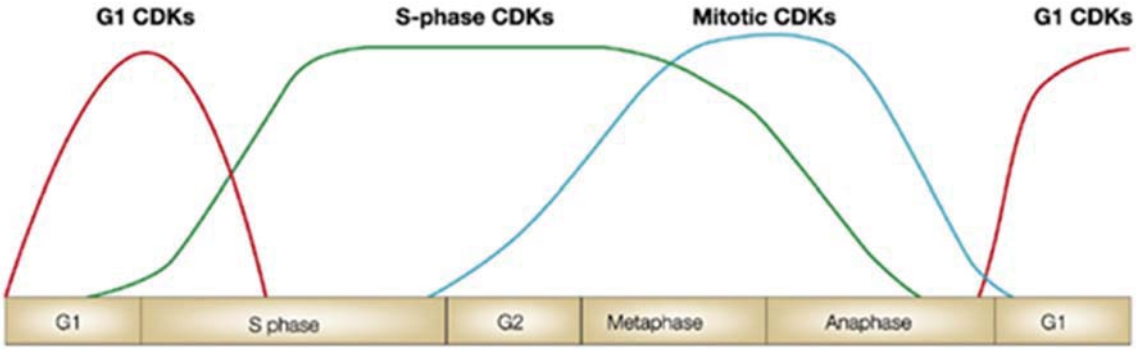
B an intron

C centromere

D promoter

15 Cyclins are regulatory proteins that associate with cyclin-dependent kinases (CDKs) to control the different stages of the cell cycle. The right type and amount of cyclins and CDKs must be present at the different stages to ensure regulation of the cell cycle.

The diagram shows the concentrations of the different CDKs.



How could the levels of the different CDKs be regulated during these stages?

1 binding of repressor to operator

2 formation of heterochromatin

3 length of mRNA poly(A) tail

4 ubiquitination of CDKs

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

16 Which group of genes are common tumour suppressor genes?

A genes involved in DNA synthesis
B genes involved in maintenance of cell cycle checkpoints
C genes involved in signal transduction
D genes involved in stimulation of cell division

17 Chromosomal mutations were induced to produce a fertile hybrid species from cabbage and radish.

The table 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
F_1 hybrids	18
F_1 gametes	9
F_2 hybrids	18
F_2 gametes	18
F_3 hybrids	36

At which stage did the chromosomal mutation 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

18 Which observation would rule out an X-linked trait in an extended family pedigree?

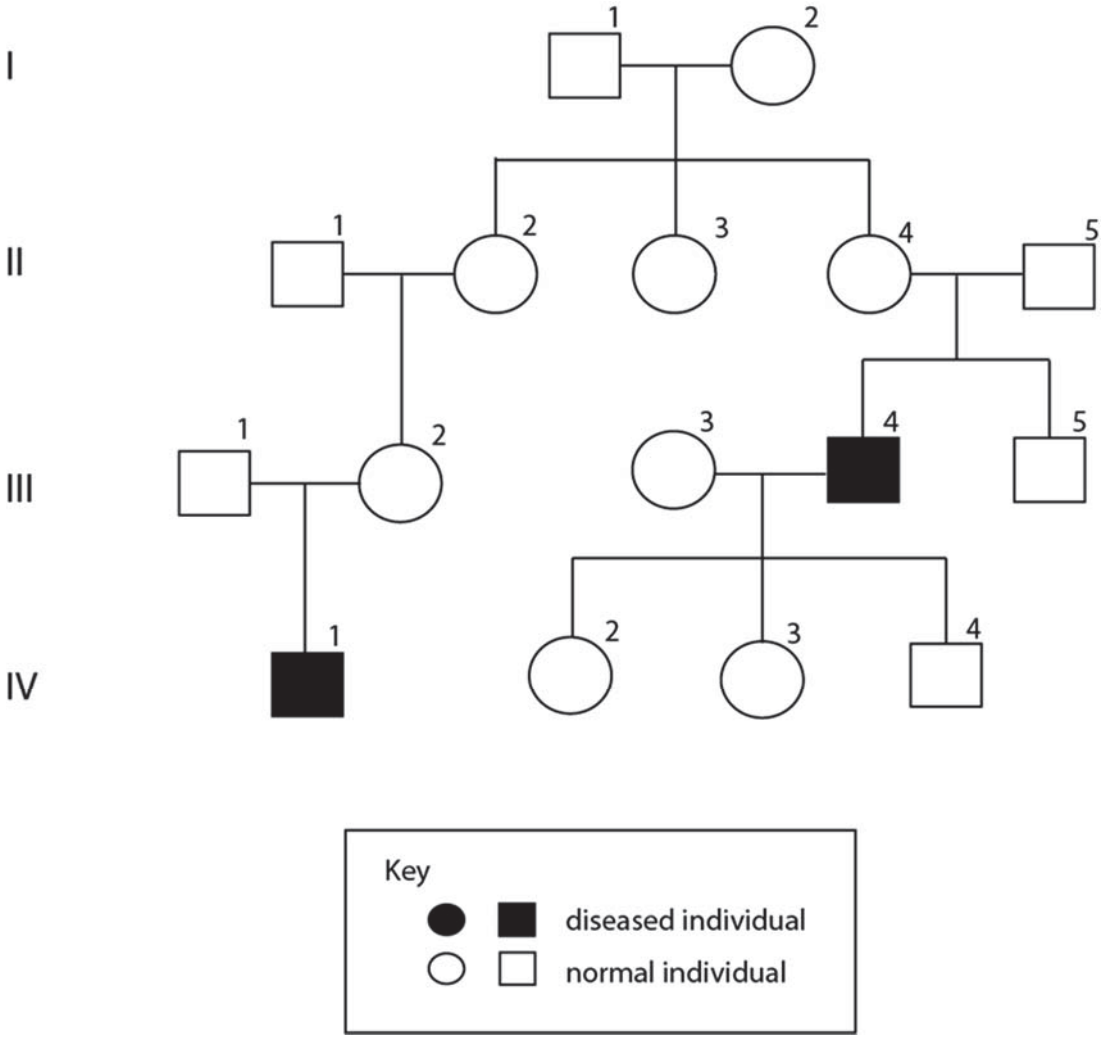
A females expressing the disease

B female-to-male transmission

C males expressing the disease

D male-to-male transmission

19 The pedigree shows the inheritance of a disease in a family for four generations.



What is the probability that individual IV-3 is a carrier of the disease?

A 0%

B 50%

C 75%

D 100%

20 A student measured the biomass that was produced by bacterium A and bacterium B in shake flasks containing glucose as substrate. For each type of bacterium, there were four replicate flasks.

The mean biomass that was produced by bacterium A and bacterium B is 487.5 mg and 257.5 mg respectively. The standard deviations of the biomass that was produced by bacterium A and bacterium B are 27.5 mg and 22.2 mg respectively.

The student then performed a t-test with the null hypothesis that there is no significant difference between the biomass that was produced by bacterium A and bacterium B.

The following formula was used to calculate the *t* statistic.

t-test

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

Keys to symbols:
s = standard deviation $\bar{x}$ = mean n = sample size
x = observation v = degree of freedom

Part of the *t* table is shown below.

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587

Which conclusion is correct?

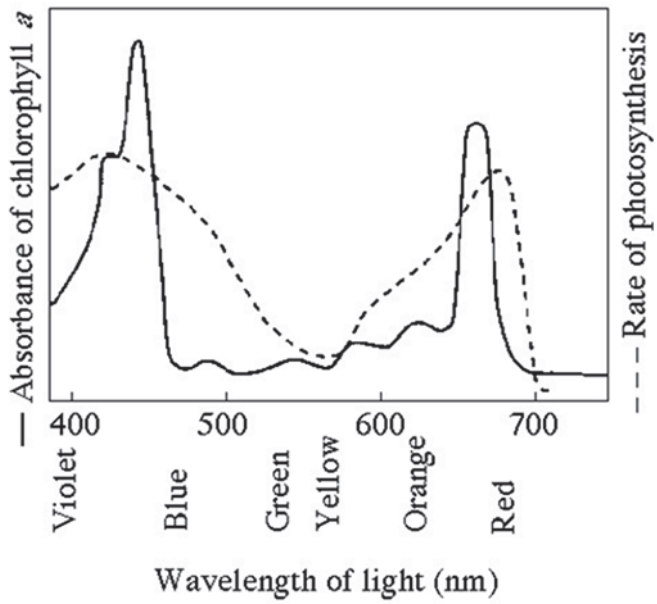
A $t_{\text{calculated}}$ is much higher than t_{critical} so it is not statistically significant. Hence, we accept the null hypothesis.

B $t_{\text{calculated}}$ is much higher than t_{critical} so it is statistically significant. Hence, we reject the null hypothesis.

C $t_{\text{calculated}}$ is much lower than t_{critical} so it is not statistically significant. Hence, we accept the null hypothesis.

D $t_{\text{calculated}}$ is much lower than t_{critical} so it is statistically significant. Hence, we reject the null hypothesis.

21 The graph shows the absorption spectrum for chlorophyll *a* and the photosynthetic action spectrum of a plant.



Why are they different?

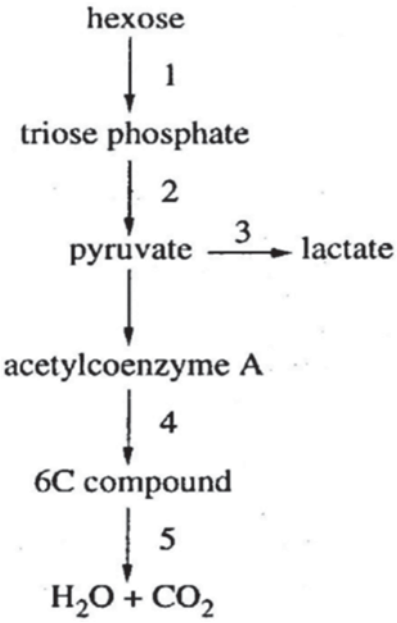
A Chlorophyll *a* absorbs different wavelengths of light to different extents.

B Chlorophyll *a* is not present in the plant.

C Chlorophyll *a* is not the only pigment in the plant that absorbs light.

D Chlorophyll *a* is the main pigment responsible for photosynthesis in the plant.

22 The diagram summarises the pathway of glucose breakdown.



Which two steps result in a net increase of ATP?

A 1 and 4

B 2 and 4

C 2 and 5

D 3 and 5

23 What is the main purpose of the second messengers in signal transduction pathways?

A allow for long distance signalling between cells

B amplify the signal by phosphorylating proteins

C relay a signal from the outside to the inside of the cell

D relay a signal from the plasma membrane to the cytoplasm

24 Why has evolution resulted in the appearance of antibiotic resistant bacteria?

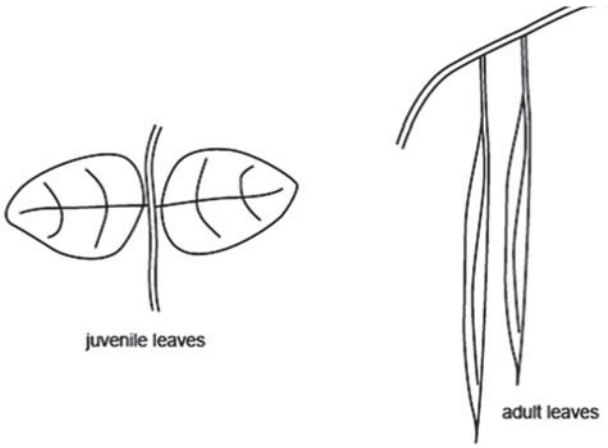
A Bacteria develop resistance due to the incomplete course of antibiotic.

B Bacteria learn the ability to neutralise the effect of antibiotic and they pass on this characteristic to their next generation.

C Bacteria modify their metabolism to cope with the presence of antibiotics.

D Bacteria that are resistant to the antibiotic survive and pass on this characteristic to their next generation.

25 Australian *Eucalyptus* trees characteristically have two types of leaves, a juvenile (young) form and an adult form. As shown in the diagram, the juvenile leaves are held horizontally and are relatively large and broad, while the adult leaves hang vertically and are long and narrow.



What is a selection pressure that is likely to have the greatest influence on the evolution of the juvenile leaf shape and position?

A competition for light

B consumption by herbivores

C high ambient temperatures

D nutrient availability

26 The various taxonomic levels of the hierarchical classification system differ from each other.

How are they different?

A inclusiveness of the different taxonomic levels

B morphological characters that are applicable to all organisms

C relative distribution of organisms throughout the environment

D relative genome sizes of the organisms

27 A park ranger was injected with antivenom immunoglobulins to treat a snake bite. The treating doctor explained that the injection would not protect him against future snake bites.

What type of immunity does the antivenom immunoglobulin confer?

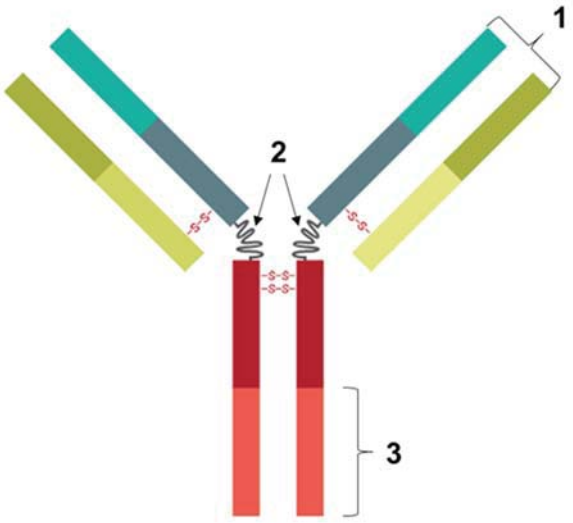
A active and artificial immunity

B active and natural immunity

C passive and artificial immunity

D passive and natural immunity

28 The diagram shows the structure of an antibody IgG.



Which statement about the structures labelled 1 to 3 is incorrect?

A Structure 1 differs in the different classes of antibodies produced by the same cell.

B Structure 1 is highly variable and specific to the epitope of the antigen that it binds to.

C Structure 2 allows flexible movement of the two arms of the antibody for binding to antigens.

D Structure 3 is important for interaction with effector cells and molecules.

29 Which statement about climate change is true?

A As average global temperature rises, average precipitation increases.

B Melting sea ice has a greater effect on global sea level rise than melting land ice.

C Shrinking sea ice in the Artic is fully offset by growing sea ice in the Antarctic.

D Water vapour, carbon dioxide, methane and nitrogen are greenhouse gases.

30 Levels of carbon dioxide in the atmosphere fall during summer in the northern hemisphere.

What best explains this trend?

A seasonal decrease in the use of fossil fuel and wood for heating

B seasonal increase in the amount of carbon dioxide dissolved in the oceans

C seasonal increase in the rate of decay of organic matter

D seasonal increase in the rate of photosynthesis in the northern hemisphere

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME **ANSWERS**

BIOLOGY CLASS 2bi2_____/2IPbi2_____

REGISTRATION NUMBER

BIOLOGY 9744/02

Paper 2 Structured Questions

25 August 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Biology class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid

Answer **all** questions 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 the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/12
2	/12
3	/8
Section B	
4	/12
5	/12
6	/10
7	/10
Section C	
8	/13
9	/11
Total	/100

This document consists of **29** printed pages.

Section A

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

1 Fig. 1.1 shows the process of collagen synthesis in a fibroblast cell.

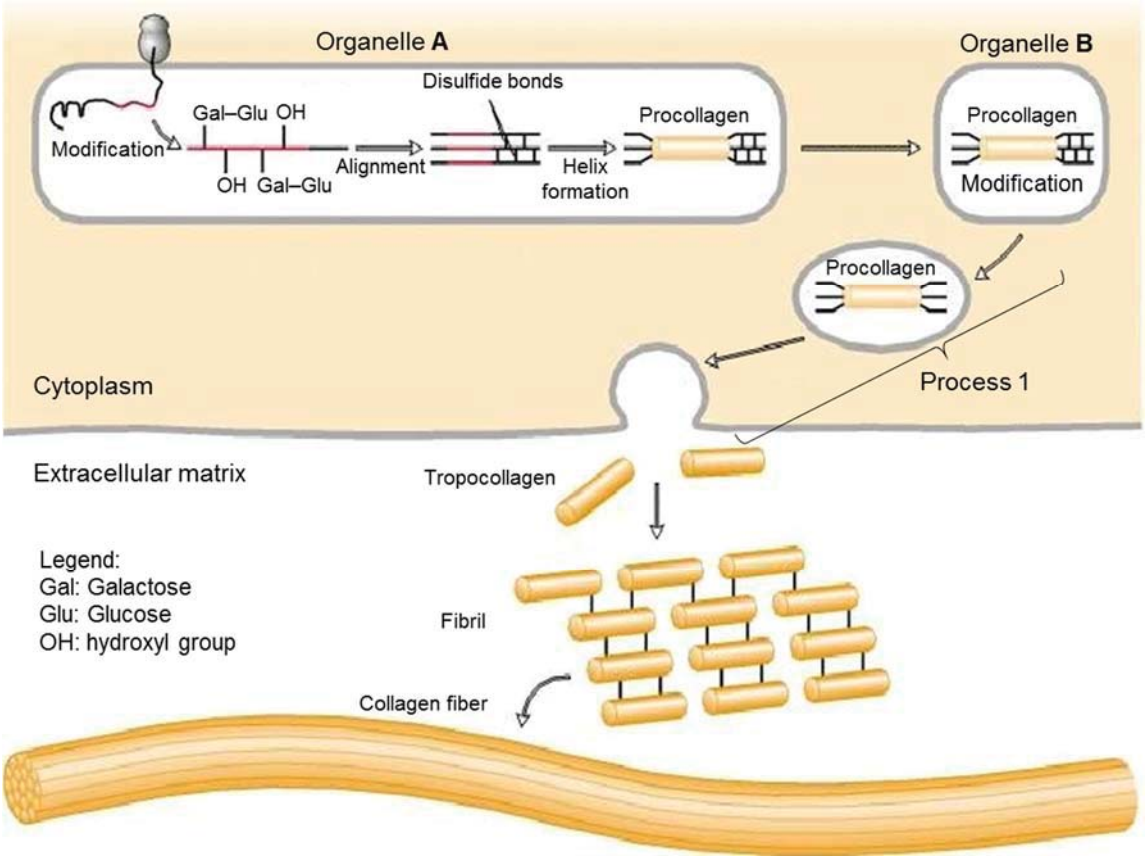


Fig. 1.1

(a) Identify organelles **A** and **B** in Fig. 1.1.

Organelle **A**: Rough endoplasmic reticulum

Organelle **B**: Golgi apparatus [1]

(b) Collagen has hydroxyproline and hydroxylysine, which are not present in many other proteins. Based on Fig. 1.1, deduce how these modified amino acids are incorporated into collagen.

1. Proline and lysine amino acids are incorporated to polypeptide chain during **translation** by **ribosomes**;
2. Polypeptide chains enter the **rER** where they are **chemically modified**;
3. **Addition of hydroxyl groups to R groups (hydroxylation)** of proline and lysine; [2]

(c) Describe the bonds formed between the polypeptide chains of procollagen.

1. **Disulfide bonds** between **sulfudryl (–SH) groups of cysteine** residues;
2. **Hydrogen bonds** between **–NH group of glycine** on one strand and **–CO group of amino acid residues** on another strand;

[2]

(d) Procollagen needs to be transported out of the cell via process 1.

(i) Describe process 1.

1. **Exocytosis**;
2. **Secretory vesicle** containing procollagen **buds** off from the **trans face** of the **Golgi apparatus**;
3. Moves along **microtubules** **towards cell surface membrane**;
4. **Membrane of the vesicle** **fuses** with the **cell surface membrane**;

[3]

(ii) Suggest why it must be transported out of the cell via process 1 and cannot be transported across the membranes out of the cell directly.

1. Procollagen molecule is **too large to pass through the cell surface membrane**;
2. **Lack of protein channels/carriers** to transport it across the membrane;

[2]

(e) With reference to Fig. 1.1, suggest why tropocollagen is less soluble than procollagen.

1. **Ends of the procollagen** are **hydrophilic**/**contains -OH groups** and can **interact with water**;
2. As the **ends of the procollagen** are **cleaved** to form tropocollagen, tropocollagen can no longer interact with water;

[2]

[Total: 12]

2 Mutations can be inherited or acquired in a person's lifetime. Inherited mutations must be present in the parent's germ cells in order to be passed on to the child. On the other hand, acquired mutations arise due to environmental factors or errors in the cell cycle.

(a) Identify three specific phases in the cell cycle where different types of mutations are likely to happen.

Synthesis (S) phase of interphase, **metaphase/anaphase**, **prophase I** of meiosis;

[1]

(b) Explain how mutations occur in the phases identified in **(a)**.

1. S phase:

- **incorrect nucleotide incorporated** into DNA due to **errors in complementary base-pairing** by **DNA polymerase** during DNA replication resulting in a **nucleotide-pair substitution mutation**; OR
- **additional nucleotide incorporated** into DNA by **DNA polymerase** during DNA replication resulting in a **nucleotide-pair insertion mutation**; OR
- **DNA polymerase skip a nucleotide** during DNA replication resulting in a **nucleotide-pair deletion mutation**;
- Errors in proofreading by DNA polymerase;

2. Metaphase/Anaphase:

- **Non-disjunction** occurs whereby **a pair of homologous chromosomes to fail to separate in during anaphase I** OR **sister chromatids fail to separate during anaphase II** OR **sister chromatids fail to separate during mitosis** resulting in **aneuploidy**;
- due to **improper attachment of microtubules to kinetochore** proteins on **centromere**; (metaphase)
- **cohesin** protein complex **not cleaved/degraded**; (anaphase)

Prophase I:

- **Misalignment of homologous chromosomes** during prophase I
- leads to **unequal crossing over**, resulting in an insertion/deletion of a segment of the chromosome
- crossing over of non-homologous chromosomes

[3]

(c) In some cases, a mutation in the coding sequence of a gene does not change the amino acid sequence of the protein.

Explain why such a mutation has no effect on the amino acid sequence of the protein.

1. Due to **degeneracy/redundancy** of the genetic code;
2. **Same amino acid** can be coded for by **more than one codon**;
3. Due to the **wobble base effect** on the **3rd base** of many **codons**;
4. **Mutation** to the 3rd base of these codon leads to an altered codon for the **same amino acid**;

[3]

(d) Distinguish between gene mutation and chromosome structural mutation.

Gene mutation	Chromosomal structural mutation
1. Changes in DNA/nucleotide sequence of a gene	Changes in chromosome structure/exchange chromosome segments/ DNA/nucleotide sequence of gene (mostly) unchanged
2. Alters a single gene locus on a chromosome	Alters more than one loci on chromosomes
3. Caused by deletion, insertion, substitution or inversion of one / several nucleotides	Deletion, inversion, translocation or duplication of chromosomal fragments / several gene loci
4. Give rise to new alleles	Rearrangement of loci of genes / alleles / reshuffling / recombination / new combination of alleles
5. May change amino acid sequences or form non-functional proteins/ silent, missense, nonsense mutation	Amino acid sequences usually unchanged but changes the level of expression of genes / inactive, hyperactive, underproduction or overproduction of gene product
6. Play more important role in evolution than chromosomal mutations because new alleles increases variation in the gene pool for natural selection to operate	Play a less important role in evolution than gene mutations because chromosomal mutations involve only reshuffling of alleles that already exist in gene pool
7. Example: sickle cell anaemia	Cri-du-chat syndrome/ Chronic myelogenous leukaemia (CML)
8. More frequent	Less frequent

[3]

(e) The accumulation of mutations may increase the chances of cancer. One of the causative factors of cancer is loss of immunity.

Explain the role of the immune system in preventing cancer.

Ref. to **natural killer cells**/**antibodies** bind and **recruit NK cells** which bind to germline encoded receptors / **cytotoxic or $CD8^+$ T cells** bind to specific antigens on cancer cells;

Ref. to release **cytotoxic granules** and **induce apoptosis/programmed cell death**;

[2]

[Total: 12]

3 Fig. 3.1 shows the development of B cells and the fate of a specific B cell after encountering an antigen.

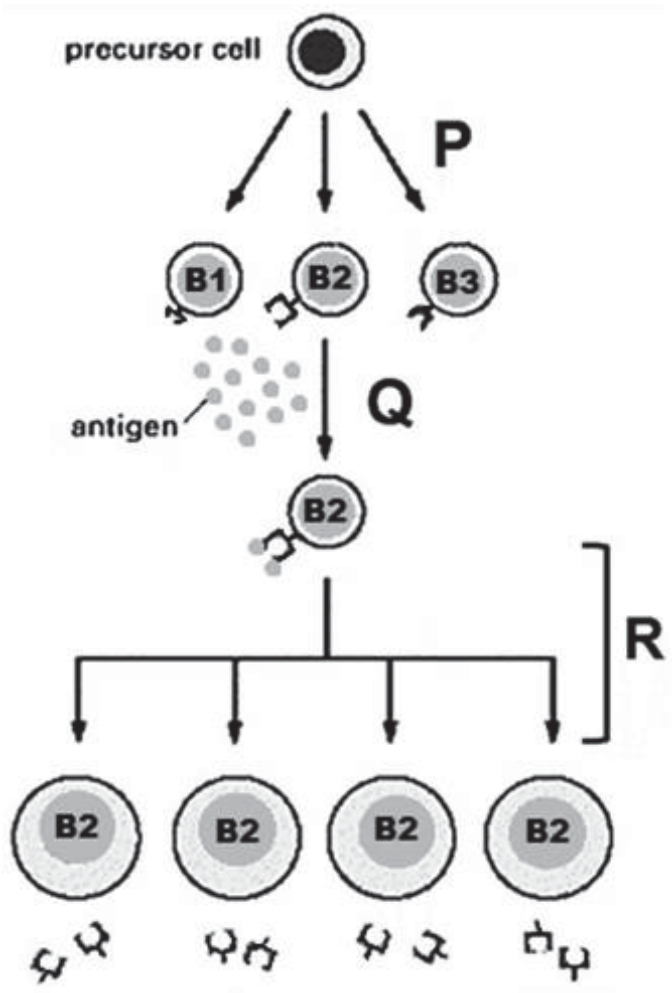


Fig. 3.1

(a) With reference to Fig. 3.1,

(i) describe the genetic mechanism that occurs during process **P**, and explain its biological significance,

1. **Somatic recombination** of **V, D and J gene segments** of the variable region of the immunoglobulin genes / of **V, D and J gene segments** at heavy chain locus and V and J segments at a light chain locus;
2. This results in combinatorial diversity which generates a **wide diversity of B cells** such as B1-B3;
3. Each B cell has a **distinct/ specific BCRs** which recognises a single specific antigen/epitope that is complementary to its antigen binding-sites;
4. Allow binding to and **elimination** of a **wide range of different antigens**;

[3]

(ii) explain how process **Q** leads to process **R**.

1. Binding to a specific antigen, which is phagocytosed, and fragments of antigen are presented on MHC (ref to **antigen presentation**);
2. Recognised by helper T cells, causing the naïve B cell (B2) to become **activated**;
3. This causes B2 to undergo **clonal expansion** / expand in numbers by mitosis;
4. and **differentiation** to produce **plasma cells** and **memory B cells**;
5. Plasma cells secrete **antibodies** that are **specific to the same antigen**;

[3]

(b) After eliminating the antigens, the plasma cells would undergo apoptosis. Only a small number of memory B cells would persist in the blood for a long period of time after the infection.

Memory B cells have similar properties to haematopoietic stem cells. Compare memory B cells and haematopoietic stem cells.

1. Similarity:

- Both are able to **self-renew**
- Both undergo **differentiation**
- Both are **not specialised** to perform specific functions;
- Both have **telomerase** activity (reject long telomeres)

2. Difference:

- Memory B cells can **only differentiate into plasma cells** whereas HSC can **differentiate into all types of blood cells**;
- Memory B cells are **unipotent** vs HSCs are **multipotent**;
- Memory B cells have undergone somatic recombination hence their **genomes are different** from each other whereas HSCs are **genetically identical**;

[2]

[Total: 8]

CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

Section B

For Examiner's Use	
Section B	
4	**/12**
5	**/12**
6	**/10**
7	**/10**

Section B

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

4 The rate of respiration in cells can be controlled by regulating the activity of various enzymes involved in respiration.

Phosphofructokinase (PFK), an important enzyme in glycolysis, can be regulated by adenosine triphosphate (ATP) and adenosine monophosphate (AMP). It catalyses the phosphorylation of fructose-6-phosphate (F-6-P) to fructose-1,6-bisphosphate.

Fig. 4.1 shows the T and R states of PFK under high and low concentrations of ATP respectively.

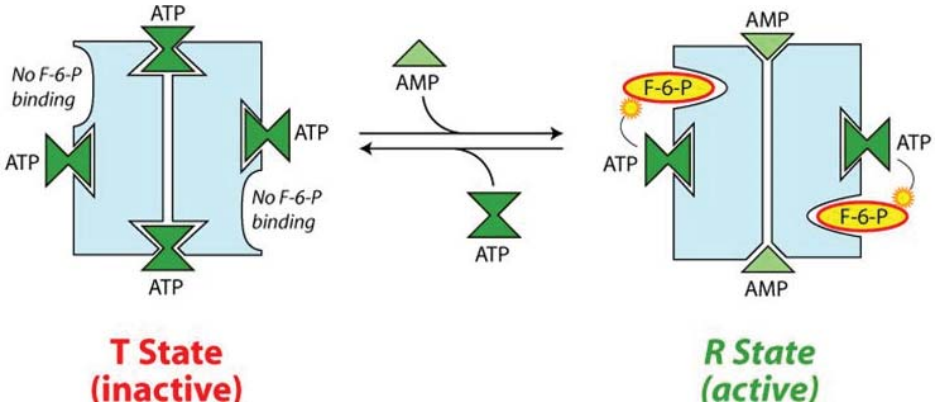


Fig. 4.1

(a) With reference to Fig. 4.1,

(i) describe two roles of ATP in the PFK-catalysed reaction,

1. ATP serves as a **substrate**, binding to the **active site** of PFK for the phosphorylation of F-6-P;
2. ATP also serves as an **allosteric inhibitor (reject: non-competitive inhibitor)**, binding to the **allosteric site** of PFK
3. **Changes the conformation of the active site** to become inactive/T state, **preventing binding of F-6-P**;

[2]

(ii) explain the effect of AMP on the rate of glycolysis.

1. AMP serves as an **activator**, binding to the **allosteric site** of PFK;
2. **Changes conformation of active site** of PFK to become **active/R state**;
3. **F-6-P can bind** to the active site of PFK, leading to **phosphorylation of F-6-P**;
4. **Increase** formation of **fructose-1,6-bisphosphate**, **increasing rate of glycolysis**;

[4]

Fig. 4.2 shows the results of an experiment investigating the effect of temperature on a reaction catalysed by PFK. The same starting concentration of substrate and the same starting concentration of enzyme were used for each temperature tested. Reactions were kept at different temperatures for periods of one, two and five hours, after which the quantities of product formed were determined.

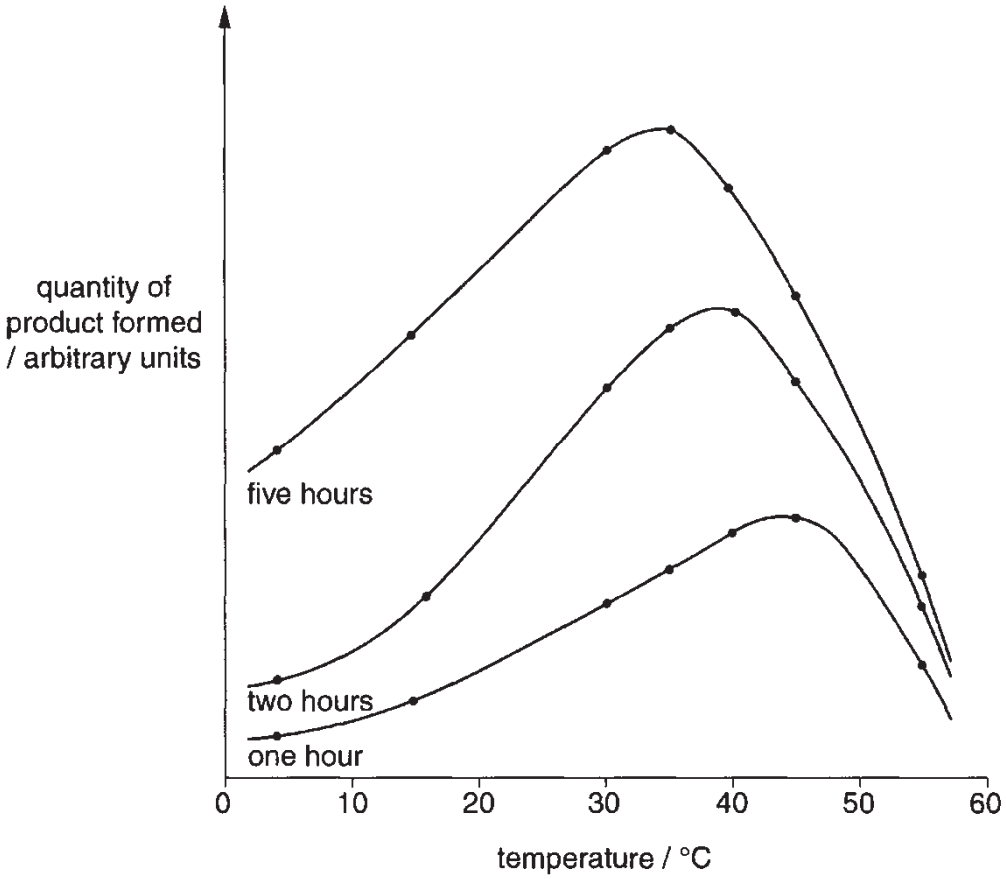


Fig. 4.2

(b) Explain the effect of increasing temperature on the quantity of product formed from the reactions kept at different temperatures for one hour.

1. Increase temperature **up to optimum** results in increase **kinetic energy**;
2. increase frequency of **effective collisions**;
3. Increase formation of **enzyme-substrate complexes** and hence products;
4. Further increase in temperature **beyond optimum** results in **breaking of weak bonds such as hydrogen bonds, ionic bonds, hydrophobic interactions**; (at least two bonds)
5. **Change three-dimensional conformation** of **active site** of enzymes, resulting in **denaturation** of enzymes;

[4]

(c) Explain the difference in the optimum temperature for the reactions after one, two and five hours.

1. **Optimum temperature** is **lower** when reactions are **incubated** for a **longer** period of time;
2. Longer period of incubation results in **more denaturation** hence **less (effective) enzyme available** to catalyse the reaction; (effective = correct conformation of active site to bind to the substrate catalyse reaction)

[2]

[Total: 12]

5 In cats, coat colour is determined by the X-linked, codominant alleles: black (B) and orange (O). A calico female, which is the homogametic sex, is bred many times with a black male. They produced the following offspring:

black female 27

calico female 20

black male 31

orange male 18

(a) Explain the meaning of the terms:

(i) *X-linked*,

Found on the X chromosome; [1]

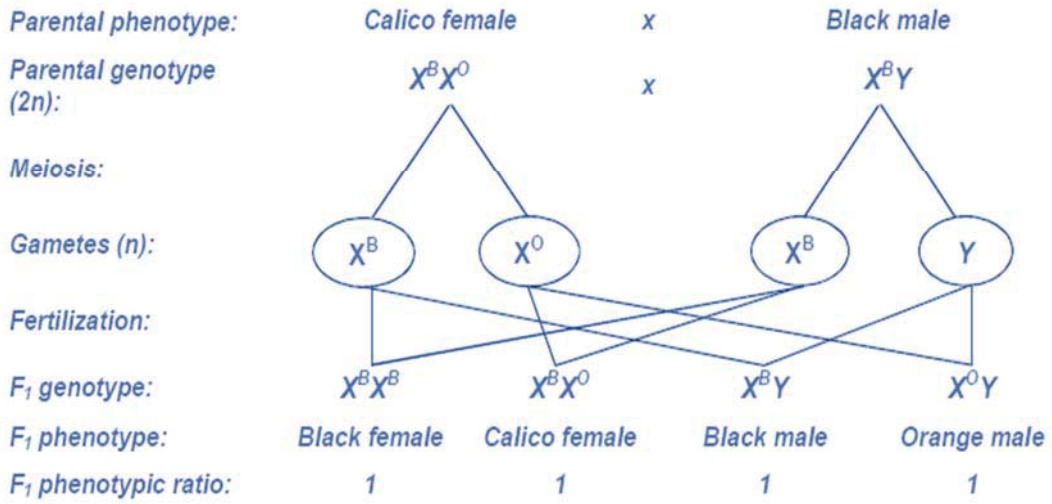
(ii) *codominant*.

Relating to two alleles of a gene that are both fully expressed in a heterozygote;

[1]

(b) Draw a genetic diagram in the space below to show the expected phenotypic ratio of the offspring from the cross described.

Let X^B represent the X-linked, codominant allele for black coat;
Let X^O represent the X-linked, codominant allele for orange coat.



Both parental phenotypes and genotypes are correct;
All possible gametes from each parent are correct;
Genetic diagram correctly shows 4 possible combinations of gametes;
The phenotypes of all F_1 genotypes are correct;
The expected F_1 phenotypic ratio is correct;

[5]

(c) Carry out a chi-squared (χ^2) test to determine whether the observed data fits the expected phenotypic ratio of the offspring from the cross described.

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

v = degree of freedom, **c** = number of classes, **O** = observed value, **E** = expected value

Table 5.1 shows part of the table of probabilities for the chi-squared test.

Table 5.1

degrees of freedom	probability, p				
	0.10	*0.05*	*0.02*	*0.01*	*0.001*
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

Show your working clearly and state your conclusion in the space below.

	Expected numbers	*Observed numbers*	*O-E*	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Black female	*24*	*27*	*3*	*9*	*0.375*
Calico female	*24*	*20*	*-4*	*16*	*0.667*
Black male	*24*	*31*	*7*	*49*	*2.042*
Orange male	*24*	*18*	*-6*	*36*	*1.500*

Calculated χ^2 value = 4.58 (3 sf);

Clear working shown;

Degree of freedom = 4 - 1 = 3;

Calculated χ^2 value (4.58) < critical χ^2 value (7.82) at p = 0.05
OR
Probability that the deviation from expected ratio is due to chance is more than 0.05, i.e. p > 0.05;

Conclusion:

The difference between observed ratio and expected ratio is not statistically significant.

OR

The observed data fits the expected phenotypic ratio of the offspring from the cross described;

[5]

[Total: 12]

6 During photosynthesis, carbon dioxide reacts with ribulose bisphosphate (RuBP) to form two molecules of glycerate 3-phosphate (GP). This reaction is catalysed by the enzyme Rubisco.

Rubisco can also catalyse a reaction between RuBP and oxygen to form one molecule of GP and one molecule of phosphoglycolate. However, phosphoglycolate cannot be used in the light-independent reaction of photosynthesis.

Fig. 6.1 shows both the reactions catalysed by Rubisco.

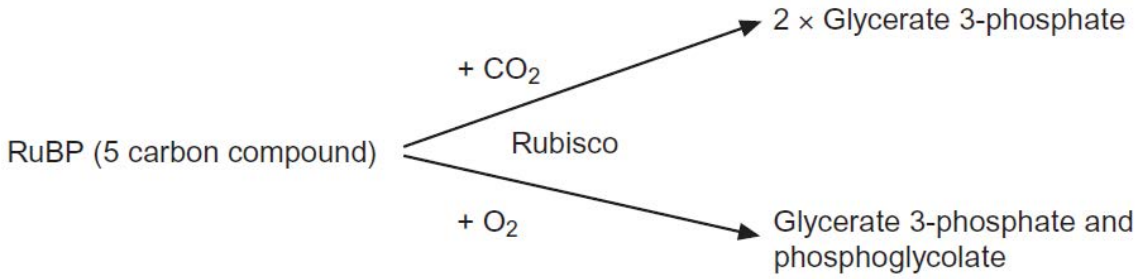


Fig. 6.1

(a) (i) State exactly in a cell where the enzyme Rubisco is found

Stroma of chloroplast; [1]

(ii) Use the information provided to give the number of carbon atoms in one molecule of phosphoglycolate.

Two; [1]

(b) A scientist investigated the effect of different concentrations of oxygen on the rate of absorption of carbon dioxide by leaves of soya bean plants. His results are shown in Fig. 6.2.

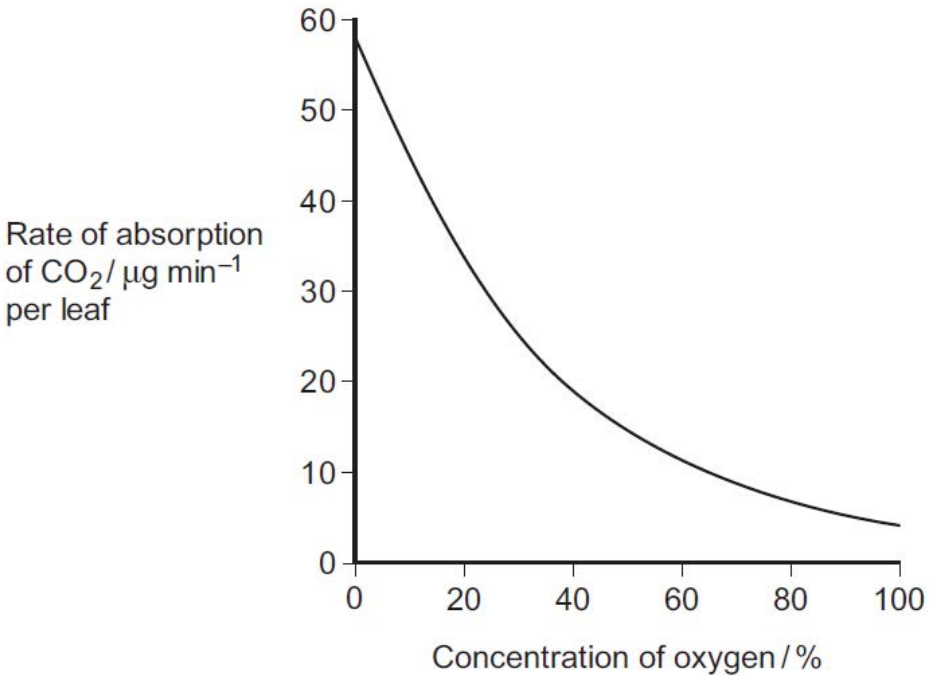


Fig. 6.2

(i) Use Fig. 6.1 to explain the results shown in Fig. 6.2.

Rate of absorption of CO_2 decreases as concentration of oxygen increases;

Oxygen **competes** with carbon dioxide for the active site of Rubisco;

As concentration of oxygen increases, less Rubisco / RuBP binds / reacts with carbon dioxide;

Less RuBP would be regenerated to join with carbon dioxide; [2]

(ii) Using the information provided and your knowledge of the light-independent reaction, explain why the glucose yield from soya bean plants is decreased at higher concentrations of oxygen.

Less glycerate 3-phosphate / GP would be produced;

Less glyceraldehyde 3-phosphate / G3P / triose phosphate would exit the Calvin cycle as raw material for glucose synthesis;

Less RuBP would be regenerated;

[3]

(c) Another scientist investigated the uptake of radioactively labelled carbon dioxide in chloroplasts. She used three tubes, each containing different components of chloroplasts.

Table 6.1 shows the uptake of radioactively labelled carbon dioxide in each tube.

Table 6.1

Tube	Contents of tube	Uptake of radioactively labelled CO_2 / counts per minute
A	Stroma and grana	96 000
B	Stroma, ATP and reduced NADP	97 000
C	Stroma	4 000

(i) Explain why the result in tube **B** is similar to that in tube **A**.

ATP **and** reduced NADP are produced by grana / thylakoids OR present in both tubes A and B;

[1]

(ii) Use the information in Table 6.1 to predict the uptake of radioactively labelled carbon dioxide if tube **A** was placed in the dark. Explain your answer.

4000 counts per minute OR same as in tube C;

Light-dependent reaction does not occur OR ATP and reduced NADP are not produced;

[2]

[Total: 10]

7 A student investigated respiration in a population of yeast growing in a sealed container.

Fig. 7.1 shows the results of his investigation.

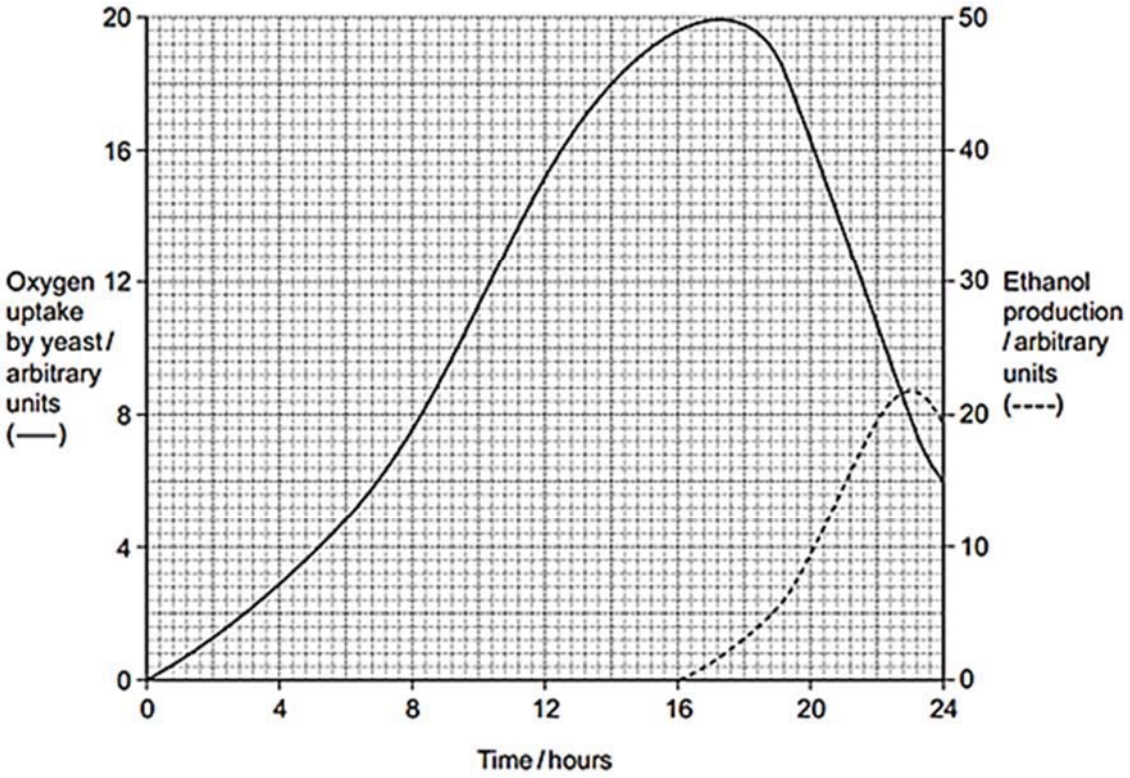


Fig. 7.1

(a) Calculate the rate of oxygen uptake in arbitrary units per hour between 2 and 4 hours.

(2.8 - 1.2) / (4 - 2) = 0.8 arbitrary units per hour;

[1]

(b) With reference to Fig. 7.1, explain the changes in oxygen uptake and ethanol production by yeast during this investigation.

1. *(Describe the changes in oxygen uptake with values correctly quoted from at least one axis)*;
2. *(Describe the changes in ethanol production with values correctly quoted from at least one axis)*;
3. *(Explain why oxygen uptake increases from 0 to 17.2 hours)*
   Aerobic respiration / Oxidative phosphorylation / Reproduction of yeast cells;
4. *(Explain why oxygen uptake decreases from 17.2 to 24 hours)*
   Oxygen concentration decreases / becomes limiting;
5. *(Explain why ethanol production increases as oxygen uptake decreases)*
   Anaerobic respiration / Ethanol or alcoholic fermentation;
6. (*Explain why ethanol production decreases from 23 to 24 hours)*
   Glucose concentration decreases / becomes limiting / Ethanol reaches toxic level and kills the cells;

[6]

(c) Sodium azide is a substance that inhibits the electron transport chain in respiration. The student repeated the investigation but added sodium azide after 4 hours.

Suggest and explain how the addition of sodium azide would affect oxygen uptake and ethanol production by yeast.

(compulsory point) Oxygen uptake decreases / stopped;

Oxygen is the final electron acceptor in the electron transport chain;

(compulsory point) Ethanol production starts earlier / More ethanol produced;

Yeast switches to anaerobic respiration / ethanol or alcoholic fermentation;

[3]

[Total: 10]

CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

Section C

For Examiner's Use	
Section C	
8	**/13**
9	**/11**

Section C

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

8 The endocrine system facilitates the communication between different cells through the release of hormones into the bloodstream. Binding of hormones to receptors on or within target cells initiates signal transduction, which may result in a change in gene expression.

(a) Fig. 8.1 shows the signalling pathway of glucocorticoid receptor (GR) mediated gene expression. GR is activated when it is bound to glucocorticoid (S), which is a steroid hormone. Activated GR binds to glucocorticoid response elements (GREs) within the promoter of target genes. This results in the recruitment of the chromatin remodelling complex, BRG1 complex.

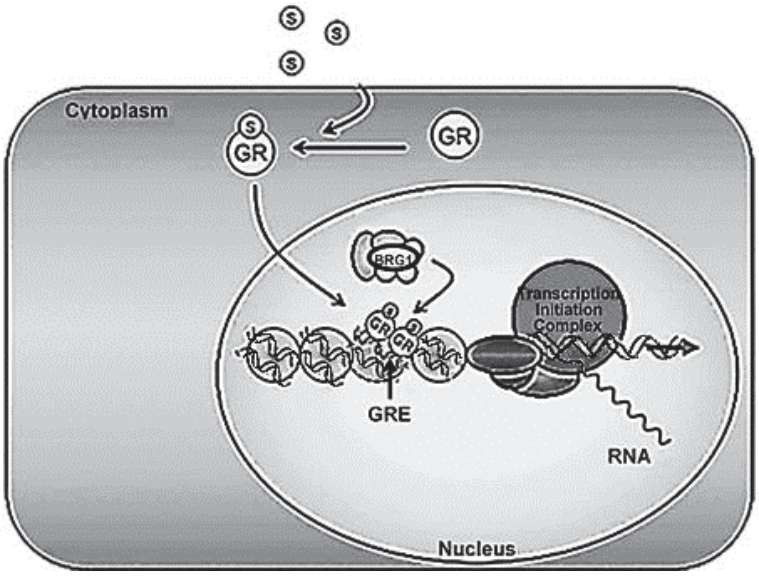


Fig. 8.1

(i) GRs are known to have highly conserved regions that are structurally important for its function.

With reference to Fig. 8.1, describe two structural features of GR that allows it to carry out its role.

1. **DNA binding site**
2. **Complementary in shape** and charge to the sequences at the **GRE**, allowing it to **bind to GRE**
3. **Binding site for steroid hormones/S**
4. **Complementary to shape of S**, to allow **change in conformation of GR** to activate GR/ allow binding to GRE in promoter
5. **Small and hydrophilic**
6. **Pass through nuclear pore**
7. **Binding site for BRG1 complex**
8. To allow **binding/recruitment of BGR1** regulate gene expression
9. **GR-GR binding site**
10. To recruit RNA polymerase and transcription factors for the formation of the transcription initiation complex

[4]

Fig. 8.2 shows the effect of BRG1 complex binding to the promoter of a target gene.

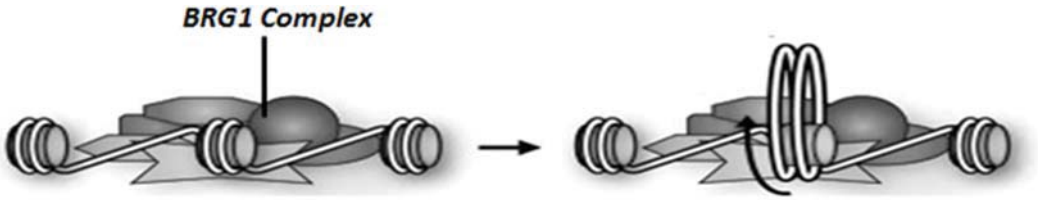


Fig. 8.2

(ii) With reference to Fig. 8.2, describe the effect of BRG1 complex binding to the promoter on gene expression.

1. Glucocorticoids increases the rate of transcription/gene expression
2. Glucocorticoids binds to/activates GR which then binds to GRE
3. BRG1 / chromatin remodeling complex which causes the **negatively charged DNA** to be **less tightly coiled** around the **positively charged histones**
4. RNA polymerase and transcription factors can access / bind to the promoter to initiate transcription / promote assembly of TIC at the promoter [2]

(iii) Briefly describe one other mechanism that may bring about a similar effect on gene expression as described in **(ii)**.

1. Demethylation of DNA at cytosine nucleotides decondenses chromatin
2. Acetylation of histones at lysine residues, decreases interaction between DNA and histones allows chromatin to decondense
3. Activators binds to enhancers, promoting assembly of TIC

R: enzyme inhibition

[1]

(b) The signal transduction pathway in Fig. 8.3 is initiated by the binding of the growth factor (GF) to the receptor tyrosine kinase (RTK). This pathway controls the fundamental cellular processes such as growth, proliferation and differentiation.

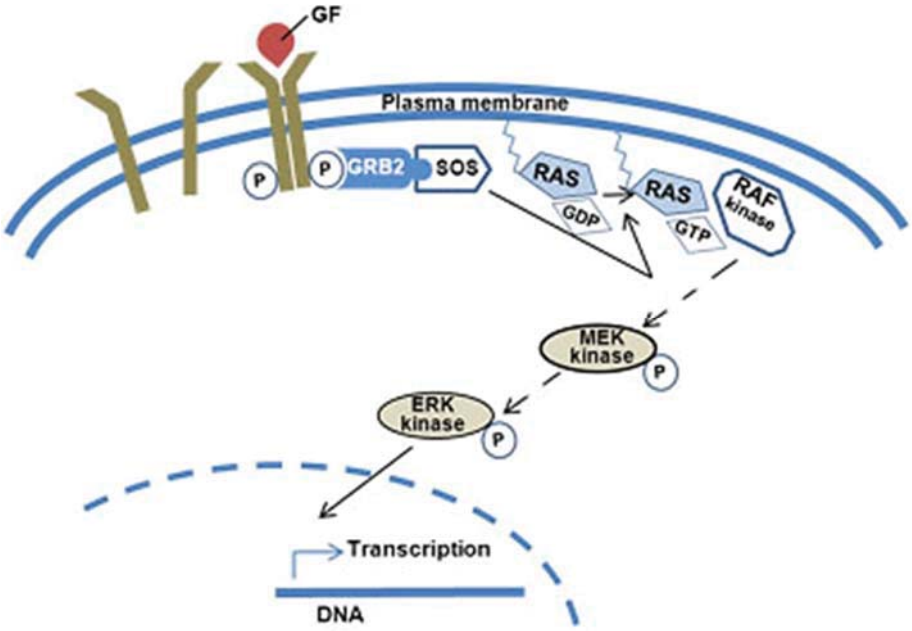


Fig. 8.3

With reference to Fig. 8.3,

(i) describe how RAS, a G protein, is activated by GF,

1. GF binds to extracellular **ligand-binding site of specific transmembrane receptor** which causes the **dimersiation** of two receptor subunits
2. **Conformational change** in the intracellular domain of receptor results in **activation of intrinsic tyrosine kinase**
3. Intrinsic kinase activity of each subunit in the intracellular domain **cross-phosphorylates / autophosphorylates the tyrosine residues**
4. **Grb2** binds to the phosphorylated tyrosine residues which in turn binds to the **SOS protein OR Grb2-Sos complex is activated** and
5. In turn **activates Ras when GDP is displaced with GTP**

[4]

(ii) explain one significance of the series of events that occur after the activation of RAS.

1. Allows **signal transduction** when activated ras protein triggers a **phosphorylation cascade** **via kinases** / allows signal transduction where Ras activates Raf which in turn phosphorylates Mek and then phosphorylates Erk
2. ERK relays the signal to the **nucleus**, where **it induces the expression of gene** leading to cell proliferation/growth/differentiation

   OR
3. **Signal amplification** occurs where **one activated protein activates several others** resulting in a large number of activated molecule, an example required such as ERK
4. **Large cellular response** it **induces the expression of gene** [2] leading to cell proliferation/growth/differentiation

[Total: 13]

9 Reef-building corals are marine invertebrates found in shallow, clear, tropical oceans. The corals secrete an exoskeleton of calcium carbonate that becomes the underlying structure of the coral reef ecosystem.

Zooxanthellae are a group of unicellular algae from the genus *Symbiodinium* that live within the cells of reef-building corals. The relationship has been described as mutualistic since it is beneficial to both the corals and the zooxanthellae.

(a) Evidence shows that the mutualistic relationship between reef-building corals and zooxanthellae has evolved from free-living algae invading corals that initially did not contain algae.

(i) Corals are usually found in shallow areas at depth of less than 40 metres. However, some coral reefs extend even deeper, up to about 130 metres.

Explain why this is possible for deep-sea corals.

1. No reliance on light;
2. (reef-building corals) algae/zooxanthellae, photosynthesise;
3. depth limit to penetration by light / light absorbed as penetrates water;
4. AVP; e.g. different feeding methods / deeper waters (may be) nutrient rich [2]

(ii) Suggest the benefits to the zooxanthellae of their association with the corals.

1. Physical structure to obtain light for coral reefs that are located in shallower waters;
2. Carbon dioxide from respiration of coral polyps can be used as raw material for photosynthesis by zooxanthellae;
3. Inorganic nitrogen and phosphorous from the waste products of the coral polyps' metabolic processes serve as nutrients for zooxanthellae (since low conc. Of nitrates and phosphate ions in the sea);
4. Ref. coral and food caught / suspension feeding / catching prey, provides nutrients / needed for growth of algae;
5. Protection from predation;
6. Protection from too much ultraviolet radiation as corals make compounds which act as sunscreens;

[2]

(iii) During stressful conditions, coral bleaching may occur where zooxanthellae are expelled from coral. Coral bleaching can lead to death of the coral.

Suggest one reason why permanent loss of zooxanthellae can lead to death of the coral.

1. Decreased source of food in the form of sugars and other compounds; accept nutrients if qualified by ref. to photosynthesis or production by zooxanthellae
2. Lack of organic compounds / named compound ; accept no carbon fixation
3. Loss of (main) source of (chemical) energy;
4. Loss of inorganic ions for deposition of skeleton that algae obtain from sea;
5. Loss of protective algal layer from harmful effects of sunlight;

[1]

(b) The temperature range for healthy survival of reef-building coral is 25 °C – 29 °C. Increased sea temperature associated with global climate change is known to be an environmental stress that can cause coral bleaching.

(i) Suggest why the areas of sea containing coral reefs are susceptible to increased temperature resulting from global climate change.

Idea that shallow bodies of water, heat up quicker / more susceptible to extreme temperature fluctuations, than deeper water;

[1]

(ii) Raw sewage released into the oceans may contain bacteria that cause disease in corals.

Suggest how global warming increases the rate of coral bleaching caused by bacterial disease.

1. Increased bacterial multiplication thus bacterial infectivity increases;
2. Leading to stress conditions for coral, causing corals to expel the zooxanthellae; [1]

(c) Recently, the International Union for Conservation of Nature (IUCN) has assessed over 47% of reef-building coral species as threatened, or near-threatened, with a global risk of extinction.

Explain how the loss of reef-building corals reduces biodiversity at different levels.

1. Levels of biodiversity affected are, genetic, species, community, ecosystem, loss of reservoir for biomedicines;

2. **Genetic biodiversity**
    a. which is the loss of genomes / loss of genes (if species become extinct)
    b. Loss of aquatic genetic resources and alleles within a species;

3. Reduced **species biodiversity**
    a. loss of different coral species;
    b. loss of species within the genus *Symbiodinium*,
    c. loss of species that are reliant on coral

4. Reduced **community biodiversity** if more than one species is lost;

5. Reduced **ecosystem biodiversity**;
    a. Loss of primary producers / autotrophs
    b. Effect on energy flow / food web, accept example
    c. Loss of habitat for, other species / fish / marine invertebrates;
    d. Reduced / affected interactions
    e. Recycling of matter altered

6. Corals have evolved chemical defences to protect themselves from predators or pathogens → loss of coral species also mean loss of such reservoir to develop useful drugs / pharmaceuticals;

[4]

[Total: 11]

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME **ANSWERS**

BIOLOGY CLASS 2bi2_____/2IPbi2_____

REGISTRATION NUMBER

BIOLOGY 9744/03

Paper 3 Long Structured and Free-response Questions — 29 August 2017

Additional Materials: Answer Paper — 2 hours

READ THESE INSTRUCTIONS FIRST

Write your Biology class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid

Sections A and B
Answer **all** questions in the spaces provided on the question paper.

Section C
Answer any **one** question on the answer paper provided.

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 the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/25**
Section B	
2	**/25**
Section C	
3 / 4	**/25**
Total	**/75**

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

Section A

Answer the question in this section.

1 Fig. 1.1 shows two electron micrographs of cells **A** and **B**, both of which are not shown to scale.

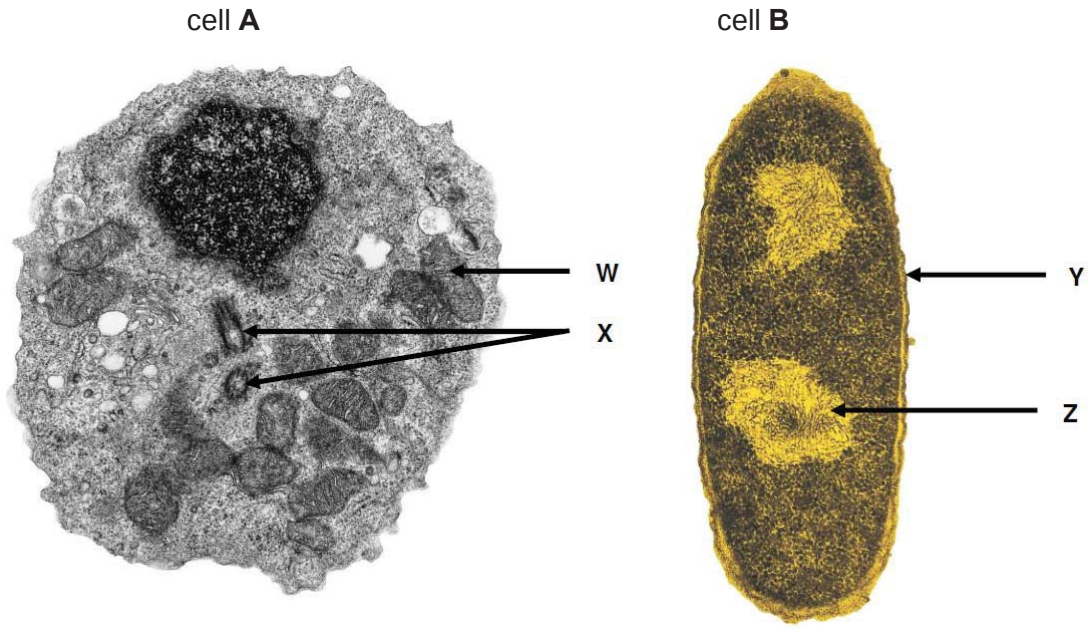


Fig. 1.1

(a) Name the structures labelled **W** to **Z** in Fig. 1.1.

W Mitochondrion *(Reject: Mitochondria)*

X Centrioles *(Reject: Centriole, Centrosome)*

Y Peptidoglycan cell wall *(Reject: Cell wall)*

Z Nucleoid *(Reject: DNA, Chromosome)*

[2]

4 correct – 2 marks

2-3 correct – 1 mark

0-1 correct – 0 mark

(b) Some scientists support the theory that structure **W** in cell **A** originated from cell **B**.

(i) Give two pieces of evidence that support this theory.

- Circular DNA
- 70S ribosomes
- No introns
- No histones
- Similar size (1 to 10 microns)
- Similar shape (oval / oblong)
- Use oxygen in ATP production
- Multiply by binary fission
- W has double membrane

[2]

(ii) Explain why it is advantageous for cell **A** to have many copies of structure **W**.

(role of mitochondria)
able to respire aerobically

(advantage of having many mitochondria)
can produce more ATP / release more energy

[2]

(c) Outline the process in which cell **B** divides into two cells.

1. Binary fission
2. (description of DNA replication)
3. (description of chromosome segregation)
4. (description of cell separation)

[3]

(d) A scientist investigated the effect of a specific drug on two strains of the same species of cell **B**.

- One strain, SR, shows a **stringent response** in the presence of this drug. Part of the response involves stopping cell division. This gives this strain a greater resistance to the effect of this drug.

- The other strain, non-SR, cannot carry out a stringent response.

The scientist grew cultures of the SR strain and the non-SR strain containing the same number of cells. He then stopped each strain from dividing and exposed them to different concentrations of the drug. After a fixed time, he estimated the number of living cells remaining in the cultures.

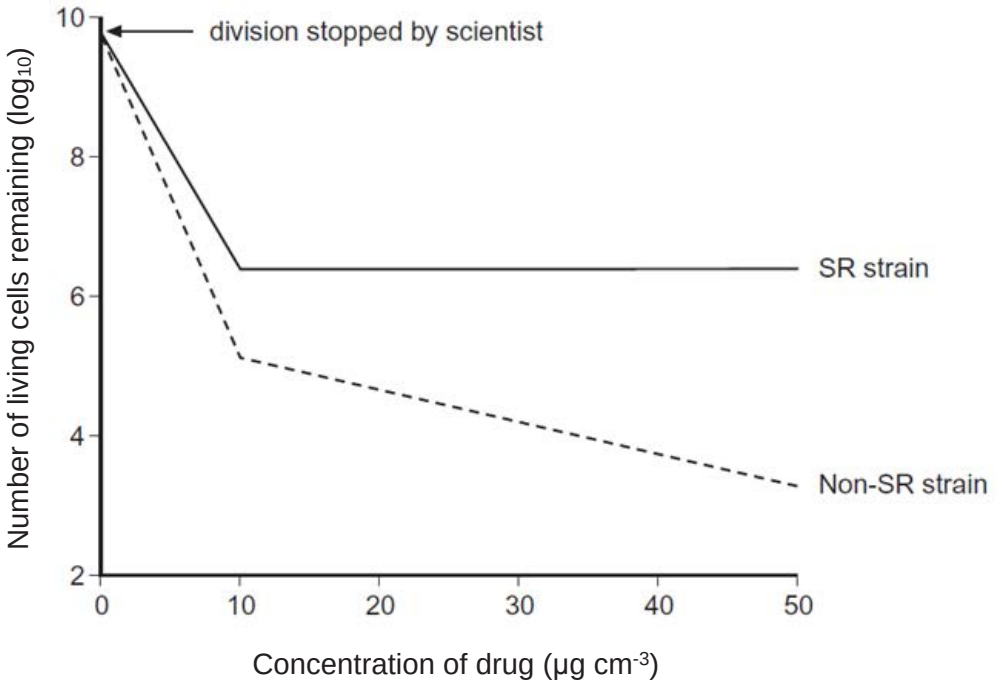


Fig. 1.2

(i) With reference to Fig. 1.2, describe the differences in the effect of increasing the concentration of drug on the SR strain and the non-SR strain.

In general (from 0 to 50 µg/cm^3 of drug), the difference between the number of living cells of SR strain remaining and that of non-SR strain increases with increasing concentration of drug.

From 0 to 10 µg/cm^3 of drug, non-SR strain shows a greater decrease ($10^{9.8}$ to $10^{6.4}$ cells) in the number of living cells remaining than SR strain ($10^{9.8}$ to $10^{5.1}$ cells).

From 10 to 50 µg/cm^3 of drug, number of living cells of SR strain remaining stays constant at $10^{6.4}$ cells while that of non-SR strain descreases from $10^{5.1}$ to $10^{3.2}$ cells.

Bonus mark: Correct number of living cells remaining stated when describing the decrease for SR or non-SR strain

[3]

(ii) The scientist concluded that stopping cell division is not the only way in which the stringent response gives resistance to this drug.

Explain how Fig. 1.2 supports this conclusion.

Even though cell division of both strains was stopped by the scientist at the start of the experiment, there was still more living cells of SR strain than non-SR strain remaining regardless of the drug concentration.

[1]

(e) Another scientist attempted to sequence the genome of cell **A**. Due to the sheer size of the genome, the chromosomes could not be sequenced directly. Each chromosome must first be digested by a restriction enzyme into smaller fragments. Each purified restriction fragment is then sequenced – a process that involves two procedures.

Fig. 1.3 shows the first procedure of the sequencing process, which is a modified Polymerase Chain Reaction (PCR). The DNA sample is divided into four separate sequencing reactions, each containing all four of the standard deoxynucleotides and the DNA polymerase. Only one of the four dideoxynucleotides (ddG, ddA, ddT, or ddC) is added to each reaction.

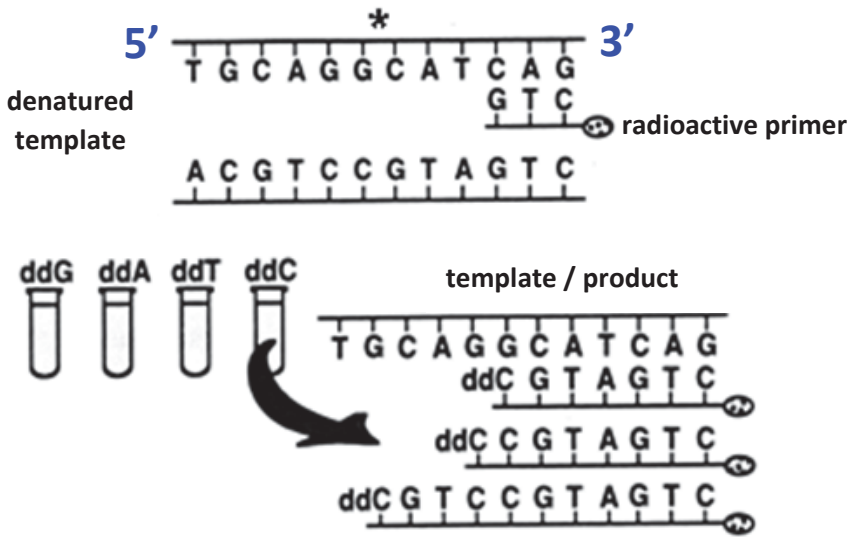


Fig. 1.3

Fig. 1.4 shows the structure of a dideoxyribonucleotide.

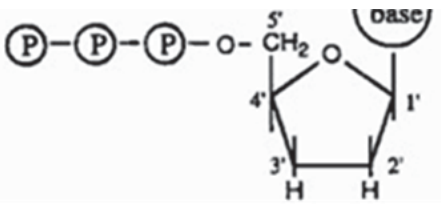


Fig. 1.4

The second procedure of the sequencing process produces a result shown in Fig. 1.5, from which the DNA sequence can be read.

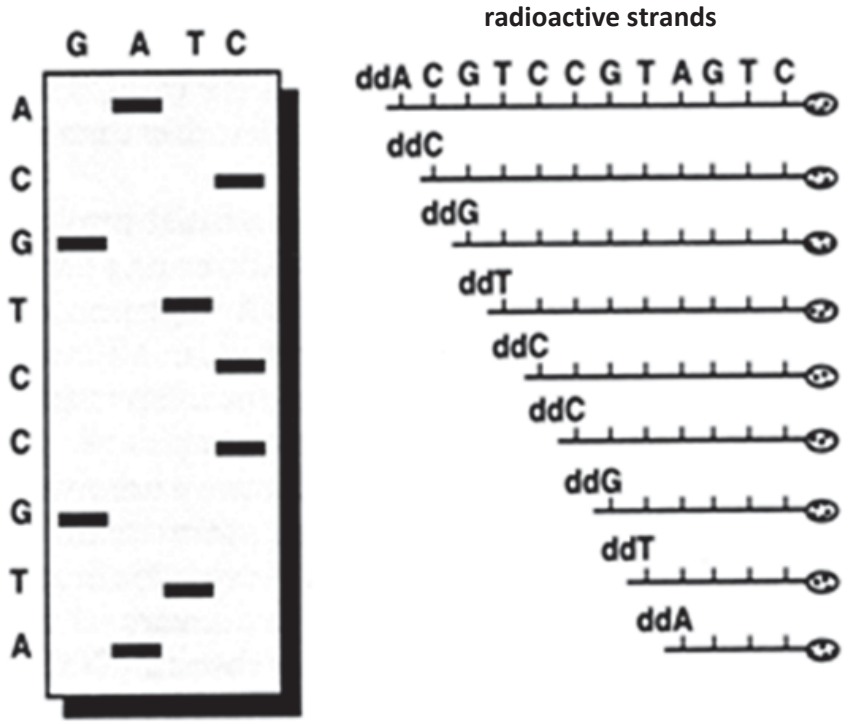


Fig. 1.5

(i) On Fig. 1.3, label the 5’ and 3’ ends of the DNA marked with an asterisk (*). [1]

(ii) Describe four features that distinguish the process in Fig. 1.3 from that of *in vivo* DNA replication.

feature of comparison	modified PCR	*in vivo* DNA replication
DNA polymerase used	Taq polymerase (heat-resistant) (lacks proofreading ability)	DNA polymerase (not heat-resistant) (has proofreading ability)
primers used	radioactive DNA primers	non-radioactive RNA primers
DNA replication	continuous	continuous for leading strand, discontinuous for lagging strand
temperature	three different temperatures (94°C → 64°C → 72°C)	one temperature
location	within PCR tube in thermocycler	within cell
separation of the two strands of DNA	by heat	by helicase
nucleotides	four types dNTPs and one type of ddNTPs	four types of dNTPs
template strand	only one of the two parental strands is used	both parental strands are used
specificity of DNA replication	selective (specified by primer)	non-selective (whole DNA strand)

[4]

(iii) With reference to Fig. 1.4, explain the need to use dideoxyribonucleotides in the sequencing process.

Absence of 3'-OH group in the deoxyribose

Cannot form phosphodiester bond between adjacent nucleotides

DNA chain elongation stopped

DNA fragments of varying length can be separated and analysed to determine the DNA sequence.

[2]

(iv) Describe the procedure that would give rise to the result shown in Fig. 1.5.

Gel electrophoresis

An agarose gel was submerged in a buffer solution containing ions that will conduct electricity.

DNA fragments were loaded into wells close to the cathode / negative electrode.

A direct current was applied at opposite ends of the gel.

Negatively charged DNA moved toward the anode / positive electrode.

Shorter DNA fragments moved faster and further than longer ones.

Autoradiography / X-ray film was used to see the radioactive DNA bands.

[5]

[Total: 25]

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CANDIDATE NAME			
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

Section B

For Examiner's Use	
Section B	
2	/25

Section B

Answer the question in this section.

2 (a) First seen as poisons, then as life-forms, then biological chemicals, viruses today are thought of as being in a grey area between living and nonliving.

State three characteristics of life and for each, explain how dengue virus (DENV) challenges the concept of what is considered living.

Characteristic of life	Virus as non-living
1. Organisation	Viruses lack organelles and cellular structures, hence are considered acellular.
2. Metabolism	Viruses cannot generate or store energy and lack metabolic machinery e.g. mitochondria, ribosome.
3. Growth	Viruses do not grow in size.
4. Homeostasis	Viruses do not have the ability to carry out homeostasis.
5. Adaptation	
6. Response to stimuli	Viruses do not respond to stimuli outside a host cell. Many viruses do not have a latency phase in their life cycles.

[4]

(b) DENV infects its host cell through interaction with specific receptors. Human monocytes and mouse neural cells are main targets of DENV infection.

Fig. 2.1 shows the reproductive cycle of DENV, a single-stranded positive-sense RNA virus.

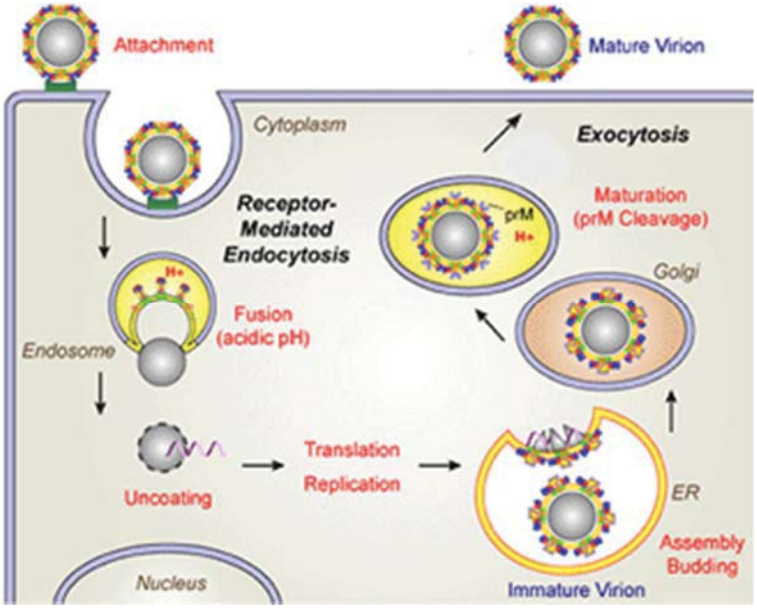


Fig. 2.1

With reference to Fig. 2.1, describe the differences between the reproductive cycles of DENV and human immunodeficiency virus (HIV).

	DENV	**HIV**
Entry	DENV enters by receptor-mediated endocytosis.	Fusion of viral envelope and host cell membrane
Fusion of membranes within host cell	Fusion of viral envelope and endosomal membrane	No fusion within host cell
Integration	No integration of viral genome	Integration of viral genome
Replication of viral genome	Viral (+)ssRNA genome replicated by viral RNA-dependent RNA polymerase, using viral (+)ssRNA as template	Proviral DNA is replicated as infected T-cell replicates. Viral (+) ssRNA genome is transcribed from the integrated proviral DNA by host RNA polymerase.
Release	Exocytosis	Budding

[3]

(c) When a pathogen like DENV invades the human body, the main defence against such pathogen is the immune system.

Briefly explain one advantage and one disadvantage of the innate and adaptive immune responses against invading DENV.

	Advantage	**Disadvantage**
Innate Immunity	rapidly recognizes and responds to pathogens ability to recognise a large range of antigen through non-specific binding	does not provide a person with long-term immunity against an invading pathogen
Adaptive immunity	produces T and B cells that **specifically and efficiently** target the pathogen and infected cell, e.g. antibody-secreting B cells and cytotoxic T cells long-term immunity through development of memory cells	takes longer to respond to an invading pathogen than the innate immune response

[4]

(d) DENV is a member of the genus *Flavivirus*, which contains a number of important human pathogens, usually vector-borne. DENV is particularly notable in that it exists as four antigenically distinct serotypes (denoted as DENV-1 to DENV-4), within which there is considerable genetic variation in the guise of phylogenetically defined "genotypes".

Fig 2.2 shows a phylogenetic tree of DENV serotypes based on the analysis of non-structural-5 (*NS-5*) gene from DENV using molecular methods.

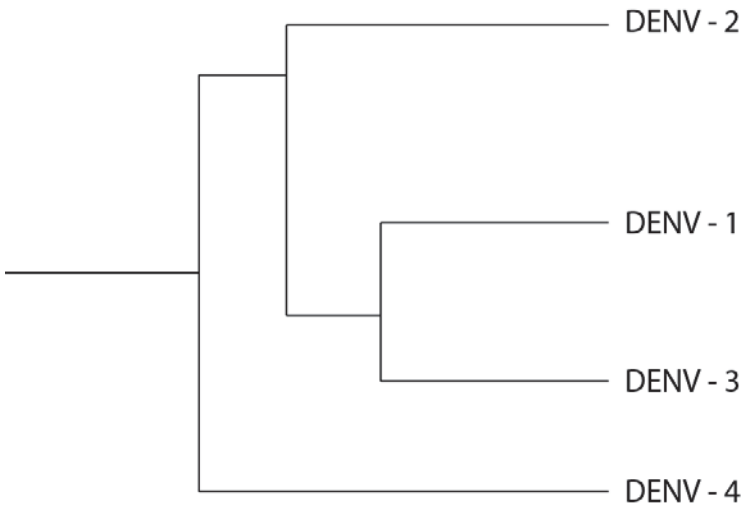


Fig. 2.2

(i) Explain the advantages of using molecular methods in classifying viruses.

1. Analysis of molecular data is **objective** since the comparison of bases A,T,C,G present is unambiguous, whereas criteria for comparisons involving the shape of a structure may be difficult to standardise. Therefore, classification based on observable characteristics like anatomy may be subjective.
2. **Less difficulty in defining characters** for molecular data as compared to structural features / differentiate two organisms with similar morphologies or very different morphologies
3. Molecular data are **readily available for analysis** and can be **easily interpreted**
4. Allow us to compare **neutral changes** in organisms
5. For molecular data, differences in DNA / amino acids can be **quantified** by analysing nucleotide and amino acid sequences. The degree of relatedness can be inferred and quantified by calculating the nucleotide differences between species.
6. Conversely, small genetic differences, may result in major phenotypic differences. In such instances, vast differences in morphology can exaggerate the evolutionary distance between two species

[3]

(ii) Describe the phylogenetic tree of DENV serotypes shown in Fig. 2.2.

1. DENV-4 first diverge
2. Followed by DENV-2 and the
3. final split between DENV-1 and DENV-3

[3]

(iii) A different research group published another version of phylogenetic tree of DENV serotypes.

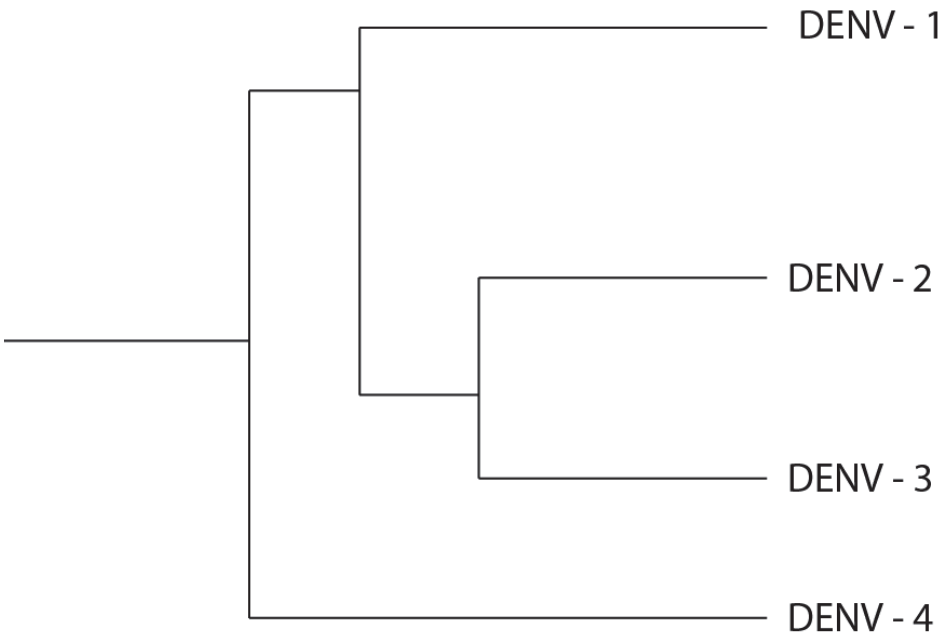


Fig. 2.3

Suggest one reason why the phylogenetic tree in Fig. 2.3 is different from that in Fig. 2.2.

1. Use of different gene segment during nucleotide analysis
2. DENV 1, 2 and 3 are too closely related to each other, molecular analysis not able to distinguish them with confidence [1]

(iv) One question on the origin of DENV is why it exists as four distinct serotypes. This can be explained in two ways:

- through geographical partitioning in different primate populations
- evolution in sympatry (within a single population)

Using your knowledge in evolution, explain how DENV has evolved into four distinct serotypes through geographical partitioning.

1. Dengue viruses infects primates
2. Primates move to different geographical regions/presence of physical barrier resulting in geographical isolation→ genetically isolated
3. Dengue viruses accumulates mutation independently through antigenic drift
4. Differential selection pressure → Alleles more adapted will have higher chance of being passed on to the next generation / differential reproductive success
5. no gene flow to allow for genetic recombination and reassortment (antigenic shift) → evolved into different serotypes through time

[4]

(v) Suggest how evolution into the four DENV serotypes can take place through sympatry.

1. **Mutation in the DENV receptor** resulting in **binding of DENV to different cell types**, preventing **antigenic shift**

[1]

(vi) Suggest and explain one possible selection pressure for the evolution into the four DENV serotypes.

1. Neutralizing antibodies and other specific host immune response
2. Explain: negative selection pressure, e.g. removal of virus from the body, unable to replicate in host cell
3. Non-neutralizing antibodies
4. Explain: positive selection, e.g. unable to neutralized virus, DHF → increase infectivity of virus
5. Presence of sufficient vector (e.g. mosquitoes)
6. Explain: negative / positive selection, e.g. more mosquitoes increase transmission of DENV
7. Temperature of host
8. negative / positive selection, e.g. increase temperature in the environment will affect mosquito reproduction/DENV reproduction in mosquito

[2]

[Total: 25]

Section C

Answer **one** question in this section.

Write your answers on the separate answer paper provided.

Your answers 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 section (a), (b) etc., as indicated in the question.

3 (a) With reference to named examples, explain how the gene expression in prokaryotes can be regulated using inducible and repressible systems. [13]

A. Inducible [max 9]

1. E.g. **lac operon**;
2. Lac operon controls the expression of genes that encode proteins involved in the **breakdown of lactose** / an inducible system controls the expression of genes that encode proteins involved in a **catabolic pathway**;
3. Transcription is usually turned off, and is **turned on only in the presence of lactose / an inducer**;
4. **Negative control** by **Lac repressor** coded by *lacI* gene which is constitutively expressed;
5. In the absence of lactose, **Lac repressor** is in active form and **binds to operator**;
6. **RNA polymerase cannot bind to promoter**, **preventing transcription**;
7. In the presence of lactose,
    a. **lactose is transported into the cell** via lactose permease;
    b. and β-galactosidase **converts lactose to allolactose**;
8. **Allolactose binds to lac repressor;**
9. **changes its three dimensional conformation**, **inactivating the Lac repressor**;
10. **Lac repressor can no longer bind to the operator**,
11. **RNA polymerase can now bind to promoter**, **allowing transcription** of *lacZ*, *lacY*, and *lacA* genes;
12. **Positive control** by **catabolite activator protein** (CAP);
13. In the presence of lactose, when **glucose** levels is **high**, **cAMP** levels is **low**;
14. CAP is **inactive** and **cannot bind to CAP site**, hence **rate of transcription** is **low**;
15. When **glucose** level is **low/absent**, **cAMP** levels **increases**;
16. **cAMP binds to CAP**;
17. **changes its three dimensional conformation**, **activating CAP**;
18. **Active cAMP-CAP complex binds to CAP site**, **increasing rate of transcription** by RNA polymerase;

B. Repressible [max 6]

19. E.g. **trp operon**;
20. trp operon controls the expression of genes that encode proteins involved in the **synthesis of tryptophan** / a repressible system controls the expression of genes that encode proteins involved in an **anabolic pathway**;
21. Transcription is usually turned on, and is **turned off when tryptophan / co-repressor is in excess**;
22. **Negative control** by **Trp repressor** coded by *trpR* gene which is constitutively expressed;
23. At low levels of tryptophan, **Trp repressor** is in **inactive** form and cannot bind to operator;
24. **RNA polymerase can bind to promoter**, **allowing transcription** of *trpE*, *trpD*, *trpC*, *trpB*, and *trpA* genes;
25. When levels of tryptophan is high, **tryptophan binds to Trp repressor**;
26. **changes its three dimensional conformation**, **activating the trp repressor**;
27. **Active Trp repressor binds to the operator**;
28. **RNA polymerase cannot bind to promoter**, **prevent transcription**;

Award once only:

- 6 and 28
- 11 and 24

QWC [1]

Clear, organised flow without ambiguity to include separate sections on inducible and repressible systems;

(b) Explain the advantages of regulating gene expression at different levels in eukaryotes and suggest why prokaryotes have fewer levels of gene regulation. [12]

Advantages: [at least 1 per level, max 8]

1. Chromatin Level

a. **Longer term switching genes on and off** to restrict expression of genes;

b. Allow for **specialisation/differentiation** of cells;

c. **More efficient / less wasteful of resources** as only genes required for cellular functions are expressed; (only awarded at chromatin level – most significant)

2. Transcriptional Level

a. Rate of transcription can be regulated to **meet shorter term requirement** of the cell;

b. Combinatorial control allow **flexibility in regulation** of transcription in **response to changes in signals or stimuli spatially and temporally**, when the appropriate combination of specific transcription factors are present;

c. Coordinate control allow **simultaneous transcription** of genes with related functions/involved in the same metabolic pathway in the presence of the activators;

3. Post-Transcriptional Level

a. Alternative splicing allow for production of **different proteins variants from a single gene**;

b. **Degradation** of **unprocessed or incompletely processed mRNAs prevent wastage of resources** in translation of these mRNAs;

4. Translational Level

a. Half-life of RNA will affect **how long translation of the mRNA can occur** and hence the amount of protein produced, **preventing continuous translation** of mRNA and production of proteins that may not be needed;

b. **Polyribosomes** can **translate mRNA at the same time** to make **multiple copies** of a polypeptide very quickly;

5. Post-translational Control

a. Allow for **rapid production of functional protein from stored precursor** by phosphorylation/cleavage for **immediate responsiveness** to cell conditions / signals; (accept able to convert between active and inactive form quickly in response to signals)

b. Allow for activation of protein where it is needed ensuring **safe transport / storage** of **inactive** form of protein;

c. Allows **recycling of amino acids** from proteins that are no longer required for cellular functions;

Fewer levels in prokaryotes:

6. Prokaryotes are **unicellular** or colonial / do not organise into tissues, organs, and systems hence they **do not specialise** in any particular function, and there is **no need long term switching on and off of genes controlled at the chromatin level**;

7. Control of gene expression in prokaryotes occurs **mainly at the transcriptional level** to allow each cell **express different genes at different times in response to the transient resources** available in the environment (to meet short term requirement);

8. **Operon** systems in prokaryotes enable **coordinate control** of related genes by clustering and regulating them under a single promoter unlike in eukaryotes where related genes are scattered and usually on different chromosomes, hence their **transcriptional level** of control is **less complex**;

9. Prokaryotes **lack introns**, hence **unable to have (alternative) splicing**;

10. Prokaryotes **lack nuclear envelope/nucleus**, hence **transcription and translation occur simultaneously**, and they **cannot have post-transcriptional control and translational control is limited**;

11. Prokaryotes **lack membrane-bound organelles** required for many post-transcriptional modification, hence they have **limited post-translational control**;

QWC [1]

Scientific argumentation is exemplified by having

- **At least one advantage of regulating gene expression linked coherently to the correct stage of the process**
- **At least one characteristic of prokaryotes that is different from eukaryotes linked coherently to why prokaryotes have fewer levels of control**

[Total: 25]

4 (a) Explain the need for a large amount of non-coding sequences in eukaryotes. [13]

1. Centromeres

a. Centromeres are the constricted regions on chromosomes where **two sister chromatids are attached** during nuclear division;
b. Centromeres allow **attachment of spindle fibres/microtubules** via **kinetochore** proteins;
c. This enables the **separation of sister chromatids or homologous chromosomes** to opposite poles of the cell during nuclear division;

2. Telomeres

a. Telomeres are the **ends of linear eukaryotic chromosomes**;
b. At one of the two ends of chromosomes, there is a **single-stranded 3' overhang** which **folds back and hybridises with the same complementary sequence in the opposite strand**, stabilised by **telomere-binding proteins**;
c. Telomeres **prevent the ends of chromosomes from degradation by exonucleases**;
d. Telomeres **prevent fusion of the ends of different chromosomes**;
e. Telomeres provide a counting mechanism for the number of cell division a cell has undergone, thus **preventing unlimited cell proliferation** in adult tissue;

3. Introns

a. Introns are non-coding sequences **interspersed between exons in genes**;
b. After transcription, introns are **excised** through **RNA splicing**;
c. Introns allow **alternative splicing** to occur, producing **different mRNAs** which give rise to **different proteins**, using a **single gene**;

4. Promoters

a. Promoters are found **upstream** of the **transcription start site** of genes;
b. Promoters serve as **recognition sites** for the binding of **general transcription factors** and **RNA polymerase** to **initiate transcription**;

5. Enhancers and silencers

a. Enhancers and silencers are **regulatory elements**, usually found distal from the promoter,;
b. **Enhancers** can be bound by **activators** which **increases the rate of transcription**;
c. **Silencers** can be bound by **repressors** which **decreases the rate of transcription**;

QWC

Clear, organised flow without ambiguity and to include at least 4 different types of non-coding sequences and their roles;

(b) Explain the normal functions of embryonic stem cells (ESCs), distinguish between ESCs and induced pluripotent stem cells (iPSCs), and compare the pros and cons of their use in research and medical applications. [12]

A. Normal functions of ESCs [at least 2]

1. ESCs are derived from cells of the **inner cell mass of blastocyst**, about 4 to 5 days post fertilisation;
2. The inner cell mass will eventually **develop into the fetus**;
3. They are **pluripotent** and can give rise to **any type of cells in the body, except extra-embryonic cells**;
4. They **lack self-organising ability** to form an entire organism;

B. Distinguish ESCs and iPSCs [1]

1. ESCs are pluripotent stem cells **derived from inner cell mass of blastocyst**; same as A1 – award once only
2. iPSCs are **normal adult somatic cells that are reprogrammed to be pluripotent**;

C. Pros and Cons of ESCs vs iPSCs

Similarities: [at least 2]

1. Pros: Both are pluripotent and are able to be induced to **differentiate to any type of cells** in the body;
2. Cons: Both have the potential of continued self-renewal, hence both have risks of resulting in **uncontrolled cell division / formation of tumour**;
3. Cons: Differentiation of cells is difficult to control and cells **may change into unintended types of cells** in the body;
4. Pros: Both can be easily cultured in laboratories in large quantities;

Differences [at least 3]

ESCs	**iPSCs**
1. **Need to ensure match in antigens / immunocompatibility** since donor's antigens will be different from patients	**No need to ensure match in antigens / immunocompatibility** since cells are from patient and will have same antigens
2. Has **risk of rejection** by immune system	**No risk of rejection** by immune system
3. **Need for immunosuppressant** to prevent rejection, which might lead to weakened immune system	**No need for immunosuppressant** to prevent rejection
4. **Lower risk of uncontrolled cell division / tumour formation** as genome is not altered / cells obtained from inner cells mass is in the early developmental stages and have less accumulation of mutations	**Higher risk of uncontrolled cell division / tumour formation** as genome is artificially reprogrammed by insertion of genes / cells obtained from adult somatic cells which is late in the developmental stages and may have accumulated mutations
5. The harvest of ESCs involved usage and destruction of human embryo which would **raise ethical concerns as it violate the sanctity of life and is tantamount to murder**	**Overcomes the ethical issues** caused by the use of ESCs as cells are obtained from patients themselves
6. More costly due to the need to ensure successful in vitro fertilisation and check for immunocompatibility	Less costly as cells are obtained from patients

QWC [1]

Scientific argumentation is exemplified by having

- **Direct comparison with one similarity and one difference of pros and/or cons of ESCs and iPSCs of their use in research and medical applications**

[Total: 25]

H

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Practical Examination
Higher 2

CANDIDATE NAME	**ANSWERS**		
BIOLOGY CLASS	2bi2_____/2IPbi2_____	REGISTRATION NUMBER	

Biology

9744/04

Paper 4 Practical

15 August 2017

2 hours 30 minutes

READ THESE INSTRUCTIONS FIRST

Write your name and Biology class on all the work you hand in.
Circle your practical shift and laboratory in the boxes.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions 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 workings 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 the brackets [ ] at the end of each question or part of question.

Shift		
1	2	3
Laboratory		
BI23	BI24	CM44

For Examiner's Use	
1	**21**
2	**20**
3	**14**
Total	**55**

This document consists of **25** printed pages.

1 In this question, you will investigate the effect of the colour of light on the rate of photosynthesis.

The light-dependent reaction of photosynthesis can be examined by the reduction of an artificial electron acceptor, 2,6-dichlorophenolindophenol (DCPIP). DCPIP is blue when oxidised, and turns colourless when reduced.

oxidised DCPIP (blue) → reduced DCPIP (colourless)

In this experiment, chloroplast suspension will be mixed with oxidised DCPIP solution, which will give a blue-green solution.

chloroplast + oxidised DCPIP (blue-green) → chloroplast + reduced DCPIP (green)

You are provided with:

- chilled chloroplast suspension in a brown vial with lid
- oxidised DCPIP solution
- 5 cm^2 cellophane papers of two different colours (red and green)
- access to spectrophotometer (wavelength set at 620 nm)

*Read through steps **1** to **11** and prepare a table to record your results in **(a)**, before starting the investigation.*

Proceed as follows:

1 Wrap the bottom part of a test tube with a red cellophane paper and secure it with a rubber band near the top edge of the cellophane paper.

2 Repeat step **1** with a green cellophane paper.

3 Prepare a chloroplast-DCPIP mixture by adding 2 cm^3 of DCPIP solution to 18 cm^3 of chloroplast suspension in a 50 ml beaker. Gently swirl the beaker to ensure homogeneity. The mixture should appear blue-green. If the mixture appears light green, add another 1 cm^3 of DCPIP solution.

4 Wrap the 50 ml beaker containing the chloroplast-DCPIP mixture with aluminium foil to prevent exposure to light.

5 Add 3 cm^3 of chloroplast-DCPIP mixture into each of the two test tubes prepared in steps **1** and **2**, and another test tube not wrapped with coloured cellophane paper.

6 Place all three test tubes at a distance of 10 cm from the lamp and switch on the lamp for five minutes.

7 After five minutes, decant the solution in each test tube to a plastic cuvette.

8 Blank a spectrophotometer with about 3 cm^3 of chloroplast suspension (without DCPIP) at 620 nm, and then measure the absorbance of the solution in each cuvette.

9 Repeat steps **5** to **8** with clean test tubes to obtain a second set of readings.

10 Prepare a boiling water bath. Add 18 cm^3 of chloroplast suspension to a boiling tube and boil it for about three minutes. Allow the chloroplast suspension to cool to room temperature.

11 Repeat steps **3** to **9** with the boiled chloroplast suspension.

(a) Record your results in a suitable form in the space below.

Table of absorbance of chloroplast-DCPIP mixture containing unboiled or boiled chloroplasts under different colours of light

chloroplasts	colour of light	absorbance of the solution at 620 nm / Abs		
		reading 1	reading 2	average
unboiled	red			
	green			
	white / colourless			
boiled	red			
	green			
	white / colourless			

Data:
There should be a total of 12 raw data recorded in the table.

Average:
Any recorded average absorbance must be calculated correctly.

Precision:
All recorded absorbance must be written in 3 decimal places.

Trends:
For unboiled, absorbance should be the highest for green light and lowest for white light. For boiled, all absorbance should be similar or higher than that for unboiled, green light.

Headings:
(as shown in the table above)

[5]

(b) Use the grid below to display your results from **(a)**.

Type of graph:
Since colours of light are discrete categories, a bar graph should be drawn rather than a line graph. Bars should have equal width and all six bars should not stick together like a histogram.

Axis labels and orientation:
y-axis: dependent variable (average absorbance)
x-axis: independent variable (colours of light)
The x-axis label and markings should make sense.

Scale for both axes:
At least half the grid (i.e. 35 out of 70 big squares) should be occupied by the bars drawn. Bars should be evenly spaced out. Markings on the y-axis should also be equidistant. Precision of average absorbance should be consistent (same for all y-axis markings and same as in table).

Points plotted:
All points must be accurately plotted with a sharp pencil and within the grid area. If the value of the point is at the grid line, the point should be plotted on the grid line and not above/below it.

[4]

(c) Describe the purpose of having a test tube not wrapped with coloured cellophane paper in the given procedure.

It acts as a positive control to show that photosynthesis will occur in the presence of light, therefore any change in the rate of photosynthesis is solely due to the change in the colour of light available for photosynthesis.

[1]

(d) Discuss the need for step 11.

It acts as a negative control to show that reduction / decolourisation of DCPIP will only occur when chloroplasts carry out photosynthesis.

Boiling denatures proteins / enzymes required for photosynthesis.

Just need to do one tube with boiled chloroplasts under white light (rather than three tubes with boiled chloroplasts under red/green/white light).

[3]

(e) Discuss what your results from **(a)** suggest about the effect of the colour of light on the rate of photosynthesis.

Rate of photosynthesis is higher under red light than green light.

Accept: Correct description of trend obtained by the student in (a)

Reference to photosynthetic pigments / light absorption / DCPIP reduction

e.g. More red light is absorbed by the photosynthetic pigments in the chloroplasts / Green light is reflected by the chloroplasts / Greater reduction in the blue-green colour intensity of the chloroplast-DCPIP mixture under red light.

[2]

(f) **(i)** Identify one significant source of error in the given procedure.

- The lamp is not the only source of light for photosynthesis.
- Heat is emitted from the lamp.

[1]

(ii) Suggest one modification to the given procedure to reduce the errors identified in **(f) (i)**.

- Perform the experiment in dim light.
- Place a beaker of water / clear glass block to serve as a heat shield between the lamp and the tubes.

[1]

(g) One student did a similar experiment with eight replicates to determine the effect of red light and blue light on the rate of photosynthesis.

Table 1.1 shows the results obtained by the student.

Table 1.1

absorbance of the solution at 620 nm / Abs	
red light	blue light
0.047	0.040
0.055	0.044
0.049	0.032
0.045	0.045
0.050	0.039
0.044	0.042
0.060	0.050
0.052	0.036

Carry out a t-test to determine if red light and blue light have the same effect on the rate of photosynthesis at 5% level of significance, assuming a normal distribution and equal variance.

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

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

Keys to symbols:
s = standard deviation $\bar{x}$ = mean n = sample size
x = observation v = degree of freedom

(Please refer to the t-table given to you separately.)

You may continue your workings in the space on the next page.

Let μ_1 represent the population mean of the absorbance of the solution under red light.
Let μ_2 represent the population mean of the absorbance of the solution under blue light.

H_0: μ1 = μ2
H_1: μ1 ≠ μ2

[1 mark awarded for correct hypotheses]

Using GC,
$\bar{x_1}$ = 0.05025
$\bar{x_2}$ = 0.041
s_1 = 0.005338539
s_2 = 0.005580579
t-value = 3.387719986 = 3.39 (2 dp)
p-value = 0.0044195444
Degrees of freedom = 14

[1 mark awarded for stating correct sample means, standard deviations and t-value or p-value]

From the t-table,
At p = 0.975, critical t-value is 2.145.
Calculated t-value > critical t-value
OR
p-value from GC < 0.05

[1 mark awarded for making the above comparison relating to t-value / p-value]

We reject H_0 / accept H_1 and conclude that at 5% significance level, there is significant difference in the effect of red light and blue light on the rate of photosynthesis. Any difference is not due to chance or sampling error.

[1 mark for correct conclusion]

[4]

[Total: 21]

2 In this question, you will investigate the water potential of potato tissue and onion epidermis.

You are provided with known concentrations of sucrose and distilled water as shown in Table 2.1.

Table 2.1

solution	concentration of sucrose solution / mol dm^{-3}
W	0.0
S1	0.3
S2	0.6
S3	1.0

You are also provided with:

- potato cylinders
- methylene blue solution
- onion scale leaf incubated in solution **S3**

*Read through steps **1** to **9** and prepare a table to record your results in **(a)**, before starting the investigation.*

Proceed as follows:

1 Add 6 cm^3 of distilled water into a test tube and label it "**W**". Place another 3 cm^3 of distilled water into a vial and label it "**W-blue**". Add one drop of methylene blue into the vial **W-blue** and mix well. This would colour the distilled water blue without significant alteration of the water potential.

2 Repeat step 1 to dispense sucrose solution **S1**, **S2** and **S3** into appropriately labelled test tubes and vials.

3 Using a scalpel, ensure that any potato skin present is trimmed off. Cut the potato cylinders into 5 mm thick discs

4 Place 10 potato discs into the test tube **W** and leave it to incubate for 25 minutes. Ensure that the discs are completely soaked in the solution. During this time, you may proceed on to part **(f)** or other parts of the Question Paper.

5 After 25 minutes, decant the liquid in test tube **W** into a suitably labelled clean test tubes.

6 With a Pasteur pipette, collect a small amount of the coloured solution in the vial **W-blue**.

7 Very gently, by squeezing on the Pasteur pipette, introduce one drop of the coloured liquid into the centre of the decanted liquid from **W** as shown in Fig. 2.1. Be careful not to disperse the coloured liquid with any sudden squeezing of the Pasteur pipette. Withdraw the pipette slowly.

Fig. 2.1

8 Observe whether the drop of coloured liquid remains in the same position, floats or sinks, and how fast it occurred. Release another drop of coloured liquid and continue until you are certain you have made the correct observation about the behaviour of the drop of coloured liquid.

9 Using clean pipettes, vials and test tubes, repeat steps 4 to 8 with solution **S1**, **S2**, and **S3** in turn. In a similar manner, introduce one drop of coloured liquid from **S1-blue**, **S2-blue**, and **S3-blue** into the decanted liquids of **S1**, **S2**, and **S3** respectively, after incubating the potato discs for 25 minutes.

(a) Record your observations in the space below.

concentration of sucrose solution / mol dm^{-3}	observation
0.0	floats slowly
0.3	sinks very slowly
0.6	sinks slowly
1.0	sinks quickly

H1: Correct heading for independent variable (name of solution / concentration of sucrose with units)

H2: Correct heading for dependent variable (observation)

O: records four observation for S1 to S3 and W

T: records W as “floats” and S3 as “sinks”

R: records relative rates of movement

[4]

(b) If the coloured drop sinks, it implies that the coloured drop is denser than the decanted liquid. Suggest why the decanted liquid becomes less dense after the incubation with potato discs.

Max two from:

1. Relationship between density, mass and volume
2. Volume of water surrounding potato / incubating liquid increased
3. Mass of sucrose remained the same [2]

(c) Explain the behaviour of the coloured drop in the liquid decanted from tube S1 in terms of movement of water molecules and water potential of the potato tissue.

Max four from:

1 **F** Coloured drop in S1 **floats** because the **decanted liquid became more dense**;

2 **F** Potato cells contains **more solutes in cytoplasm** / cell sap in vacuole than S1

3 **F** **Water potential** in potato cells is **more negative** than S1;

4 **F** Water molecules move from surrounding **S1 into potato cells**

5 **F** **Osmosis** across cell membrane into potato cells

6 **F** Liquid surrounding S1 become more dense because **mass of sucrose / number of molecules of sucrose remains unchanged but volume in surrounding decreases**

1 **S** Coloured drop in S1 **sinks** because the **decanted liquid became less dense**

2 **S** Potato cells contains **less solutes in cytoplasm**/cell sap in vacuole than S1

3 **S** **Water potential** in potato cells is **more positive** than S1

4 **S** Water molecules moves from **potato cells to surrounding S1**

5 **S** **Osmosis** across cell membrane into the solution

6 **S** Liquid surrounding S1 become less dense because **mass of sucrose / number of molecules of sucrose remains unchanged but volume in surrounding increase**

[4]

(d) A student wanted a more accurate estimation of the range of sucrose concentration of the potato tissue.

Describe two modifications to the method that can increase the accuracy of the estimated range of sucrose concentration found in the potato cells.

1. Decrease the interval of sucrose concentrations to intervals of 0.01 mol dm^{-3} / increase the number of different sucrose concentrations used between 0.2 to 1.0 mol dm^{-3}
2. Dimensions of potato discs cut may not be accurately obtained using a ruler and scalpel, use a microtome to minimize variations
3. AVP

---

[2]

(e) Another student conducted a similar experiment to investigate the effect of placing pieces of potato tissue in varying concentrations of sucrose solution by measuring the change in mass of the potato tissue after incubation.

At the start, each potato tissue was weighed to obtain the initial mass. Each sample of potato tissue was then incubated in a different concentration of sucrose solution for a set time. After the incubation time, the potato tissue was removed and the final mass of the potato tissue was recorded.

The results of his investigation were tabulated and a graph was drawn as shown in Fig. 2.2.

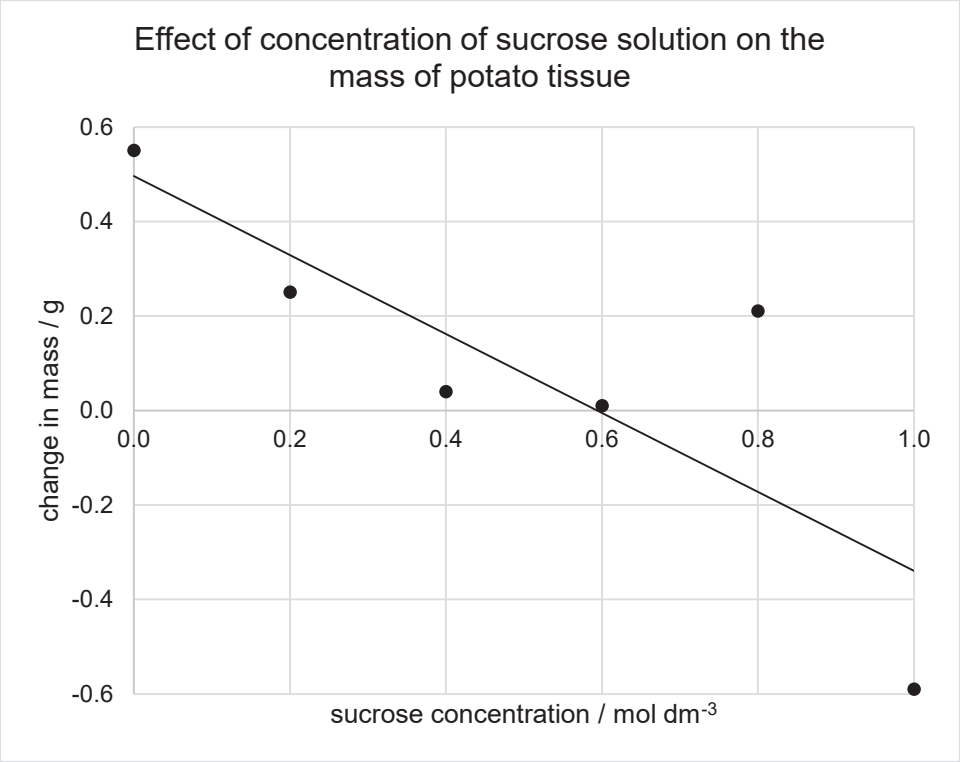


Fig. 2.2

(i) Circle the data point that is likely to be an anomaly. [1]

Circle plotted point at the 0.8 mol dm^{-3} sucrose

(ii) Based on your understanding of water potential, state and explain why this data point was chosen to be an anomaly.

1. State: Point is clearly inconsistent with the decreasing trend shown;
2. Explain: Water potential of the 0.8 mol dm^{-3} sucrose solution is likely to be more negative than the water potential of the cytoplasm in the vacuole of potato cell, water from the potato cell will move out into the surrounding water;

[2]

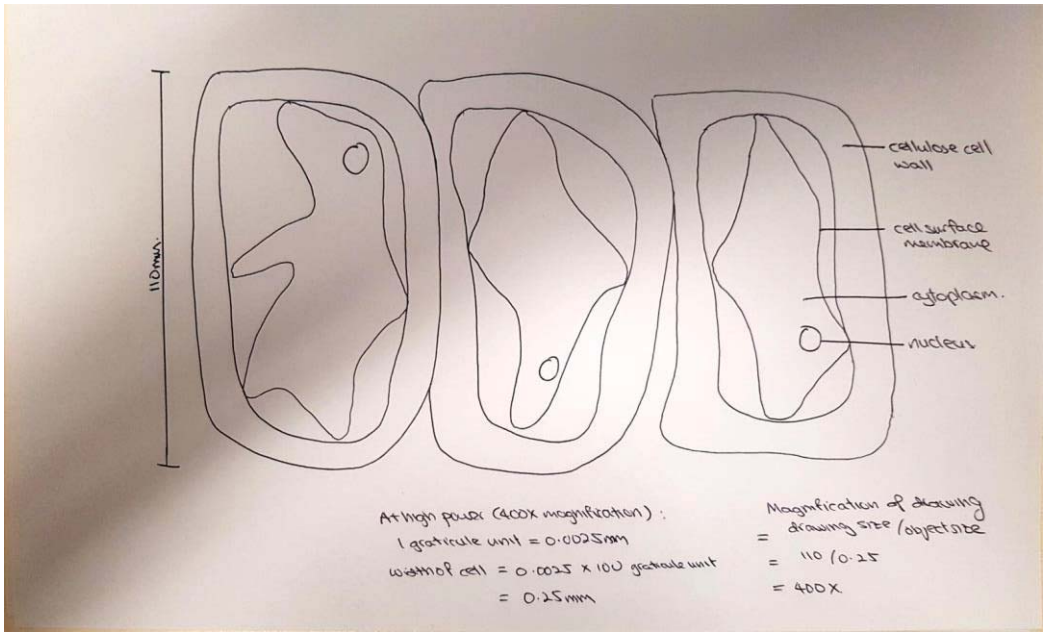
(f) You are required to observe the effects of treating onion epidermal cells with sucrose solution. You are provided with a scale leaf from the bulb of a red onion that has been incubated in solution **S3**.

10 Make a shallow cut on the outer surface of the scale leaf. Using a pair of forceps, peel off a thin sheet of epidermis.

11 Place the epidermal peel on a microscope slide with a drop of solution **S3** that was used to keep the onion leaf moist in the petri dish. Using forceps and mounting needle, spread out the epidermis flatly without tearing the peel. Cover with a cover slip.

12 Observe the onion epidermal cells under an appropriate objective lens of the microscope.

In the space below, make an accurate and labelled drawing of three adjacent pigmented cells that are clearly visible in the field of view. Calculate the magnification of your drawings.



Max five from:

1. Clear continuous lines with no shading
2. Draws three adjacent epidermal cells
3. Depicts plamolysed plant cells with detached cell membrane from cell wall with some intact attachment points;
4. Correct relative proportion of thickness of cell wall to cell membrane
5. At least 3 correctly labels from: cytoplasm, cellulose cell wall, cell surface membrane, vacuole
6. Correct calculations with working

[5]

[Total: 20]

3 Human activities over the past centuries have led to increased emission of carbon dioxide, resulting in rising atmospheric carbon dioxide concentration. Since carbon dioxide is the raw material for photosynthesis in green plants, it is important to understand how elevated carbon dioxide concentration would affect the rate of photosynthesis.

There are three types of photosynthetic mechanisms in green plants: C3, C4, and CAM. Most agricultural crop plants either use the C3 or C4 mechanism.

The C3 pathway involves the use and subsequent regeneration of ribulose 1,5-biophosphate (RuBP) in a cyclic series of reactions called the Calvin cycle. The first product of photo-assimilation of carbon dioxide is 3-phosphoglycerate, a three-carbon sugar, hence the term C3 pathway of photosynthesis.

The C4 plants begin their carbon dioxide uptake in mesophyll cells of leaves, forming a four-carbon molecule, oxaloacetate. This four-carbon molecule is changed into aspartic acid or malic acid, which is then transported immediately to bundle sheath cells. Here, the carbon dioxide is released and utilised in the C3 biochemical pathway. Thus, the C4 plant mechanism first traps carbon dioxide in the mesophyll cells, and then transports and concentrates the carbon dioxide in the bundle sheath cells, where it is utilised in the C3 pathway. Since C4 plants have a mechanism for concentrating carbon dioxide in the bundle sheath cells of leaves, it is hypothesised that their photosynthetic rates will not respond to rising carbon dioxide concentration to the same extent as C3 plants.

Using this information and your own knowledge, design an experiment to determine the effect of different concentrations of carbon dioxide on the rate of photosynthesis of C3 and C4 plants.

Comparison of the results would then allow the testing of the hypothesis that elevated carbon dioxide concentration has a greater effect on C3 plants than on C4 plants.

You must use:

- fresh green leaves from C3 and C4 plants
- plastic straw (for cutting out leaf discs)
- 0.1% sodium hydrogen carbonate solution (you need to remove the gas from the air spaces in the leaf discs so that they will sink in sodium hydrogen carbonate solution)

You may select from the following apparatus and use appropriate additional apparatus:

- normal laboratory glassware, e.g. test-tubes, boiling tubes, beakers, measuring cylinders, syringes, glass rods, white tile, etc.
- bench lamp
- stopwatch

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 diagram(s), if necessary, to show, for example, the arrangement of the apparatus used
- 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 repeatable as possible
- include layout of results tables and graphs with clear headings and labels
- use the correct technical and scientific terms
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 14]

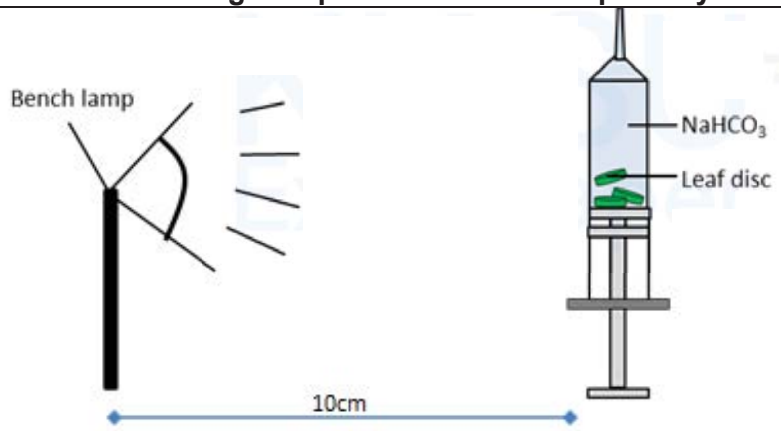
Planning Answer Scheme

Introduction	Mark scheme:
Aim To investigate the effect of different concentrations of $NaHCO_3$ on the rate of photosynthesis of C3 and c4 plants.	
Role of $NaHCO_3$ Increase in concentration of sodium hydrogen carbonate will increase amount of carbon dioxide available for carbon fixation during the light-independent reaction of photosynthesis (R! Calvin cycle). Hence, rate of the light-independent reaction would increase, leading to the faster regeneration of ADP and $NADP^+$ for light-dependent reaction/ photophosphorylation.	
The **oxygen** produced from photolysis of water would increase buoyancy of leaf discs, causing them to **float to the surface** of the solution.	Explain observation of leaf disc floating [T1]
Hence, rate of photosynthesis can be determined by taking the inverse of the time taken for all leaf discs to float to the surface of the solution. (The less the time taken for leaf discs to float to the surface, the faster the rate of photosynthesis.) Reject counting of bubbles because bubbles will not form, reject collect gas as gas won't be released.	Explain how to determine rate of photosynthesis [M1]
Variables	
Independent variable: concentration of sodium hydrogen carbonate (accept carbon dioxide) + 5 different values;	State independent variable + 5 values uniformly spaced or derived [IV]
Dependent variable: time taken for leaf disc to float to surface of solution; (ECF if other method used, must give set time)	State dependent variable [DV]
Constant variables: size of leaf discs, light intensity/distance from lamp, volume of sodium, temperature, AVP (at least 2);	State 2 constant variables [CV]
Procedure	
1. Prepare 50.0 cm^3 of different concentrations of sodium hydrogen carbonate solution by **simple dilution**.	Describe procedure to vary independent variable [M2]

Concentration of sodium hydrogen carbonate solution / %	Volume of sodium hydrogen carbonate solution / cm^3	Volume of distilled water / cm^3
0.10	50.0	0.0
0.08	40.0	10.0
0.06	30.0	20.0
0.04	20.0	30.0
0.02	10.0	40.0

0.00% can be counted as a concentration

n over

2. Use a **straw** to cut out 100 discs (accept: 20 – 100 discs) from the leaves of C3 and C4 plants and place them in separate labelled petri dishes. This is to ensure that each discs are of the same size and hence would contain **similar amount of chloroplast in each disc**.	Explain why variables need to be kept constant + describe how they are kept constant [CV1]
3. **Keep the discs in the dark** to ensure that leaf discs are not undergoing photosynthesis before the experiment.	Describe procedure needed to ensure same start point [M3]
4. Remove the plunger from the $5cm^3$ syringe and add 5 leaf discs of C3 plant (accept: 1 – 5 discs) into the syringe. 5. Replace the plunger and push it into the syringe, taking care not to damage the discs.	
6. Fill the syringe with **$5cm^3$ of 0.1% $NaHCO_3$**. Ensure that each experiment uses the same volume of $NaHCO_3$ as **changes to the volume will affect the concentration of carbon dioxide**.	Explain why variables need to be kept constant + describe how they are kept constant [CV2]
7. Place a finger over the nozzle to point the syringe upwards and create a vacuum environment. 8. **Draw the plunger to remove any gas present** in the leaf discs. Leaf discs will start to sink to the bottom. 9. Repeat steps 6 to 7 to ensure that all the leaf discs sink to the bottom. **Discs that float in the solution would affect the time taken** for it to float causing the results to be inaccurate.	Describe procedure needed to remove gas in leaf discs to ensure accuracy of results. [M4]
10. Place the syringe **10cm (accept: 10 – 50cm) away from the bench lamp** and use plasticine to hold the syringe in place as shown in the diagram. This ensures that the light intensity is constant as **light intensity will affect the rate of light-dependent reaction of photosynthesis**.	Explain why variables need to be kept constant + describe how they are kept constant [CV3]
	Well-labelled diagram [D]
11. Before starting the reaction, allow the leaf discs to **acclimatise for 3 minutes** (accept 1-5min) to **allow leaf discs to stabilise in the set up to ensure reproducibility of results**.	Describe procedure needed to acclimatise before starting to ensure reproducibility of results [M5]

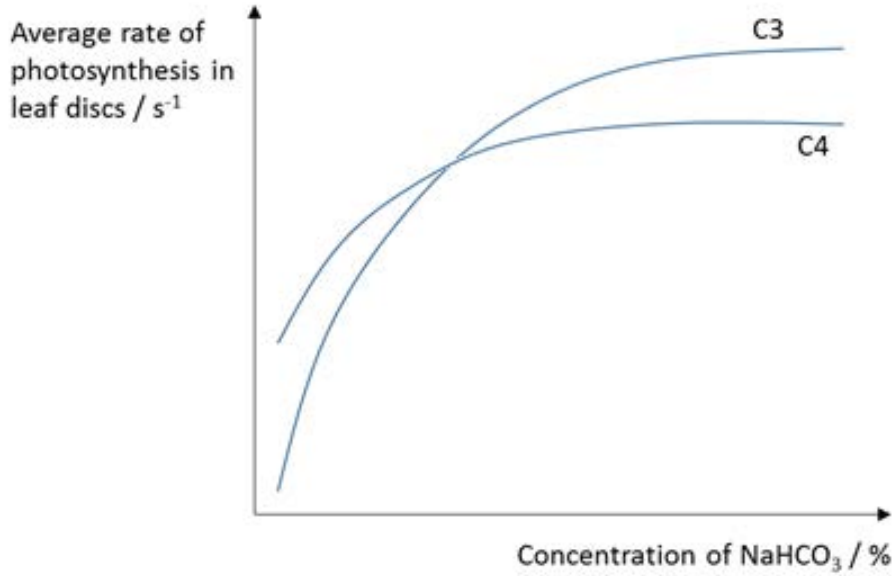
n over

12. After 3 minutes, switch on the lamp and start timing using a stopwatch. 13. Record the time taken for all the leaf discs to rise to the surface.	[M1]
14. Repeat steps 4 to 13 to obtain **two more readings** (three sets of data) using the same concentration of $NaHCO_3$ solution to **minimise error by calculating average**, ensuring **reliability** of results.	Reliability: Repeat experiment at least two more times and calculate mean [M6]
15. Repeat steps 4 to 14 using leaf discs from C4 plant. 16. Repeat steps 4 to 15 using 0.02%, 0.04%, 0.06%, and 0.08% $NaHCO_3$ to obtain results for the different concentrations.	
17. Repeat steps 4 to 13 to using **boiled and cooled leaf discs** from C3 plants as a control to show that the **rise of leaf discs is due to the oxygen produced when leaf discs undergo photosynthesis and not due to other factors**. Do the same for leaf discs from C4 plants.	Describe control experiment [C]
18. Repeat **entire experiment twice**, using **fresh solutions and leaf samples** to ensure **reproducibility** of the results obtained.	Reproducibility: Repeat entire experiment at least two more times with new reagents [M7]
Other constant variables: • Temperature – place thick clear glass in front of lamp to prevent set up from heating up due to the heat from the lamp OR use thermostatically controlled water bath to maintain constant temperature as fluctuations in temperature will affect the rate of photosynthesis • Reject pH because $NaHCO_3$ is a pH buffer.	Explain why variables need to be kept constant + describe how they are kept constant [CV4]
Results	
19. Record the results in the table below and calculate the rate of photosynthesis by taking the inverse of the average time taken for leaf discs to rise.	Show how results are to be presented in a table with independent and dependent variables in appropriate columns/rows [R1]

Type of plant	Concentration of $NaHCO_3$ / %	Time taken for leaf discs to rise / s				Rate of photosynthesis / s^{-1}
		Trial 1	Trial 2	Trial 3	Average	
C3	0.02					
	0.04					
	0.06					
	0.08					
	0.10					
C4	0.02					
	0.04					
	0.06					
	0.08					
	0.10					

n over

20. Plot a best-fit line/curve of rate of photosynthesis/s^{-1} against concentration of $NaHCO_3$/%.



Sketch graph to show relationship between independent and dependent variable [R2]

Safety precaution

Areas of risk	Safety Precautions
1. $NaHCO_3$ is an irritant / allergen	Wear gloves when handling it. Wash thoroughly when in contact with skin.
2. Bench lamp is a source of electrocution	Ensure hands are dry when handling with bench lamp.
3. Scalding during boiling of leaf discs	Wear goggles when boiling
4. Bench lamp will become hot after being switched on for a period of time	Do not touch the lamp
5. Bright light from lamp can cause damage to retina of eyes	Avoid looking directly into the light source

Risks/safety: state the hazard and precaution [S]
max 2m

n over

T = Theory

IV, DV, CV = Independent Variable, Dependent Variable, Constant Variable

M = Method

C = Control

R = Results

S = Safety

n over