1 Most wild plants contain toxins that deter animals from eating them. A scientist discovered that a toxin produced by a certain plant was also toxic to the same plant if it were applied to the roots of the plant. To find out why the plant was not normally killed by its own toxin, he fractionated some plant cells and found that the toxin was in the fraction that contained the largest cell organelle. He also found that the toxin was no longer toxic after it was heated.

Which statements are consistent with the scientist's observations?

1 The toxin is stored in the central vacuole.

2 The toxin cannot cross the membrane of the organelle in which it is stored.

3 The toxin is stored in chloroplast.

4 The toxin is likely to be lipid-soluble.

5 The toxin may be an enzyme.

A 1, 2 and 5

B 1, 4 and 5

C 2, 3 and 4

D 3, 4 and 5

2 The distribution of membranes in three cell types – a prokaryotic cell, a liver cell and an enzyme-secreting cell from the stomach – is determined. For each cellular structure, the amount of membrane is expressed as a percentage of the total amount of membrane in the cell.

Which row of values best represents the membrane distribution in the three cell types?

CM: cell membrane rERM: rough endoplasmic reticulum membrane
IMM: inner mitochondrial membrane OMM: outer mitochondrial membrane

	prokaryotic cell			liver cell			stomach cell		
	CM	rERM	IMM	rERM	OMM	IMM	rERM	OMM	IMM
A	99	0	0	35	7	28	60	16	4
B	99	0	0	35	7	28	60	4	16
C	52	12	36	60	7	28	35	4	16
D	52	12	36	60	28	7	35	4	16

3 A certain cell surface membrane is made entirely of phospholipids and is 7 nm thick. A volume of 1 mm^3 of this membrane was homogenised and dropped onto the surface of water in a large tray. The phospholipids spread out to form a continuous thin film.

What is the expected surface area of this film?

A 143 000 mm^2 because the phospholipids formed a single layer

B 143 000 mm^2 because the phospholipids formed a double layer

C 286 000 mm^2 because the phospholipids formed a single layer

D 286 000 mm^2 because the phospholipids form a double layer

4 Magnesium ions are usually added to a polymerase chain reaction in the form of magnesium chloride. The reaction rate of *Taq* polymerase decreases as the concentration of magnesium chloride is reduced.

What is the role of the magnesium ions?

A co-enzyme for *Taq* polymerase

B co-factor for *Taq* polymerase

C competitive inhibitor of *Taq* polymerase

D non-competitive inhibitor of *Taq* polymerase

5 A peptide consists of ten amino acids of four different kinds.

What is the number of tRNA molecules required to translate the mRNA for this peptide?

A 4

B 10

C 12

D 30

6 Which row best describes the functions of the enzymes involved in DNA replication?

	unwinding of the DNA molecules	assembly of the leading strand	filling in of gaps between new DNA fragments	fusing together of new DNA fragments
A	polymerase	ligase	polymerase	helicase
B	helicase	polymerase	polymerase	ligase
C	ligase	polymerase	helicase	polymerase
D	helicase	polymerase	ligase	polymerase

7 The packing of DNA in the nucleus is necessary to compact the DNA to fit within the nucleus.

The following statements describe this process.

1 Looped domains are formed with the aid of chromosome scaffold.

2 Further coiling results in formation of condensed chromatin as seen in metaphase.

3 DNA winds twice around a histone octamer to form nucleosome.

4 Subsequent coiling results in the formation of a solenoid fibre.

Which combination correctly describes the sequence of DNA packing?

A 1, 3, 4, 2

B 1, 4, 3, 2

C 3, 1, 4, 2

D 3, 4, 1, 2

8 Which row correctly describes the transfer of DNA from one bacterium to another?

	binary fission	transduction	conjugation
A	bacterial chromosome and plasmids passed to daughter cells	DNA transferred by bacteriophage from one bacterium to another	single strand of F plasmid transferred from one bacterium to another
B	bacterial chromosome and plasmids passed to daughter cells	bacterium takes up foreign DNA from culture medium	double-stranded F plasmid transferred from one bacterium to another
C	only plasmids passed to daughter cells	DNA transferred by bacteriophage from one bacterium to another	single strand of F plasmid transferred from one bacterium to another
D	only plasmids passed to daughter cells	bacterium takes up foreign DNA from culture medium	double-stranded F plasmid transferred from one bacterium to another

9 In an experiment, influenza A virus was engineered to have H1N1 envelope with H5N2 genome.

When the virus reproduces, what would be expected in the progeny?

A H1N1 envelope with H5N2 genome

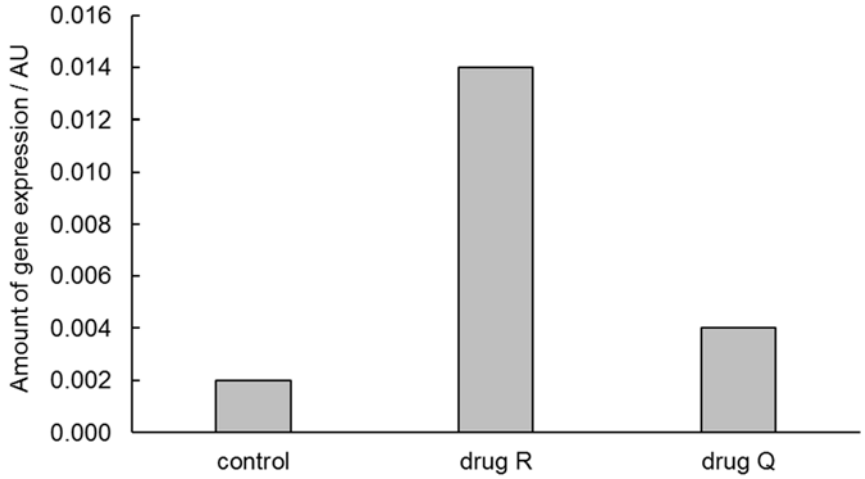
B H5N2 envelope with H1N1 genome

C H5N1 envelope with H5N1 genome

D H5N2 envelope with H5N2 genome

10 Drug R is a DNA methyltransferase inhibitor and drug Q is a histone deacetylase inhibitor. An experiment was carried out to investigate the effects of drug R and Q on the expression of a gene.

The graph shows the experimental results.



Which statements are possible explanations for the results shown?

1 Drug R increases gene expression by preventing methylation at CpG islands at the promoter.

2 Inhibiting DNA methylation is more effective in increasing gene expression than inhibiting histone deacetylation.

3 Drug Q results in weaker binding of histones to DNA.

4 Drug Q increases gene expression by increasing the accessibility of RNA polymerase to the promoter.

A 2 and 4 only

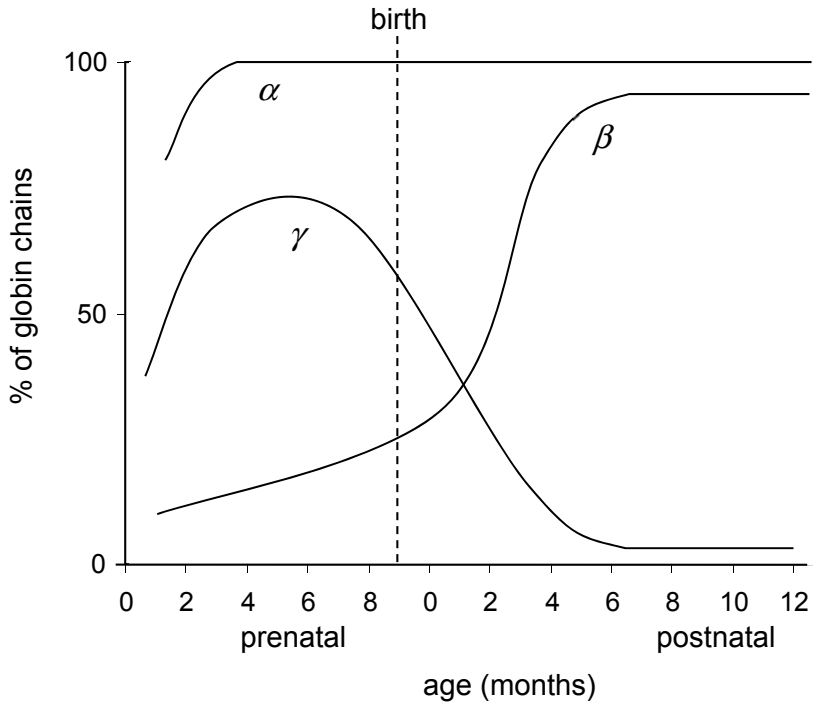
B 3 and 4 only

C 1, 3 and 4

D 1, 2, 3 and 4

11 The globin gene family in humans consists of α, β and γ genes. These genes code for the globin chains that make up haemoglobin and are expressed at different levels during different developmental stages.

The graph shows the expression of the various globin chains during the prenatal (fetal) and postnatal (after birth) periods.



Which statement could **not** account for the differences in the levels of expression of globin chains?

A A growth factor triggers the expression of a transcription factor that increases the rate of *β*-globin gene expression during the postnatal period.

B Alternative splicing results in the differences in the levels of expression of globin chains during the prenatal period.

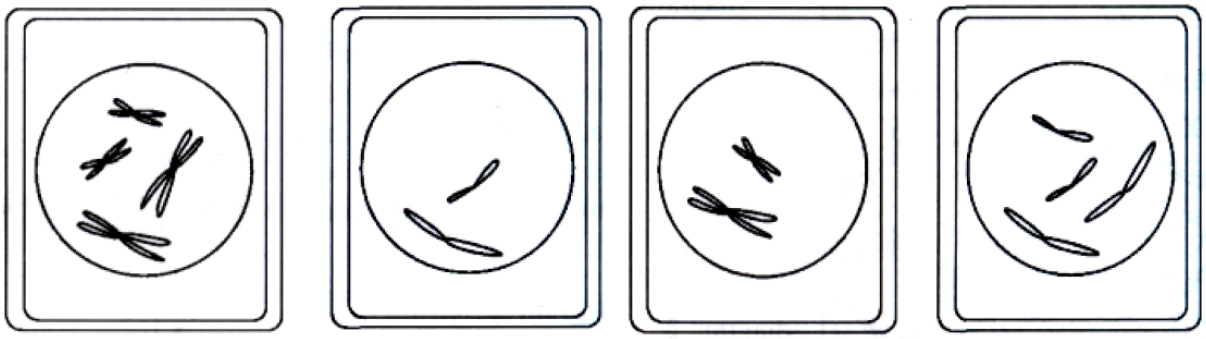
C Methyl groups are added to regulatory sequences of *γ*-globin genes during the postnatal period, allowing for some proteins to bind.

D The shortening of poly(A) tail in the mRNA of *γ*-globin genes reduces its stability, resulting in a decrease in the rate of expression of *γ*-globin chains during the postnatal period.

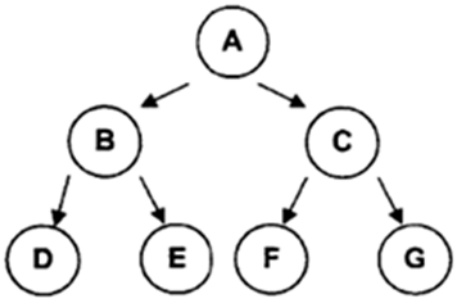
12 A diploid cell contains four chromosomes.

Which diagram shows the nucleus at prophase of mitosis after a meiotic cell cycle?

A **B** **C** **D**



13 The diagram shows cell A undergoing meiosis to produce four daughter cells, D, E, F and G.



If no crossing over occurred during meiosis, which cells would be genetically identical?

A B and C

B D, E, F and G

C D and E; F and G

D none

14 Which event does **not** increase the chance of cancerous growth?

A amplification of *p53* gene

B amplification of *ras* gene

C increase in telomerase activity

D loss of immunity

15 Which statements are **true** about all stem cells?

1 Stem cells can be induced to differentiate by environmental signals.

2 Stem cells are easily isolated and propagated.

3 Stem cells are able to develop into whole organisms if implanted into the womb.

4 Stem cells make more stem cells under appropriate conditions.

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

16 Which observation best describes the process of natural selection?

A change from simple to more complex organisms over time
B change in size of the population over time
C different rates of reproductive success of different genotypes
D spontaneous occurrence of advantageous mutations

17 Which statement is **not** an example of a macroevolutionary process?

A As a result of human activities, one bird species becomes extinct.

B Birds and insects have wings that evolved separately.

C One lion species splits to form two lion species over time.

D Over a short period, the frequency of a single gene declines from 10% to 8%.

18 A comparison of the following was made between human, rabbit, mouse, and chimpanzee:

- DNA coding sequence of the β globin gene
- DNA sequence in the introns of the β globin gene
- amino acid sequence of the β globin polypeptide.

The table shows the sequence similarity for the organisms being compared.

	sequence similarity (%)		
organisms being compared	coding DNA	intron	amino acid sequence
human and chimpanzee	100	98.4	100
human and rabbit	89.3	67	92.4
human and mouse	82.1	61	80.1

What could be concluded from the information given?

A A human is more closely related to a mouse than a rabbit.

B The comparison between human and rabbit indicates that the differences in their DNA did not always make a difference to the amino acid sequence.

C The variation between human and chimpanzee occurs in a region of the β globin gene that codes for amino acids.

D The variation in the intron sequence between human and mouse would account for some of the differences in the amino acid sequence.

19 Which region of the chloroplast has the lowest pH when sunlight shines on the organelle?

A intermembrane space

B starch grain

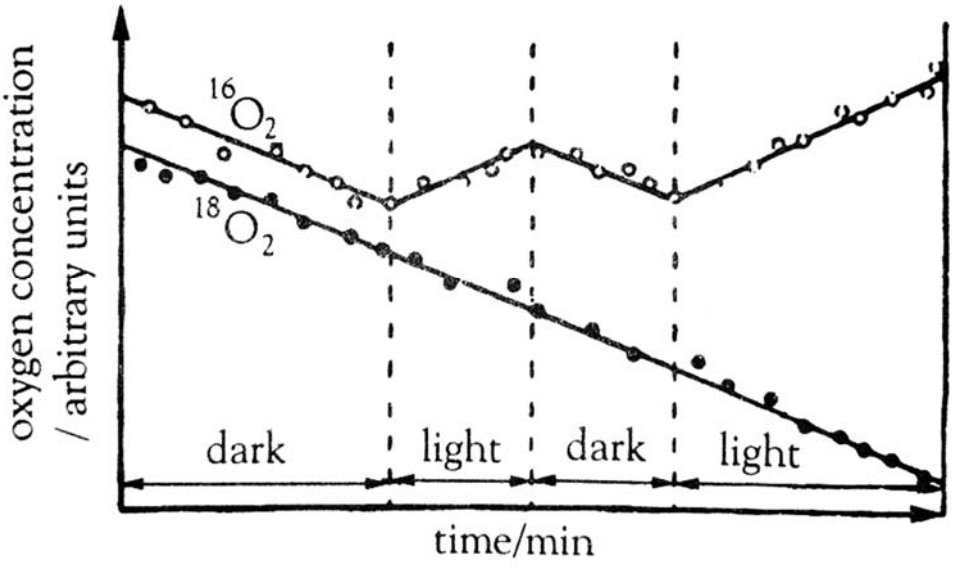
C stroma

D thylakoid space

20 Isotopes of oxygen can be used to distinguish between oxygen absorbed by plants and oxygen evolved.

A mixture of oxygen isotopes, $^{16}O_2$ and $^{18}O_2$, was supplied to a suspension of the unicellular alga *Chlorella* which had previously been exposed to $^{16}O_2$ only. During the following hour, changes in the concentration of these gases in the suspension were measured in light and dark conditions.

The graph shows the results.



What caused the concentration of $^{16}O_2$ to rise in when light was provided?

A $^{18}O_2$ formed a decreasing proportion of the oxygen evolved.

B $^{16}O_2$ was absorbed at different rates in light and dark.

C $^{16}O_2$ was being produced in photosynthesis but was not being absorbed in respiration.

D $^{16}O_2$ was being produced in photosynthesis faster than it was being absorbed in respiration.

21 Which statement correctly describes a difference between aerobic and anaerobic respiration?

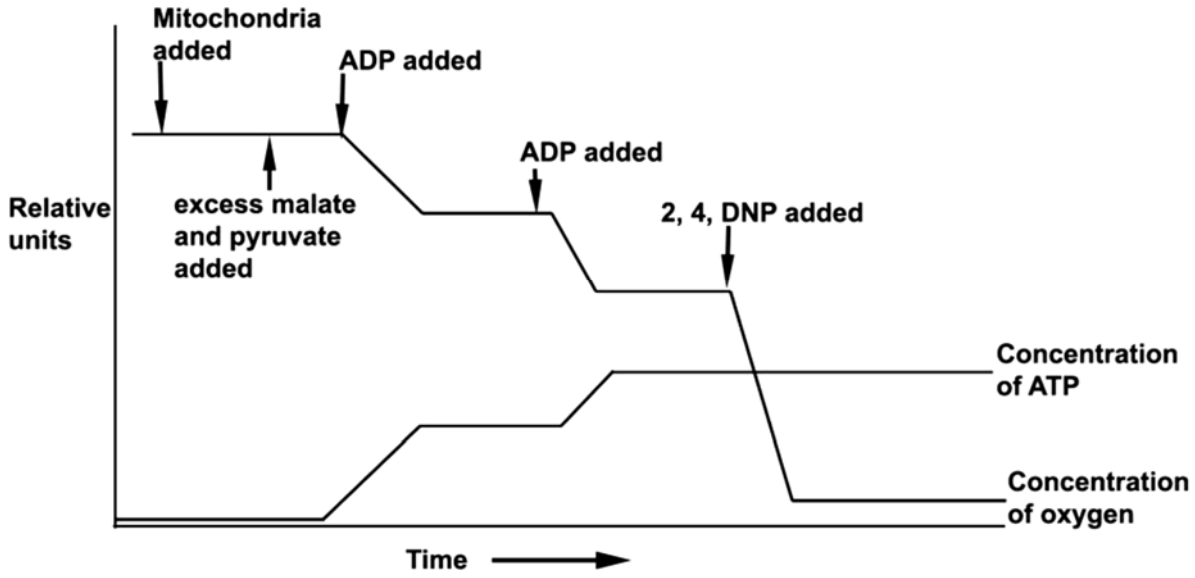
A Lactate is formed in aerobic respiration in animals, whereas alcohol is formed in anaerobic respiration in plants.

B Oxidation is complete in aerobic respiration, whereas oxidation is incomplete in anaerobic respiration.

C Pyruvate is formed in aerobic respiration, whereas pyruvate is not formed in anaerobic respiration.

D The energy released in aerobic respiration is stored in ATP, whereas the energy released in anaerobic respiration is not stored in ATP.

22 The graph shows the use of oxygen and the synthesis of ATP by isolated mitochondria upon the addition of various compounds.



What could be deduced from the graph?

1 ADP is not normally required for the process of respiration to occur.

2 2, 4, DNP allows the process of respiration to proceed without ATP synthesis.

3 The rate of respiration in this experiment is limited by the availability of malate and pyruvate.

A 2 only

B 3 only

C 1 and 2 only

D 1 and 3 only

23 What is an example of a test cross?

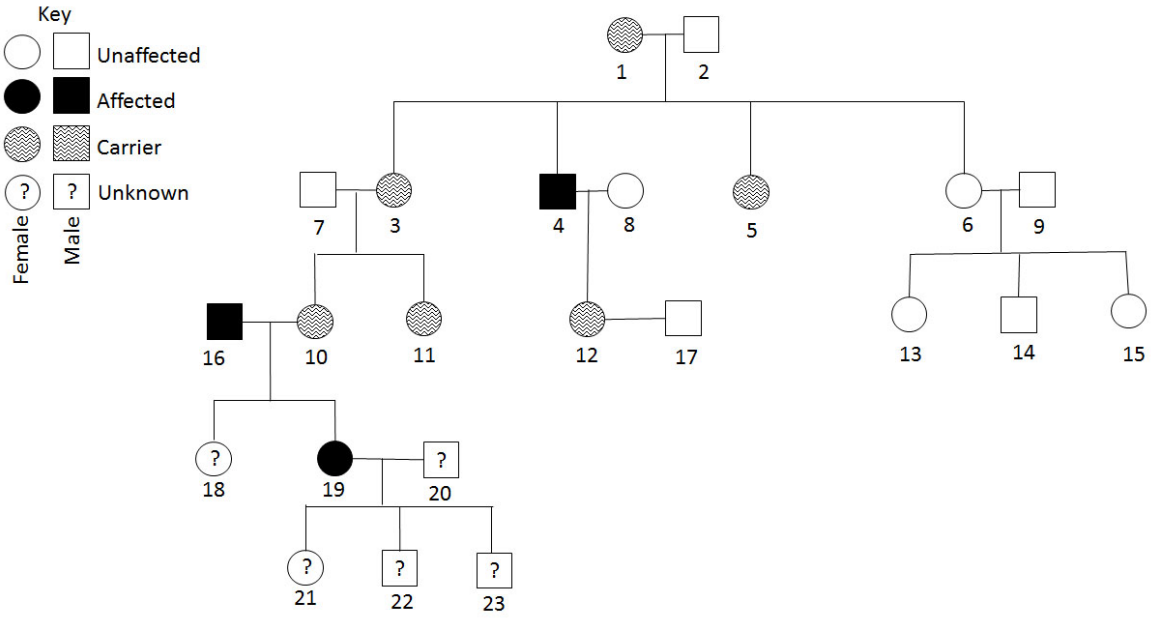
A dominant parent x hybrid

B dominant parent x recessive parent

C hybrid x hybrid

D hybrid x recessive parent

24 The pedigree shows the inheritance of an X-linked recessive trait.



What is the probability of individual 22 being affected?

A 0%

B 25%

C 50%

D 100%

25 Coat colour in some mammals is controlled by a gene with four alleles. The order of dominance for these alleles, in descending order, is as follows:

agouti (**C**), chinchilla ($\mathbf{C^c}$), Himalayan ($\mathbf{C^h}$), albino (**c**).

How many different genotypes for coat colour are possible?

A 8 **B** 10 **C** 12 **D** 16

26 Which enzyme is **not** involved in the regulation of signal transduction pathways?

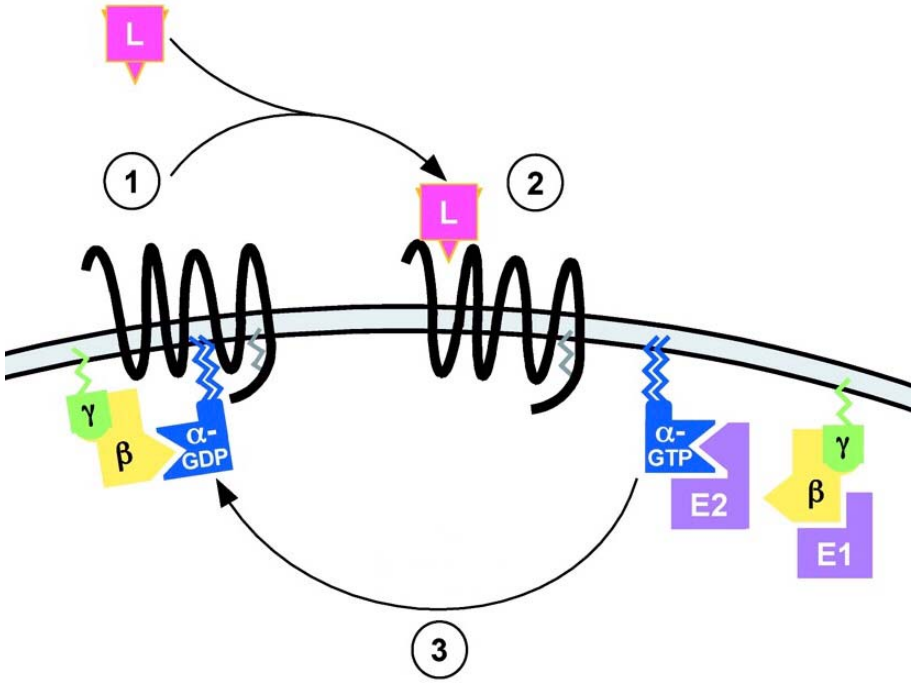
A GTPase

B kinase

C phosphatase

D phosphorylase

27 The diagram shows part of a cell signalling pathway.



Which of the following correctly describes the numbered steps in the cell signalling pathway?

1 A heterotrimeric G-protein is associated with an active cell surface receptor that has seven transmembrane domains.

2 The binding of ligand L to the G-protein linked receptor is required for the activation of downstream effectors, E1 and E2.

3 A molecule of GDP displaces the GTP on the alpha subunit of the G-protein, causing the alpha subunit to reassociate with the beta-gamma complex.

A 1 only

B 2 only

C 1 and 3 only

D 1, 2 and 3

28 Which statement is **not** true about the structure of all antibodies?

A Antibodies are built from equal numbers of large (heavy) and small (light) peptide chains.

B Antibodies are secreted and function away from the cell.

C Antibodies have multiple identical antigen binding sites.

D Antibodies have heavy chains that determine their isotypes.

29 What describes a virus such as influenza which emerges suddenly and spreads globally?

A endemic

B epidemic

C pandemic

D zoonotic

30 Which data is **not** an evidence of climate change?

A carbon dioxide concentration measured from air bubbles trapped in an ice core from the Antarctic

B changes in glacier formation and melting through photographs and maps

C maximum temperatures recorded during summer each year

D analysis of pollens from plants preserved in different layers of lake bed sediments

2018 SH2 H2 Biology Prelim P1 Answers

Question	Answer	Question	Answer	Question	Answer
1	**A**	11	**B**	21	**B**
2	**B**	12	**C**	22	**A**
3	**C**	13	**C**	23	**B or D**
4	**B**	14	**A**	24	**D**
5	**B**	15	**A**	25	**B**
6	**B**	16	**C**	26	**D**
7	**D**	17	**D**	27	**B**
8	**A**	18	**B**	28	**B**
9	**D**	19	**D**	29	**C**
10	**D**	20	**D**	30	**C**

Section A

Answer the question in this section.

1 Fig. 1.1 shows a section of a cell surface membrane.

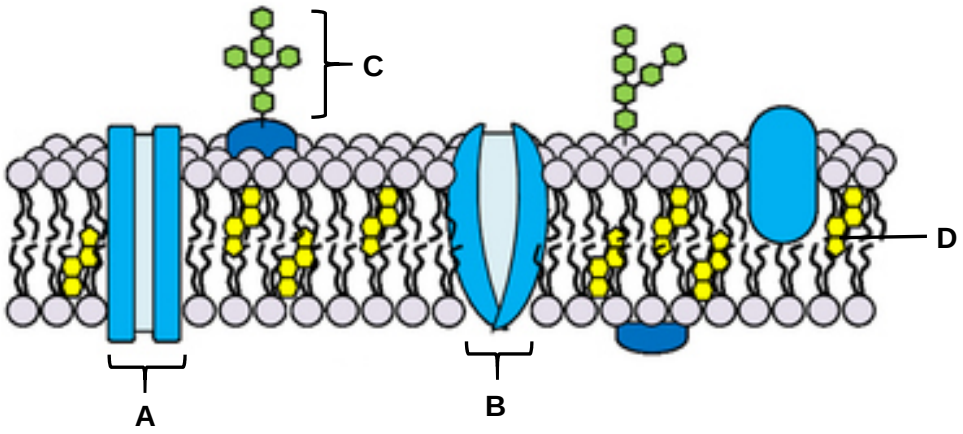


Fig. 1.1

(a) Name the structures labelled **A**, **B**, **C** and **D**.

(4 correct – 2 marks; 2 or 3 correct – 1 mark; 0 or 1 correct – 0 mark)

A **channel protein**
(Reject: transmembrane / integral / intrinsic membrane protein)

B **carrier protein**
(Reject: transmembrane / integral / intrinsic membrane protein)

C **oligosaccharide / sugars / carbohydrate**
(Reject: glycoprotein)

D **cholesterol** [2]

(b) Describe how structures **A** and **B** are held in the membrane.

1. **hydrophobic interactions between the non-polar hydrocarbon tails of the phospholipid bilayer and the hydrophobic R groups of the non-polar amino acids in the exterior surface of the proteins;**

2. **hydrophilic interactions between the phosphate heads of phospholipids in the bilayer and the polar and charged R groups of amino acids in the exterior surface of the proteins;** [2]

(c) For hydrophilic molecules to enter a cell, they require the help of either structure **A** or **B**.

State and explain which of the two structures allows a faster entry into the cell.

1. **Structure A (channel protein);**
2. **Hydrophilic molecules do not need to bind to the channel protein in order to enter the cell;**
3. **Channel protein does not need to undergo any conformational change to allow the entry of the hydrophilic molecules into the cell;**
4. **Carrier protein, on the other hand, requires the hydrophilic molecules to bind to it before it undergoes a conformational change that results in the transport of the hydrophilic molecules into the cell;**

[3]

(d) State **two** possible functions of structure **C**.

1. **increases the hydrophilic characteristics of lipids and proteins;**
2. **stabilises the conformation of many membrane proteins;**
3. **contributes to cell-cell recognition / communication;**
4. **contributes to cell-cell adhesion;**
5. **contributes to signal transduction;**
6. **used as antigens in the body's immune responses;**
7. **protects the cell membrane from mechanical damage;**
8. **AVP**

[2]

(e) Suggest why there seems to be a greater diversity in the molecular structures of **A** and **B** (proteins) than that of **C** (carbohydrates).

1. **greater variety of monomers – at least 20 different amino acids / variety due to side chains or R groups;**
2. **more types of bonds – hydrogen bonds, ionic bonds, disulphide bonds, hydrophobic interactions;**
3. **more levels of structure – primary, secondary, tertiary, quaternary;**

[2]

(f) The fluid mosaic model was first proposed by S.J. Singer and Garth L. Nicolson in 1972 to explain the structure of the cell surface membrane.

Explain why it is called fluid mosaic.

1. **fluid – phospholipids and proteins free to move laterally along the membrane;**

2. **mosaic – proteins embedded / studded / scattered in the phospholipid bilayer OR phospholipids and proteins distributed asymmetrically across the bilayer;** [2]

(g) Comment on the significance of structure **D** in the cell surface membrane.

1. **maintains membrane fluidity when temperature changes OR provides mechanical stability;**

2. **prevents leakage of polar molecules;** [1]

[Total: 14]

Name: _____ **Biology Class: 2bi2___**

Section B

For Examiner's Use	
Section B	
2	**/9**
3	**/12**

Section B

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

2 In an experiment to investigate the effect of insulin on glucose uptake by muscle cells, the concentration of free glucose inside muscle cells was measured with respect to the extracellular glucose concentration, in the presence of insulin (labelled as insulin) and in the absence of insulin (labelled as control).

Fig. 2.1 shows the results of the experiment.

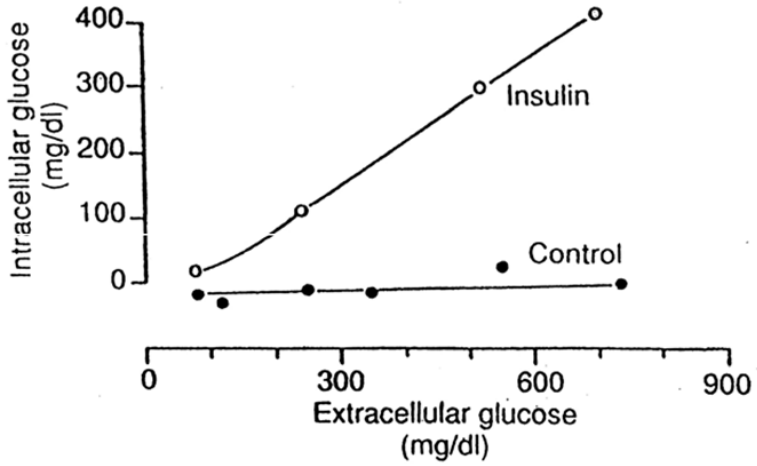


Fig. 2.1

(a) With reference to Fig. 2.1, describe the effect of insulin on glucose uptake by muscle cells.

1. **Insulin leads to an increase in glucose uptake / intracellular glucose concentration in the muscle cells;**

2. **In the absence of insulin, intracellular glucose concentration remains constant at about 0 mg/dl as extracellular glucose concentration increases from 78 (70 – 80) to 733 (720 – 740) mg/dl;**

3. **In the presence of insulin, intracellular glucose concentration increases from 22 (10 – 30) to about 400 (400 – 420) mg/dl as extracellular glucose concentration increases from 78 (70 – 80) to about 700 (690 – 710) mg/dl;** [3]

(b) (i) Name the type of receptor that insulin binds to on the muscle cell.

Receptor tyrosine kinase / Tyrosine kinase receptor;
(Reject: Insulin receptor; RTK) [1]

(ii) Explain how the binding of insulin to its receptor could result in the effect shown in Fig. 2.1.

1. **The binding of insulin to its receptor would induce a conformational change in the receptor, bringing the two internal tyrosine kinase domains closer together;**
(Reject: cause receptor dimerisation)

2. **Contact between the two adjacent tails of the receptor would activate their tyrosine kinase function, leading to cross-phosphorylation / autophosphorylation of the tyrosine residues present in the tails of the receptor;**

3. **The fully activated receptor would trigger the assembly of adaptor proteins on the receptor tails, which will further recruit and activate other downstream relay molecules via phosphorylation;**

4. **More glucose transporters (GLUT4) would become embedded in the plasma membrane, increasing the glucose uptake / intracellular glucose concentration in the muscle cells;** [4]

(c) Suggest how the effect of insulin on glucose uptake by muscle cells could be terminated.

1. **degradation of insulin by enzymes;**

2. **endocytosis of insulin-RTK / ligand-receptor complex;**

3. **increase in the activity of phosphatases / enzymes that dephosphorylate proteins;** [1]

[Total: 9]

3 Succinate dehydrogenase is an enzyme in the Krebs cycle, which catalyses the conversion of succinate to fumarate by dehydrogenation.

Malonate is an inhibitor of succinate dehydrogenase. An experiment was carried out to investigate the effect of malonate on respiration. Isolated liver mitochondria were placed in six reaction tubes, with contents as shown in Table 3.1. The corresponding rates of oxygen uptake were measured and also tabulated.

Table 3.1

tube	volume of substance added / cm^3				rate of oxygen uptake / arbitrary units
	buffered liver mitochondria suspension	2% glucose solution	2% pyruvate solution	0.2% malonate solution	
1	2.00	0.00	0.00	0.00	1.1
2	2.00	0.01	0.00	0.00	1.2
3	2.00	0.00	0.01	0.00	17.8
4	2.00	0.00	0.01	0.01	6.7
5	2.00	0.00	0.01	0.02	2.2
6	2.00	0.00	0.04	0.02	15.5

(a) Explain why rate of oxygen uptake can be used as an indicator of rate of respiration.

Oxygen is the final electron acceptor in oxidative phosphorylation; [1]

(b) Explain why glucose has no effect on the rate of oxygen uptake.

1. **Enzymes for glycolysis were absent in Tube 2;**
2. **Hence, glucose was not oxidised to pyruvate / no pyruvate was present for Krebs cycle to take place;** [2]

(c) **(i)** With reference to Table 3.1, describe the effect of adding pyruvate to tube **3**.

1. **Adding pyruvate increased the rate of oxygen uptake by about 16 folds (highest among the 6 tubes);**
2. **The rate of oxygen uptake increased from 1.1 arbitrary units in Tube 1 to 17.8 arbitrary units in Tube 3;** [2]

(ii) Explain your answer to **(c) (i)**.

1. **Pyruvate was converted to acetyl CoA in the link reaction;**
2. **Acetyl CoA then entered the Krebs cycle, which produced NADH and $FADH_2$;**
3. **NADH and $FADH_2$ then passed their electrons down the electron transport chain until they reached molecular oxygen, which was reduced to water;** [3]

(d) Account for the difference in rate of oxygen uptake between tubes **5** and **6**.

1. **In the presence of malonate, rate of oxygen uptake increased from 2.2 arbitrary units in tube 5 to 15.5 arbitrary units in tube 6 when the volume of pyruvate added increased from 0.01 cm^3 in tube 5 to 0.04 cm^3 in tube 6;**
2. **Malonate acted as a competitive inhibitor of succinate dehydrogenase / competed with succinate for the active site of succinate dehydrogenase;**
3. **The inhibitory effect of malonate could be overcome by increasing the concentration / volume of pyruvate, which consequently gave more succinate;**
4. **When substrate / succinate concentration increased, the frequency of effective collisions between substrate / succinate and enzyme / succinate dehydrogenase molecules was higher than that between substrate / succinate and inhibitor / malonate molecules;** [4]

[Total: 12]

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Name: _____ **Biology Class: 2bi2___**

Section C

For Examiner's Use	
Section C	
4	**/8**
5	**/9**
6	**/10**

Section C

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

4 **(a)** Outline the cell theory.

1. ref to smallest unit of life;
2. ref to all cells come from pre-existing cells;
3. ref to living organisms are composed of cells; [3]

(b) Endosymbiotic theory holds that the organelles distinguishing eukaryotic cells evolved through symbiosis of unicellular prokaryotic cells.

Fig. 4.1 shows the electron micrograph of a photosynthetic bacterium, *Rhodopseudomonas viridis* (x60,000). The internal photosynthetic membranes extend the entire length of the bacterium and are visible in cross section on the right of the cell, and in tangential section on the left of the cell.

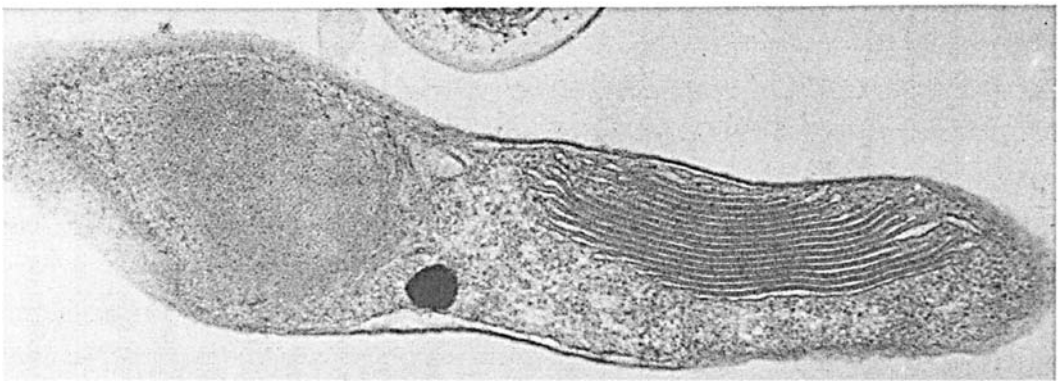


Fig. 4.1

(i) Calculate the actual length of the bacterium shown in Fig. 4.1.

Draws a line on bacteria cell to indicate length

Length = magnified size/60000 =

[1]

(ii) With reference to the visible structures in Fig. 4.1, describe how the structure of *R. viridis* supports and does not support the endosymbiotic theory.

***Support*:**

Stacked membrane structure resembles thylakoid stacks in a chloroplast;

Multiple stacks within cell resembles the multiple thylakoid stacks in a chloroplast;

[2]

***Does not support*:**

presence of cell wall, which is not found in a chloroplast;

(iii) Describe **two** other lines of evidence that support the endosymbiotic theory, but may not be visible in Fig. 4.1.

1. **70S ribosomes found in bacteria and chloroplast;**
2. **Circular DNA found in bacteria and chloroplast;**

[2]

[Total: 8]

5 Bacteriophages play an important role in regulating microbial ecology of many ecosystems because of their impact on bacteria.

Fig. 5.1 shows the electron micrograph of some bacteriophages.

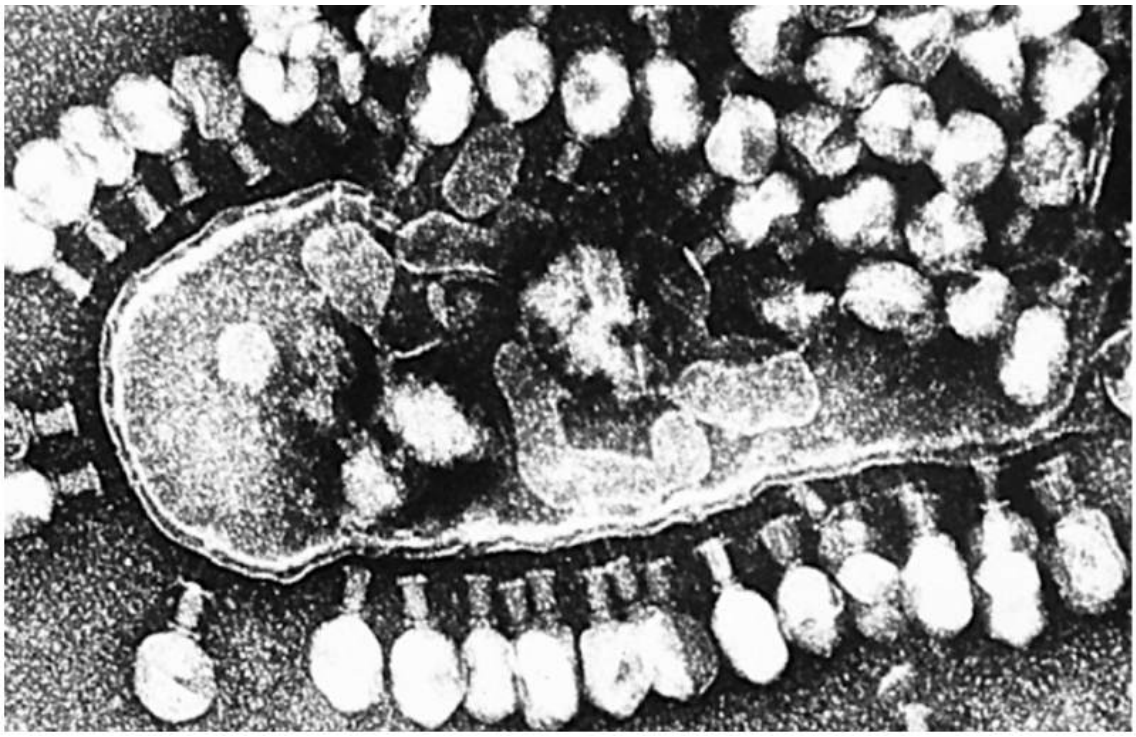


Fig. 5.1

(a) (i) Identify the reproductive cycle shown in Fig. 5.1.

Lytic cycle;

[1]

(ii) Describe how the bacteriophage genome is inherited in the reproductive cycle identified in **(a)(i)**.

1. **Tail sheath contracts and injects phage genome into host cell;**
2. **Host cell machinery directed to synthesize phage protein and to replicate phage genome;**
3. **Phage proteins assembled to form phage heads, tails and tail fibres;**
4. **Phage genome is packaged inside capsid during assembly of phage heads;**
5. **Phage lytic enzyme damages peptidoglycan cell wall + osmotic lysis + release of phage particles;** [3]

(b) Describe the process through which bacteriophages may contribute to bacterial survival.

1. **Gene transfer between bacterial cells by transduction;**
2. **Packaging of bacterial DNA inside capsid during assembly of new viral particle;**
3. **Donor bacterial DNA may carry advantageous alleles for new bacterial host cell;**
4. **Recombination between donor DNA and host DNA may result in new advantageous phenotype;** [3]

(c) Describe **two** similarities between the reproductive cycles of bacteriophages and animal viruses.

1. **Specificity for host cell + ref to binding to specific host receptors;**
2. **Directs synthesis of new viral particles using host cell machinery;** [2]

[Total: 9]

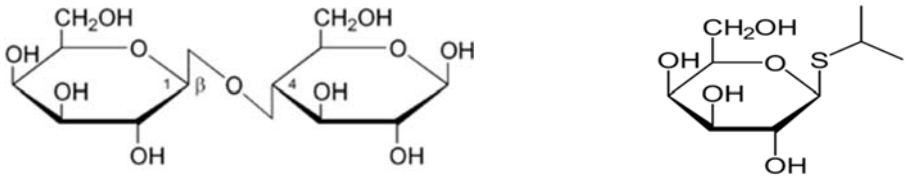
6 The term “operon” was coined by Jacob and Monod, who characterised the first defined classical operon, the *lac* operon, in *Escherichia coli*. While working to elucidate the *E. coli lac* operon, Monod and his colleagues developed a range of biochemical tools.

(a) Outline the features of an operon and explain how gene expression may be regulated in general.

1. **Promoter + operator + structural genes + terminator;**
2. **Ref to structural genes involved in related biochemical pathway;**
3. **Ref to inducible operon + transcription turned on by effector molecule;**
4. **Ref to repressible operon + transcription turned off by effector molecule;**
5. **Ref to effector molecules, such as activators/repressors + bind to DNA sequence + turn on/off transcription;** [3]

(b) Isopropyl-β-D-thiogalactoside (IPTG) was used in Monod’s experiments to identify the *lac* repressor protein, and to induce the *lac* operon.

Fig. 6.1 shows the molecular structure of lactose and IPTG.



lactose IPTG

Fig. 6.1

With reference to Fig. 6.1, explain how IPTG is able to induce the *lac* operon and suggest **one** advantage of using IPTG instead of lactose in Monod’s experiments.

1. **ref to structural similarity between IPTG and galactose;**
2. **β-galactosidase cannot cleave IPTG, hence inducer concentration will remain constant through experiment;** [2]

(c) The discovery of F factors carrying the *lac* operon allowed Monod to construct stable partial diploids for his experiments.

Four strains of bacteria were grown in glycerol (no glucose), with or without IPTG.

Table 6.1 shows the results of some of Monod's experiments. The plus sign or minus sign indicates presence or absence of β-galactosidase or permease activity.

Table 6.1

strain	genotype	β-galactosidase		permease	
		without IPTG	with IPTG	without IPTG	with IPTG
1	$O^+Z^+Y^+$	-	+	-	+
2	$O^+Z^+Y^+$/ F$(O^+Z^-Y^+)$	-	+	-	+
3	$O^{m1}Z^+Y^+$	+	+	+	+
4	$O^+Z^-Y^+$/ F$(O^{m1}Z^+Y^-)$	+	+	-	+

O^+ represents wildtype operator
O^{m1} represents mutant operator
Z^+ represents wildtype *lacZ*
Z^- represents no *lacZ*

(i) From the results of experiments using strains **1** and **2**, Monod concluded that the wildtype is inducible and Z^+ is dominant to Z^-.

Complete Table 6.1 to show the results that will support the above conclusions. [1]

(ii) State and explain **one** conclusion that could be drawn from the results of experiments using strains **3** and **4**.

1. O^{m1} is a constitutive mutation (OWTTE);
2. ref to polymerase always bound to operator and allowing expression of the structural genes;

OR

3. operator is cis-acting (OWTTE);
4. Y is only expressed when induced but Z is induced with or without IPTG; [2]

(iii) Suggest and explain how the results of experiments using strain **1** would differ if the bacteria were grown in glycerol and glucose.

1. ref to results -/-/-/- with and without IPTG;

AND

2. ref to low cAMP in presence of glucose + inactive CAP;
3. ref to inactive CAP + not binding to CAP-binding side on promoter + no transcription; [2]

[Total: 10]

Name: _____ **Biology Class: 2bi2___**

Section D

For Examiner's Use	
Section D	
7	**/12**
8	**/12**

Section D

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

7 **(a)** Define and state an example of a multipotent stem cell.

1. **Differentiate into cell types of a tissue / organ;**
2. **Haematopoietic stem cell;** [2]

(b) **(i)** One unique feature of stem cells is their ability to differentiate into different cell types, where some genes are silenced and some genes are expressed.

Explain how stem cells achieve this.

1. **DNA methylation occurs on the CG islands of DNA;**
2. **Recruits Histone Deacetylases;**
3. **Histone deacetylation on lysine residues of histone tails;**
4. **Increases the positive charge of histone tails and increases electrostatic forces of attraction between histone tails and DNA;**
5. **Decrease gene expression / silencing of certain genes resulting in differentiation;**

[Opposite way of expressing idea will be awarded equivalent marks] [4]

(ii) During the process of differentiation, specific proteins are produced.

Account for the roles of **three** types of RNA in producing these proteins.

1. **mRNA – carries genetic information from DNA in the form of a series of codon to specify the amino acid sequences of proteins;**
2. **tRNA – serves as an adaptor molecule in protein synthesis; carries the correct amino acid to the ribosome and its anti-codon base-pairs with its complementary mRNA codon;**
3. **rRNA – component of ribosome, plays structural and catalytic role in ribosomes;** [3]

(c) A recent advancement in stem cell gene therapy is the use of CRISPR/Cas9 system to edit genes. This stem cell gene therapy can help to cure genetic diseases by removing the undesired gene and adding the corrected version in the stem cells.

The CRISPR/Cas9 system works by delivering a Cas9 nuclease complexed with a single-stranded RNA (artificial guide) into a cell.

Fig. 7.1 and Fig. 7.2 explain how gene editing is achieved using CRISPR/Cas9 system.

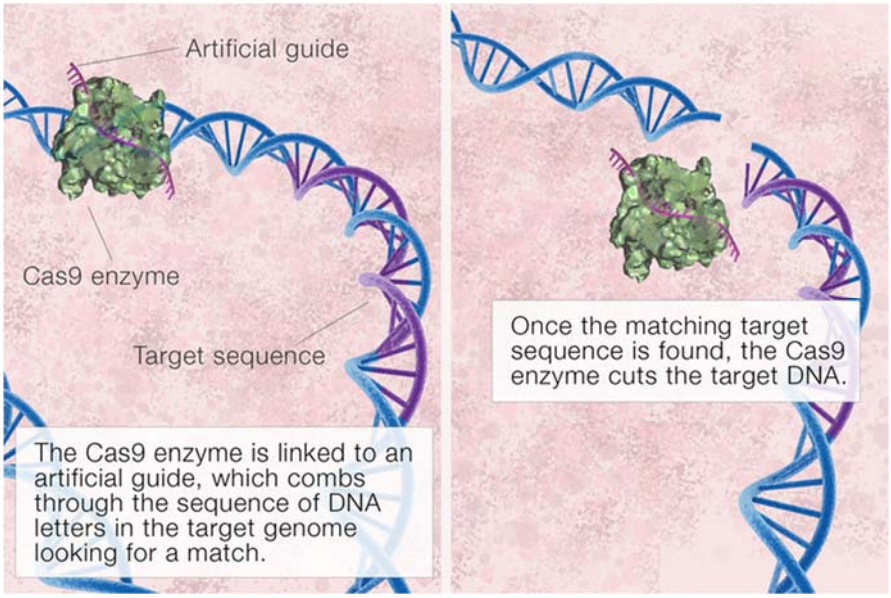


Fig. 7.1

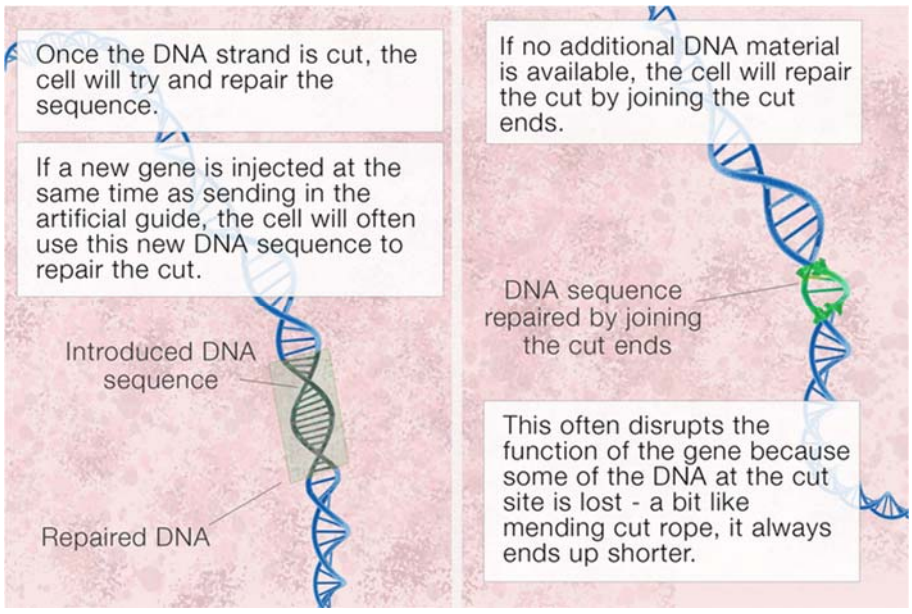


Fig. 7.2

(i) With reference to Fig. 7.1 and Fig. 7.2, explain why CRISPR/Cas9 is believed to have potential applications for treating **many** genetic diseases in humans.

1. **Different genetic diseases are caused by different genes;**
2. **Use of artificial guide allows Casp9 enzyme to find the right gene based on complementary base-pairing of the guide to the target gene to edit the gene;** [2]

(ii) Despite the potential of CRISPR/Cas9 in treating many genetic diseases, some scientists are worried about the use of such technology in humans.

Suggest **one** possible consideration.

1. **Possible off-target mutations (unintended mutations) in the genome. Mutations are deleterious;**
2. **Cost of germline editing technology is very high to the extent that only families from rich countries could afford it;**
3. **Genome editing in human embryos could have unpredictable effects to the future generation;**
4. **Technology could be used for non-therapeutic modifications, leading to loss of human diversity and eugenics;**
5. **AVP** [1]

[Total: 12]

8 (a) A single coral species is often spread across heterogenous environments, and populations that experience different temperature regimes can have markedly different responses and thresholds to thermal stress.

A study was conducted to investigate the optimum temperature for the species, *Porites porites*. Coral fragments from different environments in the wild were collected and then subjected to different temperatures in the laboratory. The amount of stress was measured for each temperature. The optimal temperature is taken as the temperature that induced the least stress in the coral fragments.

The results showed that optimum temperature varies slightly within population and varies more between the two populations of *P. porites* found in the Northern South China Sea (NSCS) and Singapore Straits (SS).

Table 8.1

coral fragments from	optimum temperature (°C)												
	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0	29.5	30.0
NSCS population	4	21	24	8									
SS population										3	15	26	7
F1				3	5	12	13	8	4				
F2		6	8	10	22	19	15	8	7	3	2		

Numbers shown in the table represents the number of coral fragments suited for the different temperature.

(i) State the term used to describe the range of phenotypes shown in Table 8.1.

1. **Continuous variation;** [1]

(ii) Explain the genetic basis behind the wide range of optimum temperatures.

1. **Quantitative characteristic controlled by polygenes / more than 2 pairs of independent genes;**
2. **Cumulative / additive effect on the trait without complete dominance;**
3. **In F2, the segregation & recombination of these 3 allele pair produce the greatest variations;**
4. **F1 fully heterozygous, intermediate;** [2]

(iii) Coral fragments within each parental population are pure-breeding, yet the coral fragments within each parental population showed variation in optimum temperature. The variation in F1 is comparable to the average of the parental variations while the variation in F2 is greater than that found in the parental populations or the F1.

Explain why there is variation in each parental population, F1, and F2.

1. **Parental lines are pure breeding, hence homozygotes at loci, variation due to environment;**
2. **F1 offspring should all be heterozygous at all loci and variation around the mean is derived from environmental influence;**
3. **F2 variation is called by individuals being genetic variation and environmental factors;** [3]

(b) In another study, a sample of 50 coral larvae from two different lines of *P. porites* was infected with equal doses of bacterium (*Vibrio natriegens*). It was observed that different lines showed pronounced differences in mortality.

The remaining larvae from the two different lines were crossed to produce the F1 hybrid and infected with the same dose of *V. natriegens*.

Table 8.2 shows the results.

Table 8.2

line of *P. porites*	mortality / % of larvae infected
resistant	0
susceptible	100
cross between susceptible and resistant *P. porites* (F1 hybrid)	0

It is thought that resistance to *V. natriegens* is controlled by a single gene.

(i) Using suitable symbols, draw a genetic diagram to show how resistance to *Vibrio* species could be inherited in the cross that produce the F1 hybrid shown in Table 8.2.

Perform monohybrid cross [3]

With parental genotype: RR x rr;

Punnet Square + correct circling of gametes;

F1 genotype: Rr;

(ii) Calculate the probability of susceptible *P. porites* resulting from crosses between:

susceptible x F1 hybrid **50%;**

resistant x F1 hybrid **0%;** [2]

(ii) Suggest **one** implication of this study to the environment.

Destruction of living population of coral reefs, may result in loss in diversity; [1]

[Total: 12]

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Name: _____ **Biology Class: 2bi2___**

Section E

For Examiner's Use	
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9	**/14**

Section E

Answer the question in this section.

9 (a) The islands of Wan-an and Lanyu, separated by 25 km, support the two nesting populations of green turtle (*Chelonia mydas*).

Fig. 9.1 shows the position of the two islands around Taiwan and nesting beaches marked with rectangles.

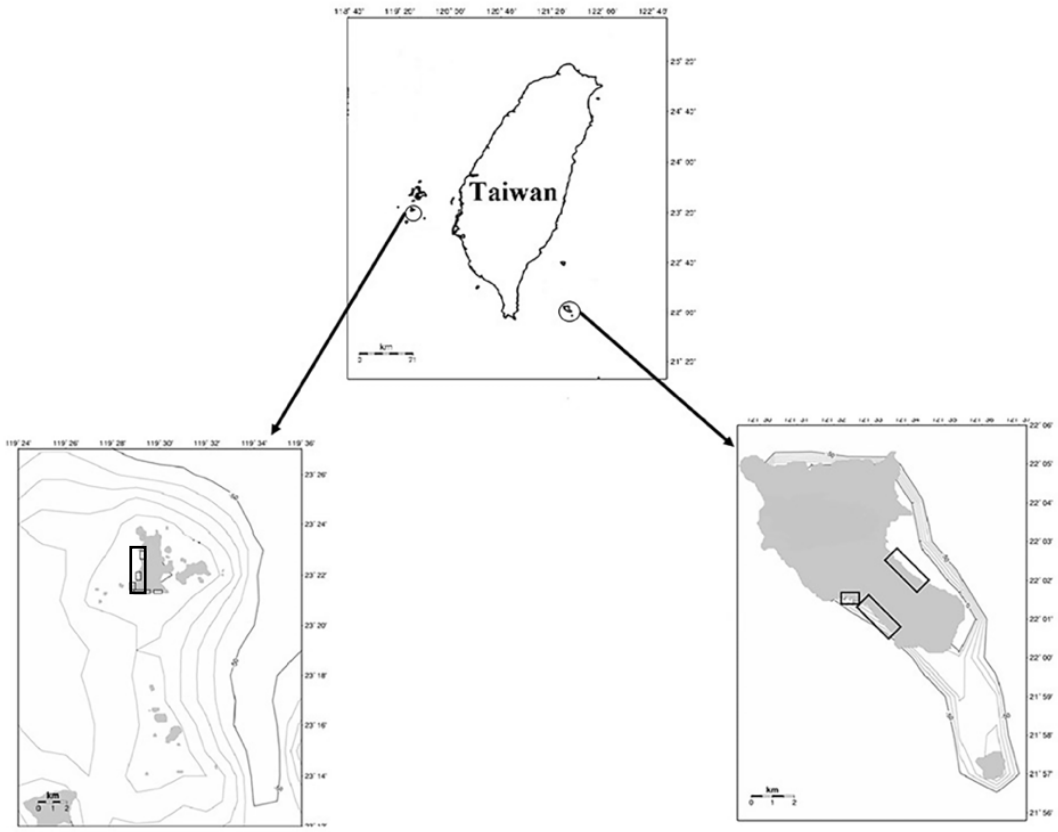

Fig. 9.1

A multi-parameter study was conducted on the two islands to observe the populations of green turtles from 1996 - 2016.

One parameter for the study is the number of new turtle nests in each island.

Fig. 9.2 shows the trend for Wan-an island.

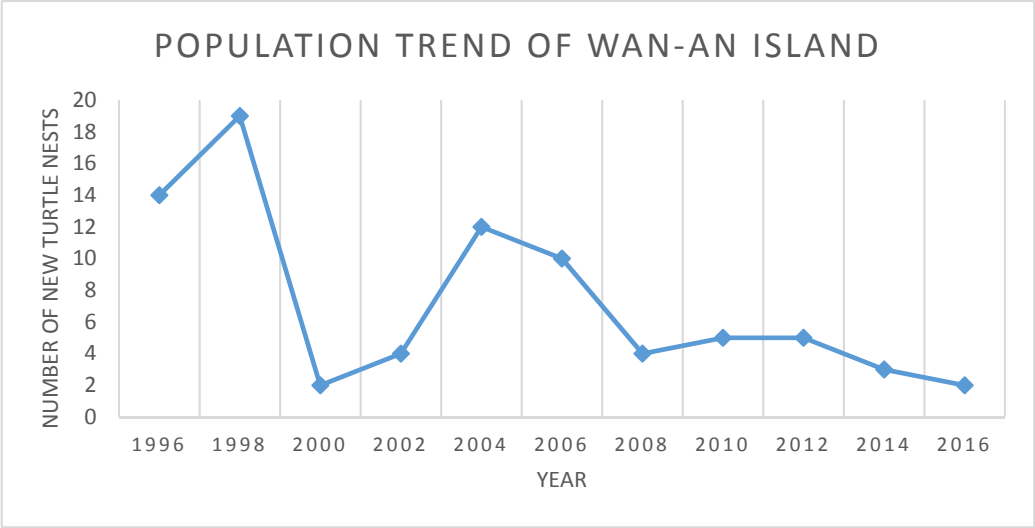

Fig. 9.2

(i) With reference to Fig. 9.2, describe the general trend observed.

- **Number of turtle nests decreased from 14 nests in 1996 to 2 nests in 2016;** [1]

(ii) Suggest **one** reason for this trend.

- **Reclamation works on the island;**
- **Building of resorts on the island;**
- **Poachers on the islands;**
- **Decreased in number of mature turtles due to increase predation;** [1]

(b) The other parameters of the study include nest depth and number of eggs produced per season.

Table 9.3 shows the comparison of mean values for the two parameters between Lanyu (L) and Wan-an (W) islands from 1998 – 2014 and the t-test results.

Table 9.3

parameter	mean value	p-value
nest depth	W > L	< 0.001
number of eggs produced per season	W ~ L	0.583

(i) With reference to Table 9.3, describe the results of the t-test.

- **There is significant difference between the nest depth of Lanyu and Wan-An turtle populations;**
- **There is no significant difference between the number of eggs produced per season of Lanyu and Wan-An Turtle population;** [2]

(ii) Based on your answer in **(i)**, comment whether the results are sufficient to consider the two populations as separate species.

- **Not sufficient;**
- **Unable to tell whether they can still reproduce to produce fertile and viable offspring;**
- **Ref: Biological speciation;** [2]

(iii) Explain how the data supports the theory of biological evolution as descent with modification.

- **Genetic variations exist in green turtles of Taiwan;**
- **Different selection pressure in Lanyu and Wan-an island;**
- **Alleles coding for advantageous traits are selected for;**
- **Higher survival and reproductive success;**
- **Produce viable, fertile offspring;**
- **Leading to changes in allele frequency;**
- **Descent with modification;** [4]

(iv) Explain why the population is the smallest unit that can evolve.

- **Individual organisms cannot evolve;**
- **An individual has the same genome its entire life, except for mutations acquired during its lifetime;**
- **Natural selection acts on individuals in a population, but only population evolves;**
- **Evolution is a process that takes place over extended periods of time as alleles coding for adaptations are passed from one generation to another;** [4]

[Total: 14]

Section A

Answer the question in this section.

1 (a) Chinese white poplar (*Populus tomentosa*) is a native tree species in China that grows in temperate areas. Its growth-dormancy cycle is driven by environmental cues such as temperature.

In a study in the early spring, all the mRNA from the cells in the cambium region of *P. tomentosa* were isolated on six different days in 2008 and converted to complementary DNA (cDNA). The cDNA was then used for polymerase chain reaction (PCR) analysis of the expression patterns of five cell cycle-related genes (*PtoCKS1*, *PtoCYCD3*, *PtoCYCB*, *PtoCDKB* and *PtoCDKA*) and one housekeeping gene (*UBQ-L*)

Fig. 1.1 shows the expression patterns of the six genes in the cambium region of *P. tomentosa*.

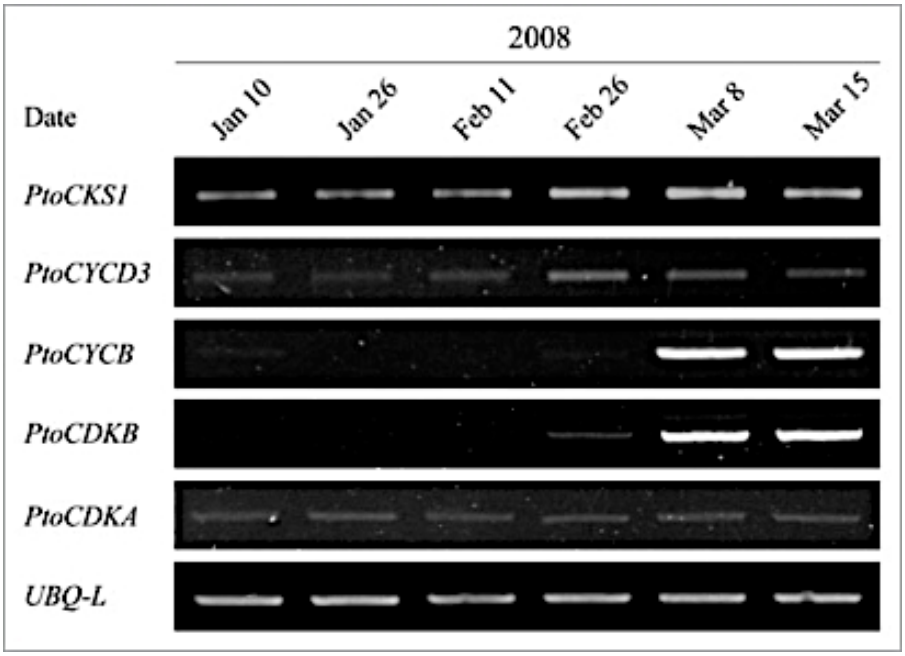

Fig. 1.1

(i) Outline the process of PCR.

_____

_____

_____

_____

_____

_____ [3]

(ii) With reference to Fig. 1.1, describe the expression patterns of *PtoCKS1*, *PtoCYCB*, and *UBQ-L.*

[3]

(iii) During the shift from dormancy to growth, the mitotic cell cycle occurs at an accelerated rate in the cells of *P. tomentosa*.

Outline the behaviour of chromosomes in mitosis.

[4]

(iv) Other than growth, explain **two** other functions of mitosis.

[2]

(b) The increase in temperature affects leaf metabolism in several ways. It affects the activity of Rubisco, the central enzyme of photosynthesis, as well as Rubisco activase, the enzyme required for Rubisco reactivation. In addition, Rubisco activase is found to be far more sensitive to heat than Rubisco.

Fig. 1.2 shows the effect of two temperatures on the activity of the two enzymes.

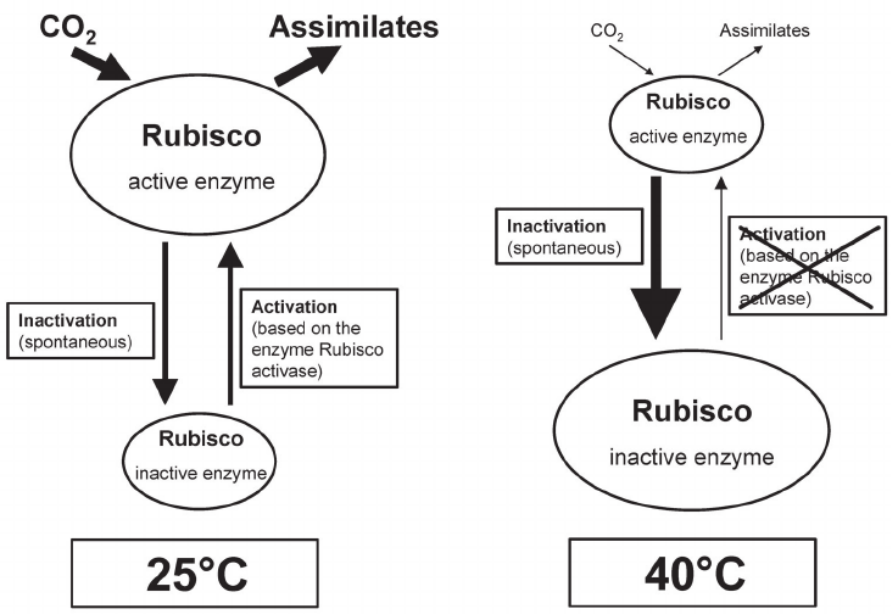

Fig. 1.2

(i) Suggest **one** reason why Rubisco activase is far more sensitive to heat than Rubisco.

_____ [1]

(ii) Describe the effect of increasing temperature from 25°C to 40°C on Rubisco activase activity.

_____

_____

_____

_____

_____

_____

_____

_____ [4]

(iii) With reference to Fig. 1.2, describe and explain the difference between the rate of photosynthesis at 25°C and that at 40°C.

[3]

(c) Other than temperature, increasing CO_2 concentration could also affect the rate of photosynthesis.

(i) Identify and explain **one** human activity over the last few centuries that has contributed to an increase in atmospheric CO_2 concentration.

[2]

(ii) Explain the effects of climate change as atmospheric CO_2 concentration increases.

[3]

(d) Dietary deficiencies of zinc and iron are a substantial global public health problem. An estimated two billion people worldwide suffer from these deficiencies. Most of these people depend on C3 grains and legumes as their primary dietary source of zinc and iron.

A study was done to determine the concentration of zinc when C3 rice plants were grown in a controlled environment at the current atmospheric CO_2 concentration, and at the elevated atmospheric CO_2 concentration predicted for the middle of this century.

Table 1.1 shows the results of the study.

Table 1.1

concentration of zinc in C3 rice plants / mg kg^{-1}	
grown at the current atmospheric CO_2 concentration	grown at the elevated atmospheric CO_2 concentration predicted for 2050
80	75
62	55
52	50
70	62
64	58
72	55
69	70
70	62

A two-sample t-test could be carried out to determine whether there is a decrease in the concentration of zinc when the C3 rice plants were grown at the elevated atmospheric CO2 concentration predicted for 2050.

(i) State the alternative hypothesis for the t-test.

_____

_____ [1]

(ii) Carry out the t-test in the space provided.

Show all your working.

[2]

(iii) State the conclusion for the t-test.

_____

_____

_____

_____ [2]

[Total: 30]

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Name: _____ **Biology Class: 2bi2___**

Section B

For Examiner's Use	
Section B	
2	**/20**

Section B

Answer the question in this section.

2 *Helicobacter pylori* is a spiral shaped, gram-negative bacterium that lives in the stomach and duodenum. In Singapore, the prevalence rate in the community (without any symptom) is estimated to increase with age — from 3% in children under the age of 5 to 71% in adults above the age of 65.

H. pylori has a genome size of approximately 1.7 Mb, with a G+C content of 35 % to 40%. Its genome sequence is highly variable. The genome of strain 26695 includes 1,587 genes, whereas the genome of strain J99 includes only 1,491 genes. Many strains carry one or more plasmids, which do not seem to carry antibiotic resistance genes or virulence genes.

(a) Compare the structure and organisation of *H. pylori* genome with its host cell genome.

[4]

Fig. 2.1 shows the major virulence and colonization factors of *H. pylori*. *H. pylori* uses its flagella and chemotaxis mechanisms to swim through the mucus lining the gastric epithelium. It attaches to the host cell surface and deliver toxins, such as CagA and VacA, into the host cell to control various aspects of host cell function.

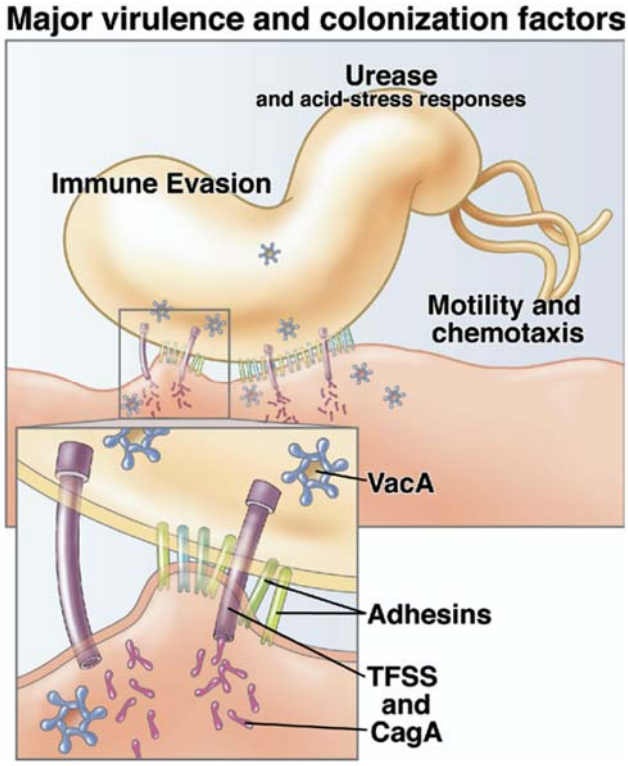

Fig. 2.1

(b) There are several ways to diagnose *H. pylori*. One method is to draw a sample of blood from the patient and test the blood for presence of *H. pylori*-specific antibody.

Explain how the presence *H. pylori* triggers the production of *H. pylori*-specific antibodies in an infected patient.

[3]

The first line therapy for *H. pylori* infection is known as triple therapy, comprising two antibiotics, clarithromycin and amoxicillin, and one proton pump inhibitor. All three drugs are administered two times a day for 14 days. Amoxicillin is similar in action to penicillin while clarithromycin binds to 23S rRNA.

(c) Discuss the deliberate use of the two antibiotics in the therapy.

[4]

Early studies found that patients with antibodies against CagA showed higher rates of gastric adenocarcinoma. The C-terminal tail of the CagA is a target for phosphorylation by kinases coded by cellular oncogenes. After phosphorylation, CagA would trigger signals that resemble the activation of receptor tyrosine kinase by growth factors, controlling proliferative activities, adhesion, and cytoskeletal organization of epithelial cells. Other studies have shown that CagA leads to increased degradation of p53.

(d) Using the information provided, explain why patients with prolonged *H. pylori* infection have an increased risk of developing adenocarcinoma.

[4]

cagA is a gene that has many variants. In particular, there are different numbers of repeat sequences located in the 3' region of the *cagA* gene of different *H. pylori* strains. Each repeat region of the CagA protein contains Glu-Pro-Ile-Tyr-Ala (EPIYA) motifs, including a tyrosine phosphorylation site. Studies confirmed that, in western countries, the incidence of gastric cancer is notably higher in patients infected with strains containing multiple EPIYA-C segments than in patients infected with strains containing a single EPIYA-C segment.

Fig. 2.2 shows three variants of CagA protein.

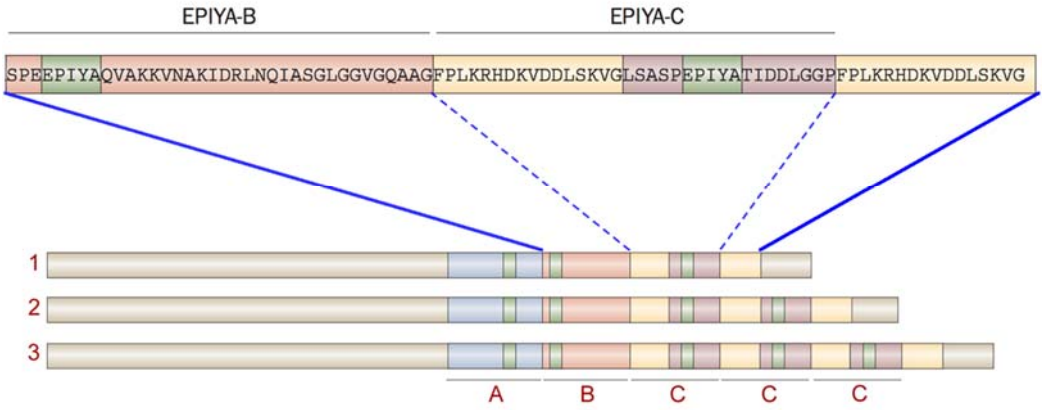

Fig. 2.2

(e) (i) Polymerase chain reaction (PCR) could be carried out on a tissue sample to determine the *cagA* variant of the *H. pylori* strain infecting the patient.

Indicate on Fig. 2.2, the ideal position of **one** set of primers to distinguish the DNA sequence corresponding to the three CagA variants by PCR.

[1]

(ii) Determine the size difference between PCR products from tissue samples containing variant **1** and variant **2** respectively.

[1]

(iii) Outline the principle and procedure of a molecular technique that could be used to determine the variant of *cagA* gene after PCR has been performed.

[3]

[Total: 20]

Name: _____ **Biology Class: 2bi2___**

Section C

For Examiner's Use	
Section C	
__ (a)	/15
__ (b)	/10

Section C

Answer **one** question in this section.

Write your answers on the separate answer paper provided.

Your answers should be illustrated with large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

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

3 **(a)** Using **three** named examples, explain the relationship between the structures and functions of carbohydrates in living organisms. [15]

(b) Describe how photosynthesis and cellular respiration complement each other in the environment, and compare the two processes. [10]

[Total: 25]

4 **(a)** Using **three** named examples, explain the relationship between the structures and functions of proteins in living organisms. [15]

(b) Describe how enzymes increase the rate of chemical reactions, and compare the actions of competitive and non-competitive enzyme inhibitors. [10]

[Total: 25]

Section A

Answer the question in this section.

1 (a) Chinese white poplar (*Populus tomentosa*) is a native tree species in China that grows in temperate areas. Its growth-dormancy cycle is driven by environmental cues such as temperature.

In a study in the early spring, all the mRNA from the cells in the cambium region of *P. tomentosa* were isolated on six different days in 2008 and converted to complementary DNA (cDNA). The cDNA was then used for polymerase chain reaction (PCR) analysis of the expression patterns of five cell cycle-related genes (*PtoCKS1*, *PtoCYCD3*, *PtoCYCB*, *PtoCDKB* and *PtoCDKA*) and one housekeeping gene (*UBQ-L*)

Fig. 1.1 shows the expression patterns of the six genes in the cambium region of *P. tomentosa*.

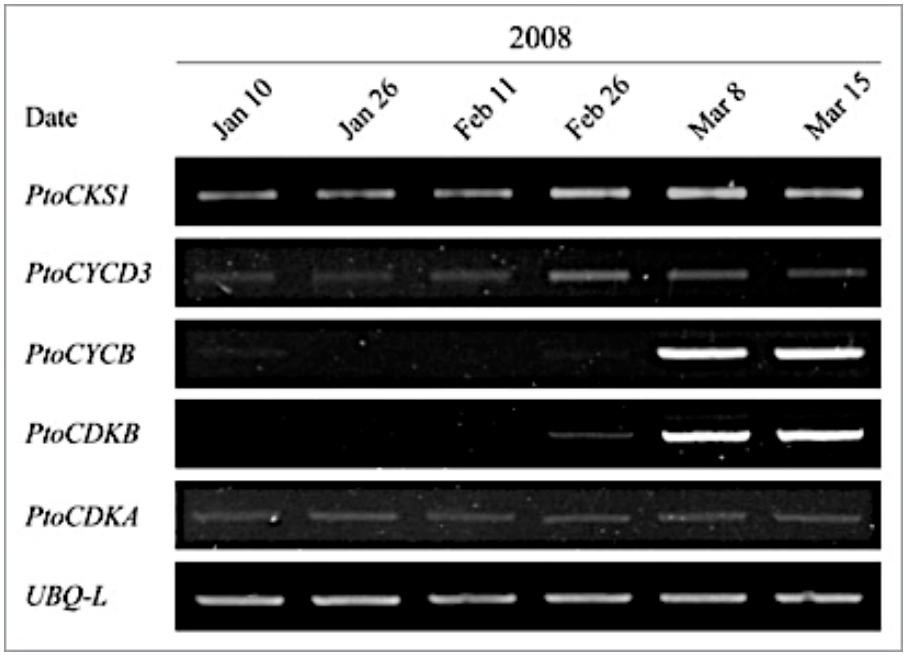

Fig. 1.1

(i) Outline the process of PCR.

Stage 1: Denaturation

1. **The reaction mix is heated to 95°C.**
2. **The double-stranded DNA separates into 2 single strands, as the hydrogen bonds between base pairs are broken.**
3. **Each strand will act as a template for the synthesis of its complementary strand.**

Stage 2: Annealing

4. **The reaction mix is then cooled slightly to 50 – 55°C.**

5. **Two types of DNA primers, the forward and reverse primers, are used.**

6. **Primers anneal via complementary base-pairing to the start and end of the target sequence (3' end of each separated DNA strand), marking the boundaries of the DNA to be amplified.**

Stage 3: Extension/Elongation

7. **The temperature is raised to 72°C.**

8. **Taq polymerase adds deoxyrinucleotides to the 3'-OH ends of each primer, using the DNA molecule as a template, extending the primers in the 5' → 3' direction.**

[For each stage, quote temperature and one subsequent explanation for 1 mark.]

[3]

(ii) With reference to Fig. 1.1, describe the expression patterns of *PtoCKS1*, *PtoCYCB*, and *UBQ-L.*

1. **PtoCKS1 – Increasing expression from Jan 10 to Mar 15**
2. **PtoCYCB – No expression from Jan 10 to Feb 26, expression starts on March 8**
3. **UBQ – L – Continous expression throughout the 8 days**

[3]

(iii) During the shift from dormancy to growth, the mitotic cell cycle occurs at an accelerated rate in the cells of *P. tomentosa*.

Outline the behaviour of chromosomes in mitosis.

1. **During prophase, chromatin fibres condense into chromosomes.**
2. **Each duplicated chromosome appears as two identical sister chromatids joined together at their centromeres.**
3. **During metaphase, chromosomes line up individually at the metaphase plate.**
4. **During anaphase, (the centromeres divide and) the sister chromatids separate.**
5. **The liberated / full-fledged chromosomes begin moving toward opposite poles of the cell.**
6. **During telophase, chromosomes reach the poles of the cell and decondense.**

[4]

(iv) Other than growth, explain **two** other functions of mitosis.

1. **Mitosis maintains genetic stability of an organism.**
2. **This is because eukaryotic cell divisions involving mitosis produce daughter cells, each containing the same number of chromosomes and the same hereditary information as the parent cell.**

3. **Mitosis occurs during the repair of worn-out or damaged tissue in the body.**
4. **Worn-out or damaged cells are replaced by new cells that are produced by eukaryotic cell divisions involving mitosis, and are therefore genetically identical to the original cells.**

5. **Mitosis is the basis of asexual reproduction.**
6. **A single parent undergoes eukaryotic cell division(s) involving mitosis, which produces offspring genetically identical to the parent.**

[2]

(b) The increase in temperature affects leaf metabolism in several ways. It affects the activity of Rubisco, the central enzyme of photosynthesis, as well as Rubisco activase, the enzyme required for Rubisco reactivation. In addition, Rubisco activase is found to be far more sensitive to heat than Rubisco.

Fig. 1.2 shows the effect of two temperatures on the activity of the two enzymes.

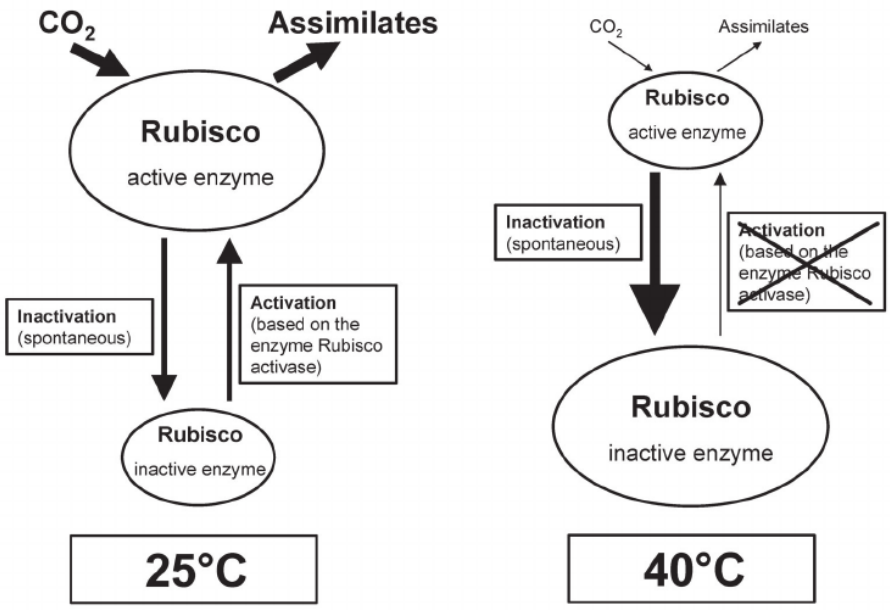

Fig. 1.2

(i) Suggest **one** reason why Rubisco activase is far more sensitive to heat than Rubisco.

Presence of disulphide bonds in Rubisco

[1]

(ii) Describe the effect of increasing temperature from 25°C to 40°C on Rubisco activase activity.

1. **Beyond the optimum temperature, the rate of reaction decreases drastically, and eventually reaches zero.**
2. **The kinetic energy of the enzyme and substrate molecules continues to increase with temperature, leading to higher frequency of collisions.**
3. **However, the rise in temperature causes thermal agitation, disrupting weak bonds (hydrogen bonds, ionic bonds, hydrophobic interactions) holding the secondary and tertiary structures are disrupted.**
4. **Thus, the structure of the active sites are distorted and no longer complementary to the substrate. As a result, substrate molecules cannot bind to the active site, and ES complex cannot be formed.**
5. **The enzyme loses its catalytic activity progressively as enzymes are being denatured by the high temperature.**

[4]

(iii) With reference to Fig. 1.2, describe and explain the difference between the rate of photosynthesis at 25°C and that at 40°C.

1. **At 25°C, there is activation of inactive rubisco to active rubisco**
2. **Due to functional Rubisco activase, hence rate of photosynthesis is high**
3. **At 40°C, there is no activation of inactive rubisco to active rubisco**
4. **While inactivation of active rubisco enzyme occurs spontaneously, low amount of active rubisco enzyme leads to lower rate of photosynthesis.**

[3]

(c) Other than temperature, increasing CO_2 concentration could also affect the rate of photosynthesis.

(i) Identify and explain **one** human activity over the last few centuries that has contributed to an increase in atmospheric CO_2 concentration.

1. **Burning of fossil fuel for transport/industrial/residential**
2. **Releases atmospheric carbon dioxide as the process combines carbon with oxygen in the air**
3. **Land use changes such as deforestation**
4. **Loss of carbon sink as carbon dioxide is taken in by trees / burning of cleared trees releases large amount of CO2**
5. **Demand for meat**
6. **Meat production result in the release of GHGs through industrial processes and rearing of cows which increases enteric fermentation**

[2]

(ii) Explain the effects of climate change as atmospheric CO_2 concentration increases.

1. **Melting of polar ice caps**
2. **Rising sea levels**
3. **Stress on fresh water supplies**
4. **Heat waves**
5. **Heavy rains**
6. **Death of coral reefs**
7. **Migration of fishes and insects,**
8. **Release of greenhouse gases in frozen organic matter**

[Any of the above with elaboration]

[3]

(d) Dietary deficiencies of zinc and iron are a substantial global public health problem. An estimated two billion people worldwide suffer from these deficiencies. Most of these people depend on C3 grains and legumes as their primary dietary source of zinc and iron.

A study was done to determine the concentration of zinc when C3 rice plants were grown in a controlled environment at the current atmospheric CO_2 concentration, and at the elevated atmospheric CO_2 concentration predicted for the middle of this century.

Table 1.1 shows the results of the study.

Table 1.1

concentration of zinc in C3 rice plants / mg kg^{-1}	
grown at the current atmospheric CO_2 concentration	grown at the elevated atmospheric CO_2 concentration predicted for 2050
80	75
62	55
52	50

70	62
64	58
72	55
69	70
70	62

A two-sample t-test could be carried out to determine whether there is a decrease in the concentration of zinc when the C3 rice plants were grown at the elevated atmospheric CO2 concentration predicted for 2050.

(i) State the alternative hypothesis for the t-test.

Mean concentration of zinc in C3 plants were lower when grown at the elevated atmospheric CO2 concentration at 2050 compared to current

[1]

(ii) Carry out the t-test in the space provided.

Show all your working.

1. **Workings for t-test shown, with mean values for x_1 (67.375) and x_2 (60.875)**
2. **T-value of 1.57 / p-value of 0.0688**

[For Point 1, if GC was used, to show mean and SD values for x_1 and x_2]

[2]

(iii) State the conclusion for the t-test.

1. **Do not reject the null hypothesis / no significant difference between x_1 and x_2**
2. **Any difference is due to chance**

[2]

[Total: 30]

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Name: _____ **Biology Class: 2bi2___**

Section B

For Examiner's Use	
Section B	
2	**/20**

Section B

Answer the question in this section.

2 *Helicobacter pylori* is a spiral shaped, gram-negative bacterium that lives in the stomach and duodenum. In Singapore, the prevalence rate in the community (without any symptom) is estimated to increase with age — from 3% in children under the age of 5 to 71% in adults above the age of 65.

H. pylori has a genome size of approximately 1.7 Mb, with a G+C content of 35 % to 40%. Its genome sequence is highly variable. The genome of strain 26695 includes 1,587 genes, whereas the genome of strain J99 includes only 1,491 genes. Many strains carry one or more plasmids, which do not seem to carry antibiotic resistance genes or virulence genes.

(a) Compare the structure and organisation of *H. pylori* genome with its host cell genome.

Similarities:

S1. ref to double-stranded nature of both genome;
S2. ref to DNA nature of both genome;

Differences:

D1. *H.pylori* genome is packed in circular chromosome while host genome is packed into multiple linear chromosomes;
D2. *H.pylori* DNA is organised into supercoiled loops associated with nucleoid proteins, while host DNA is wound around histones and arranged to form coiled coils in

[4]

Fig. 2.1 shows the major virulence and colonization factors of *H. pylori*. *H. pylori* uses its flagella and chemotaxis mechanisms to swim through the mucus lining the gastric epithelium. It attaches to the host cell surface and deliver toxins, such as CagA and VacA, into the host cell to control various aspects of host cell function.

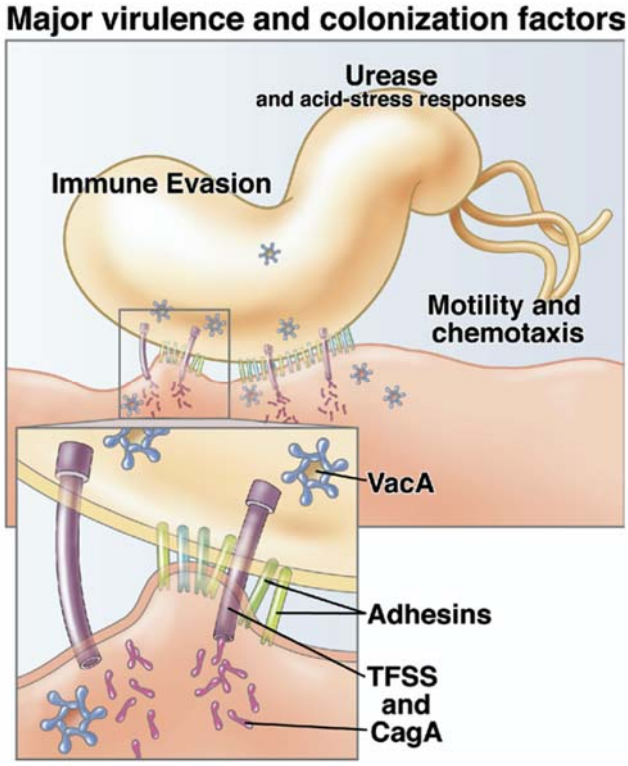


Fig. 2.1

(b) There are several ways to diagnose *H. pylori*. One method is to draw a sample of blood from the patient and test the blood for presence of *H. pylori*-specific antibody.

Explain how the presence *H. pylori* triggers the production of *H. pylori*-specific antibodies in an infected patient.

1. ***H. pylori* engulfed by dendritic cells/macrophages at the gastric epithelium and down by lysosomes to produce antigenic peptides;**
2. **Dendritic cell presents antigenic peptides to helper T cells and activates helper T cells;**
3. **Naive B cells internalizes and presents antigenic peptides;**
4. **TCR on helper T cell recognises and binds antigen on B cell and stimulates B cell to proliferate;**
5. **Some B cells differentiate into plasma cells to produce *H. pylori*-specific antibodies;**

[3]

The first line therapy for *H. pylori* infection is known as triple therapy, comprising two antibiotics, clarithromycin and amoxicillin, and one proton pump inhibitor. All three drugs are administered two times a day for 14 days. Amoxicillin is similar in action to penicillin while clarithromycin binds to 23S rRNA.

(c) Discuss the deliberate use of the two antibiotics in the therapy.

1. **Amoxicillin inhibits cell wall synthesis by inhibiting the formation of cross-links between adjacent chains of peptidoglycan;**
2. **Use of amoxicillin will result in lysis of newly divided bacterial cells**
3. **Clarithromycin prevents formation of functional ribosomes;**
4. **Use of clarithromycin prevents bacterial cells from producing necessary proteins, such as CagA , thus reducing survival of existing bacterial cells;**
5. **Ref to high mutation rate of bacteria + develop resistance to one of the antibiotics during course of treatment;**
6. **Ref to presence of second antibiotic allows resistant bacteria to be killed**

[4]

Early studies found that patients with antibodies against CagA showed higher rates of gastric adenocarcinoma. The C-terminal tail of the CagA is a target for phosphorylation by kinases coded by cellular oncogenes. After phosphorylation, CagA would trigger signals that resemble the activation of receptor tyrosine kinase by growth factors, controlling proliferative activities, adhesion, and cytoskeletal organization of epithelial cells. Other studies have shown that CagA leads to increased degradation of p53.

(d) Using the information provided, explain why patients with prolonged *H. pylori* infection have an increased risk of developing adenocarcinoma.

1. **Increased degradation of p53 leads to decreased repair of damaged DNA;**
2. **Leads to accumulation of mutations;**
3. **Higher chance for proto-oncogenes to accumulate gain-of-function mutation to become oncogene;**
4. **Oncogenes phosphorylate CagA leading to greater cell proliferation even in absence of growth factor;**
5. **Resulting cytoskeletal organisation may lead cells to demonstrate loss of contact of inhibition thus forming tumor**

[4]

cagA is a gene that has many variants. In particular, there are different numbers of repeat sequences located in the 3' region of the *cagA* gene of different *H. pylori* strains. Each repeat region of the CagA protein contains Glu-Pro-Ile-Tyr-Ala (EPIYA) motifs, including a tyrosine phosphorylation site. Studies confirmed that, in western countries, the incidence of gastric cancer is notably higher in patients infected with strains containing multiple EPIYA-C segments than in patients infected with strains containing a single EPIYA-C segment.

Fig. 2.2 shows three variants of CagA protein.

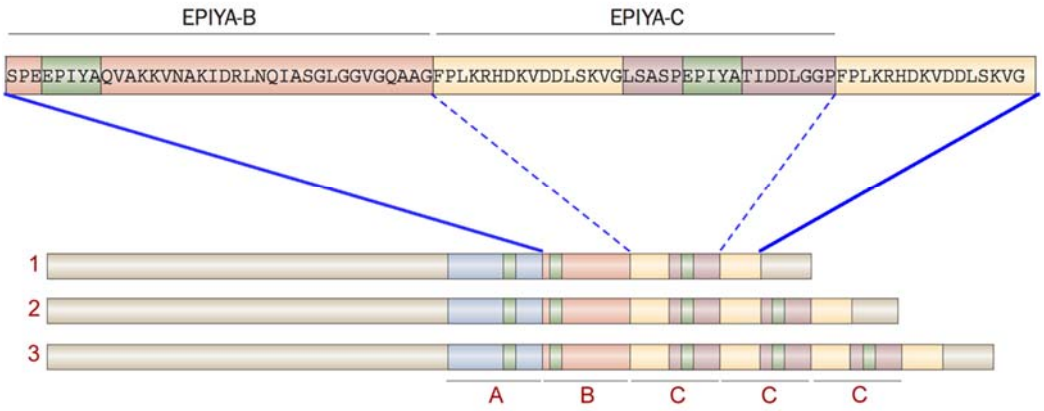
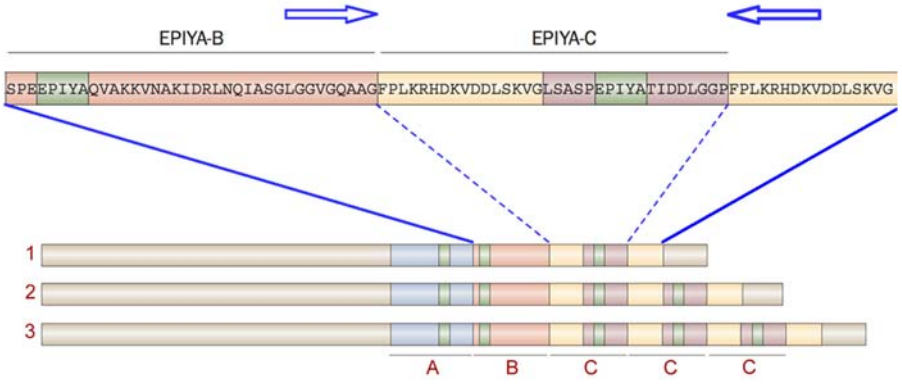


Fig. 2.2

(e) (i) Polymerase chain reaction (PCR) could be carried out on a tissue sample to determine the *cagA* variant of the *H. pylori* strain infecting the patient.

Indicate on Fig. 2.2, the ideal position of **one** set of primers to distinguish the DNA sequence corresponding to the three CagA variants by PCR.

[1]



(ii) Determine the size difference between PCR products from tissue samples containing variant **1** and variant **2** respectively.

Number of amino acid difference = 34

Number of nucleotide difference = 34 x 3 = 102

[1]

(iii) Outline the principle and procedure of a molecular technique that could be used to determine the variant of *cagA* gene after PCR has been performed.

1. **Agarose gel electrophoresis + separation of nucleic acid by size;**
2. **ref to migration of DNA molecules towards positive electrode/anode;**
3. **ref to molecular ladder + mixture of DNA fragments of known sizes added to same gel to estimate size of PCR fragment**
4. **ref to setting up gel electrophoresis**

[3]

[Total: 20]

Name: _____ **Biology Class: 2bi2___**

Section C

For Examiner's Use	
Section C	
__ (a)	/15
__ (b)	/10

Section C

Answer **one** question in this section.

Write your answers on the separate answer paper provided.

Your answers should be illustrated with large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

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

3 **(a)** Using **three** named examples, explain the relationship between the structures and functions of carbohydrates in living organisms. [15]

(b) Describe how photosynthesis and cellular respiration complement each other in the environment, and compare the two processes. [10]

[Total: 25]

4 **(a)** Using **three** named examples, explain the relationship between the structures and functions of proteins in living organisms. [15]

(b) Describe how enzymes increase the rate of chemical reactions, and compare the actions of competitive and non-competitive enzyme inhibitors. [10]

[Total: 25]

Mark Scheme for FRQ 3(a):

Starch / Glycogen	*1 mark for each valid example:* **Starch / Glycogen**	**2**
	Any 7 of the following: **1. Glycosidic bonds (are strong covalent bonds that) join many α-glucose monomers together to form starch / glycogen;** **2. Which can be released upon hydrolysis as respiratory substrates;** **3. This also forms a large molecule so that the molecule is insoluble in water;** **4. α-1,4-glycosidic bonds forms a helical structure;** **5. which causes the molecule to be compact for storage;** **6. Hydroxyl groups of glucose residues project into the interior of the helices;** **7. Hence, absence of hydrogen bonds with water causing starch / glycogen to be insoluble in water;** **8. Hence, they can be stored in large quantities without affecting the osmotic potential of cells;** **9. α-1,6-glycosidic bonds allows for amylopectin / glycogen to be highly branched;** **10. Hence, a greater amount of carbohydrates can be stored per unit volume;** **11. It also allows for many enzymes to act on it at the same time;** **12. Allows for quick release of glucose (for an increased rate of respiration);**	**7**
Cellulose	*1 mark for valid example:* **Cellulose**	**1**
	Any 4 of the following: **13. Glycosidic bonds (are strong covalent bonds) join many β-glucose monomers together to form cellulose;** **14. This also forms a large molecule so that the molecule is insoluble in water;** **15. β-1,4-glycosidic bonds allow the formation of straight chains;** **16. Hydrogen bond cross links between hydroxyl groups of adjacent chains;** **17. prevent the hydroxyl groups from forming hydrogen bonds with water hence allowing it to be insoluble in water;** **18. Also allows for formation of microfibrils and macrofibrils;** **19. which allows cellulose to have tremendous tensile strength;** **20. Allowing it to perform its function as a structural molecule;** **21. to help prevent cells from bursting / maintain shape of cell / allows for cell turgidity;**	**4**
QWC	*Attempt to relate structure to function for at least two named examples*	**1**

Mark Scheme for FRQ 3(b):

<table>
<tr><td>Complement</td><td>Any 2 of the following:
1. Photosynthesis makes the glucose that is used in cellular respiration to make ATP, while the glucose in cellular respiration is then turned back into carbon dioxide, which is used in photosynthesis;
2. Water is broken down to form oxygen during photosynthesis, while oxygen is combined with hydrogen to form water in cellular respiration;
3. Photosynthesis requires carbon dioxide and releases oxygen, while cellular respiration requires oxygen and releases carbon dioxide;</td><td>2</td></tr>
<tr><td>Similarities</td><td>Any 2 valid similarities:
4. ATP synthase catalyses the formation of ATP during chemiosmosis;
5. Electron transport chain is required for generation of an electrochemical proton gradient;
6. AVP</td><td>2</td></tr>
<tr><td>Differences</td><td>Any 5 valid differences (different from points in “Complement” section):
<table>
<tr><th colspan="2"></th><th>photosynthesis</th><th>cellular respiration</th></tr>
<tr><td>7.</td><td>cellular location</td><td>chloroplast</td><td>cytoplasm (anaerobic) & mitochondria (aerobic)</td></tr>
<tr><td>8.</td><td>equation</td><td>$6CO_2 + 6H_2O$ + light → $C_6H_{12}O_6 + 6O_2$</td><td>$C_6H_{12}O_6 + 6O_2$ → $6CO_2 + 6H_2O$ + ATP (energy)</td></tr>
<tr><td>9.</td><td>stages</td><td>2 (light-dependent and light-independent reactions)</td><td>4 (glycolysis, link reaction, Krebs cycle, oxidative phosphorylation)</td></tr>
<tr><td>10.</td><td>establishment of proton gradient</td><td>protons pumped from stroma across thylakoid membrane into thylakoid space</td><td>protons pumped from mitochondrial matrix across inner mitochondrial membrane into intermembrane space</td></tr>
<tr><td>11.</td><td>main function</td><td>production of food / energy capture / anabolic</td><td>breakdown of food / energy release / catabolic</td></tr>
<tr><td>12.</td><td colspan="3">AVP</td></tr>
</table></td><td>5</td></tr>
<tr><td>QWC</td><td>Use of table to compare photosynthesis and cellular respiration</td><td>1</td></tr>
</table>

Mark Scheme for FRQ 4(a):

Haemoglobin	*1 mark for valid example:* **Haemoglobin** (transport)	**1**
	Any 4 of the following: 1. **Amino acids are joined together by (strong covalent bonds known as) peptide bonds (to form the alpha and beta chains which are 141 amino acids and 146 amino acids long respectively);** 2. **Hydrogen bonds are formed between the –CO and –NH groups of the polypeptide backbone to form α-helices;** 3. **The 3D conformation of the protein is maintained by ionic, hydrogen bonds and hydrophobic interactions between R-groups (at least 2 bonds);** 4. **The two αβ dimers are held together mainly by weak hydrogen bonds and ionic bonds;** 5. **In contrast, the two polypeptide chains within each αβ dimer are tightly held together by mainly hydrophobic interactions;** 6. **This allows for the arrangement of hydrophobic amino acid residues within the interior of the globular structure;** 7. **allowing for the formation of a haem binding pocket/ hydrophobic environment / deep hydrophobic cleft for the haem group to bind to oxygen;** 8. **Hydrophilic amino acid residues are found at the surface of the globin;** 9. **Allowing hydrogen bonds to be formed between the water and hydrophilic amino acid residues;** 10. **Allows for solubility in a aqueous medium/ allows it to be a good transporter of oxygen in blood;** 11. **The hydrogen bonds between the two αβ dimers allow for cooperativity to occur;** 12. **When an oxygen molecule binds to / is released from one haemoglobin subunit, the binding / release induces a conformational change in the remaining subunit;** 13. **Which increases / lowers the affinity for oxygen of the remaining three oxygen binding sites respectively;** 14. **Hence facilitates the loading and unloading of oxygen;**	**4**

Collagen	*1 mark for valid example:* **Collagen** (structural)	**1**
	Any 4 of the following: **15. Amino acids join together by (strong covalent bonds known as) peptide bonds (to form the alpha chain);** **16. which has a repeating tri-peptide sequence of glycine-X-Y**; **17. where X is often proline and Y is often hydroxyproline or hydroxylysine;** **18. Polymerisation allows for the formation of a long molecule that allows collagen to function as a structural protein;** **19. Collagen is insoluble in water due to absence of hydrogen bonds with water;** **20. As glycine and proline are hydrophobic;** **21. Collagen has high tensile strength;** **22. Due to covalent cross-links between different tropocollagen molecules;** **23. Cross linking by hydrogen bonds between alpha chains / within triple helix / tropocollagen** (Reject: within collagen)**;** (award mark if linked to insolubility and tensile strength)**;** **24. Bundling for the formation of a fibril and subsequently fibres;**	**4**
G-protein linked receptor	*1 mark for valid example:* **G-protein linked receptor** (signalling)	**1**
	Any 3 of the following: **25. Amino acids join together by (strong covalent bonds known as) peptide bonds (to form the alpha chain);** **26. The presence of hydrogen bonds formed between the –CO and –NH groups of the polypeptide backbone to form 7 α-helices;** **27. The 3D conformation of the protein is maintained by ionic, disulfide, hydrogen bonds and hydrophobic interactions between R groups (at least 2 bonds);** **28. This allows for the arrangement of hydrophobic / non-polar R groups of amino acids facing exterior of α helices to interact with hydrophobic / hydrocarbon tails of the phospholipid bilayer;** **29. hence allowing for embedment of the protein in the membrane;** **30. This also allows for the formation of a binding site to allow binding of a signal molecule/ ligand;** **31. And the formation of a binding site to allow binding of the G protein;** **32. Hence allowing for the signal molecule to bind and trigger conformation change in GPLR;** **33. And activated GPLR can bind to the G protein and activate G protein when GTP displaces GDP;**	**3**

QWC	*Attempt to relate structure to function for at least two named examples*	**1**

Mark Scheme for FRQ 4(b):

How enzymes increase the rate of reactions	*Any 2 of the following:* **1. By lowering of the energy barrier and hence activation energy of the reaction;** **2. Binding of substrates to enzyme active site brings substrates into close proximity to each other;** **3. In enzyme active site, substrates undergo slight distortion and this strains bonds in the substrate that need to be broken;** **4. Substrates are held in the correct orientation such that the bonds in the substrate are exposed to chemical attack;** **5. Enzymes create the appropriate microenvironment for a reaction to occur;** **6. e.g. hydrophobic amino acids in enzyme create a water-free zone that allows non-polar reactants to react more easily / AVP;** **7. R groups of acidic and basic amino acids in enzyme active site facilitate reaction between substrates;** **8. to increase chances / rate of a reaction;** (note: mark given if one of the points from point 2 to 7 are mentioned)	**3**
Similarity	*Any 1 valid similarity:* **9. When the inhibitor binds to the enzyme's active site or site away from active site, an enzyme-inhibitor (E-I) complex is formed;** **10. The rate of the enzyme-catalysed reaction is reduced;** **11.** *AVP*	**1**
Differences	*Any 5 valid differences (on next page)*	**5**
QWC	*Use of table to compare the actions of competitive and non-competitive enzyme inhibitors*	**1**

Competitive Inhibition	Non-competitive Inhibition
○ A competitive inhibitor, as its name suggests, competes with the genuine substrate for binding to the enzyme's active site. ○ To do so, it must have a structural resemblance to the genuine substrate.	○ Unlike a competitive inhibitor, a non-competitive does not compete with the genuine substrate for binding to the enzyme's active site. ○ This is because it has no structural resemblance to the genuine substrate.
○ Binds loosely to the enzyme's active site	○ Binds loosely to the enzyme away from the active site
○ Binding of the competitive inhibitor to the enzyme's active site prevents binding of the genuine substrate to the enzyme's active site. ○ This decreases the number of active sites available for the genuine substrates to bind and form enzyme-substrate complexes, and eventually, products.	○ Binding of the non-competitive inhibitor to the site away from the active site does not prevent binding of the genuine substrate to the enzyme's active site, and vice versa. ○ When both the genuine substrate and the non-competitive inhibitor are bound, the enzyme-substrate-inhibitor (ESI) complex is formed. Products cannot be formed as the ESI complex can only be converted back to the ES complex or the EI complex. This simply prevents product formation for a limited time.
○ Increasing substrate concentration may reduce or even completely remove the effect of the competitive inhibitor. ○ With more substrate molecules present, there is a higher probability of them displacing the weakly associated inhibitor molecules from the active sites and forming enzyme-substrate complexes. (substrate will "out-compete" inhibitor) ○ With high enough substrate concentration, V_{max} of uninhibited reaction can be reached.	○ Increasing substrate concentration may reduce but cannot completely remove the effect of the non-competitive inhibitor. ○ No matter how high the concentration of substrate is, some of the enzymes will still be inhibited as the non-competitive inhibitor does not bind to the same site as the genuine substrate. ○ Even with very high substrate concentration, $V_{max.}$ of the uninhibited reaction can never be reached. ○ Rate of reaction can only be increased with an increase in enzyme concentration while keeping inhibitor concentration constant.
○ V_{max} of inhibited reaction is the same as that of uninhibited reaction. ○ K_m for inhibited reaction is higher than that for uninhibited reaction.	○ V_{max} of inhibited reaction is lower than that of uninhibited reaction. ○ K_m for inhibited reaction is the same as that for uninhibited reaction.