Civics Group	Index Number	Name (use BLOCK LETTERS)	H2

ST. ANDREW'S JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATIONS

H2 BIOLOGY **9744/01**

Paper 1: Multiple Choice

Friday 16th September 2022 1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

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

There are **30** questions in this paper. Answer all questions. For each question, there are four possible answers, A, B, C and D.

Choose the one you consider correct and record your choice in soft pencil on the separate multiple choice **Optical Answer Sheet**.

INFORMATION TO CANDIDATES

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

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

This document consists of **25** printed pages

[Turn over

1 Which group of eukaryotic cell structures all contain nucleic acids?

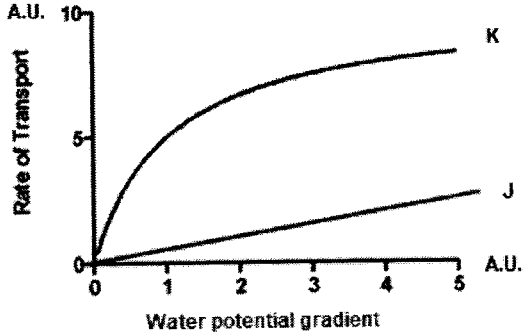
A cytoplasm, Golgi bodies, mitochondria, nuclei
B centrioles, chloroplasts, mitochondria, ribosomes
C centrioles, mitochondria, nuclei, ribosomes
D chloroplasts, mitochondria, cytoplasm, ribosomes

2 Which properties of phospholipids explain why single layers of phospholipids added to water immediately form bilayers?

1 The hydrophobic fatty acid chains repel water molecules so the tails pack together.
2 The non-polar fatty acid chains are attracted to each other by hydrophobic interactions.
3 Charged phosphate groups form hydrogen bond with water.
4 Phospholipids are insoluble in water

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

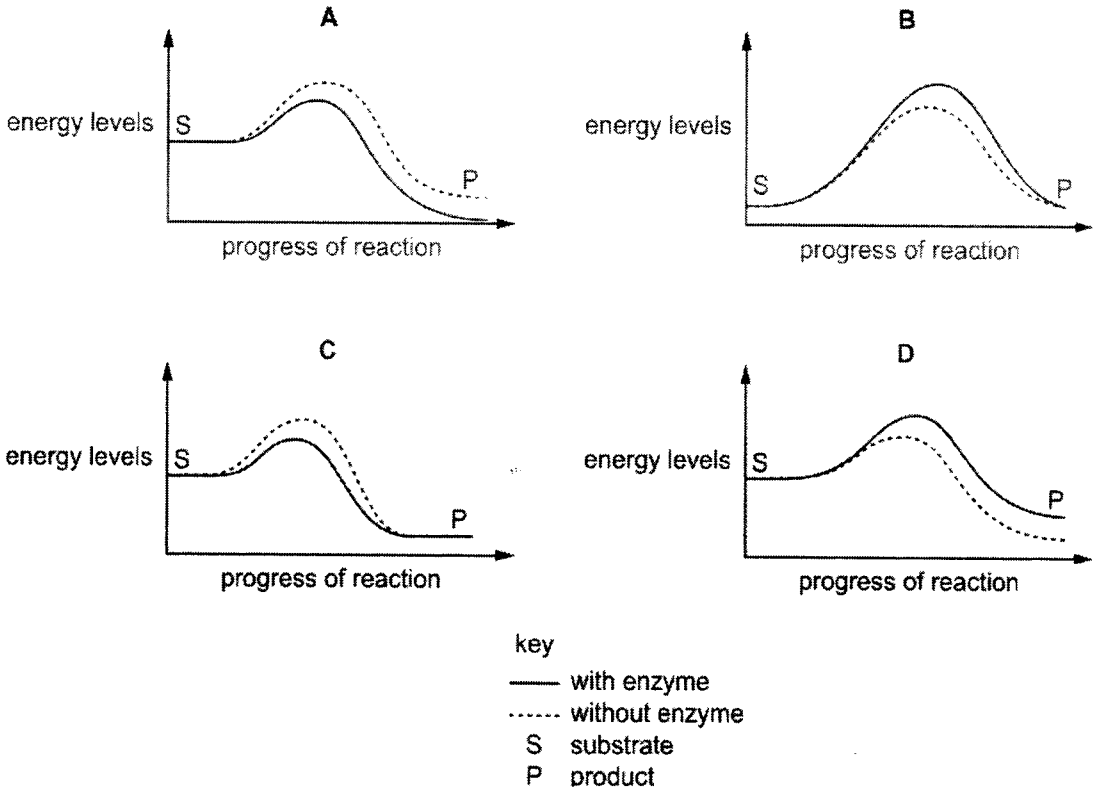
3 The graph shows rates of osmosis and facilitated diffusion of water molecules (through aquaporins) across the cell surface membrane.



Which row is correct?

	Graph K	Explanation
A	Facilitated diffusion	limited by the number of aquaporins in the cell surface membrane
B	Osmosis	allows the concentrations of water molecules inside and outside the cell to be equal in a shorter time
C	Facilitated diffusion	rate of transport approaches plateau at high water potential gradient due to dynamic equilibrium being achieved
D	Osmosis	limited by the number of transient gaps in the cell surface membrane

4 Which graph correctly shows possible changes in energy levels as a chemical reaction progresses with or without an enzyme?



5 In 2016, the United Kingdom government allowed scientists to genetically modify cells obtained from very early human embryos (immediately after fertilization till 8 cells stage).

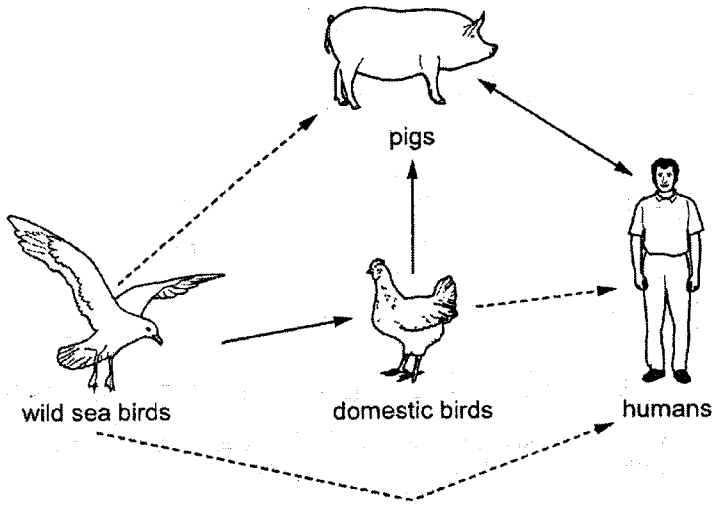
Which statement correctly describes an ethical concern about this research?

A Genetically modified iPSCs could give rise to genetically modified individuals.
B Genetically modified multipotent stem cells could give rise to genetically modified individuals.
C Genetically modified pluripotent stem cells could give rise to genetically modified individuals.
D Genetically modified totipotent stem cells could give rise to genetically modified individuals.

6 The sub-types of the influenza A virus that infect birds, humans and pigs in one area of the world in recent times are shown in the table.

	influenza A virus sub-types present		
time period	birds	humans	pigs
1918–1957	show any one of the H1–H16 antigens combined with any one of the N1–N9 antigens	H1N1	H1N1
1958–1970		H2N2	
1971 to present day		H3N2 H1N1	H3N2 H2N3

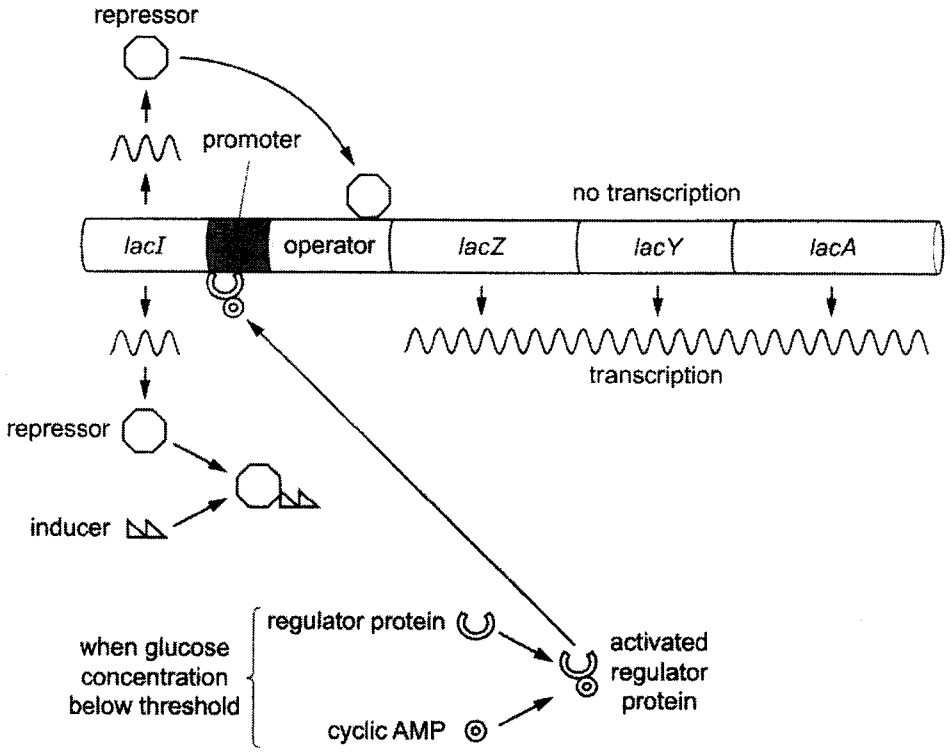
High risk of transmission of influenza A virus between species is shown by solid arrows in this diagram. A dotted arrow shows a low risk of transmission.



Which statement correctly describes a danger to human health in this area of the world?

A Antigenic drift of human viruses such as H3N2, leading to vaccines being less effective
B Antigenic drift within pigs, leading to emergence of H2N2 virus able to infect humans
C Antigenic shift of bird viruses, leading to emergence of new viruses such as H7N10
D Antigenic shift within humans, combining H2N2 from older people with H1N1 or H3N2

7 The diagram shows some of the factors affecting the expression of the lac operon.

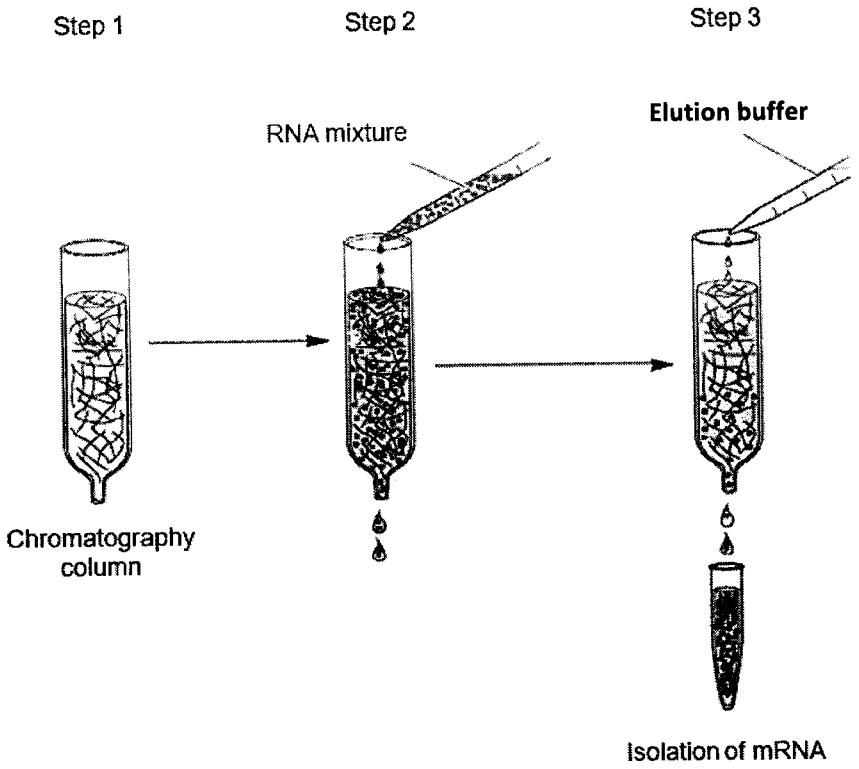


Only when the concentration of glucose is below a critical threshold can the lac operon be fully induced by the presence of lactose. As the concentration of glucose decreases, the concentration of cyclic AMP increases.

Which statement describes the role of cyclic AMP in the expression of the lac operon?

A It prevents the regulator protein from binding to the promoter when the glucose concentration is high.
B It activates the inducer to bind to the lac operator.
C It prevents the expression of the lac operon when the glucose concentration is high.
D It activates a regulator protein that helps RNA polymerase bind more effectively to the promoter.

8 The isolation of mature mRNA can be done by passing an RNA mixture obtained from homogenised tissue through a chromatography column. The procedure of the mRNA isolation is as follows:



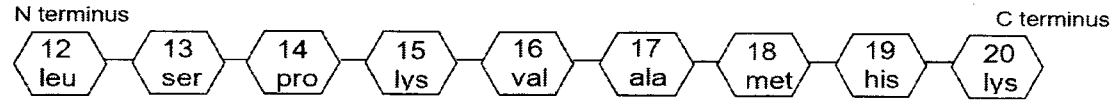
Step 1	Set up a chromatography column which contains short lengths of uracil nucleotides attached to a solid support medium.
Step 2	Add RNA mixture to the chromatography column. RNA that do not hybridise with the uracil nucleotides will pass through and leave the column.
Step 3	Add water to the chromatography column to remove and isolate the hybridised mRNA.

Which of the following statements is **not** true?

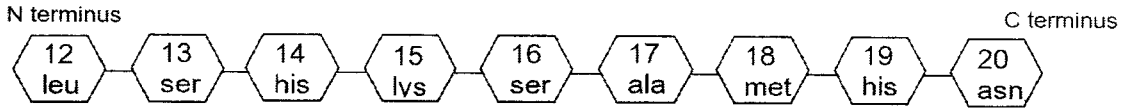
A rRNA and tRNA molecules could pass through and leave the column in Step 2.
B Complementary base pairing is responsible for the attachment of RNA to the solid support medium.
C The isolated mRNA in Step 3 do not contain introns.
D The RNA that attached to the chromatography column lack poly-(A) tails.

9 When a mutation occurs at the gene coding for protein **A1**, a structurally similar mutant protein, protein **A2**, is synthesised instead. The two proteins differ by only three amino acids, at positions 14, 16 and 20.

amino acid sequence of **normal** protein **A1**



amino acid sequence of **mutant** protein **A2**



The table shows the mRNA codons for the amino acids in these positions for proteins A1 and A2.

amino acid	mRNA codons
ala	GCU
ser	AGU UCA
pro	CCA
leu	CUU UUA
lys	AAA
ala	GCU
met	AUG
his	CAU CAC
asn	AAU
val	GUC

Which combination of mutations occurred in order to account for the amino acid sequence of the mutant protein **A2**?

1 Frameshift mutation resulting from an addition of a single nucleotide in the codon that codes for amino acid at position 14.

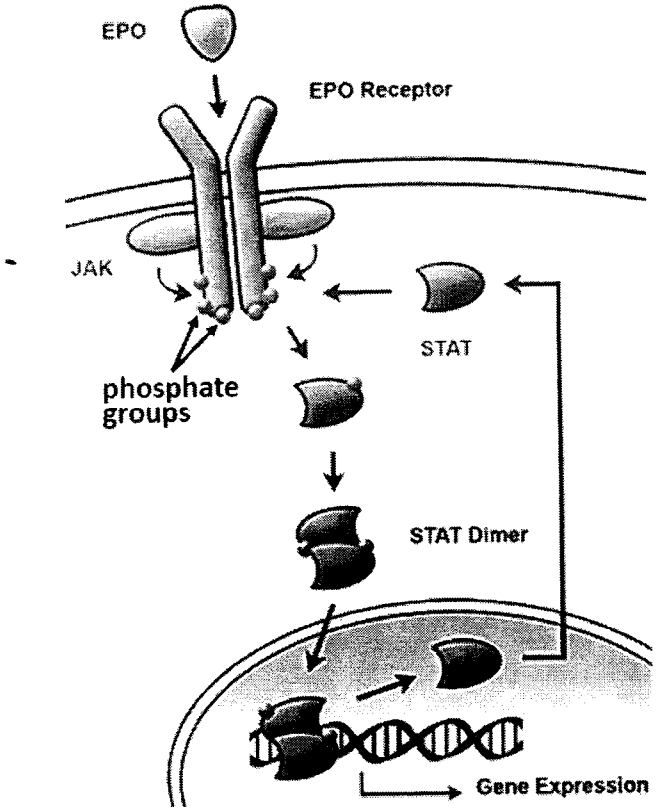
2 Substitution of a single nucleotide in the codon that codes for amino acid at position 14.

3 Frameshift mutation resulting from a deletion of two nucleotides in the codon that codes for amino acid at position 16.

4 Deletion of a single nucleotide in the codon that codes for amino acid at position 16.

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

10 The diagram shows the JAK-STAT cell signalling pathway.



Which of the following statements are correct?

1 EPO is a large and non-polar lipid hormone and hence it needs a cell surface receptor to cross the membrane.

2 Phosphorylation of STAT causes them to dimerize.

3 Gene expression is terminated when phosphatases remove phosphate groups from STAT dimers.

4 Signal amplification occurs as JAK phosphorylates different tyrosine residues on the EPO receptor.

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

11 Which of the following modification(s) would allow *E. coli* cells to start synthesising a eukaryotic protein?

1 Insertion of the cDNA which was reverse transcribed using the mature mRNA coding for the eukaryotic protein.
2 Presence of activators and histone acetylases.
3 Insertion of a eukaryotic promoter next to the eukaryotic gene in a bacterial plasmid

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

12 Which of the following is **true** of gene regulation in prokaryotes and eukaryotes?

A Gene regulation in both eukaryotes and prokaryotes can involve proteins binding to DNA.
B In eukaryotes, increase in efficiency of translation requires regulatory proteins binding to the mRNA while in prokaryotes, increase in efficiency of translation requires regulatory proteins binding to the ribosomes.
C In eukaryotes, RNA polymerase binds to the TATA box while in prokaryotes, RNA polymerase binds to the operator.
D Repressors and activators regulate expression in eukaryotes while prokaryotes are regulated by repressors only.

13 Seahorses and spider monkeys both possess a prehensile tail, allowing them to grasp and hold onto structures.

How many of the following statements is/are valid?

1 The prehensile tail is a homologous structure derived from a recent common ancestor shared by the seahorse and spider monkey.
2 The seahorse and spider monkey evolved the prehensile tail independently due to similar selection pressures in their environment.
3 The prehensile tail is an example of convergent evolution due to both species sharing the same ecological niche.
4 The prehensile tail is an example of descent with modification, as the tail shows modifications in the two species over time.

A 1
B 2
C 3
D All of the above.

14 Relationships between different primates can be found by comparing their proteins and DNA.

The protein albumin obtained from a human was injected into a rabbit. The rabbit produced antibodies against the human albumin.

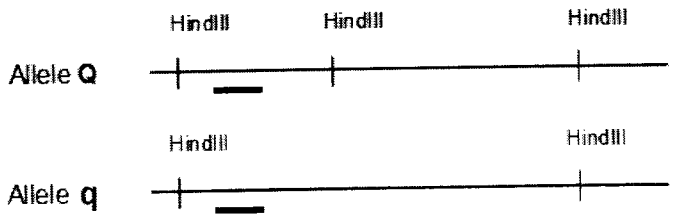
These antibodies were extracted from the rabbit and then added to samples of albumin obtained from four different animal species. Precipitation occurs when antibodies bind to albumin. The amount of precipitate produced in each sample was then measured and shown in the table below.

Species from which albumin was obtained	Amount of precipitate / arbitrary units
Rat	80
Chimpanzee	96
Marmoset	85
Trout	45

Which of the following statements is true of the results obtained above?

A Rabbit is most closely related to chimpanzee, and least closely related to trout.
B The constant region of the rabbit antibodies allows the antibodies to bind to albumin samples from the four animals tested.
C Rat and marmoset are more closely related to each other than they are to humans.
D Human shares a more recent common ancestor with chimpanzee, followed by marmoset, rat and then trout.

15 Two alleles from a gene located on a particular chromosome is shown below.

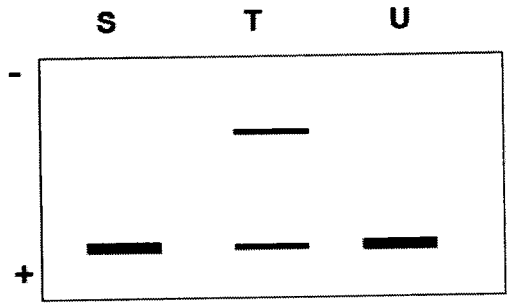


*Hind*III indicates the restriction sites for this enzyme, and the black bar indicates the position of the DNA probe used for analysis.

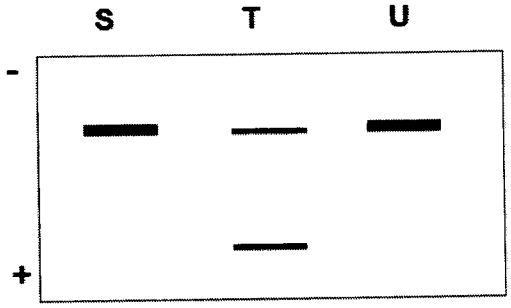
DNA fragments from three different individuals, **S**, **T** and **U**, were subjected to restriction digestion by *Hind*III and separated by gel electrophoresis.

Given that **S** and **T** are the parents of **U**, which of the following diagrams is NOT a valid result for **U**?

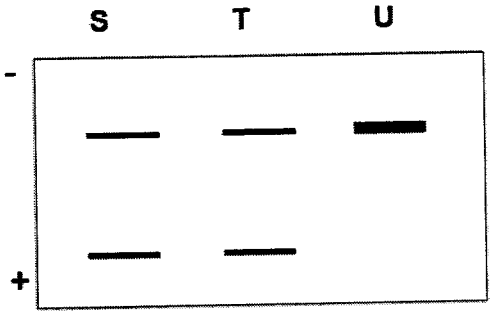
A



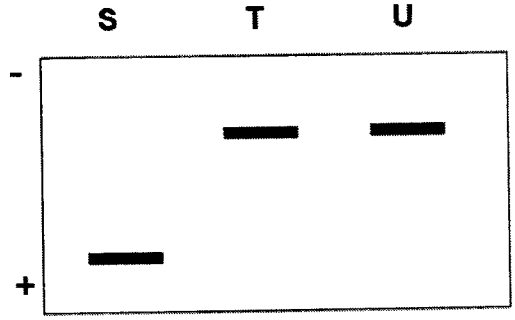
B



C



D



16 An analysis of the number of chromosomes in gametes obtained after the meiosis of 2 human germ cells are shown in the table below.

Human germ cell X undergoes meiosis to produce gametes 1-4, while human germ cell Y undergoes meiosis to produce gametes 5-8.

Human germ cell X		Human germ cell Y	
Gamete	**Number of chromosomes**	**Gamete**	**Number of chromosomes**
1	22	5	23
2	24	6	23
3	24	7	22
4	22	8	24

Which of the following descriptions is consistent with the data shown in the table above?

A Homologous chromosomes could not pair up to form bivalents in germ cell X.
B Non-disjunction of a pair of chromatids during anaphase II in germ cell X.
C Centromere of a pair of chromatids failed to divide during anaphase II in germ cell Y.
D Fusion of Gametes 2, 3, and 8 with a normal gamete will always result in offspring with Down Syndrome.

17 Certain types of cancer are associated with chromosomal rearrangements.

Which of the following is a possible consequence when a tumour suppressor gene is translocated within the centromeric sequence of another chromosome?

1 Gene is transcriptionally active.
2 Gene codes for a non-functional tumour suppressor protein.
3 The centrometric sequence is transcribed together with the gene.
4 Cell is unable to carry out DNA repair.

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

18 In cats, coat colour is determined by the X-linked, codominant alleles: black and orange. A calico (black, orange and white fur) female, which is the homogametic sex, is bred many times with a black male. Which of the following is a possible outcome of their offspring?

1 All black offspring are female cats.
2 If any orange offspring are obtained, they are male cats.
3 Probability of a female offspring being calico is 0.25.
4 Cross of a black female offspring with an orange male cat will give 1 calico female : 1 black male in the next generation.

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

19 In garden peas, the allele **T** codes for terminal position of flowers and is dominant over the allele **t**, which codes for axil position.

In an experiment, two garden pea plants, both heterozygous for terminal flowers, produced 77 offspring with flowers at the terminal position and 43 offspring with flowers at the axil position. A χ^2 test was done to determine whether the results of the experiment follow the expected pattern of inheritance.

Given that the χ^2 critical value at 1 degree of freedom and a probability of 0.05 is 3.84, which of the following conclusions can be drawn from the experiment and the χ^2 test?

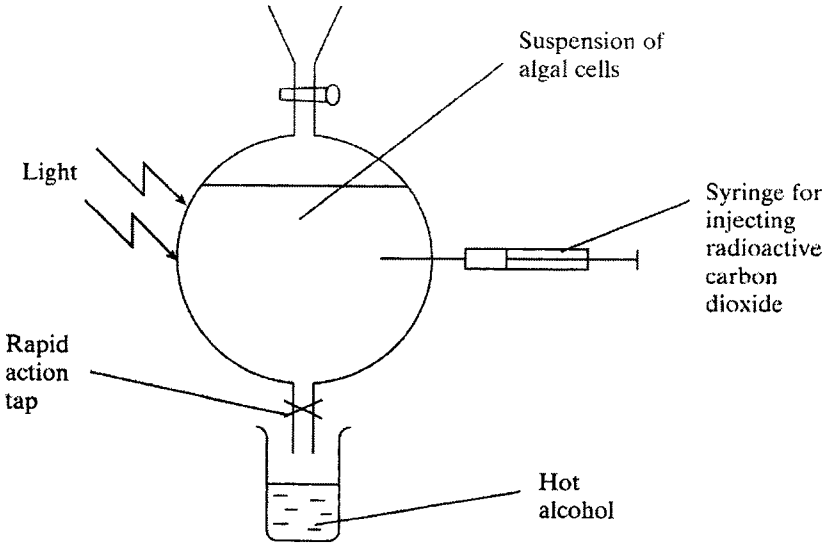
$$Note: \chi^2 = \Sigma \frac{(Observed - Expected)^2}{Expected} = \Sigma \frac{(O-E)^2}{E}$$

A Since the χ^2 value obtained from the experiment is less than 3.84, flower position in garden peas involves a single pair of segregating alleles at the **T** locus.
B Since the χ^2 value obtained from the experiment is less than 3.84, flower position in garden peas does not involve a single pair of segregating alleles at the **T** locus.
C Since the χ^2 value obtained from the experiment is greater than 3.84, flower position in garden peas involves a single pair of segregating alleles at the **T** locus.
D Since the χ^2 value obtained from the experiment is greater than 3.84, flower position in garden peas does not involve a single pair of segregating alleles at the **T** locus.

20 An investigation was carried out to find out the sequence of biochemical changes that occur during photosynthesis.

Radioactive carbon dioxide was added to a suspension of algal cells, which was placed under light conditions. At intervals, samples of the suspension were removed and dispensed into hot alcohol. These samples were analysed for different radioactively labelled compounds.

The experimental setup is shown below.



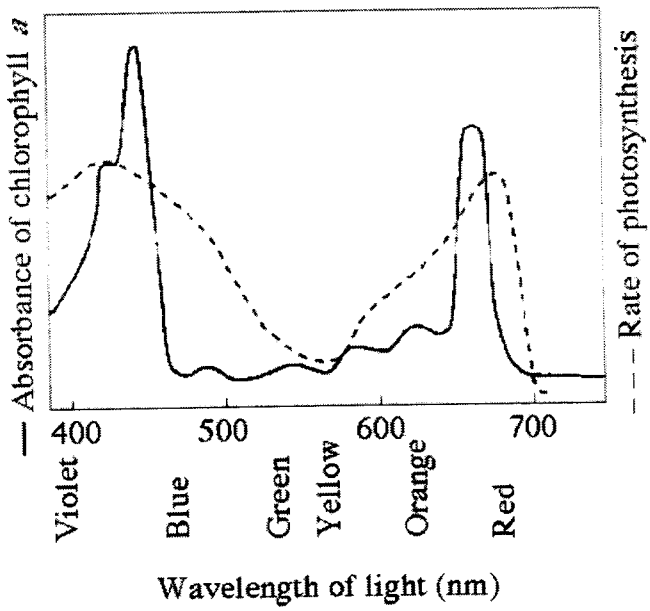
Samples were removed from the suspension at four different times, between 5 seconds and 600 seconds after the start of the experiment. In each sample, the amount of radioactivity present in three different organic compounds, **P**, **Q**, and **R** was measured, and shown in the table below.

organic compound	**amount of radioactivity present / arbitrary units**			
	5 s	60 s	180 s	600 s
P	0.01	0.08	0.17	0.67
Q	1.00	3.10	3.15	3.15
R	0.05	0.16	1.00	1.00

What are the most likely identities of the three organic compounds?

	P	**Q**	**R**
A	Rubisco	Glycerate 3-phosphate (GP)	NADP
B	Triose phosphate (TP)	RuBp	Glycerate 3-phosphate (GP)
C	5-carbon compound	Glycerate 3-phosphate (GP)	Triose phosphate (TP)
D	Triose phosphate (TP)	5-carbon compound	6-carbon compound

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



What is the reason for the difference in the absorption spectrum and the action spectrum?

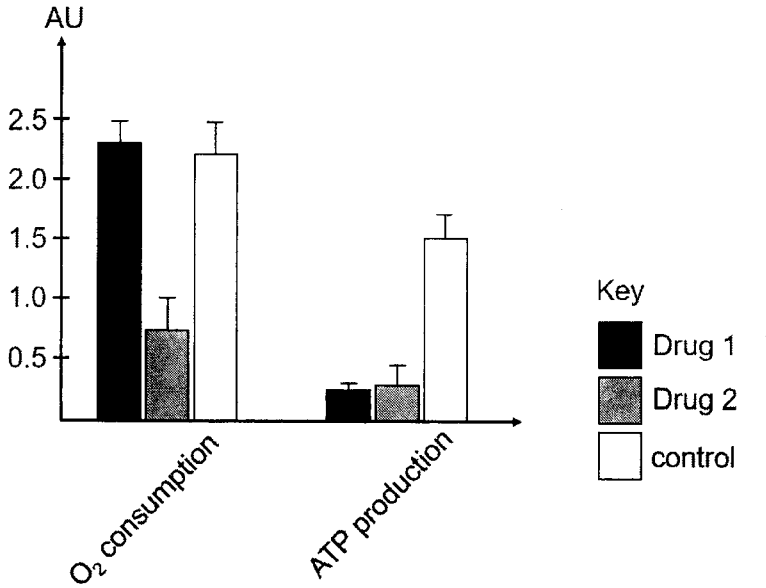
A Wavelengths of 480-630nm provide the least energy for photosynthesis.
B Chlorophyll *a* is the main pigment responsible for photosynthesis in the plant.
C There are other pigments responsible for photosynthesis in the plant.
D There are other limiting factors affecting the rate of photosynthesis in the plant.

22 Which of the following processes occur during glycolysis:

1 Two 3-carbon compounds combine to form 6-carbon compound
2 Dehydrogenation of substrate
3 Oxidative decarboxylation
4 Substrate-level phosphorylation

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

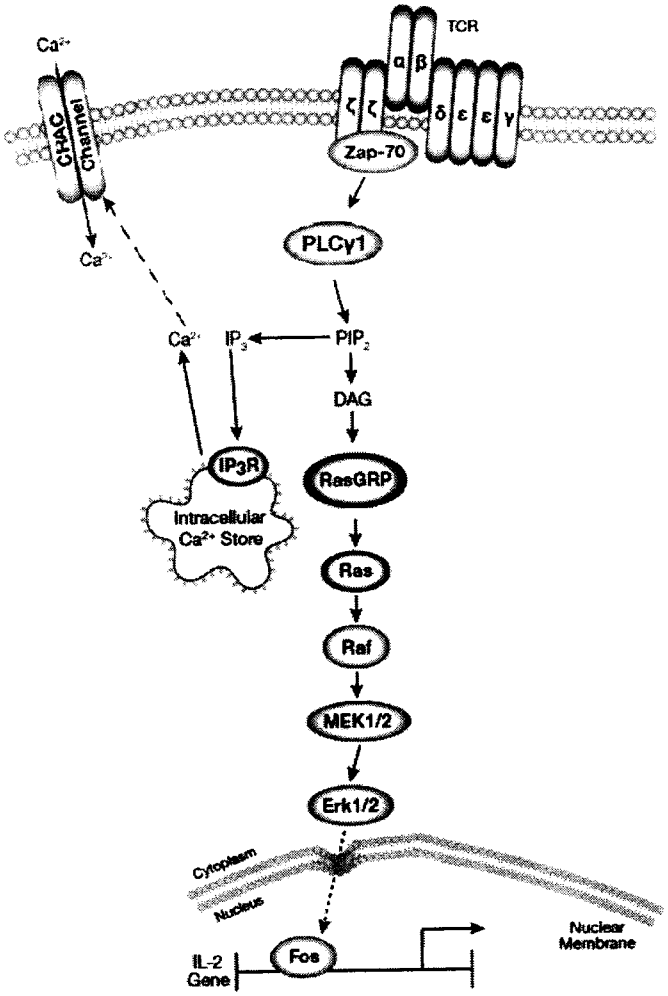
23 Two drugs, Drug 1 and Drug 2, inhibit different proteins found in mitochondria. Their effects on oxygen consumption and ATP production are recorded in the figure below.



Which of the following correctly identifies possible inhibitory mechanisms of Drugs 1 and 2 ?

	Drug 1	Drug 2
A	Inhibits ATP synthase	Inhibits a dehydrogenase involved in glycolysis
B	Inhibits cytochrome oxidase	Inhibits an electron carrier
C	Inhibits an enzyme in Krebs cycle	Inhibits ATP synthase
D	Provides an alternative pathway for H^+ to pass through the inner mitochondrial membrane	Inhibits cytochrome oxidase

24 T Cell Receptor (TCR) activation promotes several signalling cascades that ultimately determine cell fate. The diagram below shows part of the cell signalling pathway.



Which of the following can be inferred from the diagram?

1 Zap-70 activates phospholipase C (PLCγ1), which hydrolyses PIP_2 to produce the second messengers diacylglycerol (DAG) and inositol trisphosphate (IP_3).
2 IP_3 triggers the release of Ca^{2+} from the intracellular store, which promotes entry of extracellular Ca^{2+} into cells through CRAC channels.
3 Signal is amplified along the phosphorylation cascade involving kinases such as MEK1/2 and ErK1/2.
4 ErK1/2 activates Fos, which increases the transcription of IL-2 gene, leading to leading to production of antibodies.

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

25 *Greto oto* is a species of clearwing butterfly that has a proportion of its wings having no coloured scales, making them partially transparent.

Different populations of *Greto oto* have varying degree of transparency (i.e. area of wing with no coloured scales), depending on their habitat heterogeneity. Habitat heterogeneity is measured by considering the number and evenness of discreet structural elements in a habitat; the higher the number, the more complex it is.

A researcher glued 30 butterflies (all had wing transparency of 75%) at four different locations and measured the predation rate after 24 hours (defined as the percentage of glued butterflies removed by predators). He also captured 30 live butterflies from the same four locations and recorded their degree of wing transparency.

The table below shows the relationship between habitat heterogeneity, predation rate and degree of wing transparency.

Population	Habitat heterogeneity	Predation rate / %	Degree of wing transparency / %
1	8.2	67.2	72.4
2	6.9	75.4	80.6
3	4.5	83.0	85.3
4	2.1	89.6	90.7

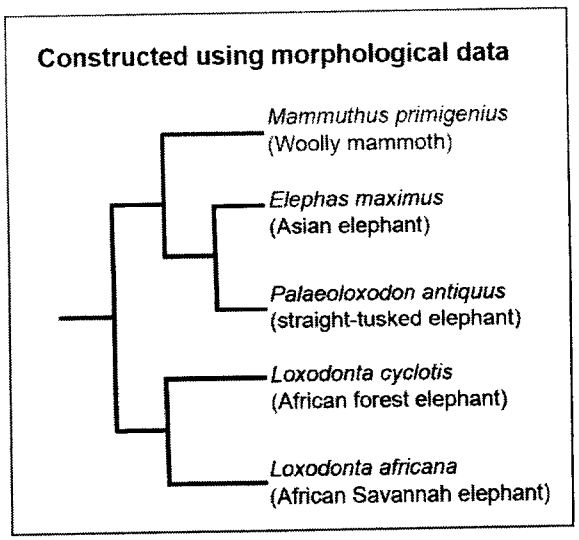
Which of the following can be deduced?

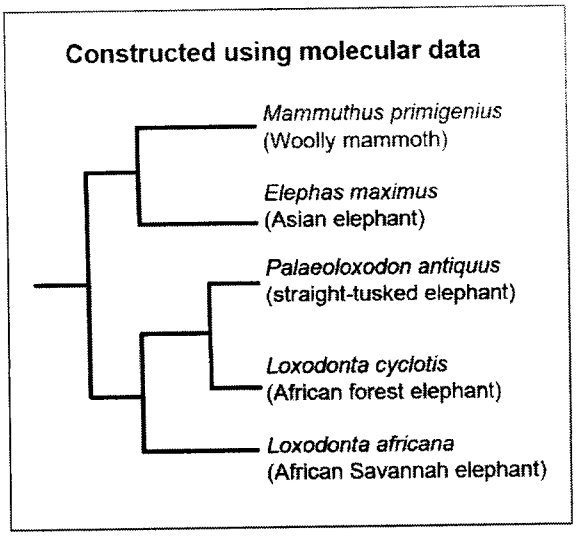
1 Predators have less success in habitats that are more complex.
2 Butterflies with higher degree of wing transparency face higher predation rates.
3 Predation acts as a selection pressure that favors wings that are more transparent.
4 Female butterflies preferred to mate with colourful males (i.e. more coloured scales on wings).

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

26 The straight-tusked elephants, *Palaeoloxodon antiquus,* were widespread across Eurasia during the Pleistocene. Phylogenetic reconstructions using morphological traits have grouped them with Asian elephants (*Elephas maximus*). The recovery and analyses of mitochondrial genomes and nuclear genomes from two *Palaeoloxodon antiquus* fossils suggest that *Palaeoloxodon antiquus* was a close relative of extant African forest elephants (*Loxodonta cyclotis*) instead.

The phylogenetic trees below show the evolutionary relationships between the elephants, using morphological and molecular data respectively.



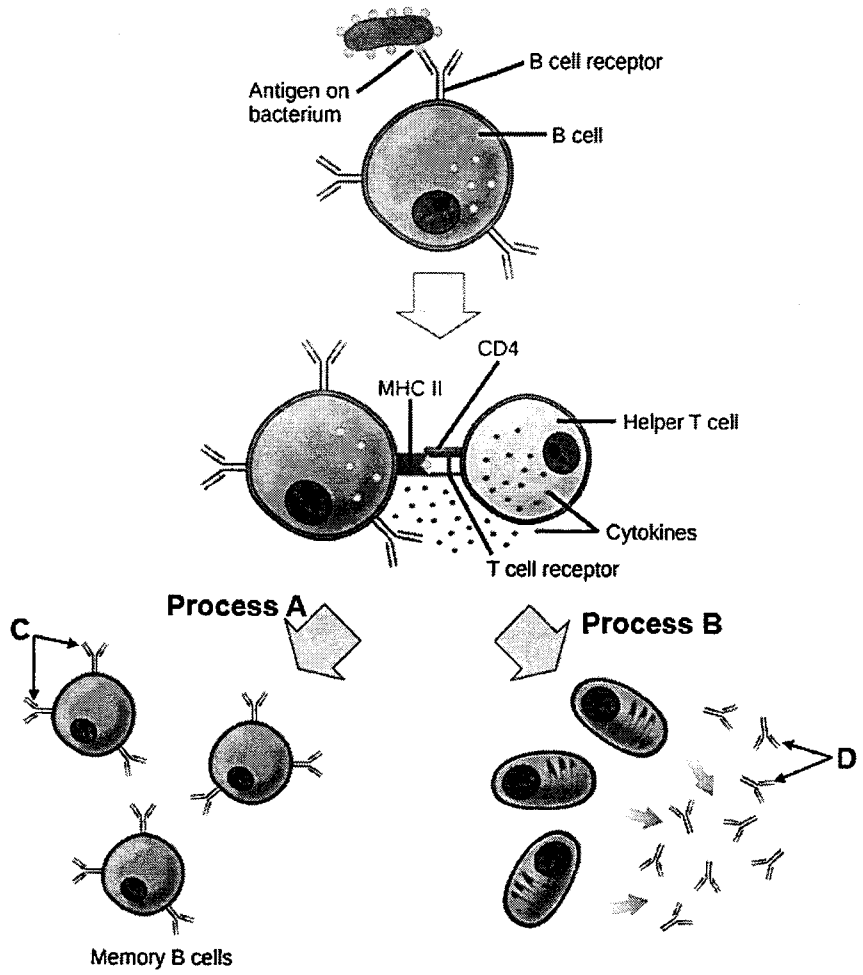


Which of the following statements can be deduced?

1 *Palaeoloxodon antiquus* and *Elephas maximus* share more morphological similarities with each other than they did with *Loxodonta cyclotis.*
2 *Palaeoloxodon antiquus* share more morphological similarities with *Mammuthus primigenius* than it did with *Loxodonta cyclotis.*
3 *Loxodonta cyclotis is more closely related to Loxodonta africana than it is to Palaeoloxodon antiquus because they are the same genus.*
4 *Palaeoloxodon antiquus* is more closely related to *Loxodonta africana* than it is with *Elephas maximus.*

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

27 The diagram below shows some processes of the adaptive immune system.



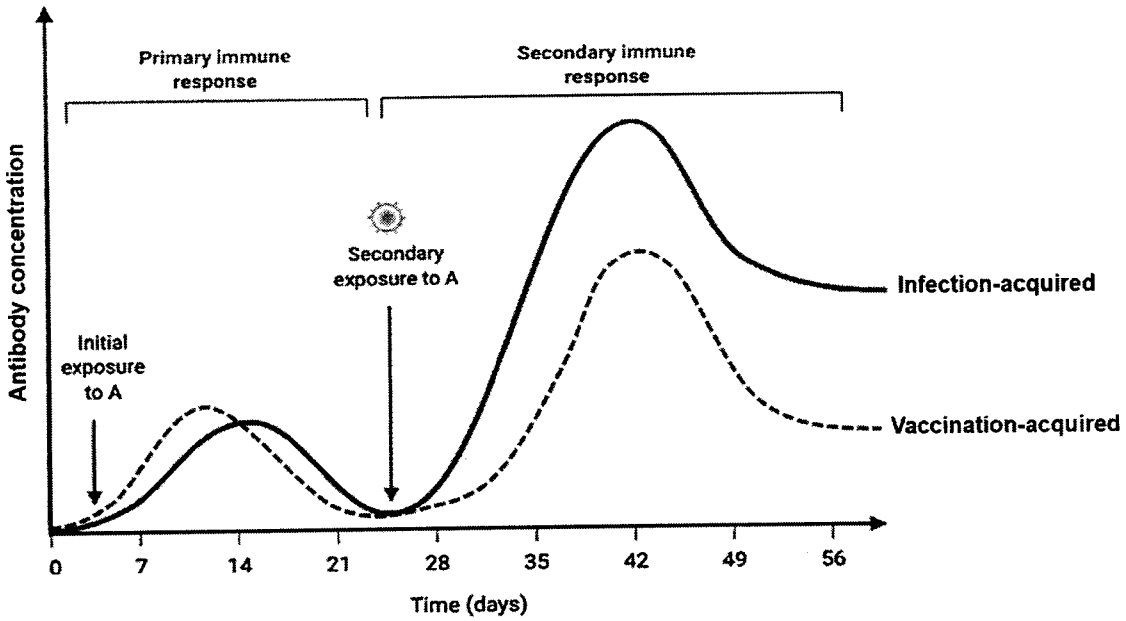
Which of the following are true?

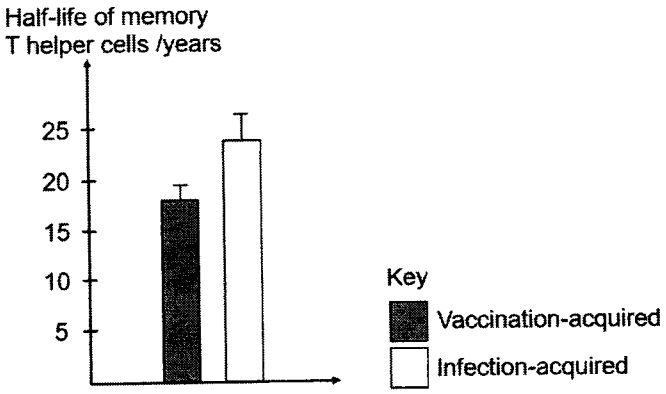
1 Processes **A** produces cells that are involved in the primary response.
2 Process **B** includes somatic recombination and somatic hypermutation.
3 Activated B cells secrete cytokines during Process **B.**
4 Structures **C** and **D** differ in the constant region of the molecule.

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

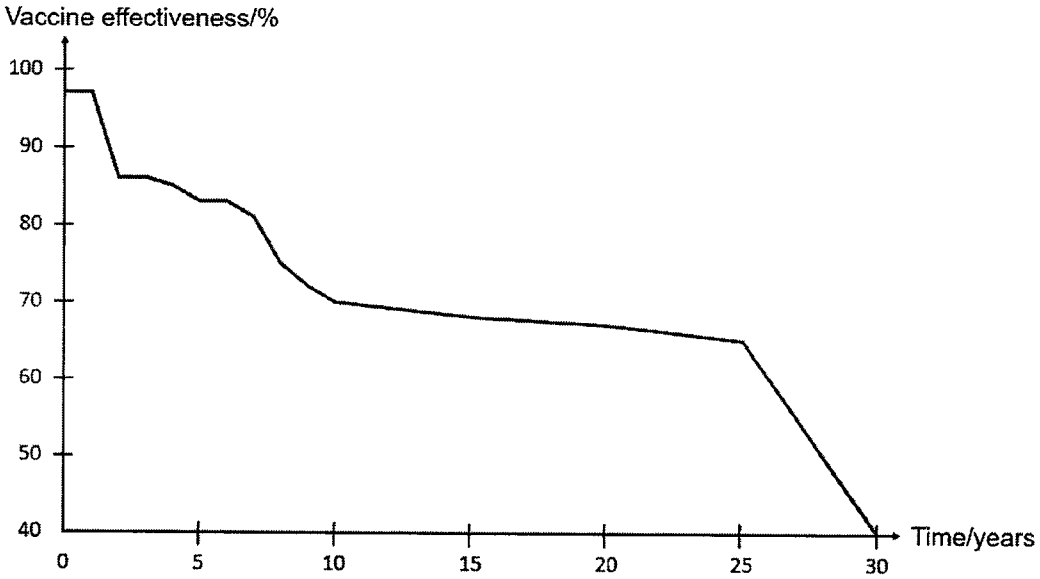
28 A study was conducted to investigate the difference between adaptive immunity acquired via normal infection vs vaccinations. The researchers obtained two comparative groups of people: one group was hospitalized from being infected with pathogen A and one group was vaccinated against pathogen A. The vaccine contained a mixture of purified viral envelope proteins.

They measured the antibody concentration during primary and secondary response, the half-life of the memory T helper cells produced against pathogen A and the effectiveness of the vaccine over a 30-year period. The diagrams below show the results of the study.





*Half-life is defined as time required for number of T helper cells to decrease by half.



Which of the following can be deduced from the results of this study?

1 A vaccinated person produces less antibodies when exposed to the actual pathogen A compared to a recovered patient who is exposed to pathogen A again.
2 If a patient was infected by pathogen A when he was 10 years old, he would have no more memory T cells specific to pathogen A when he turns 60.
3 The infection-acquired immunity will be better than vaccination-acquired immunity to protect against re-infection should pathogen A mutate.
4 The vaccine will no longer be able to protect individuals 30 years after it was given.

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

29 The table below records data collected from four countries.

Country/Region	Latitude, North/°	Summer temperature range/°C	Life cycle of *Aedes. aegypti* /days	Dengue fever cases per 100,000 people	Projected dengue fever cases per 100,000 people in 2050
Singapore	1.35	26.0 – 32.0	8	577.00	360
Heilongjiang, China	35.9	18.0 – 25.0	21	3.46	50
India	20.6	25.0 – 42.0	10	229.10	120
London, UK	37.1	15.0 – 23.0	No data	0.00	30

The projected dengue fever cases were calculated based on a 2°C increase in global temperatures predicted by current climate studies.

Which of the following statements are possible explanations of the trends shown in the data?

1 Temperatures are higher at lower latitudes (nearer to the equator) mainly due to increased deforestation, releasing more greenhouse gases.
2 *Aedes aegypti* does not live in regions colder than 23°C.
3 In 2050, regions in higher latitudes are predicted to become more hospitable to *Aedes aegypti* but regions in lower latitudes become less hospitable.
4 *Aedes aegypti* population decreases as duration of life cycle decreases, causing the number of projected dengue fever cases in 2050 to drop.

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

30 Which of the following correctly matches the example of human activity to its direct impact?

	Human activity	Impact
1	Increased beef consumption	Increased CO_2 and methane sequestered in their sinks
2	Increased burning of fossil fuel	Increased food insecurity, especially in temperate countries
3	Increased livestock farming	Intensifies water cycle
4	Increased oil palm plantations	Decreased potential for biomedicine discovery

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

End of Paper

Civics Group	Index Number	Name (use BLOCK LETTERS)	H2

ST. ANDREW'S JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATIONS

H2 BIOLOGY **9744/2**

Paper 2

Monday 29th August 2022 Total 2 hours

Materials: Question Papers

READ THESE INSTRUCTIONS FIRST

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

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

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

Conceptual error (C)	Data Quoting (D)	Expression (E)	Misreading the question (Q)

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

This document consists of 32 printed pages.

[Turn over]

QUESTION 1

(a) Fig. 1.1 shows an electron micrograph of a plant cell.

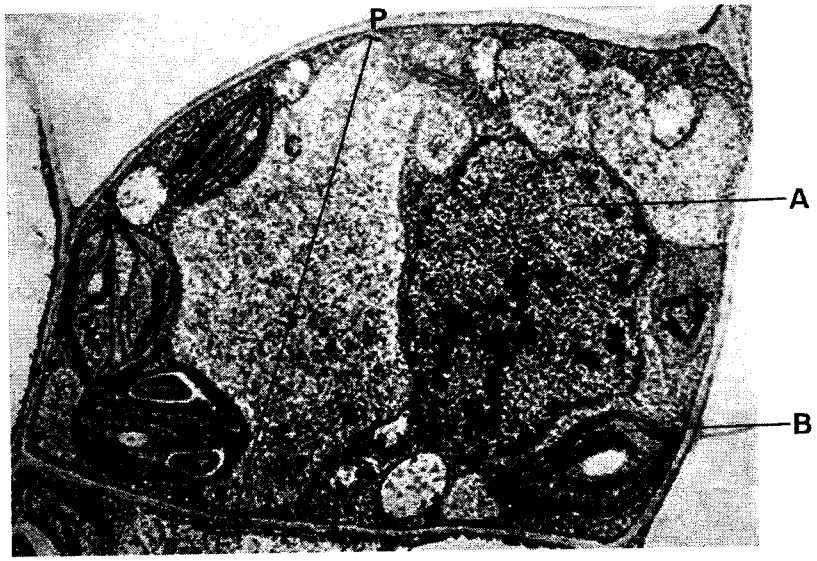


Fig. 1.1

(i) The magnification of the photomicrograph is x560. Calculate the actual length of organelle **C** in μm, along the line **P-Q**. Show your working.

Actual length of organelle **C**: ..... μm [2]

(ii) Identify organelles **A** and **B** and compare their structural features.

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

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.....[4]

(b) Cyclins are a group of proteins that regulate the cell cycle. There are four basic types of cyclins found in humans and most other eukaryotes: G1 cyclins, G1/S cyclins, S cyclins, and M cyclins.

Each cyclin is associated with a particular phase, or set of phases, in the cell cycle and helps drive the events of that phase or period. For instance, M cyclin promotes the events of M phase.

The levels of the different cyclins vary considerably across the cell cycle, as shown in Fig. 1.2.

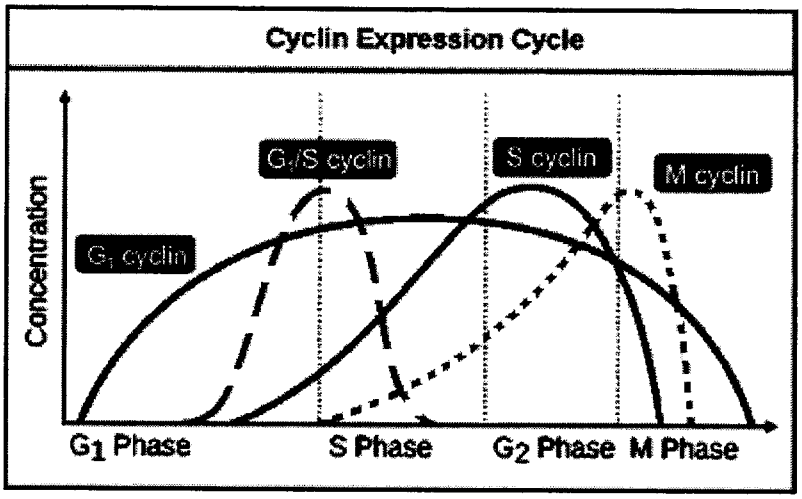

Fig. 1.2

A typical cyclin is present at low levels for most of the cycle but increases rapidly at the stage where it is needed. In order to drive the cell cycle forward, a cyclin must activate enzymes called the cyclin-dependent kinases (Cdks). In general, Cdk levels remain relatively constant across the cell cycle, but Cdk activity changes as levels of the various cyclins rise and fall.

Fig. 1.3 shows the cell cycle checkpoints and the activation periods of various Cdks. Percentage times (%T) in each phase are approximations of total cell cycle time. For instance, cells spend approximately 5% of their total cell cycle time in M phase.

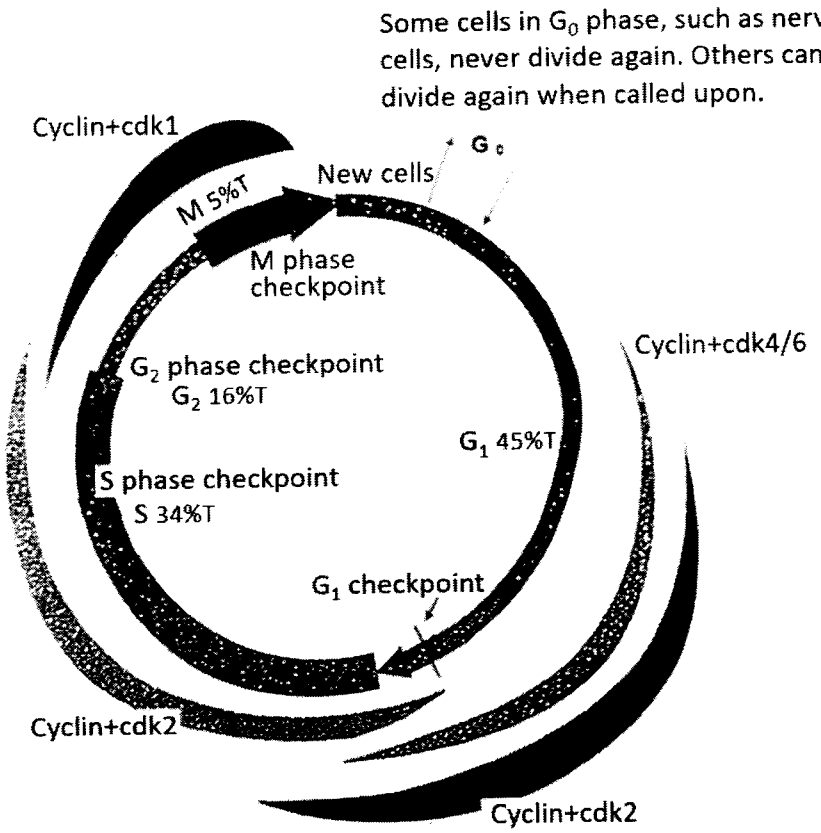

Fig. 1.3

(i) With reference to post-translational control of gene expression, suggest how cells reduce the concentration of cyclins when they are not needed in the cell cycle.

.....

..... [1]

(ii) With reference to Fig. 1.2 and 1.3, identify the molecules that are at abnormally low concentrations for cells to be arrested at S phase.

..... [1]

(iii) It was found that cancerous cells show only 2%T at G2 phase. Explain the implications of this.

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..... [2]

[Total: 10]

QUESTION 2

(a) Explain how the molecular structure of haemoglobin is related to its functions.

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.....[3]

(b) Blood arriving in the lungs from the heart is oxygenated as it passes through the pulmonary capillaries. Sickle-shaped red blood cells are present in a person with sickle cell anaemia. These red blood cells have a very high quantity of abnormal haemoglobin and take up and transport less oxygen than red blood cells containing normal haemoglobin.

The cause of the differences between abnormal haemoglobin and normal haemoglobin is a mutation in the gene that codes for one of the two types of polypeptide found in a haemoglobin molecule. This mutation leads to a change in the mRNA produced during transcription, causing a change in the primary structure of the polypeptide formed.

Fig. 2.1 shows some of the changes that occur as a result of this gene mutation.

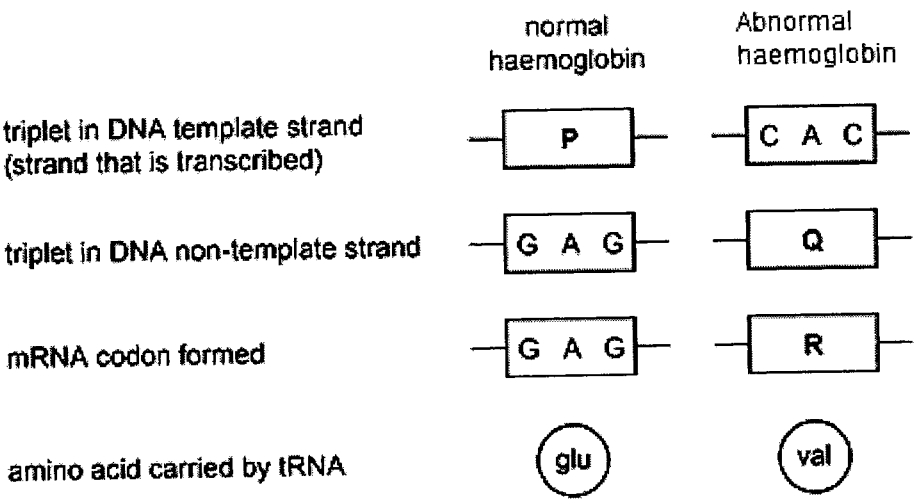

Fig. 2.1

(i) With reference to Fig. 2.1, state:

- the base sequence of DNA triplet P

.....[1]

- the base sequence of DNA triplet Q

.....[1]

- the base sequence of mRNA codon R

.....[1]

(ii) Name the polypeptide that is altered in the abnormal haemoglobin molecule.

.....[1]

(c) Fig. 2.2 shows the oxygen dissociation curve for adult haemoglobin in a person who does not have sickle cell anaemia.

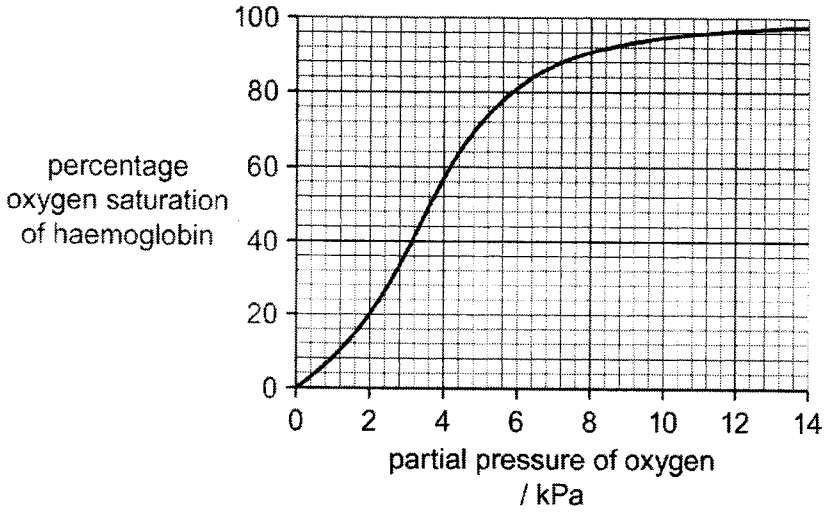

Fig. 2.2

Compared to Fig. 2.2, the oxygen dissociation curve for adult haemoglobin in a person with sickle cell anaemia is shifted to the right. The uptake of oxygen by haemoglobin in the lungs and the release of oxygen by haemoglobin in respiring tissues is different in a person with sickle cell anaemia compared with a person who does not have the disease.

With reference to Fig. 2.2, state **and** explain these differences.

Uptake of oxygen .....

.....

release of oxygen .....

.....

Explain these differences.....

.....[3]

[Total: 10]

QUESTION 3

HER2-positive breast cancer is a breast cancer that tests positive for a protein called human epidermal growth factor receptor 2. A member of the HER family of tyrosine kinase receptors (HER1–4), HER2 is an essential breast cancer oncogene.

Fig. 3.1 shows the Southern blot (DNA analysis) and Western blot (protein analysis) results of HER2 gene expression for a healthy individual and a breast cancer patient, and Fig. 3.2 shows the HER2 signaling pathway.

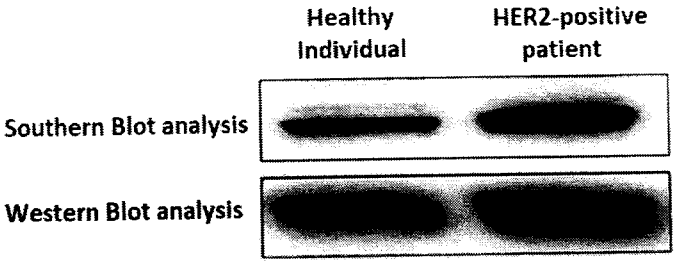

Fig. 3.1

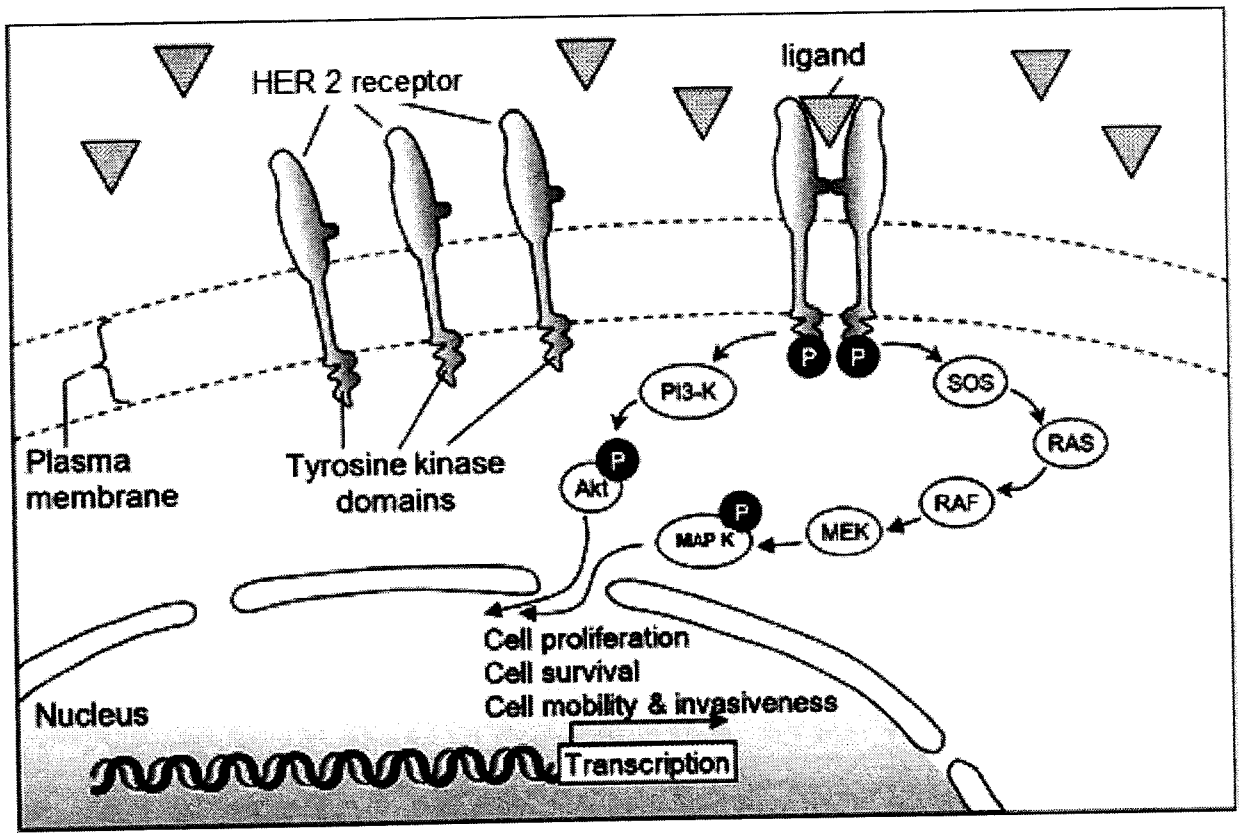

Fig. 3.2

(a) Research shows that 1 in 5 cancer patients shows an over-expression of HER2 gene. With reference to Fig. 3.1, suggest how the HER2 gene is converted to an oncogene in cancer patients.

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..... [1]

(b) Distinguish between how the HER2 receptor and a G-protein linked receptor function as transmembrane receptors upon binding of their respective ligands.

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..... [2]

(c) Patients with HER2-positive breast cancer have responded well to treatment when the drug Herceptin is used in combination with other chemotherapy drugs. Herceptin binds to the extracellular domain of the receptor.

With reference to Fig. 3.2, suggest and explain how Herceptin may act to prevent further progression of breast cancer.

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.....[3]

(d) Even with the effective treatment of Herceptin and chemotherapy, a proportion of cancer patients who were in remission, still experienced recurrence of cancer some years later.

Suggest how the cancer cells in these cases overcome the effects of Herceptin.

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..... [2]

[Total: 8]

QUESTION 4

(a) Fig. 4.1 shows the small ribosomal subunit rRNA loops containing double-stranded sections, H27, H30, H31 and H34, from bacteria and the mitochondria of mammals and plants. Note: Grey regions highlights the locations of H31 and H34.

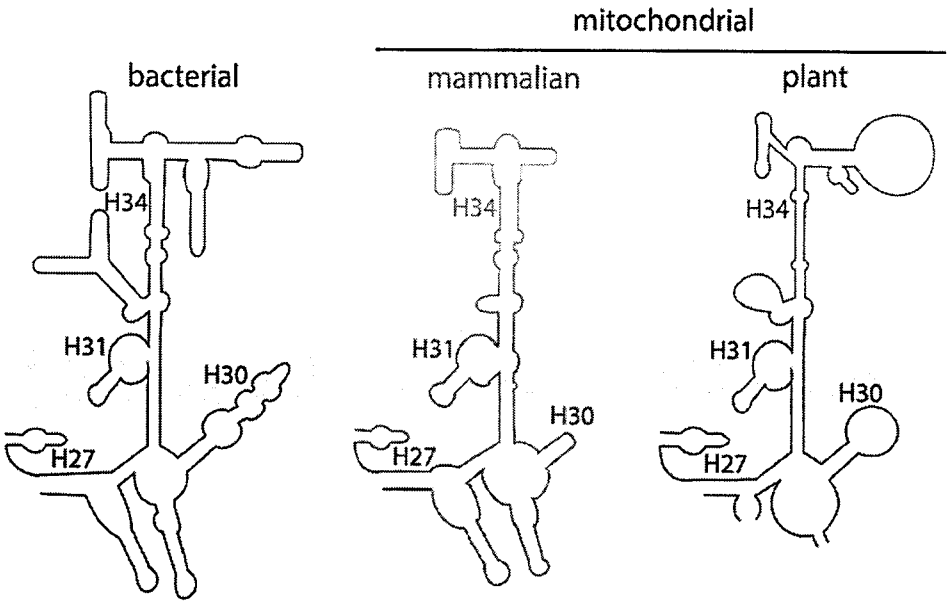

Fig. 4.1

(i) With reference to Fig. 4.1, compare the structures of the bacterial and mammalian mitochondrial small ribosomal subunit rRNA.

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..... [2]

(ii) Describe the roles of rRNA in the process of protein synthesis.

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..... [2]

(iii) Mammals and plants belong to the domain Eukarya while bacteria are grouped into their own domain, Bacteria. With reference to Fig. 4.1, comment on the suitability of using the small ribosomal rRNA structure to study the phylogenetic relationships between bacteria, mammals and plants.

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.....[3]

(b) Fig. 4.2A shows an electron micrograph of DNA replication occurring in organism X. Fig. 4.2B shows a representative diagram of the same process.

The dotted line represents the daughter strands. Ori R represents the origin of replication.

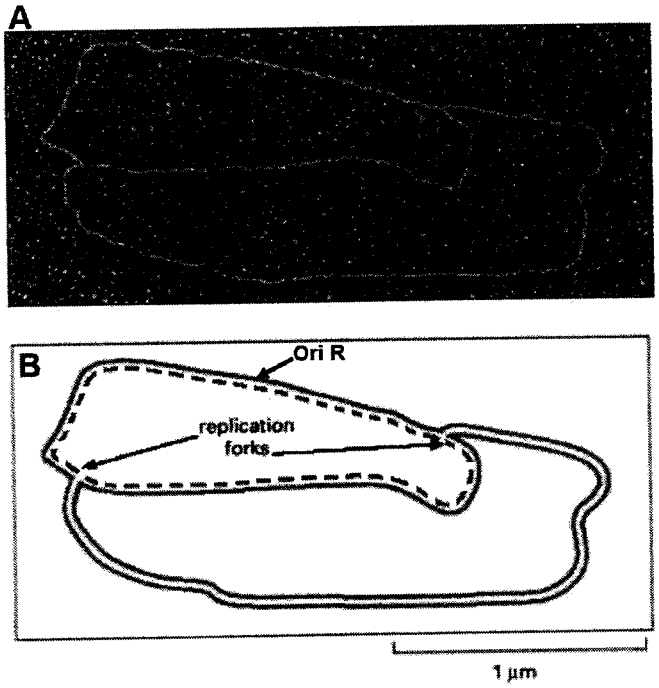

Fig. 4.2

(i) State whether organism X is a prokaryote or a eukaryote. Explain your answer.

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..... [2]

Fig. 4.3 shows a diagrammatic representation of the DNA replication process. The arrow in the diagram on the left shows the direction of the synthesis of one of the daughter strands.

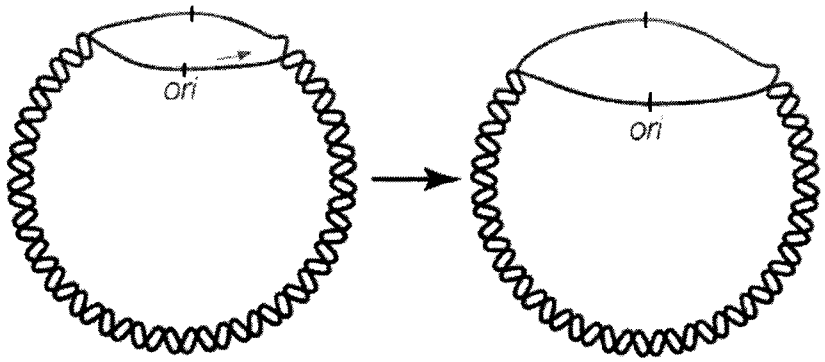

Fig. 4.3

(ii) Draw arrows in Fig. 4.3, on the DNA molecule to the right, to indicate how the Okazaki fragments are synthesised. [1]

(iii) Describe how the process of DNA replication differs between prokaryotes and eukaryotes.

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..... [2]

[Total: 12]

QUESTION 5

Gibberellins (GA) are plant hormones that regulate developmental processes such as stem elongation and flowering. Fig. 5.1 shows the effect of different levels of GA on stem elongation. Plant 1 lacks GA and has an internode length of "0" ("dwarf" plant). Plant 2 has a moderate amount of GA and an average internode length ("normal" plant). Plant 3 has a large amount of GA and so has a much longer internode length ("giant" plant).

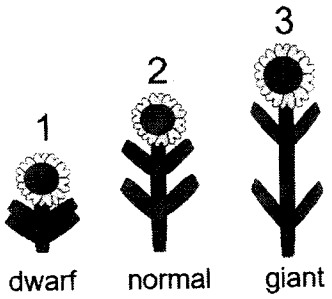

Fig. 5.1

Gene **K** encodes an enzyme responsible for one of the first steps of GA biosynthesis in *Arabidopsis* plants. The recessive allele of this gene results in GA-deficient *Arabidopsis* dwarfs. The dominant allele of Gene **T** codes for an activator which triggers the over-expression of Gene **K**, resulting in *Arabidopsis* giants.

When pure-breeding normal plants are crossed with pure-breeding dwarf plants, they produced F_1 which are all giants. Selfing of the F_1 generation produced the following F_2 generation:

443 giants
159 normal
197 dwarfs

(a) Draw a genetic diagram to show the results of the F_2 generation from the selfing of the F1 generation.

[3]

(b) (i) The expected phenotypic ratio of the F_2 generation is 9 giants : 3 normal : 4 dwarfs.

Calculate the value of χ^2 applicable to these data.

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

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

[2]

(ii) Use the calculated value of χ^2 and the table of probabilities provided to find the **probability** of the observed results differing by chance from the expected numbers.

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

Probability of observed results differing by chance from expected numbers: .....

[2]

(iii) State the conclusions that may be drawn from the probability found in **(ii)**.

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.....[3]

[Total: 10]

QUESTION 6

Bacteria can undergo genetic recombination, a process by which genetic information from one bacterium is transferred to, and then recombined with that of another bacterium.

Experiments have shown that two strains of bacteria can undergo conjugation when grown in a common medium. However, when they are separated by a filter in the Davis U-tube, as shown in Fig. 6.1, conjugation cannot occur.

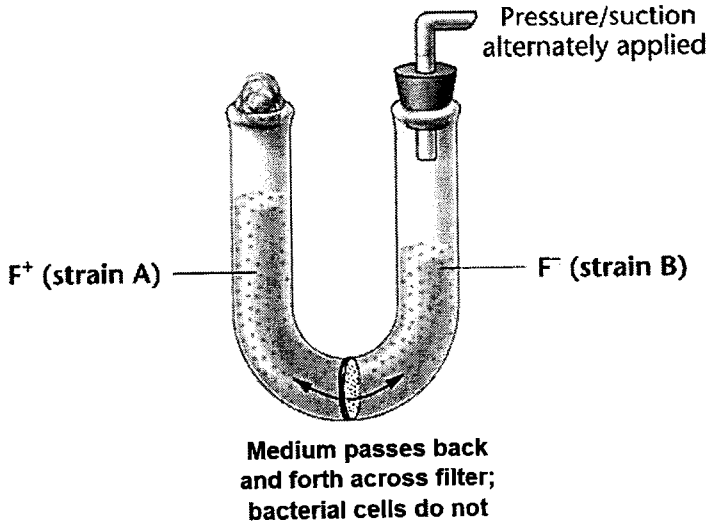

Fig. 6.1

(a) With reference to Fig. 6.1, explain why conjugation cannot occur when the two strains of bacteria are placed in the Davis U-tube.

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.....[2]

In another experiment investigating possible recombination in the bacterium *Salmonella typhimurium*, when researchers mixed *Salmonella* strains X and Y in a common medium, they recovered recombinants.

In a separate experiment using the Davis U-tube, the strains X and Y were separated by a filter, thus preventing cell contact but allowing growth to occur in a common medium. Surprisingly, when samples were removed from both sides of the filter, recombinants were recovered only from the side of the tube containing strain X bacteria. Researchers postulated that a filterable agent was released by the strain Y cells and responsible for transferring the new genetic information.

Three subsequent observations were useful in identifying the filterable agent:

1. The filterable agent was released by the strain Y cells only when they were grown in association with strain X cells.
2. The addition of DNase, which enzymatically digests naked DNA, did not render the filterable agent ineffective.
3. The filterable agent could not pass across the filter of the Davis U-tube when the pore size was reduced below the size of 20nm.

(b) (i) Suggest the source of the new genetic information which strain X cells received.

.....[1]

(ii) State the process of genetic recombination that has occurred.

..... [1]

(iii) Describe how the filterable agent could have transferred the new genetic information to strain X.

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.....[3]

Fig. 6.2 represents the reproductive cycle that a T4 phage can carry out.

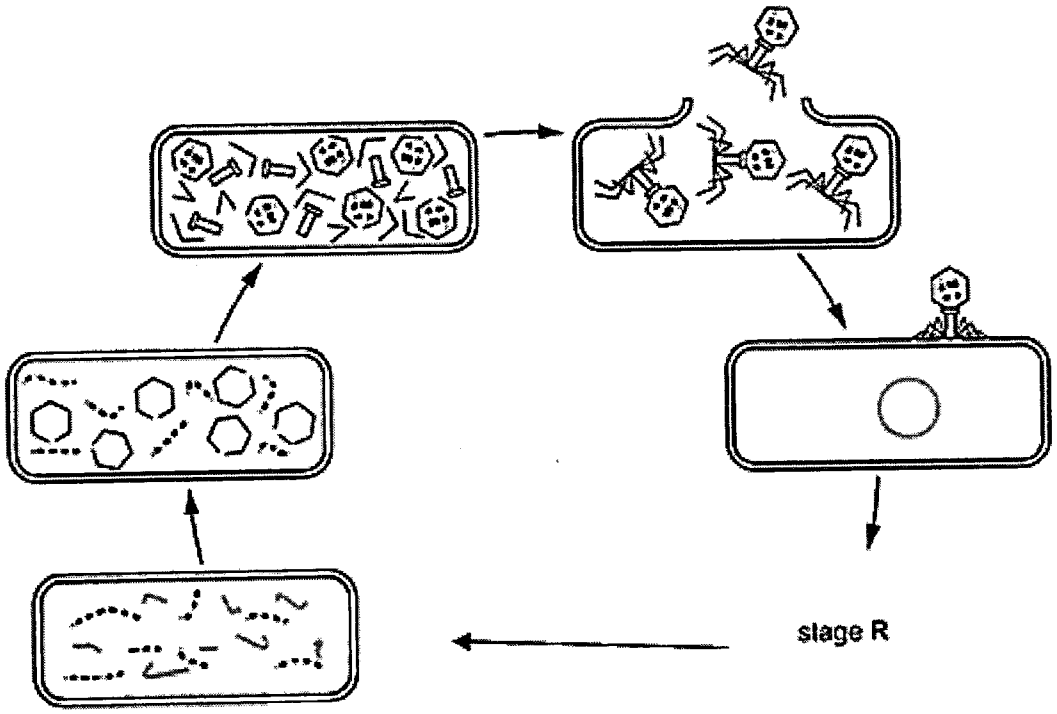

Fig. 6.2

(c) Describe what happens in stage **R** of the reproductive cycle shown in Fig. 6.2.

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.....[3]

[Total: 10]

QUESTION 7

Corals grow in shallow sea water. Corals consist of colonies of small animals called polyps. These polyps have photosynthetic protoctists called algae within their cells, which is advantageous both to the coral polyps and to the algae.

The algae that live within the cells of coral polyps can also live independently as free-living algae.

(a) The rate of photosynthesis of algae that live within the cells of coral polyps is higher than that of free-living algae.

Suggest and explain why the rate of photosynthesis in algae that live within the cells of coral polyps is higher than that of free-living algae.

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..... [2]

(b) The algae that live within the cells of coral polyps have five different chloroplast pigments.

Table 7.1 shows the light wavelengths at which each algal chloroplast pigment shows its two largest peaks of light absorption.

Table 7.1

chloroplast pigment	peak 1 wavelength / nm	peak 2 wavelength / nm
chlorophyll *a*	430	662
peridinin	456	485
chlorophyll c_2	450	396
dinoxanthin	442	471
β-carotene	454	480

Corals can be kept in glass tanks that are usually lit by lamps radiating mainly violet and blue light, with wavelengths in the range of 400 nm to 490 nm.

With reference to Table 7.1, suggest why lamps radiating mainly violet and blue light are expected to increase the growth of coral polyps more than lamps radiating light of all wavelengths.

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.....[3]

(c) ATP is used or produced at different stages in the oxidation of glucose in aerobic conditions. Complete Table 7.2 to show whether ATP is used or produced at each stage of respiration. Write either **YES** or **NO** in each box.

Table 7.2

stage of respiration	ATP used	ATP produced
glycolysis		
link reaction		
Krebs cycle		
oxidative phosphorylation		

[2]

(d) An experiment was carried out to investigate the effect of epicatechin on mitochondrial respiration in mice. Epicatechin is a naturally occurring compound in cocoa beans and so is present in chocolate. Two groups of mice, group A and group B, were used in this experiment.

- Group A was given water containing epicatechin, twice a day for 15 days.
- Group B was given water without epicatechin, twice a day for 15 days.

After 15 days, the structure of mitochondria from striated muscle cells in both groups of mice was examined. The surface area of the inner membrane of the mitochondria was divided by the surface area of the outer membrane to obtain a ratio for each mouse. Table 7.3 shows the mean ratios for the two groups of mice.

Table 7.3

group	mean ratio
A	2.0 : 1
B	1.7 : 1

The mice in group A were observed to be able to exercise longer than the mice in group B. With reference to Table 7.3, explain why the mice in group A were able to exercise for longer than the mice in group B.

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.....[3]

[Total: 10]

QUESTION 8

(a) A geneticist studied the following pedigree diagram in Fig. 8.1 of a family with several members diagnosed with a genetic condition which originated from a mutation in a particular gene.

Given that the disease is autosomal dominant, Southern Blotting was also performed using genomic DNA isolated from each family member. The DNA samples were first subjected to restriction digestion by *EcoRI*, before hybridising to probes complementary to the said gene.

The results for all family members, except those for the foetus, are shown below in Fig. 8.1. The sizes of the DNA fragments obtained after *EcoRI* digest are as indicated.

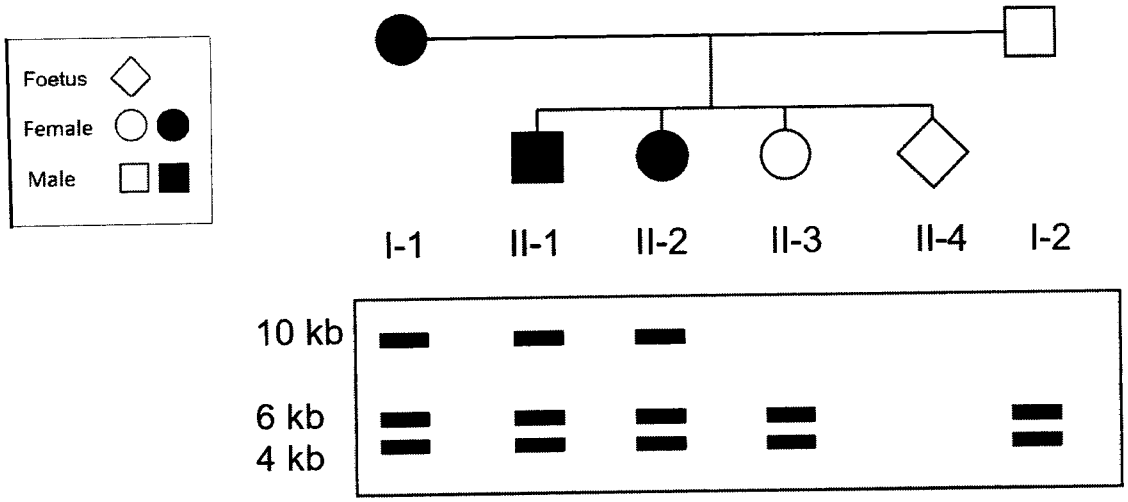

Fig. 8.1

(i) With reference to the Southern Blot results of individual **I-1** in Fig. 8.1, use arrows to indicate the relative positions of the *EcoRI* restriction sites on the region of the genomic DNA recognised by the probe.

Label ALL the restriction sites as "**R**" and indicate the length of bases in kb.

allele 1 _____

allele 2 _____

[2]

(ii) Calculate the probability of the foetus being a boy and inheriting the disease. Explain your answer.

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..... [2]

(b) Fig. 8.2 shows the possible restriction sites of a gene and the results of four individuals after subjecting their genomic DNA to Polymerase Chain Reaction (PCR) and restriction enzyme digest.

The number below each band indicates the molecular sizes of the individual fragments.

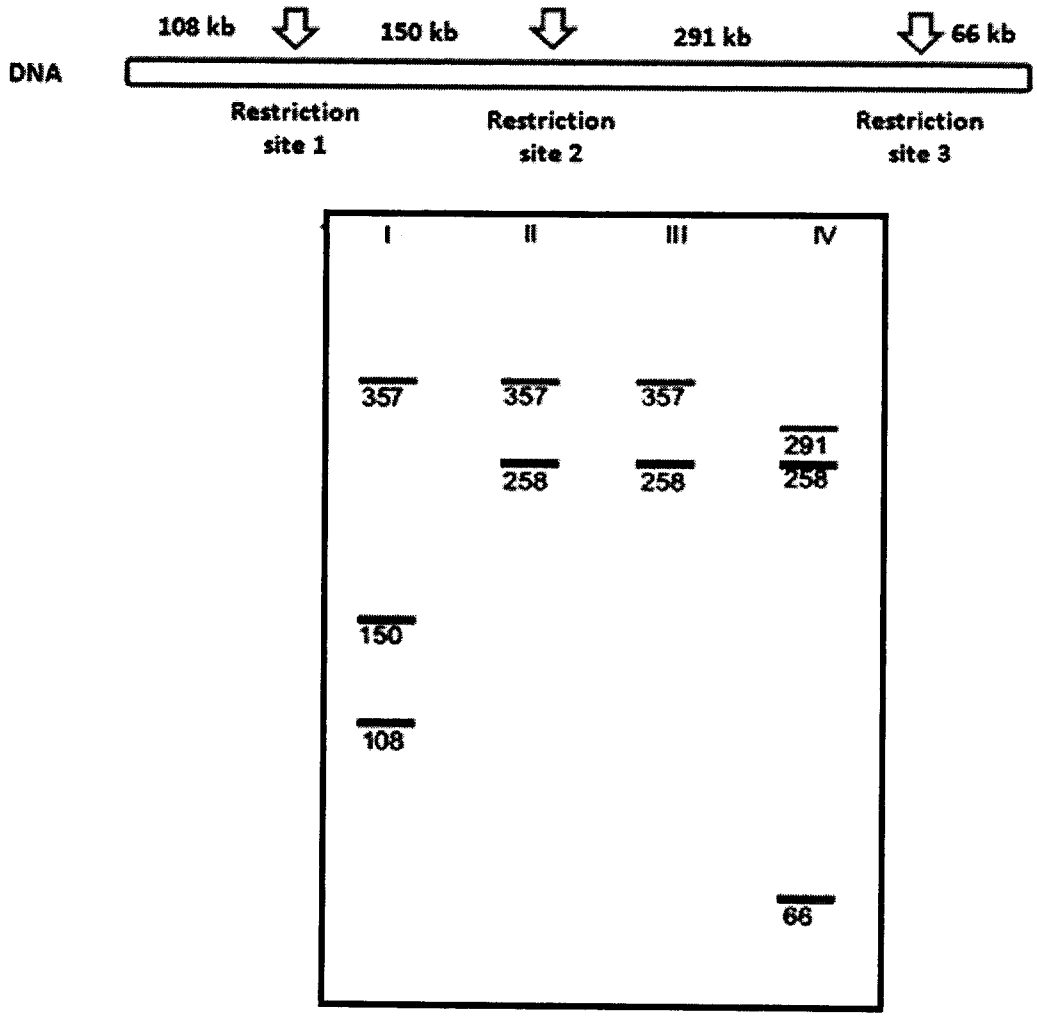

Fig. 8.2

(i) Suggest the significance of carrying out PCR for the genomic DNA samples before subjecting the samples to restriction enzyme digest.

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..... [1]

(ii) With reference to Fig. 8.2, identify the total number of alleles presented by this gene in the four individuals tested. Explain your answer.

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.....[4]

(iii) Suggest how a mutation can result in the different alleles for this gene.

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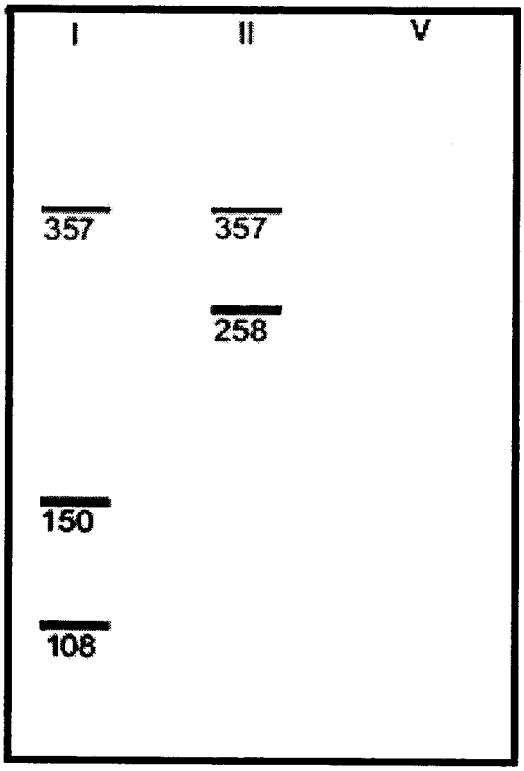
..... [1]

(iv) Individuals I and II had a child V. Draw his banding pattern in the diagram below after subjecting his genomic DNA to the same PCR and restriction digest treatment.

[1]



[Total: 10]

QUESTION 9

The genus *Heliconius* contains more than 40 species of brightly patterned butterflies. Researchers have investigated in the laboratory how one species, *Heliconius heurippa*, could have developed as a separate species. The phenotype of *H. heurippa* is intermediate between that of two other species, *H. cydno* and *H. melpomene*.

Laboratory breeding experiments showed that:

- matings between *H. cydno* and *H. melpomene* (parent species) produce fertile hybrid offspring
- controlled matings of the hybrids produce individuals identical in appearance to *H. heurippa* within three generations
- hybrid butterflies prefer to mate with each other, rather than with individuals of either of the parent species.

(a) The researchers concluded that the *H. heurippa* species could contain DNA from the two parent species as a result of hybridisation.

(i) Suggest, with reasons, one prediction that can be made about the chromosome numbers of *H. cydno* and *H. melpomene*.

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(ii) The researchers thought that, because the hybrid butterflies preferred to mate with each other, this could make speciation more likely to occur.

Give reasons why the researchers thought that this made speciation more likely.

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(b) *Heliconius* butterflies taste unpleasant to predators such as birds. The bright colours on the wings act as warnings so that birds avoid eating them.

Individual birds learn which patterns to avoid. If one *Heliconius* species is abundant, or if it has a pattern shared with another similar species, predators learn to avoid this pattern faster. Therefore, this pattern provides a selective advantage.

Fig. 9.1 shows the distribution of several *Heliconius* species in South America.

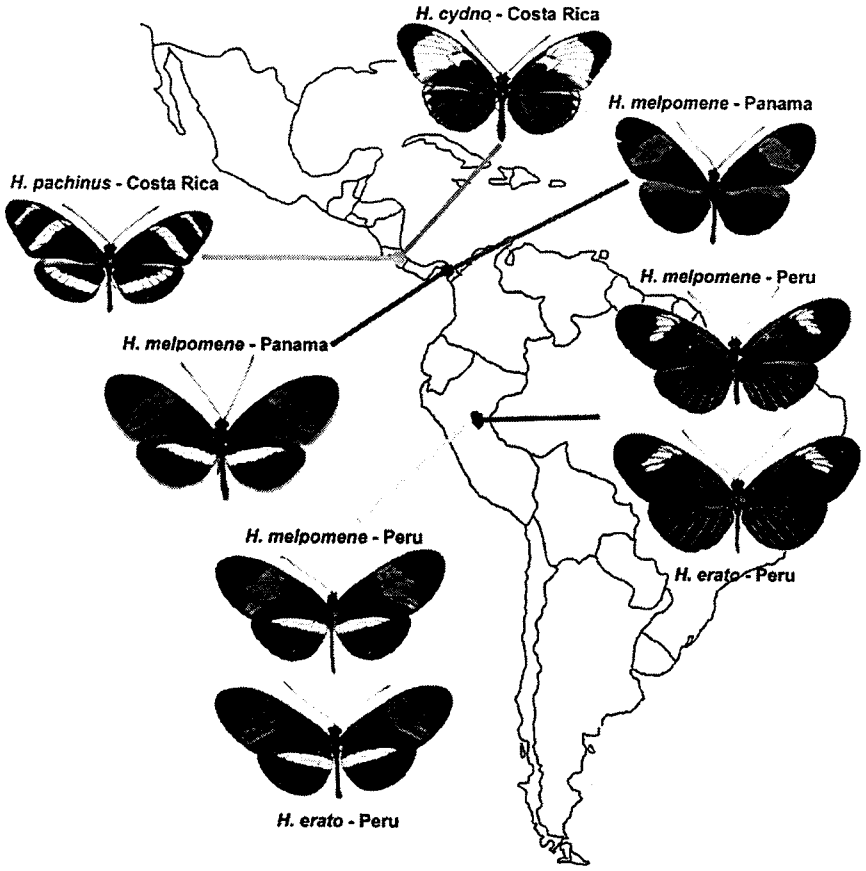

Fig. 9.1

With reference to Fig. 9.1 and your knowledge of anatomical homology and biogeography, comment on the evolutionary relationships between *H. Melpomene*, *H. cydno*, *H. pachinus* and *H. erato*.

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[Total: 8]

QUESTION 10

Fig. 10.1 shows some of the general changes in the immune system during a viral infection.

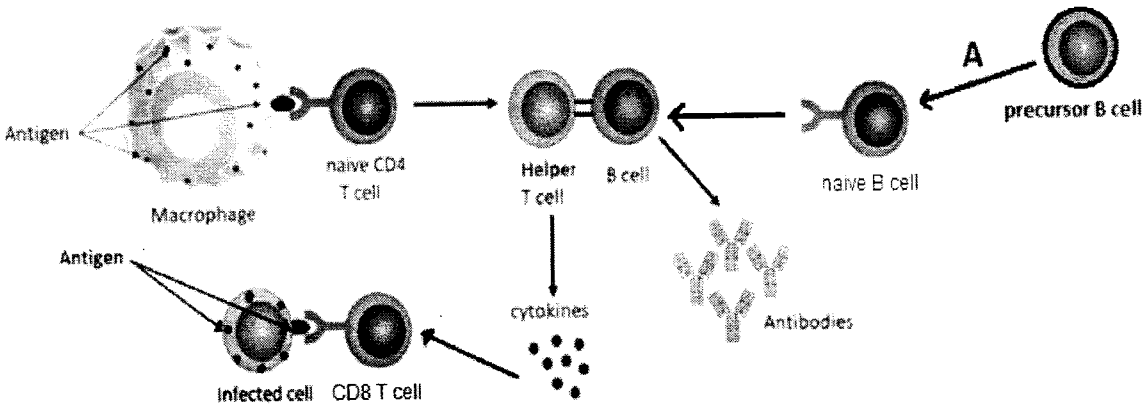

Fig. 10.1

(a) Outline the genetic mechanism that occurs in stage **A** and explain its significance in the adaptive immune response.

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(b) A HIV-infected person infected saw his CD4 T cell count decrease within the first few weeks of his infection and then start to increase again.

With reference to Fig 10.1 and your own knowledge on adaptive immunity, suggest an explanation for the changes in his CD4 T cell count.

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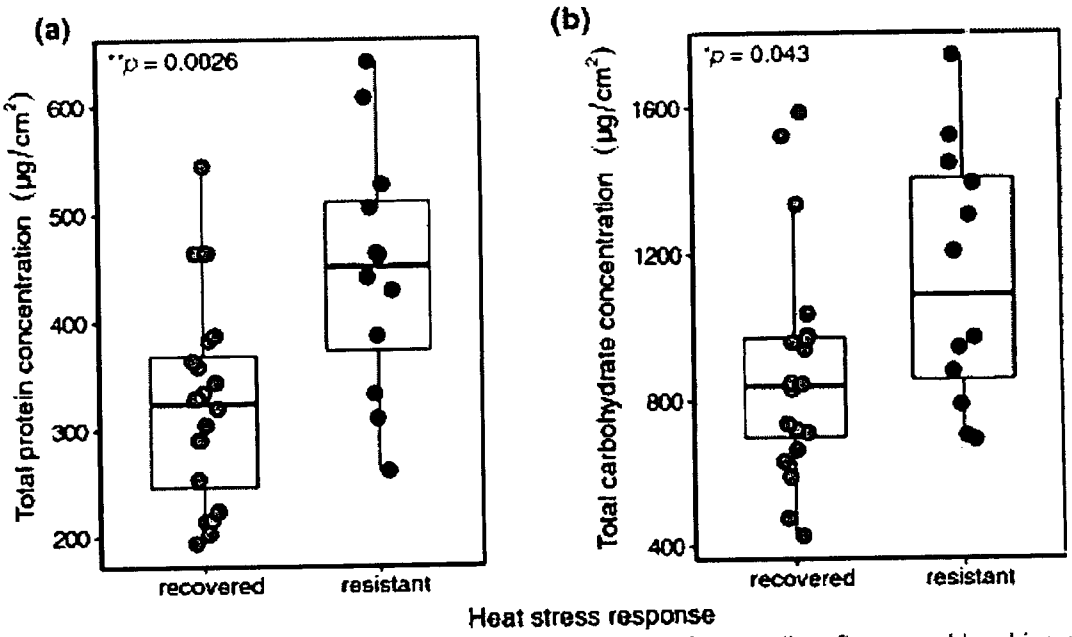
[Total: 6]

QUESTION 11

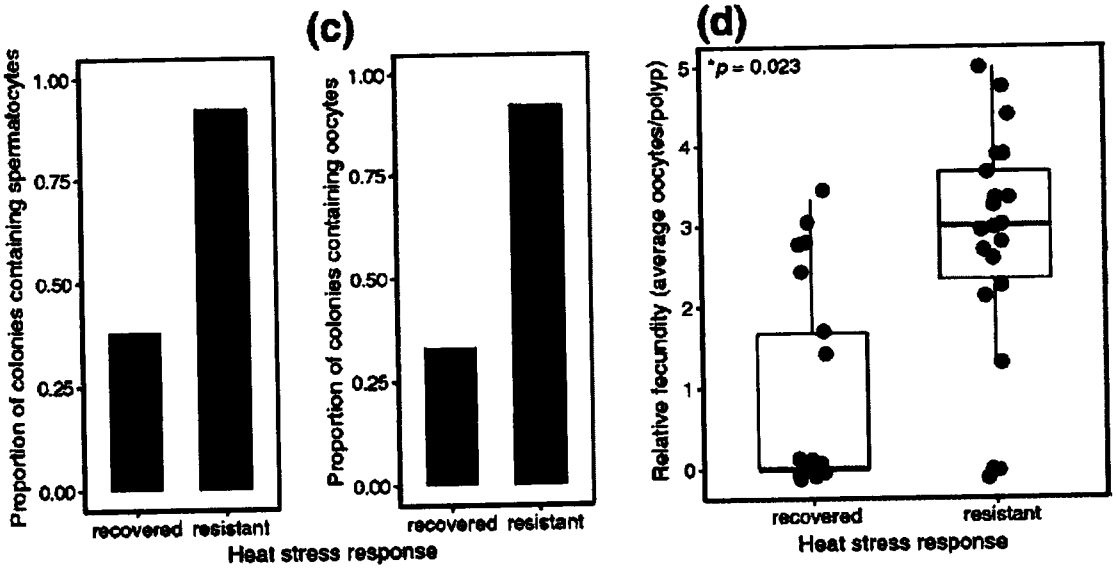
Rising seawater temperatures are contributing to coral bleaching, with mass coral bleaching events projected to increase in both frequency and severity.

Fig 11.1 shows the impact of thermal bleaching stress on stored protein and carbohydrate reserves and reproductive output of two categories of corals five months after the bleaching event – corals that were resistant to bleaching events and corals that were bleached but later recovered.

For both types of corals, zooxanthellae was able to recolonise them and both types of corals also looked visually healthy.



Energetic condition of recovered and resistant coral colonies five months after mass bleaching event. **(a)** Total protein content normalised to host tissue surface area. **(b)** Total carbohydrate content normalised to host tissue surface area. The data point represents a single colony.



(c) Proportion of recovered and resistant colonies containing spermatocytes and oocytes. **(d)** Relative fecundity (fertility) in recovered and resistant colonies. Each data point represents one colony.

Fig. 11.1

(a) Suggest which type of corals would demonstrate better promote reef recovery after disturbance. Justify your choice with evidence from Fig. 11.1.

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Synthetic biology offers the potential to isolate and cultivate the resistant strains of coral that can naturally withstand higher sea surface temperatures associated with climate change.

Fig. 11.2 shows the process of using synthetic biology in promoting community reef recovery.

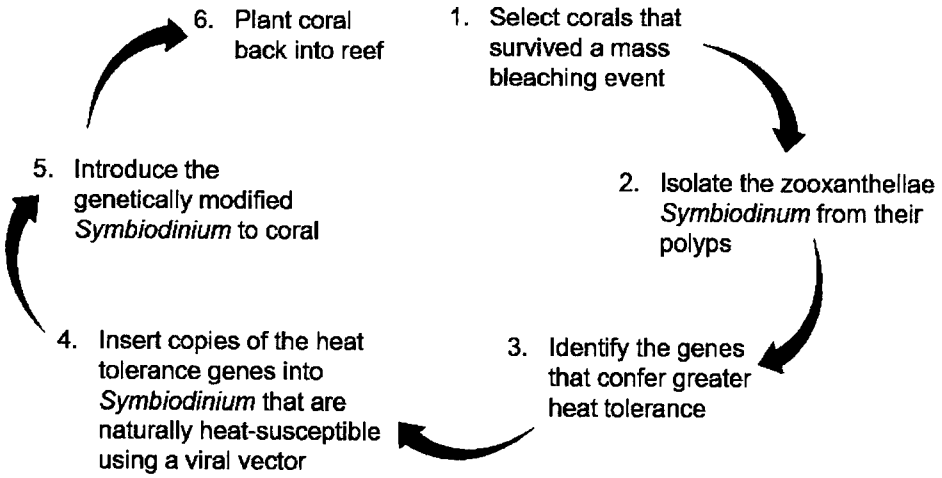

Fig. 11.2

A national survey was conducted with 1,148 Australians, measuring psychological predictors of support for a synthetic biology conservation solution to coral loss.

Participants were moderately strongly supportive of technology development and were most keen to implement genetically engineered coral with between 50 and 70% of reef remaining intact.

The findings suggest that the general public are not averse to the development of a synthetic biology solution for restoring the reef, and they may be especially influenced by whether the synthetic biology solution is shown to be effective, particularly in comparison to other conservation solutions (such as rubble stabilization, manual removal of coral predators like crown-of-thorns starfish).

However, support for a synthetic biology intervention is conditional and many participants expressed concerns about possible long-term impacts on humans, animals, and the environment as a result of deploying engineered coral.

(b) Discuss the ethical considerations that support and oppose the use of genetically engineered coral for reef restoration.

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[Total: 5]

End of Paper

Civics Group	A Level Index Number	Name (use BLOCK LETTERS)	H2

ST. ANDREW'S JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATIONS

H2 BIOLOGY **9744/03**

Paper 3 (Booklet A)

Thursday 15th September 2022 2 hours

READ THESE INSTRUCTIONS FIRST

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

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

All working for numerical answers must be shown.

Conceptual error (C)	Data Quoting (D)	Expression (E)	Misreading the question (Q)

For Examiners' Use	
1	/30
2	/9
3	/11
4 or 5	/25
Total	**/75**

This document consists of **8** printed pages.

[Turn over]

Answer **all** *questions.*

QUESTION 1

(a) SWI/SNF (SWItch/Sucrose Non-Fermentable) is a subfamily of ATP-dependent chromatin remodelling complexes found in eukaryotes. Products of SWI and SNF genes can destabilise histone-DNA interactions, resulting in sliding or ejection of nucleosomes, as shown in Fig. 1.1.

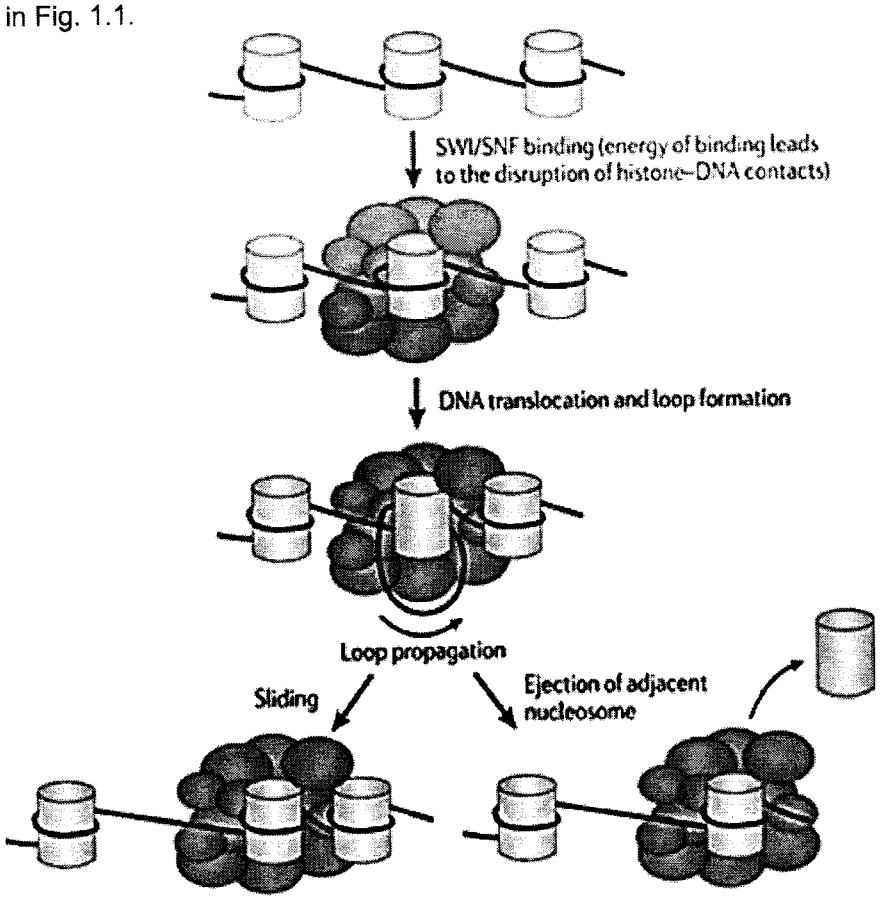

Fig. 1.1

In contrast, Polycomb Repressive Complex (PRC), with the histone methyltransferase EZH2 as its catalytic subunit, is associated with chromatin compaction.

(i) With reference to Fig. 1.1, describe how the activity of SWI/SNF complexes can lead to the active transcription of genes.

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(ii) Describe two mechanisms that can produce the same chromatin remodelling effect as PRC/EZH2 complex.

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(iii) Describe how the nucleosomes will eventually pack into chromosomes during prophase of mitosis.

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(b) Over 20% of human cancers carry a mutation in SWI/SNF complex subunit genes. Fig. 1.2 shows that the inactivation of SWI/SNF causes a failure to inhibit PRC at promoters and typical enhancers (TE) of genes involved in differentiation. The residual functional SWI/SNF complexes are preferentially localized to super-enhancers (SE) of genes maintaining cell renewal. The resulting imbalance between differentiation vs. self-renewal promotes tumorigenesis (tumour formation) .

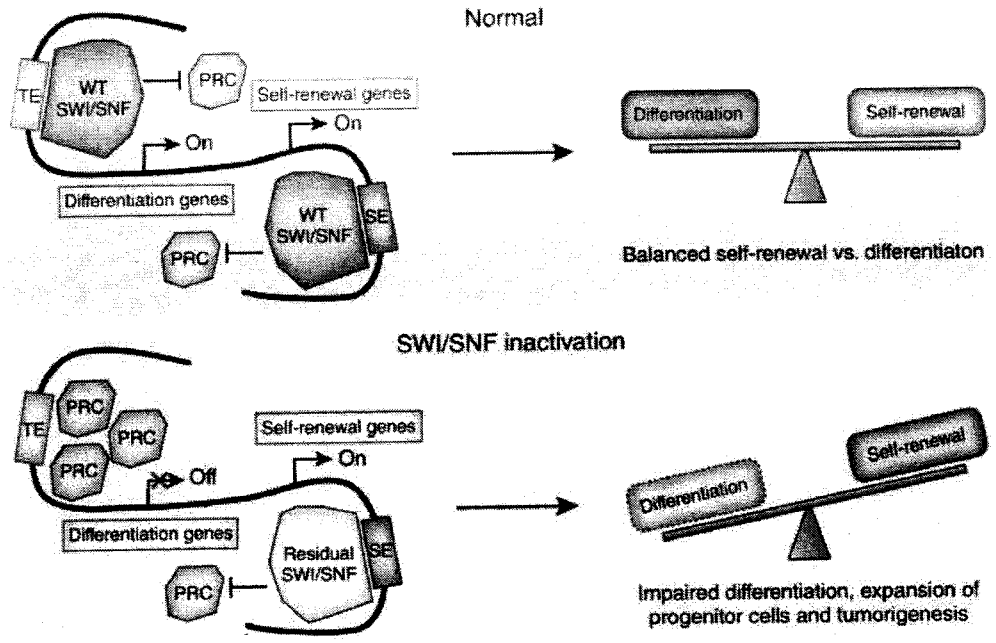

Fig. 1.2

(i) Describe the role of enhancers in the control of gene expression.

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(ii) With reference to information from **1(a)** as well as Fig. 1.2, describe the downstream effect of failing to inhibit PRC due to inactivation of SWI/SNF.

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(iii) Explain how the "imbalance between differentiation vs. self-renewal promotes tumorigenesis".

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(c) Different mutations in the proto-oncogene coding for Epidermal Growth Factor Receptor (EGFR) are associated with several cancers such as lung cancer. Lung tissue samples were taken from two lung cancer patients and cultured on Petri dishes for 24 hours. The average cytoplasmic mRNA levels (Fig. 1.5A) as well as 6-hourly protein levels (Fig. 1.5B) of EGFR and β-actin were investigated. β-actin is a house-keeping gene that is expressed in almost all cell types and is used as a positive control.

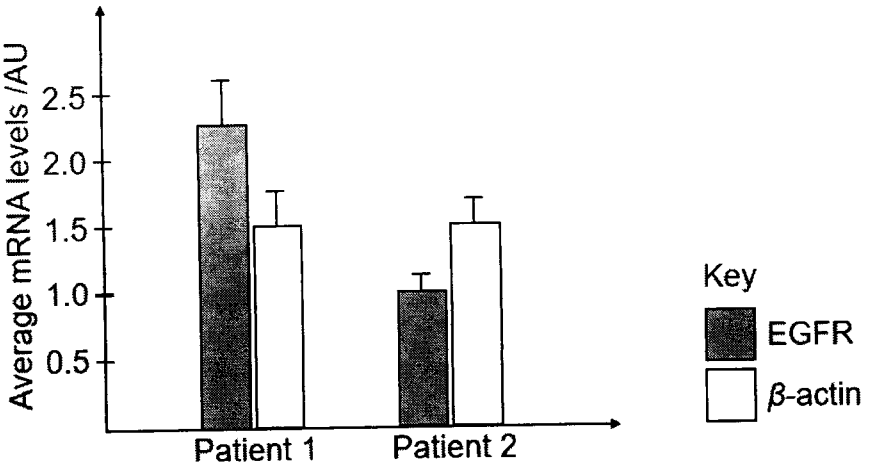

Fig. 1.3A

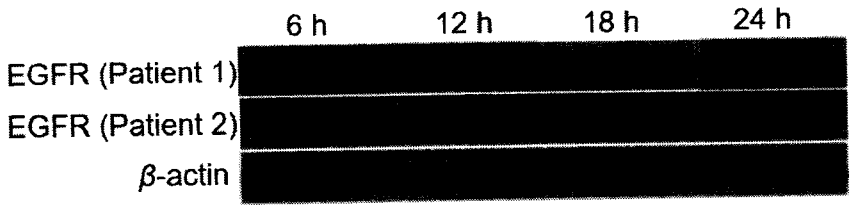

Fig. 1.3B

(i) Describe the rationale of using β-actin as a positive control.

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(ii) Describe the difference in average mRNA and protein level of EGFR between the two patients.

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(iii) Suggest and explain possible mutations in the EGFR gene of patients 1 and 2 that could result in the differences described in **c(ii)**.

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(iv) Contrast between the function of a proto-oncogene such as EGFR and a tumour suppressor gene such as p53.

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(v) The tissue samples taken from the two lung cancer patients showed mutations in several other genes besides proto-oncogenes and tumour suppressor genes.

Explain how these mutations contributed to the development of lung cancer.

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[Total: 30]

Civics Group	A Level Index Number	Name (use BLOCK LETTERS)	H2

ST. ANDREW'S JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATIONS

H2 BIOLOGY **9744/03**

Paper 3 (Booklet B)

Thursday 15th September 2022 2 hours

READ THESE INSTRUCTIONS FIRST

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

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

All working for numerical answers must be shown.

Conceptual error (C)	Data Quoting (D)	Expression (E)	Misreading the question (Q)

For Examiners' Use	
2	/9
3	/11
4 or 5	/25
Total	**/75**

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

[Turn over]

QUESTION 2

Measles is an infectious disease for which vaccines have been developed. The commonly used vaccine consists of an attenuated (weakened) form of the virus. The measles vaccine is normally given to children when they are about one year old, followed by a booster dose when they are about four years old.

Fig. 2.1 shows the number of reported cases of measles and the percentage of the population vaccinated worldwide between 1980 and 2002.

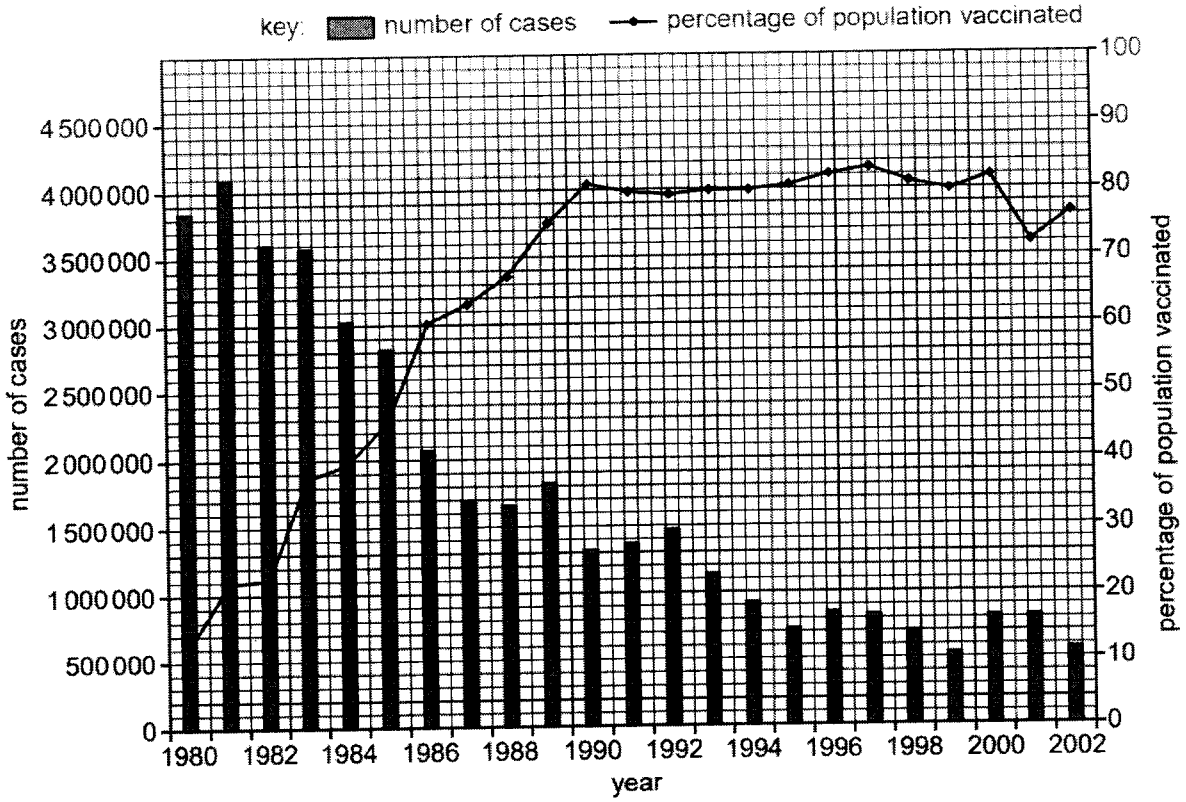

Fig. 2.1

(a) Describe the trends shown in Fig. 2.1:

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(b) The vaccination of a high enough percentage of the population can break the disease transmission cycle, giving 'herd immunity'.

The measles virus spreads easily by droplet transmission. One estimate of its reproduction number, R_o, is 15, meaning that each person infected with measles is expected to infect 15 other people.

If the percentage of people who are immune to a disease exceeds the herd immunity threshold, the disease can no longer persist in the population. Assuming 100% efficacy of the vaccine, the herd immunity threshold is calculated as:

$$100 \times (1 - 1/R_o)$$

(i) Calculate the herd immunity threshold for measles, if $R_o = 15$.

Herd immunity threshold = ...% [1]

(ii) Use Fig. 2.1 and your answer to **(b)(i)** to explain why the number of measles cases remain above 500,000.

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(c) The measles virus has a unique protein on its surface called MV-H which can bind to a protein called CD-46 on the surface of human cells. This allows the measles virus to infect these cells.

Suggest how the two proteins, MV-H and CD-46, can bind to each other.

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[Total: 9]

QUESTION 3

Fig. 3.1 shows the percentage cover of live corals and the density of herbivorous fish (plant-feeding) on a coral reef over a number of years. Due to unusually warm water, many of the corals living on the reef died in 1998.

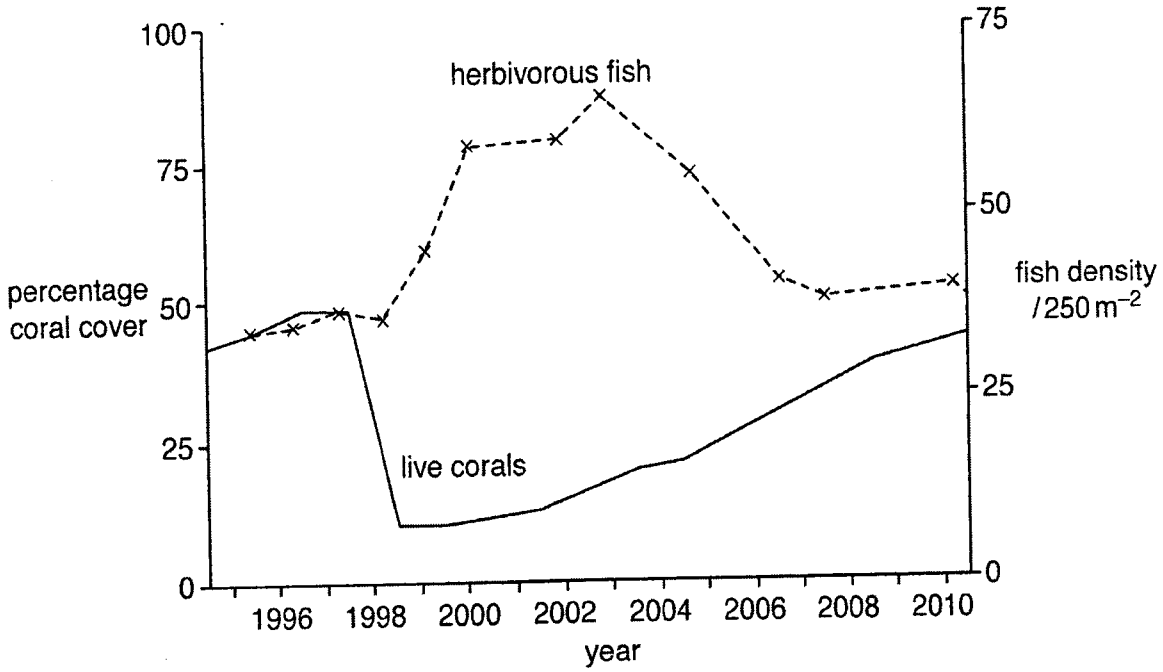

Fig. 3.1

(a) Describe the change in percentage cover of live corals shown in Fig. 3.1.

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(b) Suggest possible impacts due to the change in percentage cover of the live corals.

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(c) State a possible reason why the density of herbivorous fish increases after the death of many of the corals in 1998.

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The impact of climate change is a major threat not only for corals but also for life on earth a whole. Fig. 3.2a shows the loss of ice mass between 1992 and 2018. Fig. 3.2b shows the median extent of sea ice concentration in 1992 as compared to 2018. Fig. 3.3 the number of polar bears living in this biome.

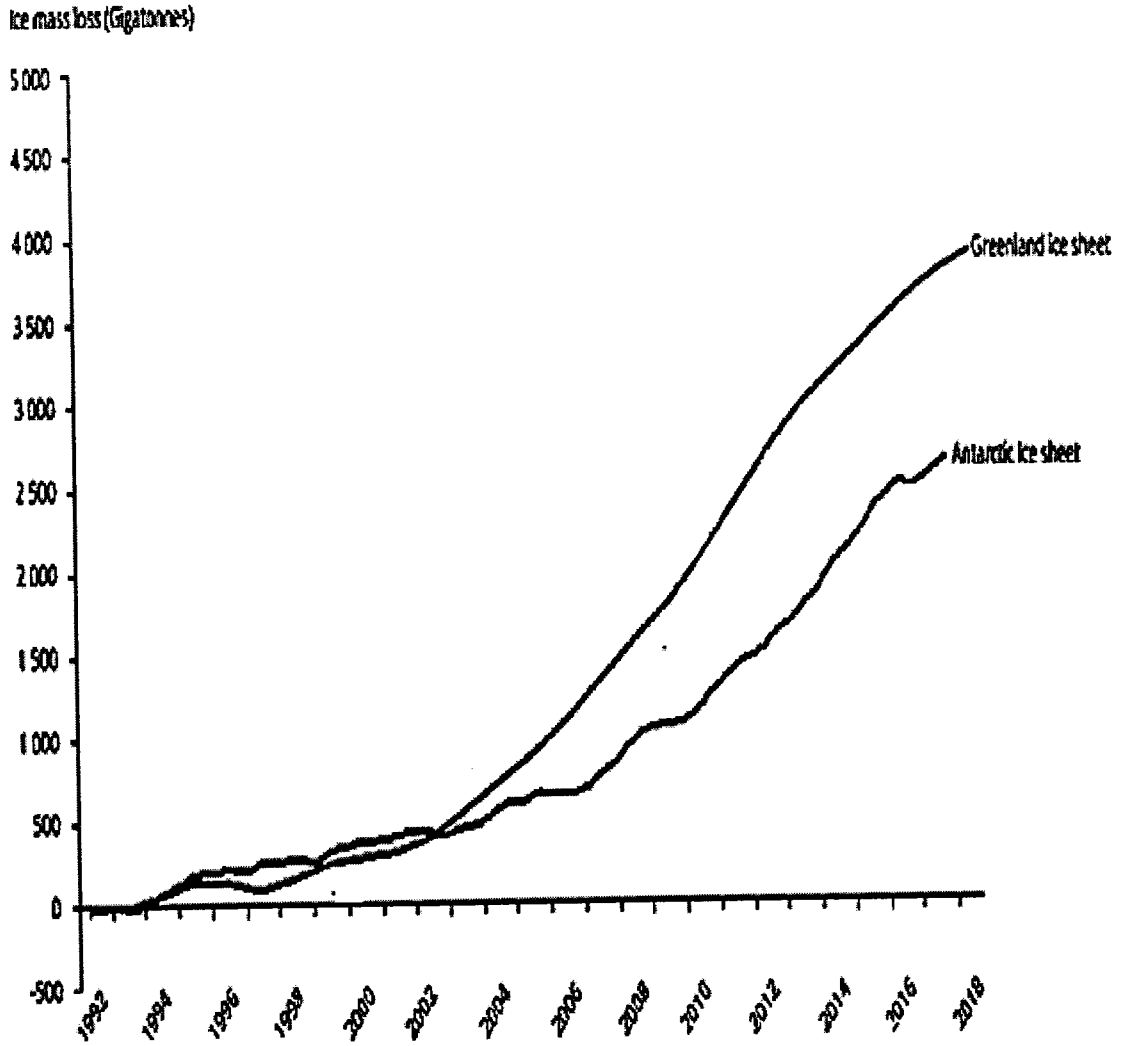

Fig. 3.2a

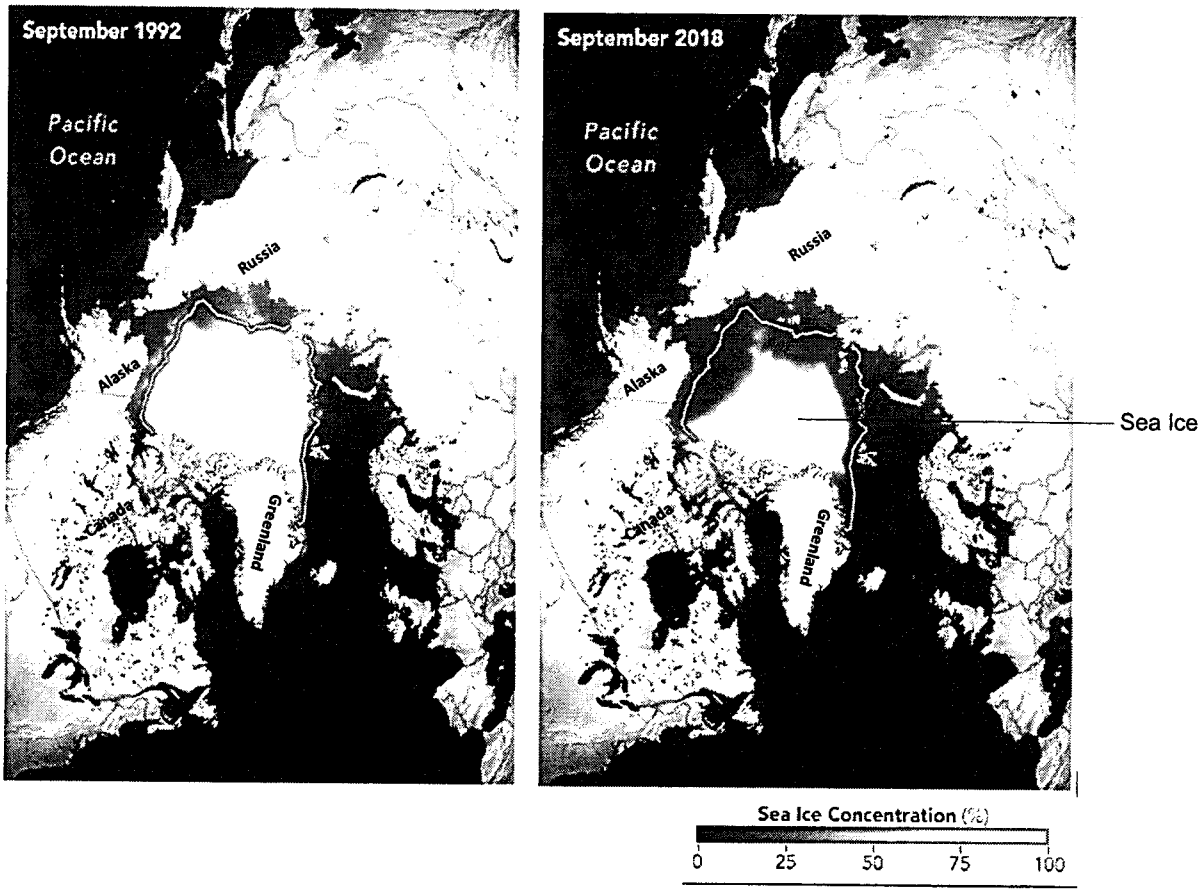

Fig. 3.2b

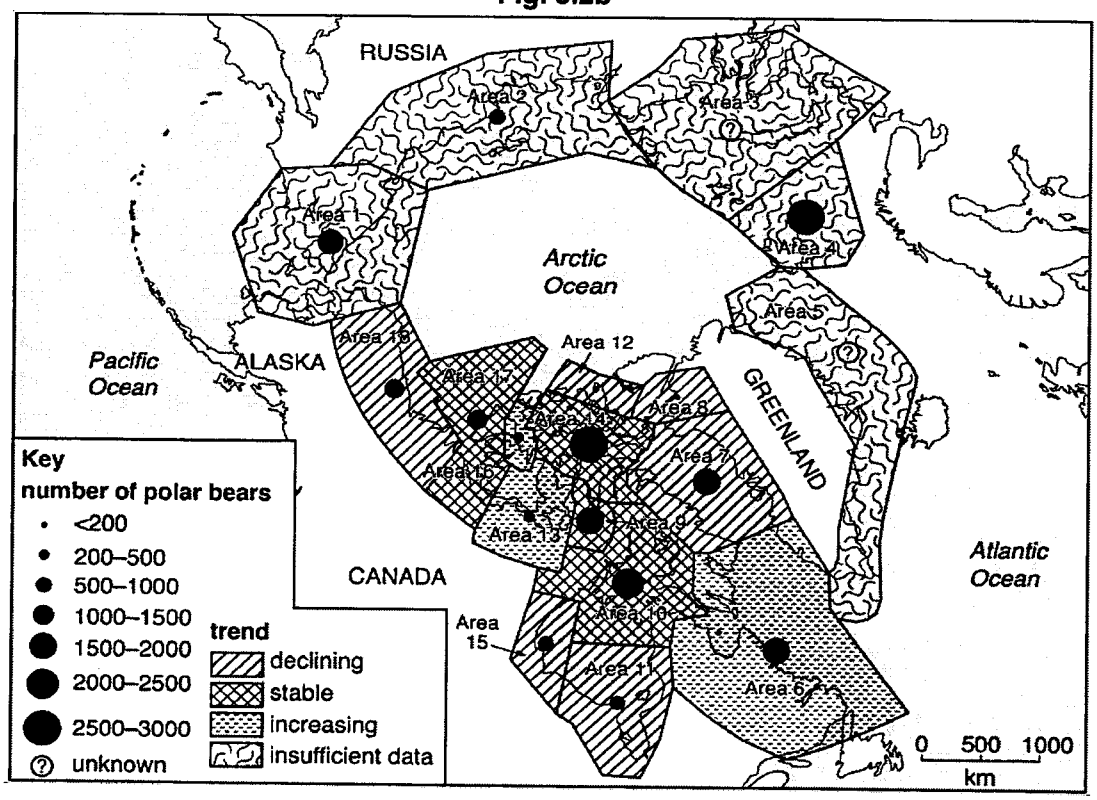

Fig. 3.3

(d) With reference to Figs. 3.2a, 3.2b and 3.3, describe and explain the evidence which suggest that polar bears are at risk of extinction as a result of climate change.

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[Total: 11]

Essay

Answer **one** question only in this section.

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

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 sections (a), (b) etc., as indicated in the question.

4 **(a)** Microorganisms such as *Escherichia coli* (*E. coli*) colonise the intestine and obtain nutrients from their surroundings. [15]
Describe how *E. coli* responds to the presence of lactose and absence of glucose in the intestine and explain how a mutation in the regulatory sequences of the *lac* operon may affect how *E. coli* respond to changes in lactose supply.

(b) The green fluorescent protein (GFP) gene was isolated from the jellyfish *Aequorea Victoria* and inserted into DNA of a species of mice, *Mus musculus*. The gene was expressed throughout the genetically modified mice resulting in the mice exhibiting bright green fluorescence when exposed to light in the blue to ultraviolet range. [10]
With the use of the various species concepts, discuss whether the genetically modified mice can be considered as the same or different species as the unmodified mice.

5 **(a)** 'Eukaryotic life is impossible without membranes.' [15]
Discuss how regulation of membrane fluidity is achieved in living organisms and justify why the statement above may be true using specific examples.

(b) With reference to named examples, describe the role of water in reactions involving biomolecules. [10]

[Total: 25]

End of Paper