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

ST. ANDREW'S JUNIOR COLLEGE
2023 JC2 PRELIMINARY EXAMINATIONS

H2 BIOLOGY **9744/2**

Paper 2

Monday 28th August 2023 2 hours

Materials: Question Paper

READ THESE INSTRUCTIONS FIRST

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

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

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

For Examiners' Use	
1	/13
2	/10
3	/12
4	/12
5	/14
6	/9
7	/11
8	/9
9	/5
10	/5
Total	**/100**

This document consists of **xx** printed pages and **x** blank page.

[Turn over

QUESTION 1

Fig. 1.1 is an electron micrograph that shows part of a eukaryotic cell.

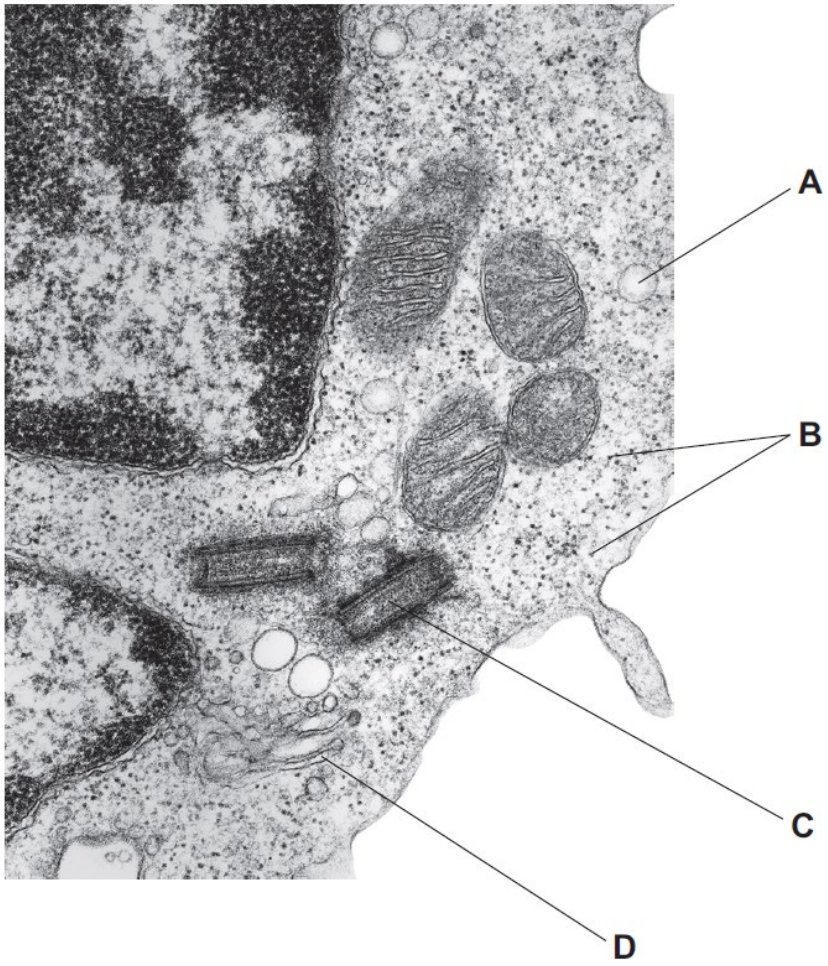

Fig. 1.1

(a) Organelle **B** is made of **two** types of molecules.

(i) Name the molecules in organelle **B** and state the process and location where each molecule is synthesized, by completing the table below:

Organelle **B**	Molecule 1	Molecule 2
1 Name	ribosomal {RNA / ribonucleic acid(s)}	protein(s)
2 Process	transcription	translation
3 Location	nucleolus	cytoplasm

(ii) Identify the organelle **B** in Fig. 1.1 and state one function of this organelle.

……..……[2]

1 Ribosome;

Function : any one

2 **Sites** of {translation of mRNA into polypeptides / synthesis of protein} ;

3 Ribosomes contain binding sites for both tRNA and mRNA ;

4 Peptidyl transferase activity present in the large ribosomal subunit catalyse the formation of peptide bonds between amino acid;

(b) Collagen is a protein produced by cells and is the most common structural protein, due to its high tensile strength, in vertebrates.

(i) To form collagen, many of the amino acids such as proline and lysine are modified by the addition of a hydroxyl group on its side chain to form hydroxyproline and hydroxylysine residues, respectively.

Vitamin C is necessary in aiding this conversion of proline and lysine to hydroxyproline and hydroxylysine. Vitamin C works by preventing the inactivation of two key enzymes, lysyl and prolyl hydroxylas, in collagen biosynthesis.

Fig. 1.2 shows the synthesis of collagen. Production of tropocollagen starts with procollagen

Procollagen, once secreted outside the cell, will be cleaved at C and N terminus to form tropocollagen.

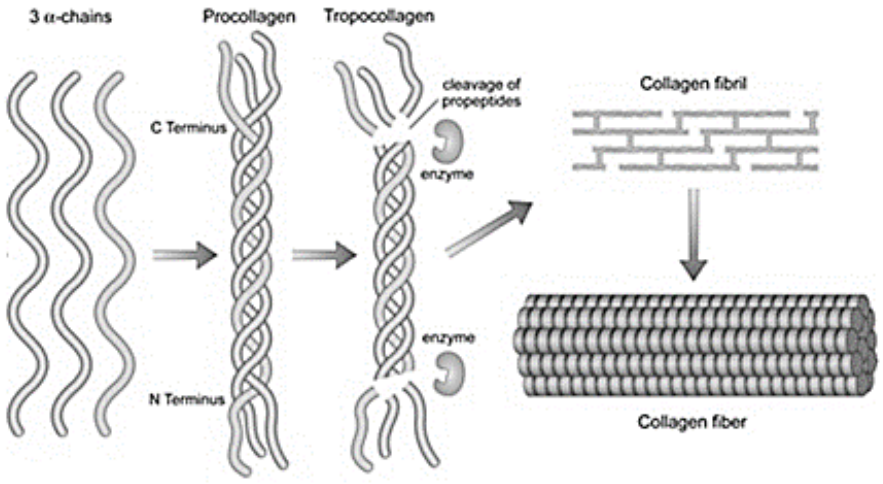

Fig. 1.2

Describe how the procollagen is synthesized and secreted out of the cell to be assembled into collagen.

……[6]

(Procollagen is made up of 3 polypeptide chains)

1 Each polypeptide is first synthesized by the ribosomes on the rER;
[Reject: polypeptide folds into its native / 3-dimensional conformation (only applies to globular proteins)] ;

2 Ref. entry of polypeptide into RER lumen; where specific amino acids in polypeptide chain undergo chemical modification with hydroxyl groups are added to proline and lysine to form hydroxyproline and hydroxylysine ;

3 The modified proteins are packaged into transport vesicles which buds off the RER and move towards of Golgi body at the cis face;

4 Further chemical modification of the protein occurs in the Golgi body (e.g. proteolysis, glycosylation, phosphorylation etc.);

5 [Based on context] Ref: presence of key enzymes, lysyl and prolyl hydroxylase, in lumen of RER or Golgi body ; (which were kept activated by Vit C)

6 Modified proteins (procollagen) are **packaged into** secretory vesicles which bud off the trans face of the Golgi body;

7 Secretory vesicles **move** toward the cell surface membrane. The vesicle's membrane **fuses** with the cell surface membrane, **releasing** the modified protein (procollagen) via exocytosis;

8 Movement of transport and secretory vesicles is guided by filaments and microtubules (components of the cell cytoskeleton) with the use of ATP as energy source;

9 Ref. formation of hydrogen bonds {involving OH groups of **hydroxylproline** (within tropocollagen) / between NH of glycine and CO of other amino acids on the other 2 chains} to stabilize procollagen structure;

10 Ref. formation of **covalent** bonds **involving hydroxylysine** (and lysine) between tropocollagen molecules to form fibrils (and association of collagen fibrils to form fiber);
[Max 6]

(ii) Cellulose is present in plants and functions as a suitable cell wall material.

Cellulose is made up of cellulose microfibrils which are formed from cellulose molecule. Each cellulose molecule is a polymer of glucose.

Describe the structure of cellulose molecule.

……[2]

1. β-glucose joined by β(1,4) glycosidic bond;
2. Adjacent monomers rotated through 180°;
3. Straight / linear chain;

[Total: 13]

QUESTION 2

Chemotherapy is used in the treatment of cancers. Common side effects during chemotherapy treatment include fatigue, hair loss, infection, etc. While the survival rate has increased due to chemotherapy for some cancers, e.g breast cancer, the quality of life has decreased because of the side effects of chemotherapy. For some patients, fatigue may persist for months or even years after the end of cancer treatment, thus affecting the physical functioning and mental health of these patients.

Various toxins are being developed as alternatives to cancer treatments, and bee venom is drawing attention as one of them. Several studies have demonstrated one of the components in bee venom, melittin, has anti-cancer effects.

Melittin is a polypeptide composed of 26 amino acids. It is an amphoteric molecule owing to the specific arrangement of amino acids, with nonpolar, hydrophobic and neutral amino acids at the end of the N-terminus, and hydrophilic and basic amino acids near the C-terminus.

Research has showed that melittin incorporates into and disrupt the functions of natural and synthetic membranes by forming pores for ions, which eventually leads to disorder in the structure of phospholipid bilayers.

(a) Explain how the molecular structure of the phospholipid allows for the formation of the phospholipid bilayer.

……[2]

1 Phospholipid molecule consists of (one) <u>hydrophilic / polar phosphate head</u> (of phospholipid) ; (two) <u>hydrophobic / non-polar fatty acid tails</u>;

2 Ref. <u>ionic bonds</u> or <u>hydrogen bonds</u> between phosphate heads or between phosphate heads and aqueous medium of the cytoplasm **and** the external environment

/ <u>hydrophobic interactions</u> between fatty acid tails; (facing away from the aqueous medium)

(b) Explain why ions can only cross the membrane via the pores formed by melittin.

……...[3]

1 Ions are <u>charged</u> *[state chemical property]* (thus ions are hydrophilic *[state physical property ie water loving or water hating]*)

2 (Ions are) therefore unable to pass through the **hydrophobic core** of the cell membrane ;

3 *[state what melittin protein can provide ie the reason for necessity of protein]* The transport of ions require specific proteins such as melittin to provide a **water-filled / hydrophilic channel**;

(c) Suggest a possible disadvantage in using melittin as an anti-cancer drug.

……
……,,,,,,,…[1]

1 Melittin does not distinguish normal or cancer cell membranes

/ will damage phospholipid bilayer structures in both normal and cancer cell ;

(d) Explain, using honey bee as an example, how an aspect of the natural environment may affect phenotype.

……[4]

Reproductive system in Honey Bees

1 Although both queen and workers are **females** developed from fertilised **diploid** eggs / have **same amount of genetic material**, they are phenotypically different;

2 [phenotype] The worker bees are sterile while the queen bee is fertile;

3 [phenotype] Worker bees are **smaller** and have **larger mouthparts** and **modified legs** (any 2 differences in pt 3) as compared to the queen bee;

[environment] Difference in phenotype is due to the diet of larva

4 In the first 3 days of hatching, all female **larvae** feed on royal jelly;

5 After 3 days, those destined to be worker bees are fed with diet consisting of honey/nectar /pollen while larvae destined to be queen are (continue to be) fed with royal jelly ;

6 The high protein content of royal jelly stimulates formation and maturation of female reproductive system in the queen bees;

[max 4]

[Total: 10]

QUESTION 3

Carbon dioxide is present in the atmosphere at a concentration of around 0.04%. This level continues to rise as the result of human activities such as the clearing of rainforests and the burning of fossil fuels. It is often said to be the factor that affects the process of photosynthesis under normal conditions and is one of the limiting factors used to increase crop yield in glasshouses.

A student investigated the effect of carbon dioxide on the rate of photosynthesis, using leaf discs cut from the leaf of a spinach plant and sodium hydrogencarbonate solution. Fig. 3.1 shows the method used by the student for his study. In this study, the student recorded the time taken for the leaf discs to rise to the surface.

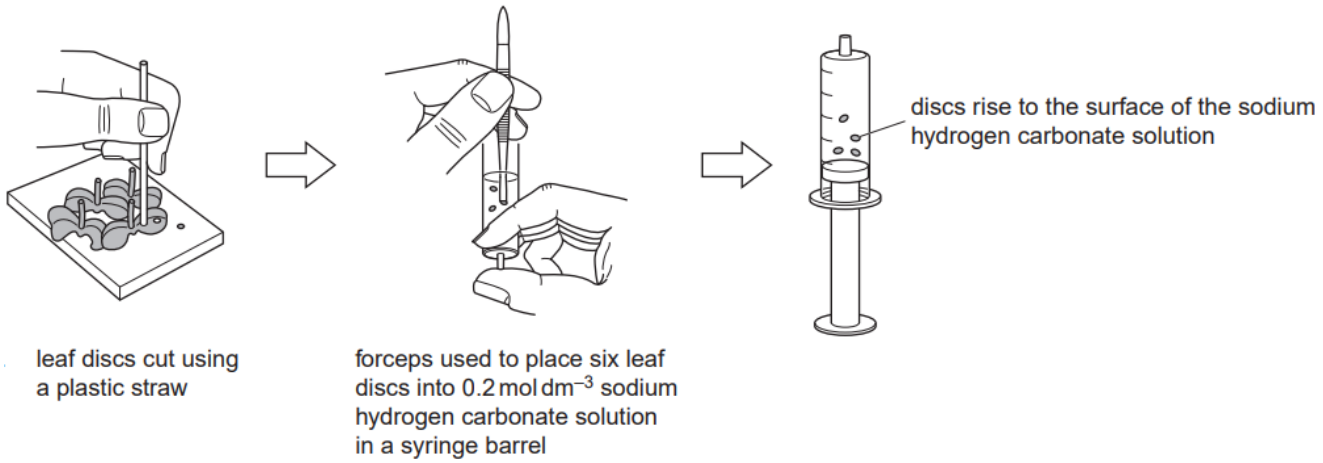

Fig. 3.1

(a) Explain the term *limiting factor*.

……..……..[2]

1 (when a process is affected by several factors) the rate is limited by the limiting factor which is in **shortest supply**;

2 directly affects the rate / biochemical process if its quantity is changed;

(b) Explain why the leaf discs rise to the surface of the sodium hydrogencarbonate solution.

……..……..[1]

1 (leaves undergo photosynthesis) oxygen gas is produced ; through **photolysis** of water;

2 oxygen gas fills up the **air spaces within the leaves** ; density of the leaves fall ; (so leaves float to the surface)
/ oxygen gas emerge as **bubbles** on the sides of the leaf discs; which provides **buoyancy** for the leaf discs to float to the surface;

Fig 3.2 shows the results the student obtained when he carried out his investigation with 6 different concentrations of sodium hydrogencarbonate solution.

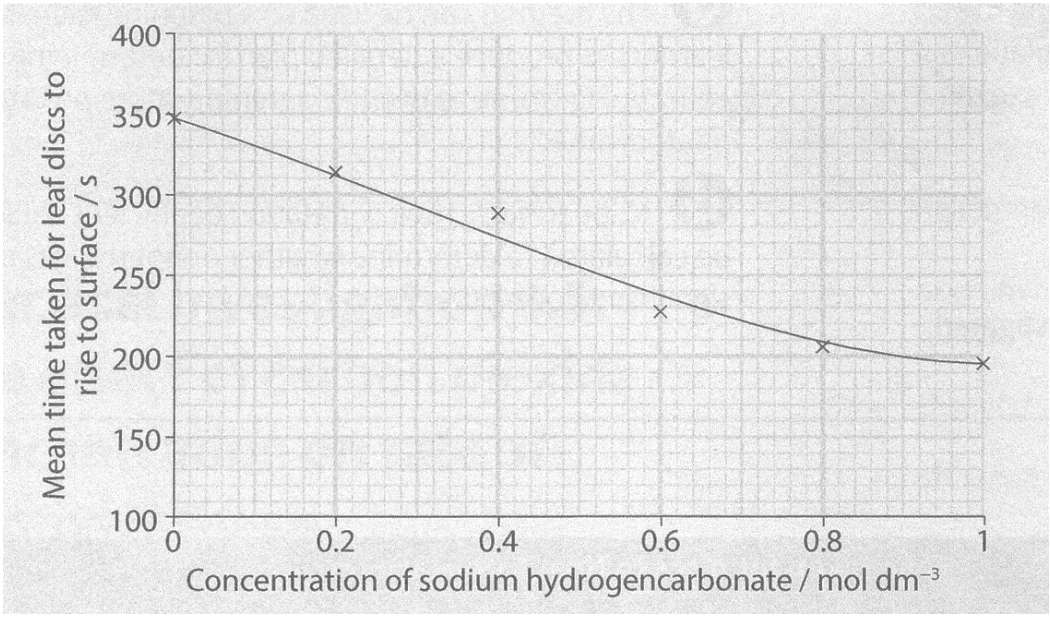

Fig. 3.2

(c) With reference to Fig. 3.2, account for the relationship between 0 mol dm^{-3} to 0.6 mol dm^{-3} of sodium hydrogencarbonate solution and the mean time taken for leaf discs to rise to the surface.

……..[4]

1 [Relationship] As concentration of sodium hydrogencarbonate solution increases from 0 to 0.6mol dm^{-3}, the mean time taken for leaf discs to rise to the surface decreases linearly from 350s to 235s (accept: 235-240s) ;

[Explanation]

2 Increase in concentration of sodium hydrogencarbonate increases the carbon dioxide concentration in the solution ;

3 (Increase in the carbon dioxide concentration) increases the **rate** at which carbon is fixed with RuBP to form PGA in the Calvin cycle ;

4 Ref. increase in rate of Calvin cycle increases the rate of NADPH (and ATP) **usage** increases / formation of $NADP^+$ (and ADP) **faster**;

5 Ref. $NADP^+$ is the **final electron acceptor** in the non cyclic photophosphorylation ; increased electron flow down the electron transport chain;

6 rate of photolysis increases (to replenish the electron which left the reaction centre) ; more oxygen gas is formed **faster** ; (thus time taken for leaf discs to rise to the surface decreases)

(d) Distinguish between the terms:

Absorption spectrum:

…….

Action spectrum:

……..[1]

1 Absorption spectrum shows the absorbance of different wavelengths of light by the chlorophyll b pigment ;
Action spectrum shows the rate of photosynthesis at different wavelengths of light ;

(e) Explain why the graphs of an absorption spectrum and the action spectrum have similar shapes.

……..[1]

1 [Explaining for the peaks for both curves being at the same wavelength] Light energy is absorbed by the pigments is used in photosynthesis
/ Higher rate of photosynthesis occurs at wavelengths that are absorbed most ; (accept reverse argument)

Fig. 3.3 shows the molecular structure of chlorophyll b with its porphyrin ring highlighted in the box. Porphyrins are a group of organic heterocyclic compounds that are comprised of four modified pyrrole subunits connected via methine bridges and form an aromatic macrocyclic structure, which has one or more side chains attached.

Many porphyrins are naturally occurring pigments. In addition to chlorophyll, haemoglobin, a protein found in red blood cells, also contains a porphyrin ring.

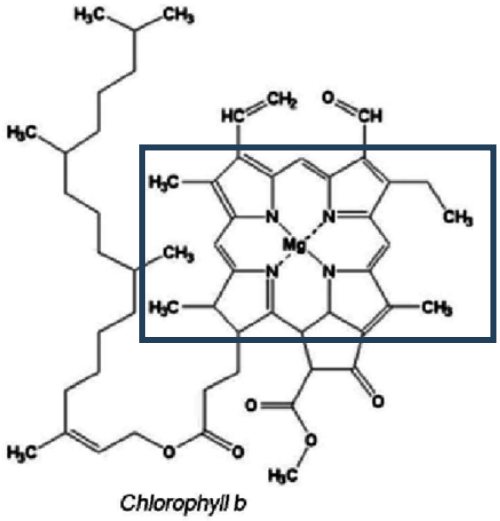

Fig. 3.3

(f) With reference to Fig 3.3, state a structural difference between the porphyrin ring of chlorophyll b and haemoglobin.

……..[1]

1 In the haem group, presence of Fe^{2+} in haemoglobin vs Mg^{2+} in chlorophyll ;
/ C, H, O and N atoms arranged around the central **iron** ion in haemoglobin vs **magnesium** ion in chlorophyll in the haem group;

(g) Chlorophyll b is described to be an accessory pigment. Describe the role of accessory pigments in photosynthesis.

……..[2]

1 Forms part of the light-harvesting cluster of pigments / photosystem / antenna complex ;

2 (a) Ref. photon of light strikes chlorophyll b and gets absorbed;
(b) Ref. energy is **passed** to the <u>special chlorophyll a</u> at the reaction centre ;

3 absorbs at light wavelengths that the special chlorophyll a does not ;
to increase the range of energies of light that is absorbed ;

[Any 2]

[Total : 12]

QUESTION 4

The red blood cells of patients with sickle cell anaemia have reduced oxygen-carrying capacity.

(a) Explain how gene mutation causes a lowering of solubility of Haemoglobin S in sickle red blood cells.

……..……..[5]

1 Ref. name of gene affected: β-globin gene / gene that encodes for β globin chain (in haemoglobin) ; (Accept: β chain)

2 base **substitution** mutation ; *T at the 17th nucleotide of the gene sequence is replaced by A ;*

3 causes a change (in 6th) amino acid from glutamic acid to valine ;

4 glutamic acid is an hydrophilic / acidic amino acid, valine is hydrophobic / non-polar acid ;

5 as a result of the mutation (which changes the primary structure), the tertiary structure of haemogloin change as the R groups of valine form different interactions with other amino acids ;

6 HbS is less soluble at **low oxygen concentrations** and stick to each other via their hydrophobic regions to form **long fibres** inside red blood cells ;

The early detection of sickle cell anaemia can help to reduce mortality rates and early intervention can be initiated to manage the disease effectively. Different techniques have been developed to detect the sickle cell disease and the carrier states with high sensitivity and specificity.

One of the ways is through electrophoresis of the isolated haemoglobin molecules. In this technique, red blood cell lysates containing the haemoglobin molecules are separated at alkaline pH. Under this condition, all haemoglobins show a negative charge.

Fig. 4.1 shows the results obtained from the separation of haemoglobin molecules isolated from red blood cell lysates of individuals who are normal (genotype Hb^AHb^A) and who have sickle cell anaemia (genotype Hb^SHb^S). Equal concentrations of the proteins were loaded in each well before separation.

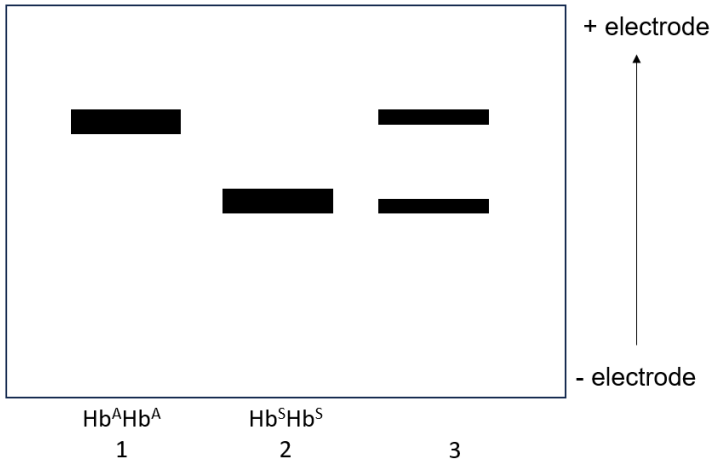

Fig. 4.1

(b) Explain how gel electrophoresis may be used to distinguish between the HbA and HbS proteins in lanes 1 and 2 respectively.

……..[1]

[Based on question and Fig. 4.1] (at alkaline pH) HbA and HbS are negatively charged and migrate towards the positive electrode ;

1 1 **less** negatively charged amino acid (glutamic acid) from HbS results in **slower** migration across gel (cellulose acetate membrane) ; [Reject: size as the size of HbA and HbS are of the same molecular size]

(c) State the genotype of the individual who provided the red blood cell lysates in lane 3. Explain your answer.

……..[2]

1 [Genotype] Hb^AHb^S (heterozygotes synthesize both HbA and HbS) ;

2 Presence of 2 bands ; thickness of bands approximately half of homozygotes in lanes 1 and 2 ;

3 Sickle cell anaemia is a **co-dominant** trait ;

The term “relative fitness” describes the total number of offspring an organism has, compared to the average number of offspring for the population.

Fig. 4.2 shows the relative fitness of individuals who are normal, diagnosed with sickle cell anaemia (SC) and sickle cell trait (SCT). Individuals with sickle cell trait do not usually show symptoms of sickle cell anaemia although they only have a copy of the normal allele.

The fitness levels of all 3 groups of individuals have been studied in both areas with and without malaria. Those with sickle cell anaemia generally show low fitness levels due to the development of various health complications which affect their overall well-being and ability to conceive or carry a pregnancy to term.

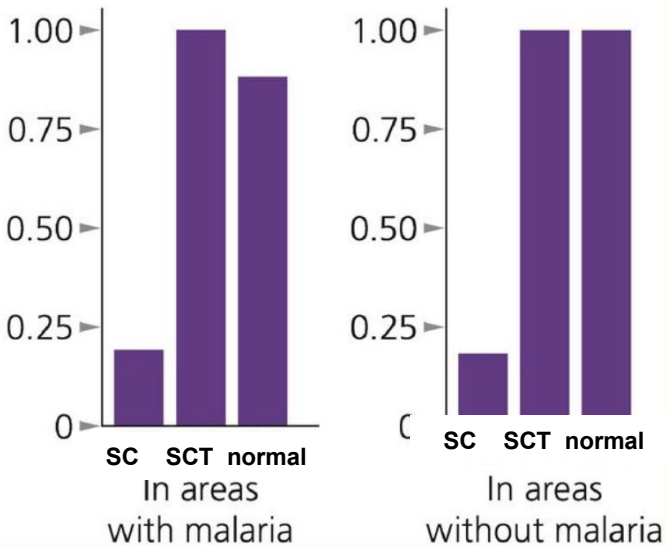

Fig. 4.2

(d) With reference to Fig. 4.2, account for the difference in relative fitness of individuals who are normal and those who show the sickle cell trait.

……..[4]

[Difference in relative fitness by normal /SCT people in different areas]

1 **Decreased** fitness of normal individuals from 1.00 in areas without malaria to 0.90 (accept greater than 0.75, less than 1.00) in areas with malaria ;

2 **No change** in fitness of individuals with SCT in areas with and without malaria; at 1.00 ; (able to survive and reproduce in both areas)

OR

1 [Difference in relative fitness by each area]
At areas with malaria, the fitness of normal individuals is **lower**, at 0.9 (accept greater than 0.75, less than 1.00), than those with SCT, at 1.00;

2 At areas without malaria, the fitness of normal and SCT individuals is **the same**, at 1.00;

3 Malaria parasite acts as a **selection pressure** in places with malaria ;

4 Individuals without Hb^S allele / individuals of Hb^AHb^A genotype are at **selective disadvantage**, decrease in fitness due to mortality from malaria ;

5 Heterozygotes (who show the sickle cell trait carry a Hb^S/mutated/recessive allele) are at a **selective advantage** (as compared to individuals of Hb^AHb^A genotype) as **malaria parasite inside sickle-shaped red blood cells are removed by the immune system** ;
REJECT heterozygote advantage without qualification;

[Total : 12]

QUESTION 5

Chronic Granulomatous Disease (CGD) is characterized by defects in the enzyme NADPH oxidase, causing phagocytes (for examples, neutrophils) to improperly clear invading pathogens.

X-CGD is the most common type of CGD and primarily affects males, with less females getting the disease. It is caused by a mutation in a gene on the sex chromosome.

(a)With reference to the information provided above, state the mode of inheritance of CGD.

……..……...

Mode of inheritance: …….. [1]

1. X-linked recessive;

(b) Explain your answer for (a).

…….……[2]

1. [why X linked and not Y linked] If gene that causes the disease is on Y chromosome, **females will not get** the **disease; as they have no Y chromosome**; (but females have a chance of getting the disease in the question context)
2. [addressing why males are primarily affected than females] Males only have <u>one X</u> chromosome; and there are no corresponding alleles in <u>Y</u> chromosome to mask the effects of the recessive allele / no other X chromosome to mask the effect of the recessive allele
   /
   Females have <u>2</u> copies of <u>X</u> chromosomes; Ref. if one copy has the recessive allele, the other copy of X chromosome might still be able to mask the effect;

3. [why (X linked) **recessive** instead of (X linked) **dominant**] If disease is caused by a dominant allele, **more females** will be **expected** to get the disease; as females have <u>two</u> copies of the <u>X</u> chromosome; (will show symptoms once inherit a dominant allele on X chromosome);

(c) A woman not affected by CGD marries a man not affected with CGD. Their daughters are all not affected, while they have some sons who are affected, and some sons who are not.

Using the symbols A/a, construct a genetic cross diagram to show the outcomes.

……..……...[4]

Let X^A represent the X chromosome with the allele A for normal NADPH oxidase
[Accept: "normal allele"]
Let X^a represent the X chromosome with the mutated allele a for NADPH oxidase
[Accept: "mutated allele"]
Let Y represent the Y chromosome
The allele for normal NADPH oxidase (A) is dominant to allele for mutant NADPH oxidase (a)

	Mother			Father
Parental phenotypes:	Not affected		x	Not affected
Parental genotype:	$X^A X^a$		x	$X^A Y$
Parental gametes:	X^A, X^a		x	X^A, Y
F1 genotypes:	$X^A X^A$	$X^A X^a$	$X^A Y$	$X^a Y$
F1 phenotypes:	Not affected female	Not affected female	Not affected male	Affected male
F1 phenotypic ratio:	2:		1 :	1

Mark scheme:

1 Key

2 Parental genotypes matching parental phenotypes and gender;

+ Parental gametes (circled);

3 F1 genotypes;

4 Genotypes correspond to phenotypes with gender ;

+ F1 phenotypic ratio ;

(d) Use the genetic cross diagram in (c) to find the probability of the couple getting a son with CGD.

……..……...[1]

1. Probability of getting son with CGD = 1 out of 2 = 0.50 or 50% or ½

Further research showed that the gene mutation causing CGD is a substitution mutation.

Fig. 5.1 shows a pedigree tree to show the inheritance of CGD, and Fig. 5.2 shows the outcomes of gel electrophoresis after isolation of the NADPH oxidase gene from each individual. The bands are made visible with the staining of ethidium bromide.

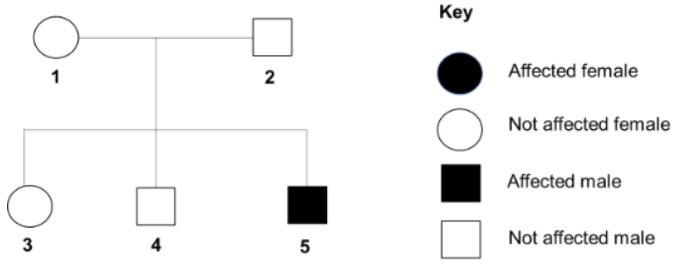

Fig. 5.1

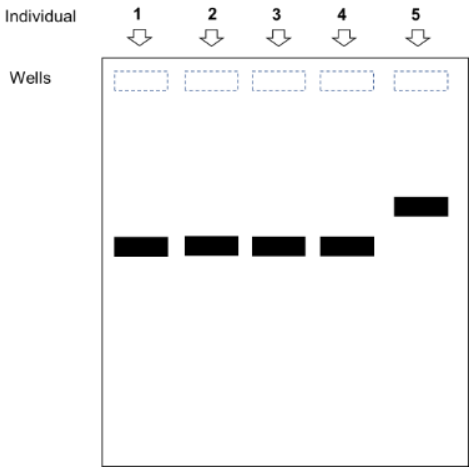

Fig. 5.2

(e) With reference to Fig. 5.1 and Fig. 5.2, identify one error in the gel electrophoresis outcomes shown in Fig. 5.2. Explain your answer.

……[2]

Error 1:

1. [Error] Ref. **thickness** of the band for individuals 2, 4, 5 should be **half / less than** individuals 1 and 3;
2. [Explain] Ref. males only have 1 copy of the gene as they have only 1 X chromosome; females have 2 copies of the gene as they have 2 X chromosomes;

OR

Error 2:

1. [Error] Ref. **Position** of individual 5 **should not be different** from the others;
   / the molecular weight of the band should be the same as others; [Reject: lesser than others]
2. [Explain] Ref. a substitution gene mutation (from question context) replaces a nucleotide (instead of adding/deleting), thus there should not be a change in its length (molecular weight);
   [Reject: a substitution gene mutation might lead to a new stop codon after transcription, leading to truncated protein ➔ gel E is reflecting the size of the DNA band, not the protein]

Researchers are trying a new treatment for CGD, where they removed stem cells which are capable of differentiating into blood cells from the patients themselves, and genetically modified them so that they no longer carried the unwanted mutation. Then, the edited stem cells were returned to their bodies, ready to produce healthy new lymphocytes such as B lymphocytes and T lymphocytes.

(f) State the name of the stem cells which are capable of differentiating into blood cells and list two properties of these stem cells.

……..……...

Name of stem cell: .....…….[1]

Properties: …….

……..…….....[2]

1. [Name] Lymphoid stem cells [Reject: adult stem cell, as it is non specific enough]

   AND

   [Any 2]
2. [Properties] Self-renewal / Stem cells are able to divide by mitosis to produce new stem cells;
3. [Properties] Undifferentiated and unspecialized / do not have cell-specific structures to carry out specific functions;
4. [Properties] Daughter cells of stem cells are able to differentiate into specialized cells **in response to appropriate chemical signals** from the body by {turning on/off expression of specific genes / differential gene expression};
5. [Properties] multipotent / able to differentiate into {a **limited range** of cell type / produce only cells of a **specific lineage;** (no mark for examples, as it is stated in question that lymphoid stem cells differentiate into T and B lymphocytes)

(g) The new treatment mentioned above is able to overcome ethical concerns on obtaining stem cells from blastocysts derived from oocytes (eggs). Elaborate on **one** such ethical concerns.

…….……[1]

[Any 1]

1. (No destruction of embryos)
   Extraction of pluripotent embryonic stem cells from the inner cell mass involves the destruction of the blastocyst; some view the early embryo as a potential human being and the destruction of the blastocyst as **anti-life;** (vs genetically modified stem cells will not involve destruction of embryos)
2. (No conflict of reproductive interest of women undergoing fertility treatment)
   Ooctyes are retrieved from women for their own in-vitro fertility treatments. If these women consent to donate some of the oocytes for research purposes, it is difficult to ensure that the highest quality oocytes are **used for their fertility treatment** instead of research purposes; (vs genetically modified stem cells will not lead to this conflict)
3. immune rejections of donated foreign stem cells if patient is a male; (vs using patient;s own genetically modified stem cells will not lead to immune rejections)

[Total:14]

QUESTION 6

(a) DNA codes for proteins within the cell. Some regions of DNA are described as non-coding.

(i) Explain why some regions of DNA can be described as 'non-coding'.

……[2]

1 [Ref. regions are regulatory sequences (e.g. promoter) / relevant exampled e.g telomere ; AND]
Not transcribed into RNA (and hence not translated into protein) ;

OR

1 [Ref. regions are regulatory sequences (e.g. introns) ; AND]
transcribed into RNA (mRNA e.g. UTR / tRNA / rRNA) but not translated into **protein** ;

2 (such DNA regions are transcribed to primary mRNA), after editing of primary {mRNA / transcript} ; they are not present in mature mRNA ;

/ [**Allow**: introns removed]

(ii) Non-coding regions of DNA show more variation than coding regions. This makes non-coding regions useful in DNA profiling. DNA profiling can be used in cases of paternity and forensics.

Suggest why non-coding regions of DNA show more variation.

……[1]

1 not selected against / AW ;

[**Allow**: doesn't affect survival]

(b) In eukaryotic cells, all RNA molecules are synthesised as pre-RNA (primary RNA transcript) and undergo some form of post-transcriptional modification to form mature RNA. For example, DNA template strand is transcribed into pre-mRNA which then undergoes post-transcriptional modification to form mature mRNA. tRNA and rRNA similarly are first synthesised as pre-tRNA and pre-rRNA, and undergo post-transcriptional modification to form mature tRNA and rRNA, respectively.

Fig. 6.1 shows part of a **pre-tRNA** molecule. Geneticists identified two mutations that can affect **this** pre-tRNA, as shown in **Fig. 6.1**.

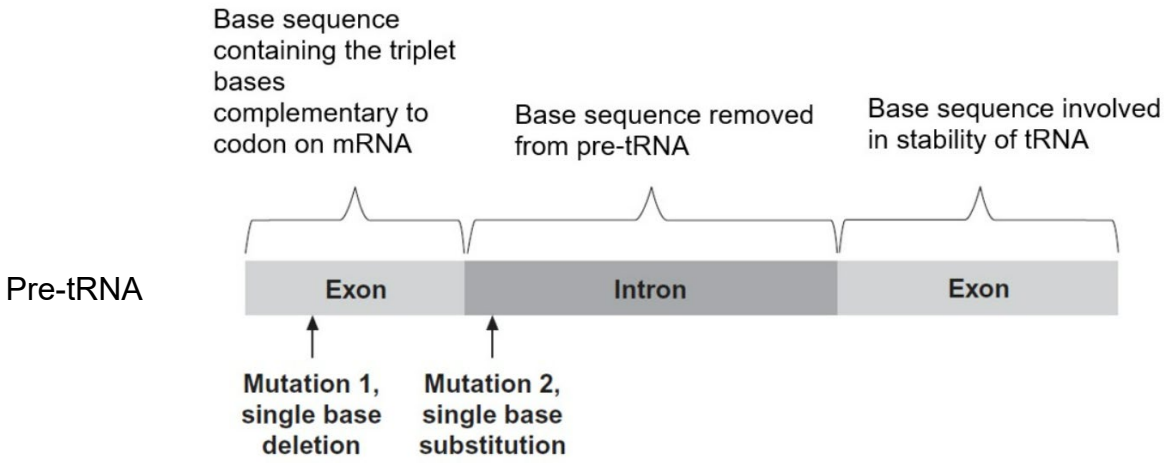

Fig. 6.1

(i) Assuming the mature tRNA formed from this mutated pre-tRNA, binds to the same amino acid as the non-mutated tRNA, explain why **mutation 1** to **this** pre-tRNA leads to the production of a less functional protein.

……[3]

1 (Mutation) changes triplets after that point / causes frameshift ;

2 Change of <u>anti-codon</u> on tRNA ; that recognise different codon on mRNA for the same amino acid (carried by tRNA);

[Marker guidance: **reject** mutated tRNA cannot bind to the original codon on the mRNA template, because there will be other non mutated tRNA which can bind to the codon]

3 (change in amino acid sequence, due to mutated tRNA anticodon recognising different codon on mRNA, lead to) Change tertiary structure of protein after translation ;

(ii) Suggest possible effect(s) **mutation 2** might have on the tRNA produced using your content knowledge and understanding of post-transcriptional modification of mRNA.

Explain your answer.

……[2]

1 (Mutation) affect <u>splice site</u> and prevents **splicing** ;

2 (so) **longer** mature tRNA formed ;

3 Ref. Clover-leaf structure of tRNA **not formed properly** ;

OR

1 (Mutation) does not affect splice site and does not affect **splicing** ; + reason e.g. base substituted is not at splice sites / branch point ;

2 (so) normal mature tRNA formed ;

3 Ref. folding into **normal** clover-leaf structure of tRNA;

(c) Contrast between translation in eukaryote and prokaryote.

……
……
……[1]

Translation in	Eukaryote	Prokaryote
Initiation step	**initiator tRNA** (tRNA that carries the amino acid **methionine** to the start codon, AUG, on mRNA	**initiator tRNA** (tRNA that carries the amino acid **formylmethionine** to the start codon, AUG, on mRNA

[Total: 9]

QUESTION 7

Mitochondria are the site of aerobic respiration in eukaryotic cells, with the main function to synthesise ATP.

(a) Explain how aerobic respiration may be affected by a decrease in oxygen availability.

……[3]

Any three:

1 Oxygen is the final electron acceptor in the electron transport chain (ETC) ;

2 (without oxygen) oxidative phosphorylation decreased / chemiosmosis (or proton gradient) decreased ;

3 regeneration of NAD/Kreb's cycle/link reaction, decreased ;

4 ATP synthesis decreases / ATP synthase activity decreased ;

OR less/decreased aerobic respiration

(b) Describe one way in which the structure of the mitochondrion is adapted for oxidative phosphorylation.

……[2]

Any 1 set for 2m [do not award if only structure or function is missing]

1 [structure] **highly folded** inner mitochondrial membrane / cristae ;

[function] increases surface area available for embedment of electron carriers and ATP synthase ;

2 [structure] presence of **intermembrane space** between inner and outer mitochondrial membrane ;

[function] allows accumulation of H^+ ;

3 [structure] impermeability of inner membrane to H^+ ;

[function] maintains H^+ gradient / H^+ only go through (channel in) ATP synthase ;

4 [structure] presence of ATP synthase ;

[function] ATP synthesis as H+ flows through the channel down a concentration gradient ;

5 [structure] linear arrangement of ETC on inner membrane ;

[function] resulting in greater efficiency

In recent years, scientists have discovered that mitochondria release a major amount of reactive oxygen species (ROS) inside eukaryotic cells. ROS are by-products of mitochondrial respiration that function as signalling molecules affecting a variety of cellular processes such as growth and proliferation of cells, regulation of autophagy and apoptosis. Fig. 7.1 showing the signalling pathway involving ROS.

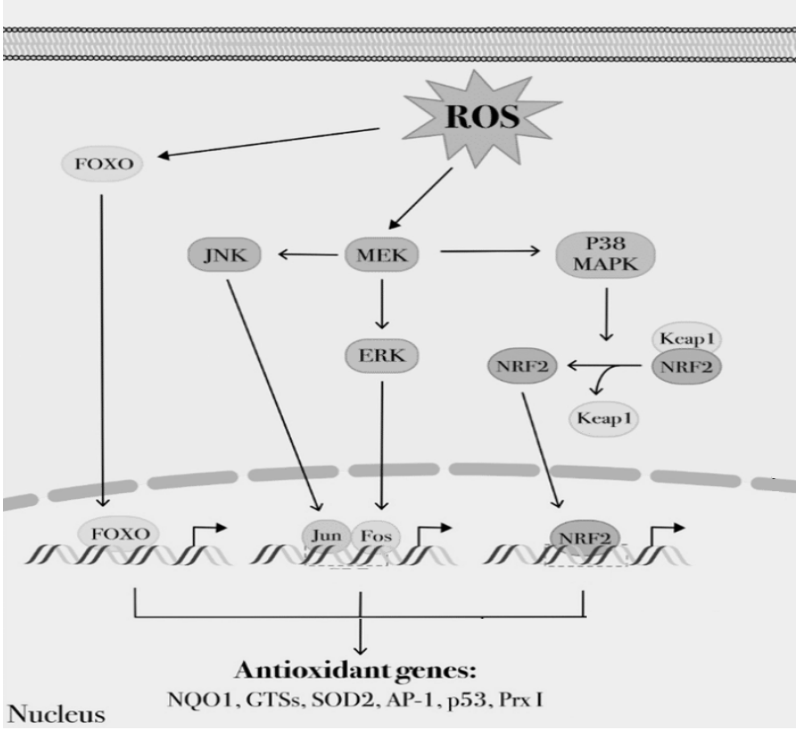

Fig. 7.1

(c) Describe the action of ROS in the signalling pathway to result in halting of cell divisions for DNA repair or eventually apoptosis of cell with DNA that is damaged beyond repair.

……[6]

1 ROS activates FOXO (in the cytoplasm) ;

(FOXO **enters the nucleus** and act as **transcription factor** / **regulatory protein** / **enhancer** to allow transcription of a specific antioxidant gene ; *[mark given in mp 7])*

2 ROS activates MEK which activates ERK (in the cytoplasm) ;

3 ERK (enters the nucleus and then) activates Fos ;

4 MEK activates JNK ;

5 JNK activates Jun ;

6 FOXO, ERK, JNK, NRF2 *(any 2)* enter the nucleus ;

7 FOXO, Jun, Fos and NRF2 (any 2) acts as **transcription factor** / **regulatory protein** / **enhancer**] to allow transcription of a specific antioxidant gene ;

8 MEK activates P38 MAPK ;

9 P38 MAPK results in removal of Kcap1 from NRF2 which become activated ;

[Max 5]

Compulsory point

10 p53 gene (an antioxidant gene) **codes** for p53 proteins (which halt cell divisions to allow for DNA repair or eventually causes apoptosis of cell with DNA that is damaged beyond repair) ;

[Total: 11]

QUESTION 8

Mutations in body cells can sometimes result in a tumour.

(a) Regulation of checkpoints of cell division is important in the mitotic cell cycle. Outline the role of the M checkpoint.

……...[1]

[Any 1]

1 M checkpoint determines whether the cell is ready to separate the duplicated chromosomes and segregate sister chromatids (of duplicated chromosome) as individual chromosomes into two new daughter cells;

2 Ref. checking for proper attachment of spindle fibres to the chromosomes;

(b) "A tumour cell population" is often described by scientists to have evolved from normal cells through natural selection.

With reference to your understanding of tumour cells and Darwin's theory of natural selection, discuss on this statement.

……..[3]

[Points of agreement to the statement] [Max 2]

1 tumour cells contain different **mutations**;
variation in the population of tumour cells allows natural selection to operate;

2 (variation causes differences in fitness/ reproductive success / survival and reproduction) tumour cells show these **characteristics which confer selective advantage** (at least 1), e.g. no longer need normal growth inhibition signals, no longer require external signal to divide, do not undergo apoptosis, can divide continuously (without undergoing apoptosis due to telomerase reactivate);

3 which enable tumour cells to **survive** longer/ undergo **division** more frequently (by mitosis) than normal cells;

4 Ref. passing down of mutated **alleles** of critical genes to progeny cells

[Points of disagreement to the statement] [Max 2]

5 Ref. the idea of population is on organism level and not cellular level;

6 Ref. only mutations in germline cells could pass down mutated alleles of critical genes to offspring (organism);

7 Ref. lack of a specific selection pressure in the context;

The African elephant *Loxodonta africana* is the largest land-living mammal. Despite the large body size and a life expectancy comparable to humans, cancer mortality in the African elephant is estimated at less than 5% compared to up to 25% in humans.

Recent studies show that in addition to the conserved *p53* gene present in all mammals, African elephants also have an additional 19 *p53* retrogenes in its genome. The *p53* retrogenes are DNA sequences which resemble the conserved *p53* gene but are devoid of introns. Each of the 19 *p53* retrogenes is structurally slightly different and some of them are found to be transcribed and likely translated.

To investigate why African elephants have so many *p53* retrogenes, scientists analyzed DNA from Asian elephants and several other closely related, but now extinct species, including the

woolly mammoth. They found that *p53* copy number expansion correlates with the evolution of increased body size and an enhanced DNA damage response in elephants.

(c) State the number of *p53* alleles an African elephant has in its genome.

……..[1]

1 40 ; (20 genes x 2 alleles per gene)

(d) Suggest how multiple copies of the *p53* genes may help the African elephants escape cancer.

……..[2]

1 (presence of multiple copies) lowers the chance of an absence of functional *p53* protein due to loss of function mutations in *p53* gene ;
/ multiple template for transcription to make more copies of functional *p53* protein ;

2 increase the likelihood of arresting cell cycle and repair DNA damage in cells, higher rates of p53-mediated apoptosis (compared to other mammals) in response to DNA damage ;

3 reducing the likelihood of mutations accumulation in other critical genes that could lead to cancer development ;

The same set of *p53* retrogenes are also present in the modern day Asian elephant. It is said that the African and Asian elephants are closely related.

(e) Describe how the genetic species concept can be used to determine if the African elephant and Asian elephant are different species.

……[2]

1 [Method] Obtain DNA / protein from both elephants, find the sequence of a gene or protein, and compare the sequences;

2 Ref. choice of a common; fast changing gene / DNA with high mutation rate ;

3 [Analysis] If percentage homology is **more than threshold or target,** then they are the same species / High degree of similarity in the two DNA sequences compared, then they are same species ;
/ If percentage homology is **less than threshold or target,** then they are the different species / Low degree of similarity in the two DNA sequences compared, then they are different species ;

[Total: 9]

QUESTION 9

Fig. 9.1 shows some naive B lymphocytes, plasma cells and memory cells.

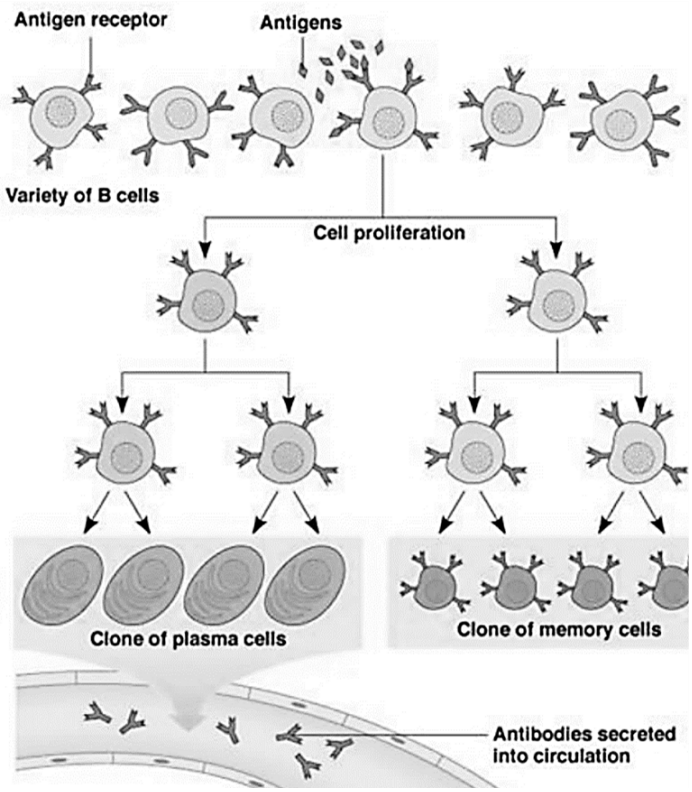

Fig. 9.1

(a) Suggest one difference in the genetic content between naive B lymphocytes (which had undergone the process of somatic recombination) and other somatic cells such as skin cells. Explain.

……[2]

1. [Difference in genetic content] mature B lymphocytes have a **shorter DNA sequence** for **heavy and light chain genes** of immunoglobulins / antibodies;

   [Explain]
2. Ref. <u>V,D,J segments</u> coding for variable regions in the heavy/light chains are being **excised**; the **remaining** segments **ligated**;

Fig. 9.2 shows the organelle make up of a B lymphocyte and a plasma cell.

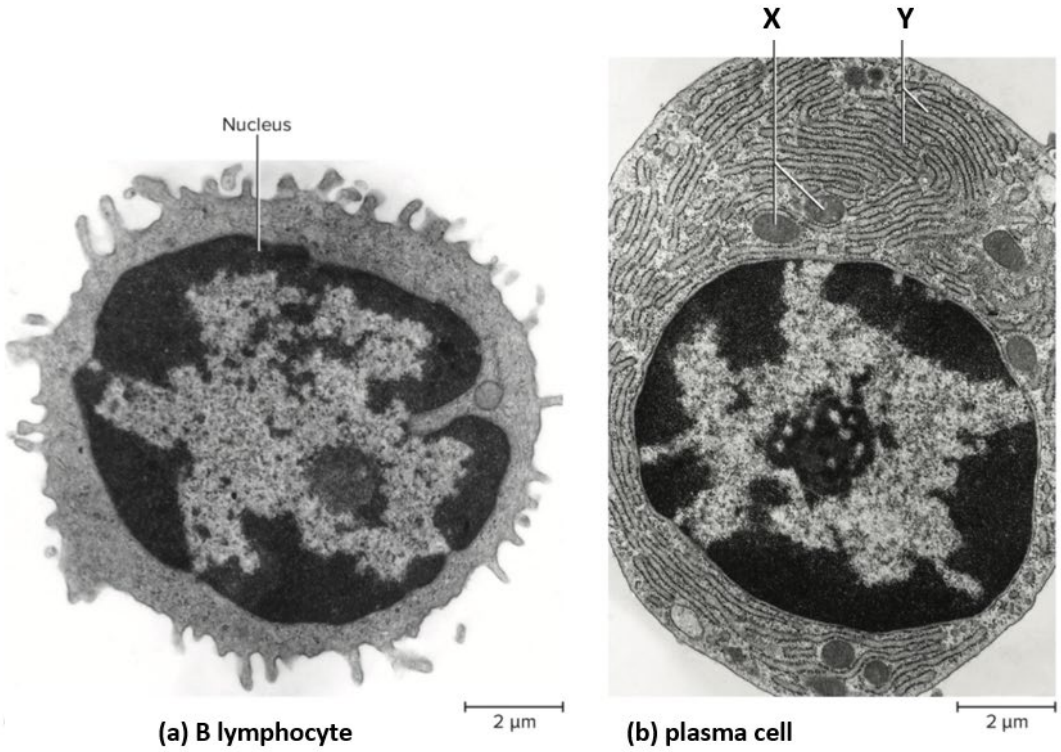

Fig. 9.2

(b) Identify organelles X and Y. Explain for the higher amounts of organelles X and Y in plasma cells.

……[3]

1. [Identify] X is mitochondria ; Y is rough endoplasmic reticulum;

2. Ref. plasma cells need to produce **more** antibodies which are <u>protein</u> in nature;
3. [need for organelle Y rER] Ref. ribosomes on rER produces proteins through translation / post-translational modifications to polypeptide chains of antibodies;
4. [need for organelle X mitochondria] Ref. production of ATP which can be hydrolysed to provide energy + e.g. of a process which needs ATP : exocytosis of antibodies / amino acid activation by aminoacyl tRNA synthase etc;
5. [need for organelle X mitochondria] Ref. production of ATP which can be hydrolysed to provide energy + e.g. of a process which needs ATP : exocytosis of antibodies / amino acid activation by aminoacyl tRNA synthase etc;

[Total: 5]

QUESTION 10

(a) A large number of alpine plant species grow in the mountains of New Zealand's South Island. Alpine plants are defined as plants that live above the treeline, which is the height above which trees cannot grow.

Fig. 10.1 shows two aspects of the history of South Island over the last 3.9 million years.

- The dashed line shows how the mean height of mountains in the Clyde region of South Island increased over time. The mountains in this range have a mean height of 2400 m at the present time.
- The solid line models the height of the treeline over time based on geological climate data. The treeline was higher when the climate was warmer, and the treeline was lower when the climate was colder, during ice ages.

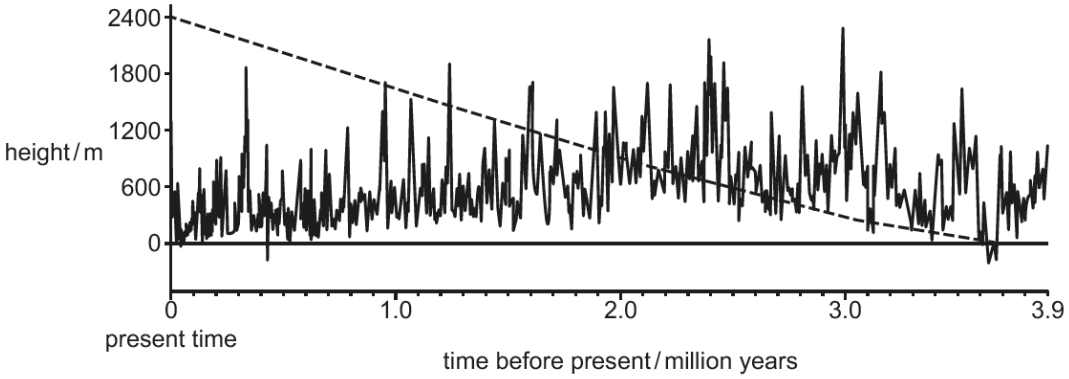

Fig. 10.1

With reference to Fig. 10.1, identify with reasons the time period when South Island's alpine plant species developed.

……[3]

1 time period = from 0.95 million years (to present) ; [Reject: between 0.95 to 1.0 million years]
2 mountain high enough to **exceed treeline** ; (from the question, alphine trees grow above the treeline)
3 the region / niches above treeline are suitable for survival of alpine plant species

(b) In the mountains of North America, when winter changes into spring, the coat colour of snowshoe hares changes from white to brown. Climatic changes have caused the snow to melt earlier. This has reduced the survival rate of snowshoe hares in these habitats.

The change in coat colour occurs when new fur replaces old fur. This is called moulting. Recent research has shown that snowshoe hares within a population moult at different times. Moulting at different times could be a major factor in ensuring the survival of snowshoe hare populations.

Climatic change has reduced the survival rate of snowshoe hares in mountain habitats.

Suggest and explain how.

……[2]

1 Ref. snow melts earlier / less snow; so less camouflage ;

2 The hares which have yet to moult (white hares) are more easily {seen / eaten / killed} by {predators / any example of predator} ;

[Total: 5]

End of paper