	ST. ANDREW'S JUNIOR COLLEGE 2023 JC2 PRELIMINARY EXAMINATIO	NS	
H2 BIOLOGY		9.	744/2
Paper 2			
Monday	28 <sup>th</sup> August 2023	21	hours
Materials:	Question Paper Set A and Set B		
READ THESE INS	TRUCTIONS FIRST		
Write your name, ci	vics group and index number on all the work you		
Write in dark blue o You may use a soft Do not use staples,	r black pen on both sides of the paper. pencil for any diagram, graph or rough working. paper clips, highlighters, glue or correction fluid.		
Answer <b>all</b> questior Write your answers	is. in the spaces provided on the question paper.		
The number of mari question or part que	ks is given in brackets [ ] at the end of each estion.	For Exam Use	iners'
		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 <b>27</b> printed pages and <b>0</b> blan	k page.	

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>B</b>	Molecule 1	Molecule 2
Name		
Process		
Location		

[3]

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

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- (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]

(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.

[Total: 13]

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.

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

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

.....[1]

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

[Total: 10]

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.



(a) Explain the term *limiting factor*.

 	[2]

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

 [1]

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





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

(d) Distinguish between the terms:

Absorption spectrum:

Action spectrum:

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

.....[1]

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]

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

 	 [2]

[Total : 12]

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.

 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 haemoglobin molecules 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<sup>A</sup>Hb<sup>A</sup>) and who have sickle cell anaemia (genotype Hb<sup>S</sup>Hb<sup>S</sup>). 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]
(c)	State the genotype of the individual who provided the red blood cell lysates in lane 3. Explain your answer.
	[2]

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.





(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.

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.

(b) Explain your answer for (a).

(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.

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

.....[1]

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.







(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.

Error:

Explanation: [2] 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:	
	[0]
	[2]

(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]

# [Total:14]

- (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'.

(ii) Non-coding regions of DNA show more variation than coding regions. This makes noncoding 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]

(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**.



(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.

(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.

(c) Contrast between translation in eukaryote and prokaryote.

.....[1]

[Total: 9]

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.

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

		[2]
 	 	 [_]

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]

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]

(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.

 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 *p*53 alleles an African elephant has in its genome.

.....[1]

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

.....[2]

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.

[Total : 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.



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





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

[	3]

[Total: 5]

(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.





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



(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]

[Total : 5]