HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**22S7__**

CENTRE NUMBER					**INDEX NUMBER**				

BIOLOGY

9744/03

Paper 3 Long Structured Questions and Free-response Questions

13 September 2023

Candidates answer on the Question Paper.

2 hours

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

There are **four** question booklets (**I - IV**) to this paper. Write your **name**, **CT group, Centre number** and **index number** in the spaces provided at the top of this cover page and on the lines provided at the top of the cover pages of Booklets **II**, **III** and **IV**.

Section A

Answer **all** questions in the spaces provided on the Question Paper.

Section B

Answer any **one** question in the spaces provided on the Question Paper.

INFORMATION FOR CANDIDATES

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

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

You are reminded of the need for good English and clear presentation in your answer.

For Examiners' Use	
Section A	
1	**/ 30**
2	**/ 10**
3	**/ 10**
Section B	
4 or **5**	**/ 25**

Final Mark	

This document consists of **21** printed pages and **1** blank page.

SECTION A

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

QUESTION 1

Migratory behaviour is commonly defined as the movement from one location to another and back, allowing animals to exploit seasonally- and geographically-variable resources or avoid unfavourable conditions.

Migratory animals are significantly threatened by the effects of habitat fragmentation and habitat loss. In the case of terrestrial mammals, this results in nearly a quarter of species being at risk of extinction.

The reindeer is one such example. In populations of reindeer, the proportion of individuals considered as “migrants” can vary dramatically. There is therefore a possibility that, under the condition that migratory behavior is genetically determined, those individuals or populations that are migratory will be further impacted by humans, and this impact could result in the permanent loss of the migratory trait in some populations.

Two subspecies of reindeer, *Rangifer tarandus*, can be found in North America. Members of the different subspecies belong to the same species but have some morphological differences and are found in different geographical locations.

Fig. 1.1 shows a reindeer.

Fig. 1.1

Table 1.1 compares the features of the two North American reindeer subspecies.

Table 1.1

feature	**Woodland subspecies, *R. tarandus caribou* (WS)**	**Barren Ground subspecies, *R. tarandus groenlandicus* (BGS)**
habitat	southern woodland (warmer)	northern tundra (colder)
type of food	tree leaves, grass	lichens, moss
summer and winter feeding grounds overlap	yes	no
carry out long migrations	no	yes
body size	large	small
colour of fur	dark	light

Fig. 1.2 shows a map of the present day western North America. The locations of sampled reindeer populations are represented by black numbered circles. Such populations are referred to as “herds” as they might not be genetically or ecologically distinct.

In Fig. 1.2, the grey-scale polygons show the distribution of the two subspecies in which

- diagonal black lines represent the Barren Ground subspecies, *R. tarandus groenlandicus* (**BGS**)
- horizontal lines, light gray, and black represent Northern Mountain, Boreal and Central Mountain Woodland subspecies, *R. tarandus caribou* (**WS**).

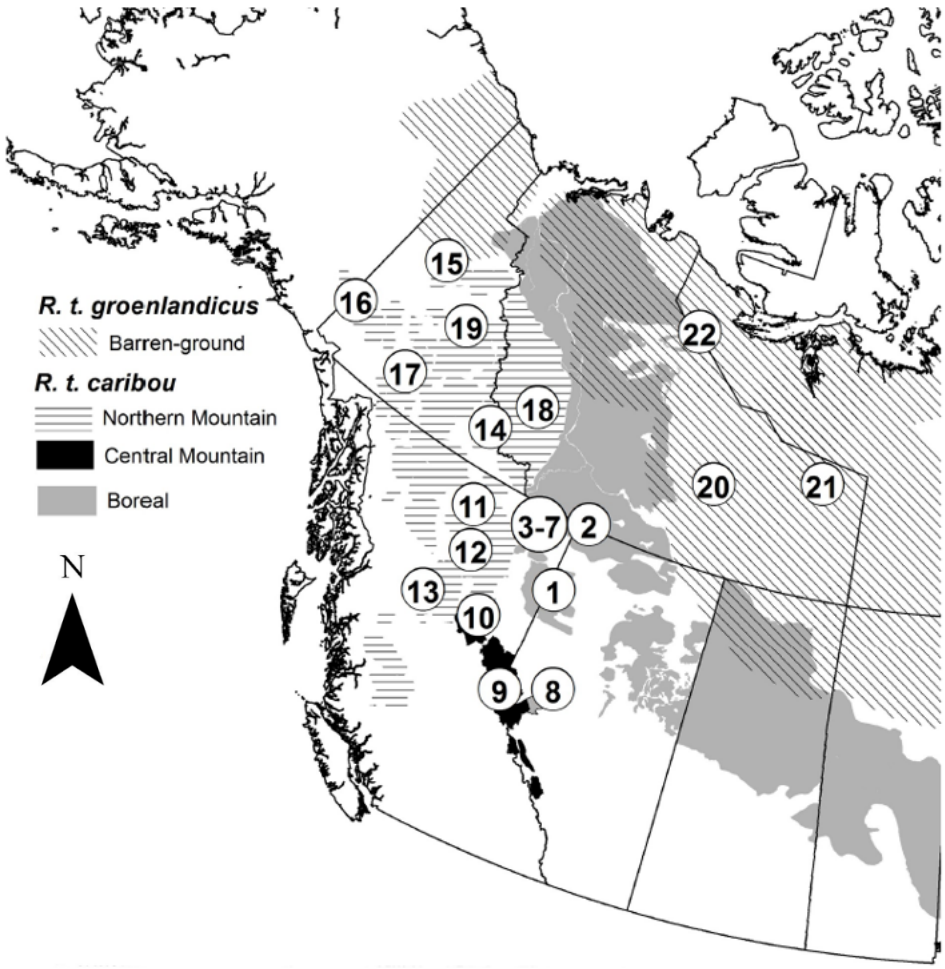

Fig. 1.2

(a) During the last ice age, an ice sheet separated southern and northern populations of *R. tarandus* in North America.

(i) Indicate on Fig. 1.2 with an “X” a possible location of the ice sheet formed during the last ice age. [1]

(ii) Explain how this ice sheet affected the evolution of *R. tarandus* to result in the two different subspecies.

[3]

(b) Assess the relative importance of natural selection and genetic drift in producing the different body sizes of the two subspecies of reindeer.

[2]

(c) Interbreeding has occurred between individuals of the two subspecies which now live in the area previously covered by the ice sheet.

Comment on how the hybrid populations compare to the pure subspecies in terms of genetic variation and potential to adapt to climate change.

[2]

Scientists have assessed the seasonal migratory behaviours of the two subspecies **BGS** and **WS**.

Fig. 1.3 shows the number of individuals in subspecies **BGS** and **WS** with varying degrees of seasonal ranges overlap, where the index ranges from 0.0 (no overlap) to 1.0 (fully overlap).

The index of seasonal range overlap is between winter and summer ranges frequented by individual reindeers.

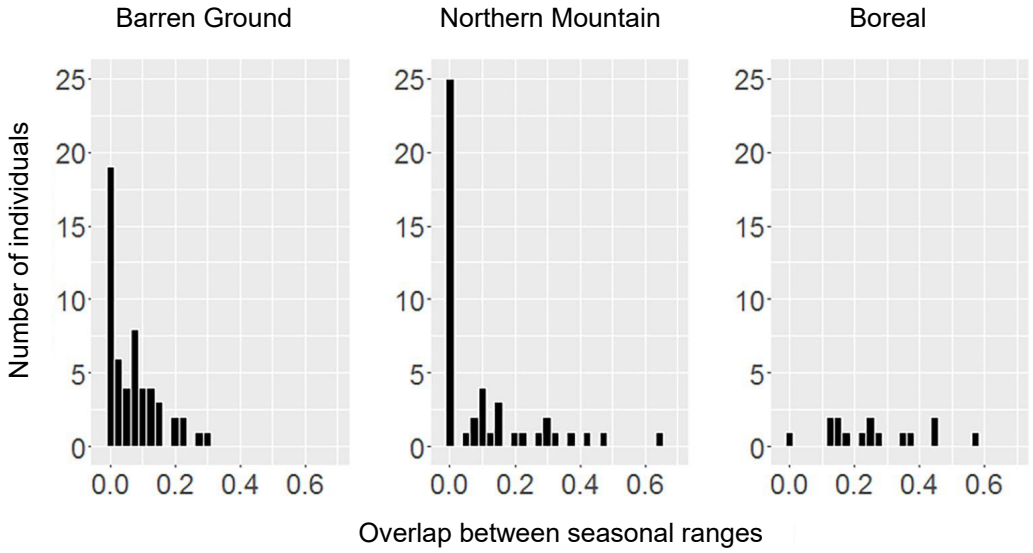

Fig. 1.3

(d) Table 1.1 in page 2 suggests that the subspecies **WS** is mainly non-migratory whereas subspecies **BGS** is primarily migratory.

Explain how the data shown in Fig. 1.3 supports the above suggestion.

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(e) Outline how molecular techniques could be used to test the hypothesis that migratory behaviour in reindeer has a genetic basis.

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Researchers have detected more than 50 single nucleotide polymorphisms (SNPs) associated with migratory behaviour, which are in genes with hypothesized roles in determining migration in other organisms. One of the strongest SNP associated with migratory behaviour was detected in the gene *UBE3D* which controls the metabolism of fat in migratory animals.

Fig. 1.4 shows the generalized relationship between rate of energy expenditure expressed as multiples of basal metabolic rate (BMR) and duration of activity in animals**.** Long-distance migratory animals clearly lie outside of the stereotypical pattern because very high rates of energy expenditure are maintained for exceptionally long periods without feeding. Such animals are expected to have higher aerobic capacity and longer endurance.

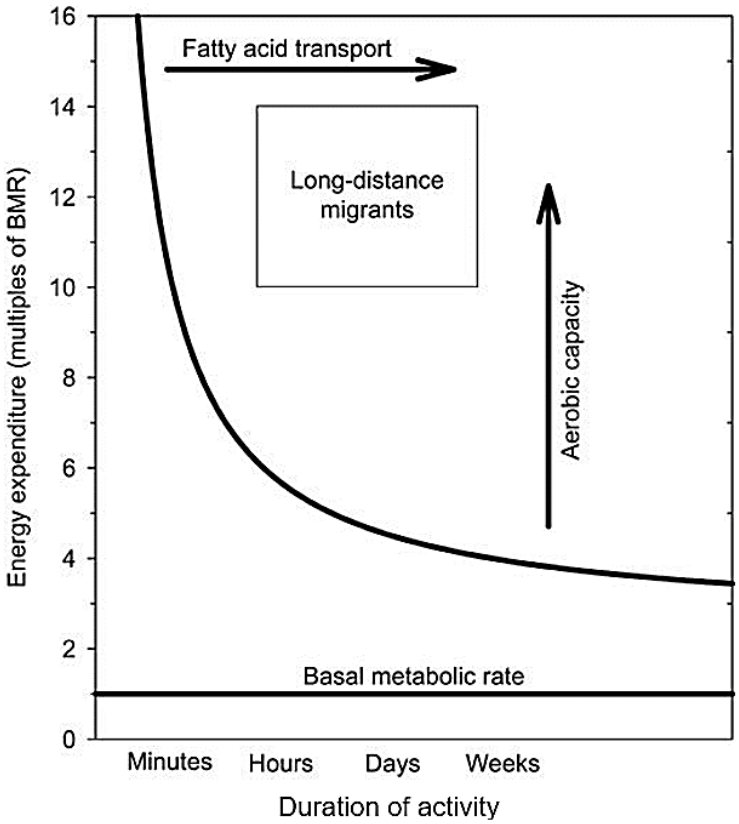

Fig. 1.4

(f) Discuss the importance of the trends observed in Fig. 1.4 for long-distance migratory animals.

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Research has shown that migratory animals alter their energy intake as well as their dietary composition and food preferences for higher amounts of fats in preparation for migration.

Fatty acids contain greater energy yield per unit mass than carbohydrates, making stored fat the most efficient fuel. The energy yield from fatty acid oxidation is high.

For example, oxidation of a molecule of fatty acid derivative 16-carbon palmitoyl CoA to carbon dioxide and water produces:

- 8 acetyl CoA, where each acetyl CoA subsequently produces 12 ATP upon complete oxidation
- 7 NADH
- 7 $FADH_2$.

However, activation of the fatty acid requires two ATP molecules.

(g)(i) Calculate the net number of ATP molecules produced from the complete oxidation of one molecule of 16-carbon palmitoyl CoA. Show your working clearly in the space provided below.

net number of ATP molecules produced = ... [2]

(ii) Suggest why fatty acids can only be respired under aerobic conditions.

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..... [2]

Besides the negative impacts of climate change on wildlife such as migratory reindeer, other woodland species also face anthropogenic stresses. For example, human activity has resulted in the forest landscapes of Europe existing as a mixture of fragments of different ages and sizes.

Fig. 1.5 shows the fragmentation of forests surrounded by developed land. Three fragments of forest **P**, **Q** and **R** are labelled on the 1910 map.

Fig. 1.5

(h) The Hardy-Weinberg principle states that allele frequencies remain constant from generation to generation.

Explain **two** reasons why this would not apply to the gene pools of species in fragments **P**, **Q** and **R.**

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(i) List fragments **P**, **Q** and **R** in order of risk of species extinction, from most to least. Explain your answer.

Most risk .... Least risk

Explanation

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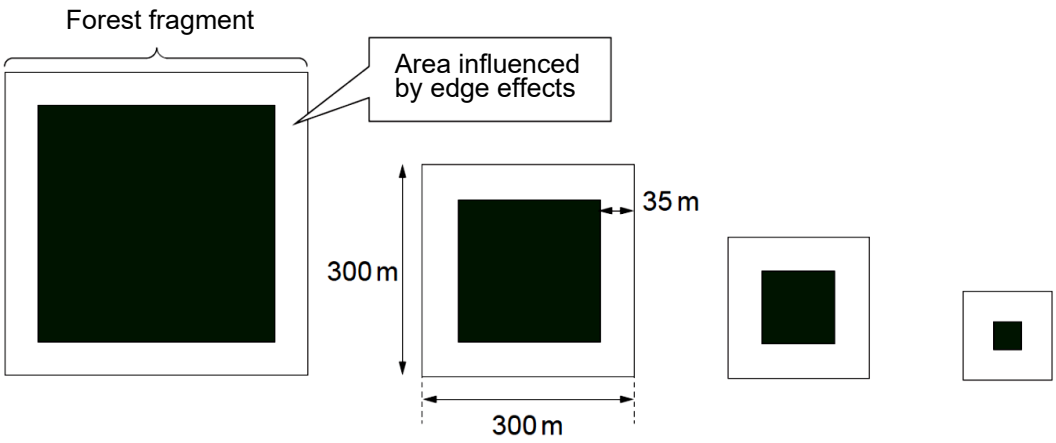
Fragmentation exposes species to potentially harmful environmental effects. These are called 'edge effects' because conditions at the edge of a forest differ from those further inside.

Fig. 1.6 shows how square forest fragments of different sizes are affected by edge effects.



Percentage of the fragment influenced by edge effects	**30.6%**	.....	**64.0%**	**88.8%**

Fig. 1.6

(j) Assuming edge effects extend 35 m into each habitat patch, calculate the percentage of the fragment influenced by the edge effects for the second largest patch.

Show your working clearly and write your answer in the space in Fig. 1.6.

[1]

(k) Describe the trend in the data and suggest how human activities could affect an abiotic factor that would differ in the area affected by edge effects.

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..... [2]

[Total: 30]

QUESTION 2

The rubella virus is an enveloped virus that shares the following common features with the influenza virus:

- RNA as the genetic material
- infect epithelial cells of the respiratory tract
- enters host cells via receptor-mediated endocytosis.

Fig. 2.1 shows the structure of the rubella virus.

Haemagglutinin (**H**) and fusion protein (**F**) are glycoproteins embedded in the viral envelope.

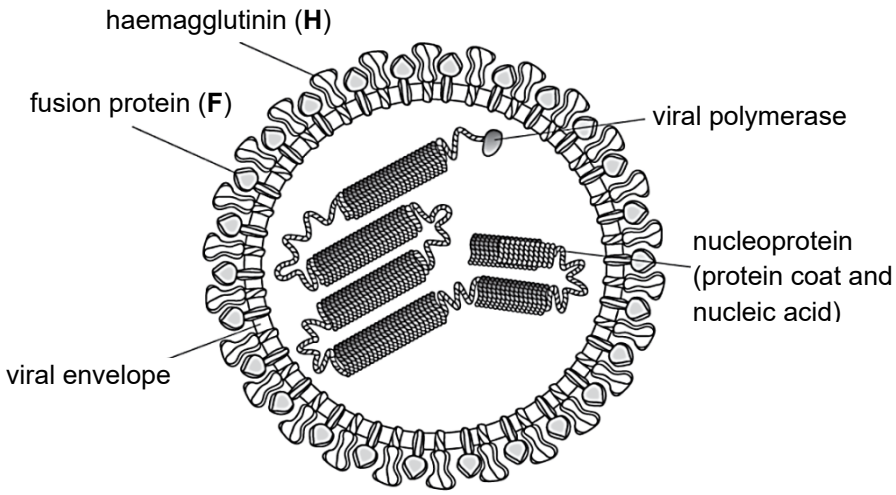

Fig. 2.1

(a) Suggest how glycoproteins **H** and **F** enable the entry of nucleoprotein and viral polymerase into the host cell.

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..... [2]

(b) Rubella virus contains a single positive sense RNA strand as the genetic material.

Suggest how the positive sense RNA strand of rubella virus is utilised in making progeny virus.

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..... [2]

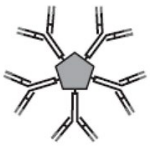
The rubella virus stimulates the production of antibodies in humans but usually causes only mild infections.

However, infection of pregnant women can cause serious problems for the developing fetus.

Antibodies can be divided into five classes.

Table 2.1 shows some information about three of the five classes of antibodies.

Table 2.1

information	class of antibody		
	IgM	IgA	IgG
shape			
number of antigen binding sites	10	4	2
can cross the placenta	no	no	yes
other details	secreted into blood	secreted into mucus, tears, saliva, colostrum[1]	secreted into blood

[1] colostrum is the first type of milk produced by the mother following birth.

Fig. 2.2 shows the levels of these three classes of antibodies produced in response to infection with the rubella virus.

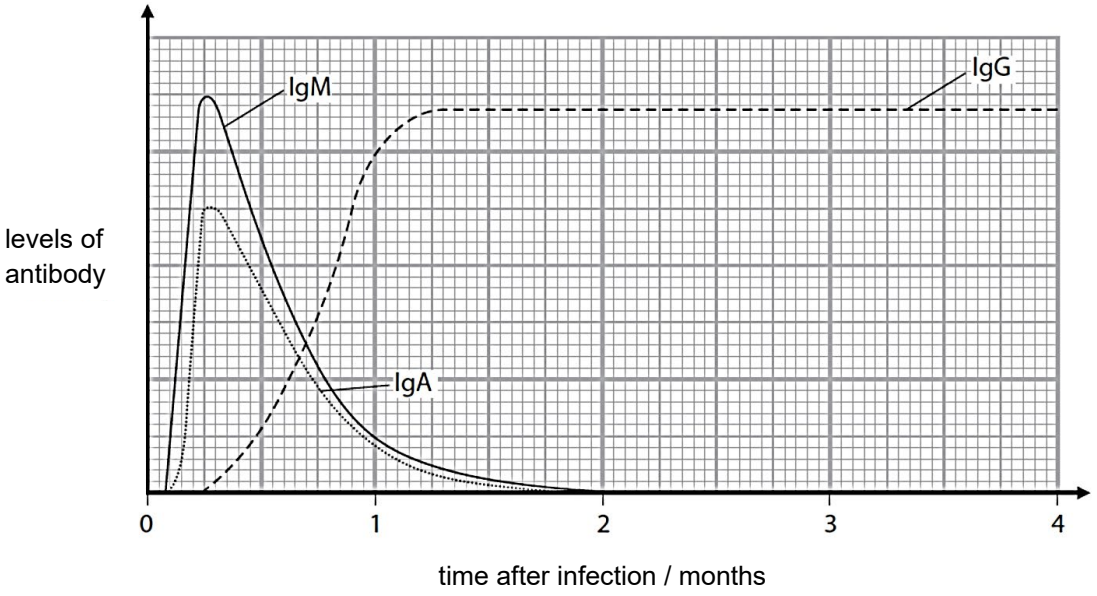


Fig. 2.2

(c)(i) Describe how activated B lymphocytes producing IgM would start to produce IgG a few weeks after infection.

[2]

(ii) Using information provided throughout the whole of this question, assess the role of these three classes of antibodies in the immune response to the rubella virus.

[4]

Total: [10]

QUESTION 3

The interpupillary distance (IPD) is the distance in millimetres between the centres of the pupils of the eyes.

Fig. 3.1 shows how IPD is measured.

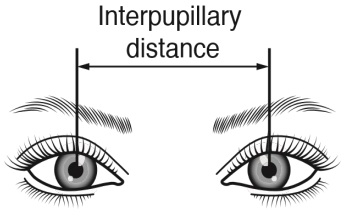


Fig. 3.1

IPD is one example of a characteristic of human facial structure that shows variation.

(a) Fig. 3.2 shows the pattern of variation in IPD in a large sample of adults.

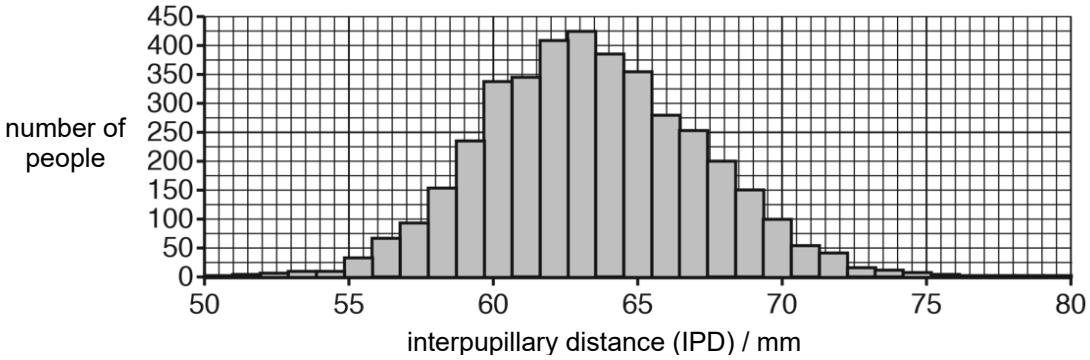


Fig. 3.2

(i) Name the type of variation shown in Fig. 3.2.

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[1]

(ii) Suggest **and** explain how genes and the environment contribute to variation in IPD in humans.

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[3]

(b) Individuals with an IPD of 70 mm or more have a mutation in the *PAX3* gene that results in less PAX3 protein being made.

The normal role of the PAX3 protein is to increase the expression of many other genes involved in embryonic development. These genes affect a range of phenotypic features such as facial structure, hearing and eye colour.

(i) State the term that is used to describe a gene, such as *PAX3*, that controls the expression of other genes **and** suggest how the PAX3 protein controls the expression of other genes.

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(ii) The chimpanzee, *Pan troglodytes*, has DNA that is 98.5% similar to humans, including possession of the *PAX3* gene.

Investigations show that chimpanzees express higher levels of the PAX3 protein during embryonic development than humans.

Fig. 3.3 shows a chimpanzee, *Pan troglodytes*.

Fig. 3.3

Suggest how knowledge of the *PAX3* gene helps scientists explain how humans and chimpanzees are very different in facial structure, even though they have very similar DNA.

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[Total: 10]

--- END OF SECTION A ---

SECTION B

Answer **one** question in this section.

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

Your answer 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 parts **(a)** and **(b)**, as indicated in the question.

QUESTION 4

The metabolism of a eukaryotic cell is tightly regulated by enzymes. Some of these enzymes interact with additional non-protein components such as inorganic ions, coenzymes and prosthetic groups.

(a) Describe the mode of action of enzymes and explain how enzyme activity can be regulated in a eukaryotic cell. [15]

Cell cycles are tightly regulated at various checkpoints. The development of cancer is a multi-step process comprising gene mutations that cause cells to bypass cell cycle checkpoints.

(b) Discuss how gene mutations contribute to the development of cancer in a cell lineage. [10]

[Total: 25]

QUESTION 5

Photosynthesis nourishes almost all of the living world directly or indirectly, as the path of the food chain is traced from plants up through animals.

(a) Describe how plants harness light energy to drive the synthesis of organic compounds and suggest how photosynthesis is necessary to sustain life. [15]

Global food insecurity has been rising due in large part to anthropogenic climate change.

(b) Discuss the consequences to the global food supply of increased environmental stress resulting from climate change. [10]

[Total: 25]

--- END OF SECTION B ---

--- END OF PAPER---

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