Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 BIOLOGY

9744/03

Paper 3 Long Structured and Free-Response Questions

21 September 2023

Additional Materials: Answer Booklet

2 hours

READ THESE INSTRUCTIONS FIRST:

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Sections B
Answer any **one** free-response question in the Answer Booklet provided.

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.

For Examiner's Use	
Section A / 50	
1	**23**
2	**15**
3	**12**
Section B / 25	
4 / 5	**25**
Total	**75**

This document consists of **16** printed pages and **2** blank pages.

Section A: Long Structured Questions

Answer **all** questions.

Question 1

As a worldwide public health pest, German cockroaches have been exposed to insecticides formulated in glucose-containing baits. The use of these insecticides is believed to have driven the evolution of glucose-averse (GA) German cockroaches that are behaviourally resistant against these baits.

(a) Explain how the use of insecticides drove the evolution of GA German cockroaches.

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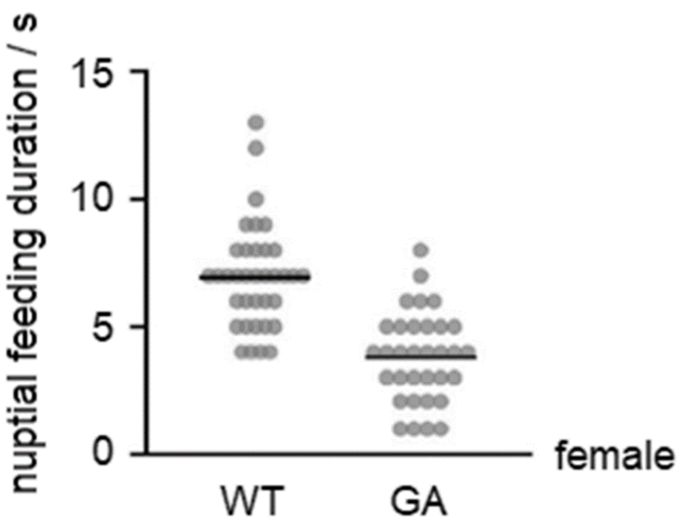
.... [3]

During courtship, wildtype (WT) male German cockroaches produce secretions, containing maltose and other oligomers, and present it to the females as a highly palatable nuptial gift. Upon accepting the gift, the female German cockroach allows the male to mate for as long as it feeds on the secretion. α-glucosidase is present in the saliva of female German cockroaches to release α-glucose from carbohydrates.

Fig 1.1 shows the nuptial feeding duration of WT and GA female German cockroaches with nuptial gift presented by WT males. Each dot represents a pair or mating, and the line represents the mean nuptial feeding duration.



Edited from Wada-Katsumata A, Hatano E, Schal C., 2023.

Fig 1.1

(b) **(i)** Describe the hydrolysis of maltose by α-glucosidase.

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.... [1]

(ii) With reference to Fig 1.1, suggest a reason for the difference in nuptial feeding duration.

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.... [2]

(iii) It is believed that the longer the nuptial feeding duration, the higher the mating success.

Explain why the survival of German cockroaches is expected to be at stake.

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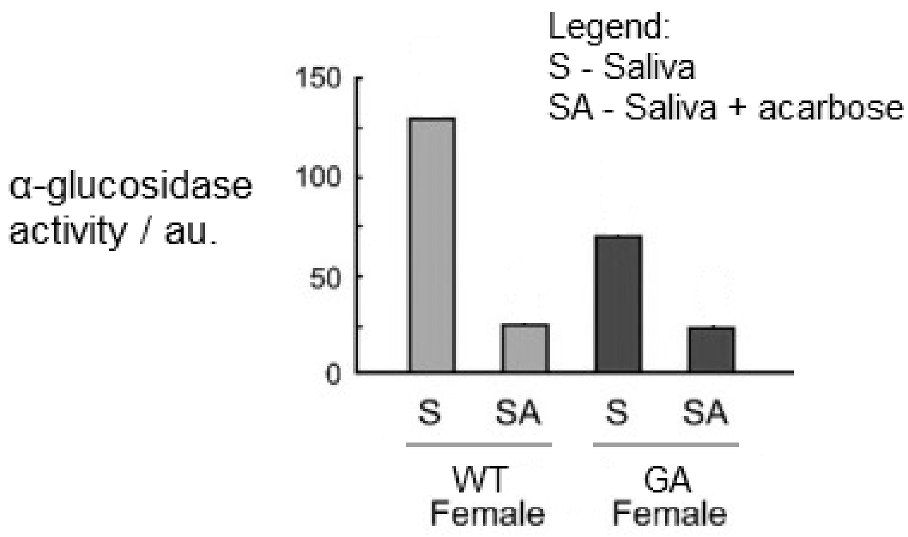
.... [2]

The reproductive success of GA German cockroaches has not been found to be significantly affected. Various studies have been conducted to investigate this phenomenon.

In one study, the activity of salivary α-glucosidase in female German cockroaches was investigated in the presence and absence of acarbose. The results are shown in Fig 1.2.



Edited from Wada-Katsumata A et.al, 2021.

Fig 1.2

(c) Explain the significance of salivary α-glucosidase activity in female GA German cockroaches to the reproductive success of GA German cockroaches.

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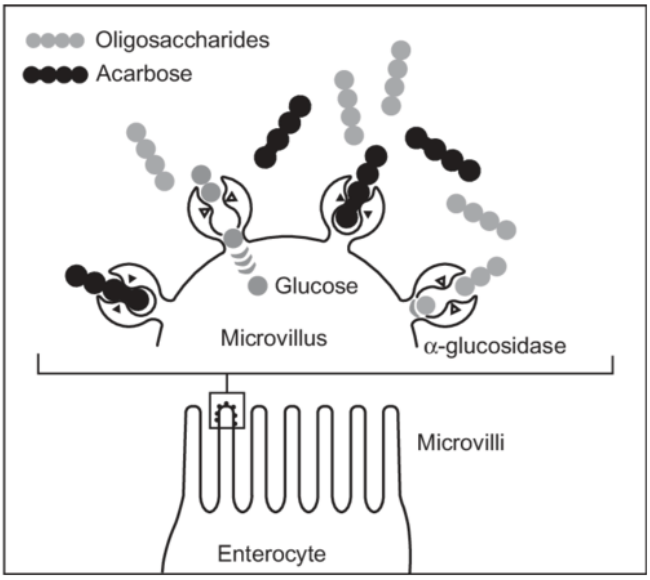
.... [2]

(d) **(i)** Identify the role of acarbose used in this investigation.

.... [1]

Acarbose is a drug commonly used in the treatment of diabetes. Fig 1.3 shows the action of acarbose in the intestines of humans.



From Rosak, Christoph & Mertes, Gabriele, 2012.

Fig 1.3

(ii) Predict if acarbose would be an effective drug in the treatment of diabetes if the patient does not limit dietary sugar consumption. Explain your prediction.

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.... [3]

To understand the synthesis of nuptial gift secretions in male German cockroaches, the protein content of the tergal gland was examined. The tergal gland is located at the abdomen of German cockroaches where the nuptial gift secretion is synthesized.

A protein named BGTG-1 was identified as a protein of interest due to its increasing amounts with maturation of the male German cockroach. Its function is unknown.

To identify the function of BGTG-1, the DNA sequence of the gene was compared with the full genome sequence of the well-studied fruit fly, *D. melanogaster*. It was found that the *BGTG-1* gene was similar in sequence to the *α-amylase* gene.

(e) Suggest how the amounts of the BGTG-1 can be regulated, after transcription, to increase with the maturation of male German cockroach.

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.... [2]

(f) **(i)** State the term used to describe the relationship between *BGTG-1* gene and *α-amylase* gene.

.... [1]

(ii) Explain what can be concluded about the relationship between *D. melanogaster* and the German cockroaches.

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.... [1]

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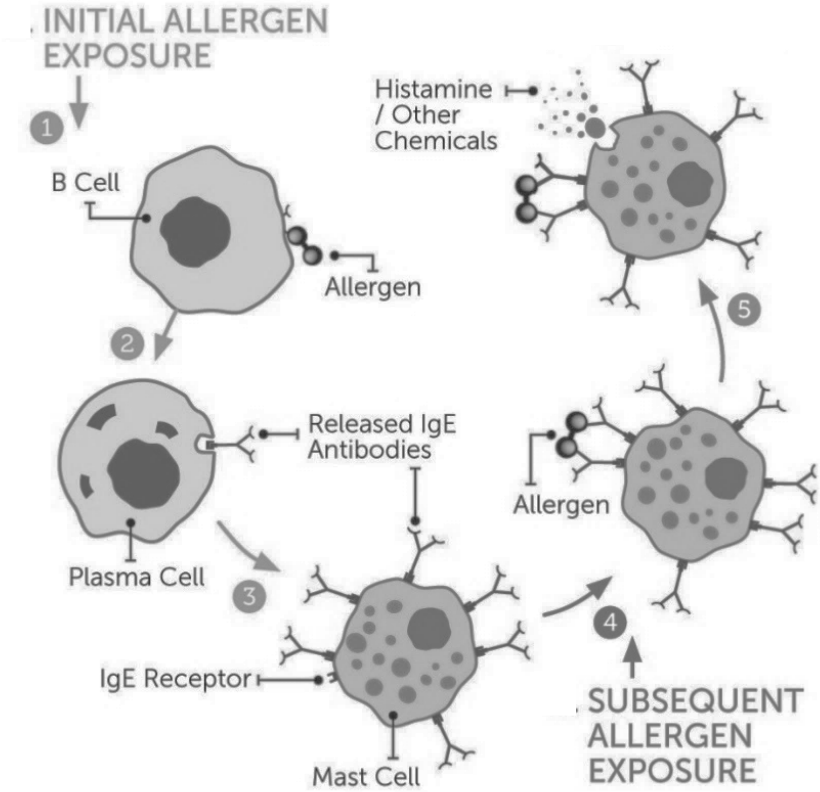
Another protein, Bla g 2, was also identified to be secreted by the tergal glands of German cockroaches. Bla g 2 is known to cause allergies, asthma, and other ailments of the human immune and respiratory system. Fig 1.4 shows the process of allergy development.



Obtained from https://www.virginiarichardson.co.uk/blog/allergyawareness

Fig 1.4

(g) With reference to Fig 1.4,

(i) contrast between activated mast cells during a subsequent allergen exposure and activated memory B cells during a subsequent infection,

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.... [1]

(ii) explain how the structure of IgE is related to its function.

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.... [2]

(h) Explain how IgE is synthesised by IgG-synthesising plasma cells.

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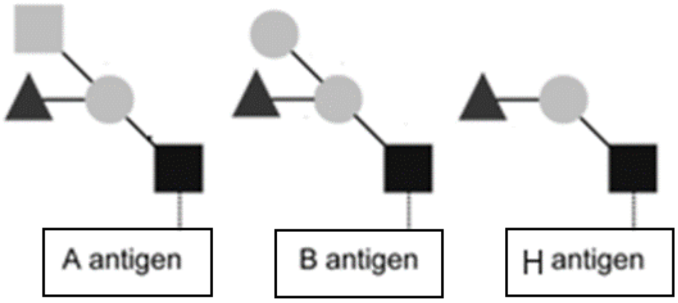
.... [2]

Total: [23]

Question 2

The ABO gene codes for the enzyme glycosyltransferase, that adds a sugar molecule to the H antigen on red blood cells. The expression of the I^A allele results in the addition of a N-acetyl-galactosamine while I^B allele results in the addition of a d-galactose. I^O allele results in no addition to the H antigen. Fig 2.1 shows part of the antigens.



Edited from Kappler & Hennet, 2020.

Fig 2.1

(a) State the organelle in which the sugar molecule is added to H antigen.

.... [1]

(b) **(i)** Complete Table 2 by putting a tick (✓) in the boxes to identify the presence of the antigens on the red blood cells.

Table 2

Phenotype	Antigens present on the red blood cells		
	A	B	H
Blood type A			
Blood type B			
Blood type AB			
Blood type O			

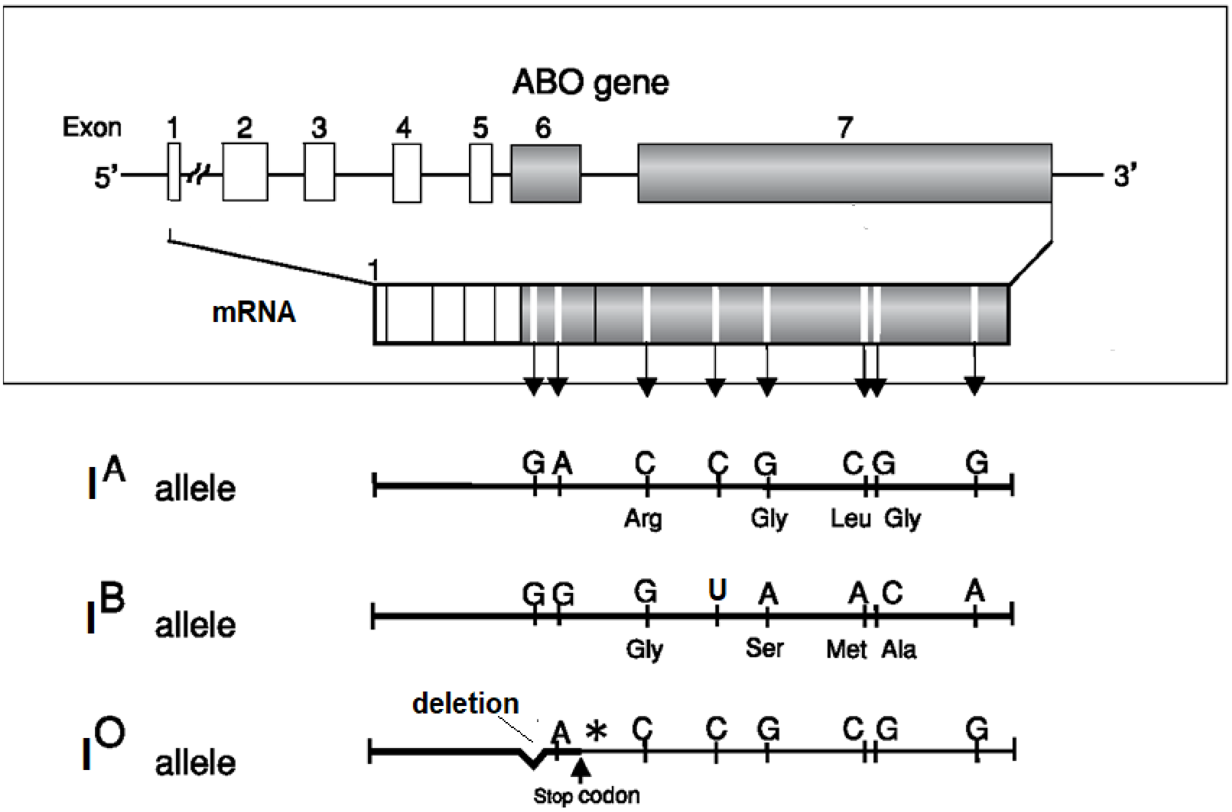
[2]

(ii) People with blood type O are known to be universal blood donors and people with blood type AB are known to be universal blood recipients.

Due to an unfortunate mistake, a person with blood type O received blood transfusion from a person with blood type AB. Using your understanding in immune response, outline how this results in blood coagulation in this recipient.

[4]

The exons 1 to 7 of the ABO gene are shown in Fig 2.2, with exons 6 and 7 shaded to indicate the regions where the alleles differ in their sequences. The I^A and I^B alleles differ by 7 nucleotides and 4 amino acids.



Edited from E. Hosei, 2008.

Fig 2.2

(c) Explain why the mRNA became shorter than the ABO gene sequence.

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.... [2]

(d) With reference to Fig 2.2, explain why the allele O is recessive while alleles A and B are co-dominant to each other.

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.... [4]

(e) Fig 2.3 shows the pedigree of ABO blood type in a family.

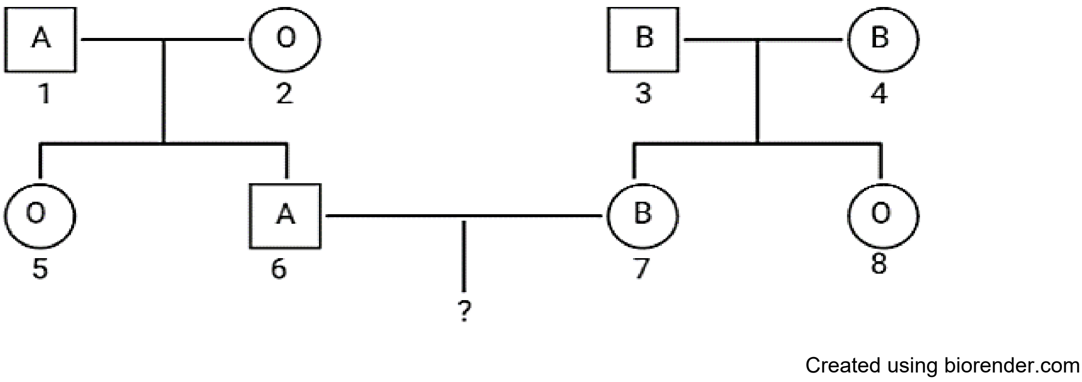

Fig 2.3

(i) State the probability of individual 7 being heterozygous at the ABO gene locus.

.... [1]

(ii) State the probability of individuals 6 and 7 having a son with blood type O.

.... [1]

Total: [15]

Question 3

The increasing global temperature can cause heat stress to crop productivity. Table 3 shows how the presence of heat stress (HT), as well as spraying of plant hormone methyl-jasmonate (MeJA), affects the net photosynthesis of wheat. Data are presented as mean ± standard deviation (*s*). The sample size (n) is shown in brackets.

Table 3

Treatments	Net photosynthesis (μmol CO_2 m^{-2} s^{-1})
Control (n = 2)	12.8 ± 1.15
HT (n = 4)	8.2 ± 0.79
MeJA + HT (n = 4)	19.4 ± 1.4

Edited from Zebus Sehar et. al (2023)

(a) Explain the term 'net photosynthesis'.

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.... [2]

(b) **(i)** Describe the effects of heat stress and spraying of the plant hormone, MeJA, on net photosynthesis.

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.... [2]

(ii) MeJA is known to increase chlorophyll production.

Explain how spraying of MeJA results in the change in net photosynthesis observed among heat stressed crops.

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.... [3]

(c) (i) A *t*-test can be used to determine whether the net photosynthesis in wheat is significantly different after the spraying of MeJA among heat stressed crops.

Calculate the value of *t* and using these formulae:

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}} \qquad \nu = n_1 + n_2 - 2$$

key to symbols

s = standard deviation
$\bar{x}$ = mean
n = sample size (number of observations)
ν = degrees of freedom

Show your working. Give your answer to 2 decimal places.

Value of *t* = ... [2]

(ii) The critical *t*-value at P=0.05 is 12.71. Explain the significance of the *t*-test value on the effect of MeJA on heat stressed crops.

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.... [3]

Total: [12]

Section B: Free-Response Questions

Answer **one** question.

Write your answers in the Answer Booklet provided.
Your answers should be illustrated by large, clearly labelled diagrams, wherever appropriate.

Your answer must be in continuous prose, where appropriate.
A **NIL RETURN** is required.

4 **(a)** There are many methods to classify organisms. Describe some methods and explain their limitations.

[15]

(b) With reference to a named genetic disease, explain how genotypic changes can positively impact the survival of patients.

[10]

5 **(a)** Explain how genetic variation can arise in nature.

[15]

(b) Compare the control of gene expression at the DNA and transcriptional level between prokaryotes and eukaryotes.

[10]

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