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RAFFLES INSTITUTION

2023 Year 6 Preliminary Examination Higher 2

CANDIDATE NAME								
CIVICS GROUP	2	3	S	0	3	INDEX NUMBER		

BIOLOGY

Paper 2 Structured Questions

9744/02

21st September 2023

2 hours

Candidates answer on Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST		aminer's Use
Write your index number, CT group & name in the spaces at the top of this page. Write in a dark blue or black pen	1	/ 10
You may use a HB pencil for any diagrams or graphs. Do not use staples, paper clips, glue or correction fluid.	2	/ 12
Answer all questions in the spaces provided on the Question Paper.	3	/ 9
The use of an approved scientific calculator is expected, where appropriate.	4	/ 11
You may lose marks if you do not show your working or if you do not use appropriate units		/ 10
At the end of the examination, fasten all your work securely together.		/ 11
or part question.	7	/ 10
	8	/ 13
	9	/ 8
	10	/ 6
	Total	/ 100

This document consists of 27 printed pages and 1 blank page



Raffles Institution Internal Examination



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(c)	Describe the structure of B and its role.
	[4]
(d)	Sodium ions cross cell surface membranes using facilitated diffusion or active transport.
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2 Staphylococcus aureus (S. aureus) is a bacterium that causes disease in humans. The bacterium is able to enter the bloodstream via open wounds or mouth sores. It divides rapidly by binary fission, entering human tissues and causing multiple infections such as pneumonia and endocarditis.

Fig. 2.1 shows how *S. aureus* divides by binary fission.



Fig. 2.1

(a) Describe two differences in DNA behaviour during binary fission in a prokaryotic cell and mitosis in a eukaryotic cell.



Scientists carried out an investigation to find the most effective concentration of an antibiotic to treat an *S. aureus* infection.

The scientists put equal volumes of a culture of *S. aureus* in five flasks.

- For the control flask, sterile distilled water was added.
- To the remaining four flasks, different concentrations of the antibiotic was added.

The scientists incubated all the flasks at 35°C for 3 hours. They then estimated the number of living bacteria in each flask.

(b) Suggest why the flasks were incubated at 35°C.

.....[1]



(iii) Explain how penicillin reduces bacterial growth as a result of this inhibition.

[3] [Total: 12]

3 Hurler syndrome is an autosomal recessive condition caused by a mutation in the *IDUA* gene. This gene, when expressed normally, codes for the enzyme iduronidase which breaks down waste in cells. When this enzyme is absent or insufficient, toxic waste accumulates in the cells, causing symptoms of Hurler syndrome.

Symptoms of Hurler syndrome are life threatening and affects an estimated 1 in every 100,000 newborns and affects males and females equally.

A study was done to investigate the use of stem cells for the treatment of Hurler syndrome.

Nine mice homozygous for the mutant *IDUA* gene were involved in this study and were divided into three experimental groups. Table 3.1 shows the treatments the mice were given.

experimental group	treatment
SC-X	Mice were injected with stem cells taken from a mouse that was not affected by the disease. Mice in this group had their immune systems suppressed.
SC-S	Mice were injected with their own stem cells to which the normal, dominant, allele of <i>IDUA</i> gene had been added by means of a viral vector.
SC-O	untreated controls

Table 3.1

(a) (i) What are the unique features of stem cells that made them suitable to treat this disease?

.....[2]

(ii) Explain why the mice in group SC-X needed to have their immune systems suppressed.

.....[1]

(b) The results of the treatments of the mice from each group are shown in Table 3.2.

Expression of the normal allele *IDUA* gene is shown on a scale increasing from + to +++. Improvement in health is shown by a tick (\checkmark). No improvement is shown by a cross (*).

group	mouse	expression of the normal allele of	improvement in health
		IDUA gene	
SC-X	1	+++	\checkmark
	2	+++	\checkmark
	3	++	×
SC-S	1	++	×
	2	++	×
	3	+	×
SC-O	1	none	×
	2	none	×
	3	none	×

Table 3.2

(i) With reference to Tables 3.1 and 3.2, compare the effects of the different treatments given to the mice in groups SC-X and SC-S.

(ii) Suggest why the expression of the normal allele of *IDUA* is different in the stem cells given to the mice in groups SC-X and SC-S.

(c) Comment on the ethical aspects of using stem cells from a healthy person for the treatment of patients with Hurler syndrome.

- [Total: 9]
- 4 Studies have shown that genes such as cyclin dependent kinase inhibitor 3 (*CDKN3*) are highly overexpressed in cervical tumours.

Fig. 4.1 shows the gene expression of *CDKN3* in healthy and cancerous cervical tissue.





(a) Calculate the percentage increase of *CDKN3* gene expression levels in cancerous cervical tissue compared to healthy cervical tissue.

Show your working clearly below.

[1]

(b) Overexpression of *CDKN3* in cervical tumours has been associated with decreased survival rates in cervical cancer patients and has been shown to trigger cells to exit mitosis and begin cytokinesis.

The data in Fig. 4.2 shows the survival rate of patients diagnosed with cervical cancer and their expression of *CDKN3* with time from the point of diagnosis.



(i) A hypothesis has been proposed that overexpression of *CDKN3* in cervical tumours results in an increased chance of patient death.

Evaluate the evidence for this using the data given.

- (c) The cell cycle is controlled by regulatory proteins, cyclins and cyclin-dependent kinases (CDKs).Fig. 4.3 shows cyclin/CDK complexes at different time points in the cell cycle.



(ii) Studies have shown that CDKN3 proteins inhibits CDK which is associated with DNA replication in the cell cycle.

With reference to Fig. 4.3, state which protein is inhibited by CDKN3.

(i)

For

Examiner's Use c-REL is another gene that has been linked to cervical cancer and its expression is correlated with the expression of CDKN3. Using molecular technology, cervical cancer cells (c-REL -/-) have been created that do not express c-REL.

Expression levels of c-REL were checked using protein analysis and the results are shown in Fig. 4.4.



Fig. 4.4

When c-REL is overexpressed in cervical epithelial cells it results in greater proliferation of cells and the cells spend less time in prophase compared to healthy cervical cells.



Fig 4.5 represents some cell stages present in c-REL -/- cervical cancer cells.

Fig. 4.5

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 	 [2]

[Total:11]

5 A scientist generates random mutations in *E. coli* to create different strains and picks four strains to study. The scientist measures the level of β -galactosidase in arbitrary units for each strain in the presence of different carbon sources, as shown in the table below.

	level of β -galactosidase in arbitrary units			
strain	lactose only	lactose and glucose		
wild type	100	15		
mutant 1	100	15		
mutant 2	0	0		

(a) Match each mutant to the possible types of mutations:

(b) Explain your answer for the mutant with the operator deletion in the presence of lactose only.

.....[2]

(c) A student made a prediction on the growth of *E. coli* and the production of ß-galactosidase (*lacZ* product) when grown in a medium with both glucose and lactose as carbon sources.

Graph 1 shows the predicted results of the growth of *E. coli* without the addition of IPTG, which is an artificial inducer. Graph 2 shows the predicted results of the growth of *E. coli* when IPTG is added to the medium.



(i) Sketch on graph 1, how the levels of cAMP is expected to change with time. [1]

(ii) State and explain if the results shown in graph 2 is expected in the presence of IPTG.

(iii) Suggest why operons are necessary in bacteria. [2]

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6 The patty pan squash plant, *Cucurbita pepo*, produces edible fruits that vary in colour.

In a dihybrid cross, a homozygous dominant plant was crossed with a homozygous recessive plant. All the resulting F₁ plants produced white fruits.

The F_1 plants were then crossed with each other to obtain the F_2 generation of 356 plants of which 268 produce white fruits, 65 produce yellow fruits and 23 produce green fruits.

(i) In the space below, draw a genetic diagram to explain the results of crossing the F₁ offspring to produce the phenotypic ratio of squash fruit colours shown in the F₂ generation. Use the symbols A, a and B, b to represent the alleles.

(ii) Test crosses were carried out on two white-fruited plants, \mathbf{P} and \mathbf{Q} , from the F₂ generation. Each of these plants had its female flowers pollinated with pollen from a green-fruit plant.

For plant **P**, half of the offspring were white and half were yellow. For plant **Q**, half of the offspring were white and half were green.

Deduce the genotypes of plants P and Q.

plant **P**

[2]

Please refer to Fig. 6.1 on page 17 to answer the following questions in 6(b).

(b) Seventy seeds were collected from two squash plants from the same *C. pepo* species. After 3 weeks, the heights of the plants which grew from these seeds were measured and recorded in two groups as seen in Fig. 6.1(a).

Fig. 6.1 (b) shows the offspring produced from a cross between one squash plant from group 1 and one from group 2.

Selfing between two squash plants from the F_1 generation resulted in offspring whose heights are measured and recorded in Fig. 6.1 (c).

(i) Calculate the percentage of seeds which germinated in the parental generation.

Show your working.

percentage of	f seeds germinated	%	[2]
---------------	--------------------	---	-----

(ii) Name the type of variation shown in Fig. 6.1(c).

Explain your answer.

[Total: 11]





[2]

7 ATP is the universal energy currency which provides the immediate source of energy for cellular processes.

Fig. 7.1 shows some ways in which ATP may be synthesised and used in cells.





(a) Complete Fig. 7.1 by writing correct terms or examples on the dotted lines provided.

(b) ATP and coenzyme A both play important roles in respiration.

Fig. 7.2 represents the molecular structure of coenzyme A.



Fig. 7.2

At one time it was thought that the oxidative phosphorylation of:

- one molecule of reduced NAD results in the synthesis of 3 ATP molecules
- one molecule of reduced FAD results in the synthesis of 2 ATP molecules.

Modern research has shown that the actual net number of ATP molecules synthesised for each glucose molecule respired is much lower than this theoretical value of 38.

- (ii) Suggest why the actual net number of ATP molecules synthesised is less than the theoretical number.
- (c) A respirometer can be used to measure the rate of respiration of germinating seeds.

Fig. 7.3 shows a respirometer.



Fig. 7.3

As respiration takes place, oxygen is used by the seeds and the coloured liquid moves down the tube.

Describe the role of oxygen in aerobic respiration.

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(d) Respirometers, as shown in Fig. 7.3, were used to investigate the effect of temperature on the rate of respiration of germinating pea seeds.

Four respirometers, **A**, **B**, **C** and **D** were set up:

- **A** and **B** in a water-bath maintained at 10°C.
- **C** and **D** in a water-bath maintained at 25°C.
- A and C each contained 30 germinating pea seeds.
- **B** and **D** each contained glass beads with a total volume equivalent to 30 pea seeds.
- The respirometers were left in the water-baths for 10 minutes.
- In each respirometer the position of the coloured liquid in the graduated tube was then marked (time 0 minutes).
- After 5 minutes the distance moved by the coloured liquid was measured.
- The volume of oxygen taken up was calculated for each respirometer.
- This was repeated after 10, 15 and 20 minutes.

Fig. 7.4 shows the results of the experiment.



Fig. 7.4

(i) Calculate the rate of oxygen uptake in cm³ per minute for respirometer **C** between 5 and 20 minutes.

Give your answer to two significant figures. Show your working.

..... cm³ min⁻¹ [1]

.....[2]

[Total: 10]

8 One way to measure genetic diversity is to find the percentage of genes that have different alleles. The table below shows the percentage of genes that have different alleles in four types of cat.

type of cat	percentage of genes with different alleles (%)
cheetah	4
domestic cat	23
lion	12
ocelot	21

(a) (i) Using the information in the table above and your own knowledge, suggest why the cheetah is the cat at highest risk if the environment changes.

(ii) Cheetahs are unusual amongst the big cats. A female cheetah often mates with several different males and gives birth to two or three cubs at a time, each having a different father.

Suggest why this may be advantageous to cheetahs.

.....[2]

Neanderthals were human or human-like animals that became extinct about 30 000 years ago and are known only from fossil remains.

Like cheetahs, Neanderthals had low genetic diversity. It has been proposed that it is the low genetic diversity of Neanderthals that could have led to their extinction.

Fig. 8.1 shows the nucleotide base sequence of a length of DNA from the gene coding for a cytochrome from a modern human, *Homo sapiens*, and the corresponding base sequences from a Neanderthal and four other primate species. Chimpanzee, orangutan and gorilla are species of ape, whilst the macaque is a type of monkey.

modern human	AT <mark>G</mark> ACCCCAATAC <mark>G</mark> CAAAATTAACCCCCTAATAAAATTAATTAACCACTCA
Neanderthal	AT <mark>G</mark> accccaatac <mark>g</mark> caaaattaaccccctaataaaattaattaaccactca
chimpanzee	AT <mark>G</mark> accccaacac <mark>g</mark> caaaattaaccccctaataaaattaattaatcactca
orangutan	AT <mark>G</mark> ACCTCAACAC <mark>G</mark> TAAAATCAACCCCCTAATAAAATTAATCAACCACTCA
gorilla	AT <mark>G</mark> ACCCCT <mark>ATACG</mark> CAAAACTAACCCCCTAACAAAACTAATTAACCACTCA
macaque	AT GACTCCAATACGCAAATCCAACCCACTAACAAAAATAATTAAT

Fig. 8.1

(b) (i) The scientific name for the Neanderthal is considered to be either *Homo sapiens* or *Homo neanderthalensis*.

A scientist considers that *Homo sapiens* is the correct name to use.

State the assumption that the scientist is making and explain why it is difficult to confirm this assumption.

Assumption: Explanation: [3] (ii) Suggest what the data in Fig. 8.1 indicate about the evolutionary relationships between modern humans, the chimpanzees and the macaques.

(iii) Explain why any such conclusions made in b(ii) need to be treated with caution.

[Total: 13]

9 Reef-building corals harbour algal symbionts from the genus *Symbiodinium*. This relationship between the two organisms is mutually beneficial for both coral and algae. However, the relationship can break down under certain environmental conditions, resulting in a phenomenon called 'coral bleaching'. The term is attributed to the normally colourful corals losing their colouration due to the loss of algal symbiont, turning a ghastly white.

A study was conducted on 50 colonies of corals of the species *Pocillopora damicornis* to investigate the environmental factors that affect coral bleaching susceptibility.

In a preliminary study, it was found that colonies of *P. damicornis* are dominated by *Symbiodinium* from genetically distinct groups, C or D.

Figure 9.1 shows the symbiont cell densities (algal cell mass per gram of coral tissue) in colonies dominated by group C (open circles and dashed line) and group D (filled circles and solid line) at each time point during the warming period and bleaching event. The bleaching event is defined as the period where 80% or more of all corals (including other species) are bleached.

The mean water temperature experienced by the corals over the 14-day period preceding each sampling point are shown as the middle line of the boxplots.



Describe and explain the relationship between mean water temperature and the trend observed

	for symbiont cell densities during the warming period.
	[3]
(b)	Compare the symbiont cell density between colonies with group C and colonies with group D <i>Symbiodinium</i> during the bleaching event.
	[2]
(c)	Suggest an explanation for the difference in symbiont cell density between colonies with group C and colonies with group D Symbiodinium during the bleaching event.
	[4]
	[1]
(d)	Suggest why although there was no change in temperature between 13 and 18 August, there was a decrease in symbiont cell density.
	[1]
(e)	Suggest the impact of the loss of coral biodiversity.
	[1]
	[Total: 8]

(a)

- **10** A variety of different membrane proteins are found on the cell surface membrane of naïve Tlymphocytes. Amongst them, the T cell receptor (TCR) has an important function in antigen presentation.
 - Fig. 10.1 shows an incomplete diagram that illustrates the process of antigen presentation.



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(a)

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(b) Compare the structure of the TCR shown in Fig. 10.1 to the structure of an antibody molecule secreted by plasma cells.

......[3] [Total: 6]

End of Paper