EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examinations 2024
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	

CIVICS GROUP	2	3	-			REGISTRATION NUMBER			

H2 Biology 9744/03

Paper 3 Long Structured and Free-response Questions

16 September 2024

2 hours

Additional Materials: 12-page Answer Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
Write your answers in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue, or correction fluid/tape.

Section A
Answer **all** questions on the **Question Paper**.

Section B
Answer **one** question on the **12-page Answer Booklet** provided.

Write your answer to each part of the question on a fresh sheet of paper.

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

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

At the end of the examination, ensure that you submit both the Question Paper and Answer Booklet.

For Examiner's Use	
Section A	
1	
2	
3	
Section B	
4 OR 5	
Total	75

This document consists of **14** printed pages and **2** blank pages.

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Section A

Answer **all** questions on the Question Paper.

1 The development of a mouse from a fertilised egg into an adult is regulated by variations in DNA methylation.

Fig. 1.1 shows the developmental stages of a mouse with corresponding levels of DNA methylation.

R, **S** and **T** represent the zygote, blastocyst and embryo respectively.

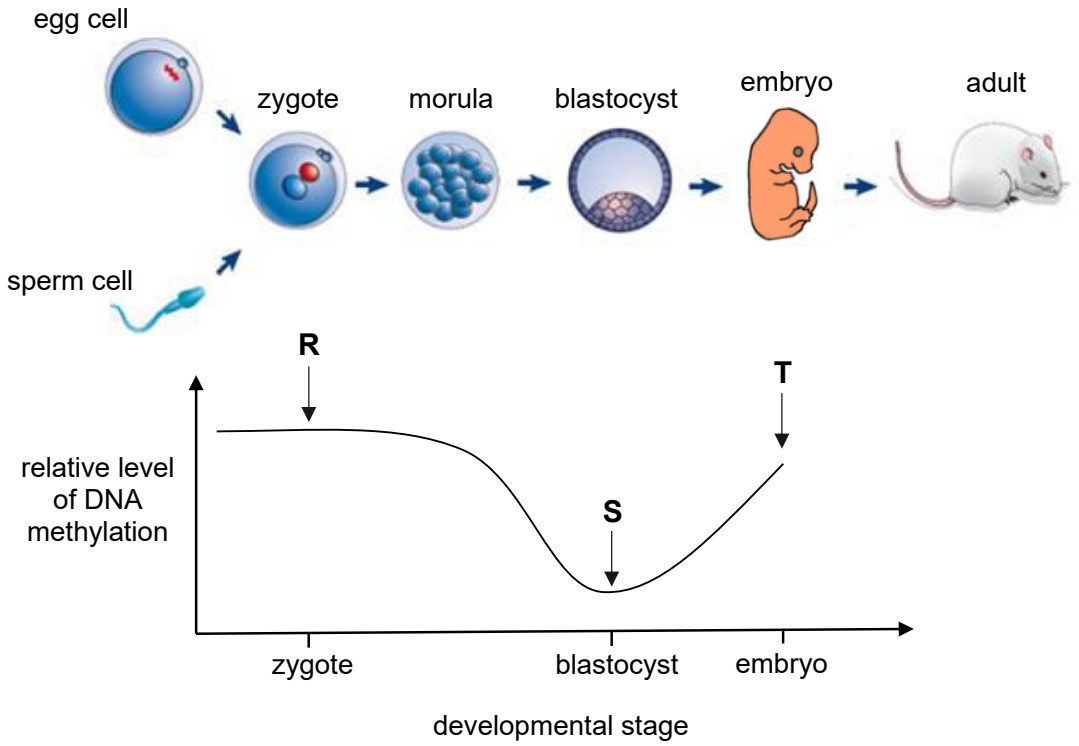

Fig. 1.1

(a) (i) Compare the features of a cell derived from the zygote with that from the inner cell mass of the blastocyst.

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(ii) Explain how changes to DNA methylation from **R** to **S** bring about differentiation.

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(iii) At different developmental stages of the mouse, the control of the telomerase gene expression is crucial.

Suggest if the telomerase gene in cells is likely to be methylated from **T** to an adult mouse.

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(iv) Active telomerase can be found in some cell types in a mouse.

Using a named example, explain the role of telomerase.

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In an experiment, chromatin from various tissues were isolated and treated with DNase, an enzyme that degrades naked double-stranded DNA. After digestion, the enzyme was removed. Any remaining intact DNA was extracted and mixed with radioactively labelled DNA probes specific for certain genes, under conditions that favoured nucleic acid hybridisation.

The levels of binding of the labelled DNA probes were measured. Some of the results are shown in Table 1.1 below.

Table 1.1

Sample	Tissue source of chromatin	Gene radioactive DNA probe is specific to	Percentage binding of radioactive DNA probe
1	Skeletal muscles	Myosin gene	25
2	Pancreas	Myosin gene	91
3	Skeletal muscles	Chymotrypsin gene	93

(b) (i) Outline the steps between extraction of intact DNA and mixing with radioactively labelled DNA probes for nucleic acid hybridization.

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(ii) State two similarities between the probes used in the experiment and primers used in Polymerase Chain Reaction (PCR).

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(iii) Suggest how DNA in the chromatin are protected from digestion by DNase.

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(iv) With reference to Table 1.1, explain which gene is more actively transcribed in skeletal muscle cells.

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(v) Explain one type of protein modification that supports your answer to **(b)(iv)**.

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Dystrophin is a cytoskeletal protein found in human muscles. The gene which encodes dystrophin has 79 exons. Mutations in this gene leads to Duchenne muscular dystrophy (DMD), which causes progressive muscle impairment in children.

One of the most common mutations in the dystrophin gene, which occurs in exon 44, results in a non-functional protein. The asterisks (*) in Fig. 1.3 show the positions where deletions were detected in exon 44 and the reading frame is indicated by the boxes.

To treat DMD, scientists modified the dystrophin gene by removing exon 44, producing a partially functional protein.

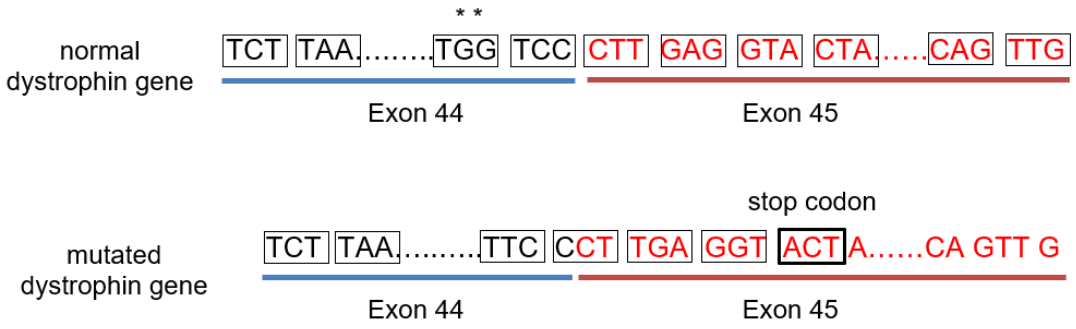

Fig. 1.3

(c) Explain how removal of exon 44 could result in production of a partially functional dystrophin protein.

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Duchenne muscular dystrophy (DMD) is a X-linked recessive disorder. Mary and John are a normal, healthy couple without DMD who gave birth to their first-born son with DMD. They went for genetic testing and discovered that Mary is a carrier.

(d) **(i)** Using suitable symbols, identify the genotypes of the following individuals.

Mary: .....

John: .....

First-born son with DMD: .....

[2]

(ii) Calculate the probability that their second child is also a son with DMD.

[1]

(e) Rare females with DMD have a translocation that disrupts the dystrophin gene on one X chromosome and causes non-random inactivation of the normal X chromosome, resulting in the expression of the disease.

Molecular characterization of the translocation junctions revealed reciprocal translocation between the X chromosome and an autosome, with both deletion and addition of nucleotides at the junction.

Suggest how reciprocal translocation and non-random X-chromosome inactivation lead to expression of the diseased phenotype.

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[Total: 30]

2 Cyanobacteria are a group of bacteria that obtains their energy through photosynthesis. They carry an operon known as phycocyanin operon which controls the expression of phycocyanin. Phycocyanin is a protein complex which serves as accessory pigment to chlorophyll in cyanobacteria. Without phycocyanin, light harvesting process is halted. The amount of phycocyanin increases from very low level to high level in the presence of light.

Fig. 2.1 below shows the structure of phycocyanin operon in the cyanobacterium *Anacystis nidulans*.

P	O	*CPCB1*	*CPCA1*	Intergenic region	P	O	*CPCB2*	*CPCA2*

Legend:

P	**:**	**promoter**
O	**:**	**operator**
CPCB1* and *CPCA1	**:**	**structural genes coding for β – subunit of phycocyanin**
CPCB2* and *CPCA2	**:**	**structural genes coding for α – subunit of phycocyanin**

Fig. 2.1

(a) Compare the lac operon to the phycocyanin operon.

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Cyanobacterium *Anacystis nidulans* has thylakoid which contain the same photosystems as the thylakoid of plant cells. Fig. 2.2 shows a hybrid phycocyanin operon. The *trpR* gene is upstream of the hybrid phycocyanin operon.

trp PO	*CPCB1*	*CPCA1*	Intergenic region	trp PO	*CPCB2*	*CPCA2*

Legend:
trp PO : trp promoter + operator

Fig. 2.2

(b) Explain the rate of production of oxygen in the cyanobacterium *Anacystis nidulans* carrying the hybrid operon when light is present and tryptophan is present.

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Fig. 2.3 shows the outer layers of cyanobacteria and bacteria **Y**.

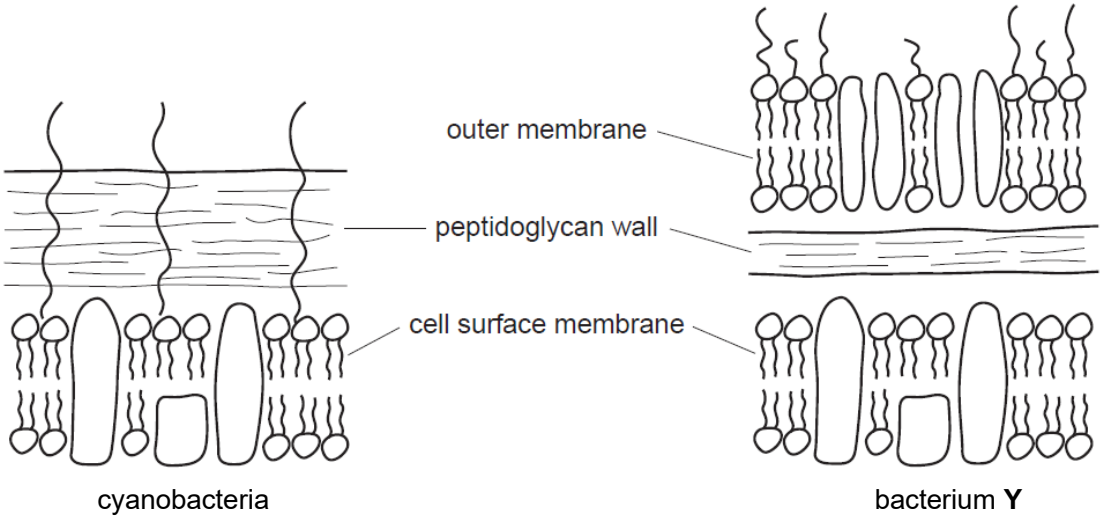

Fig. 2.3

(c) Describe how the outer layers of bacterium **Y** differ from those of cyanobacteria.

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…… [2]

Many bacteria that have a similar outer layer structure to that of bacterium **Y** are known pathogens that can cause diseases. To treat such diseases, doctors sometimes prescribe antibiotics. Gramicidin A is an example of an antibiotic.

Gramicidin A folds into a 3-dimensional configuration that inserts itself into the bacterium's cell surface membrane. It allows non-specific movement of ions which eventually cause the bacterial cell to die. Fig. 2.4 shows the interaction of Gramicidin A with the bacterium's cell surface membrane.

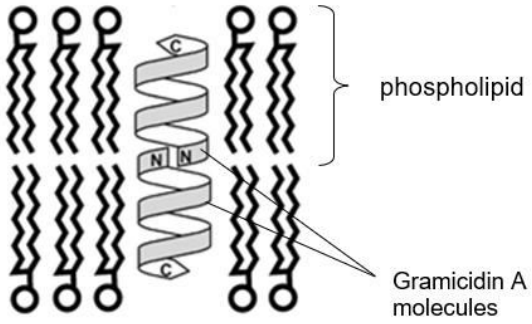

Fig. 2.4

(d) Using the information provided and Fig. 2.4, explain how Gramicidin A kills the bacterium.

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[Total: 10]

3 Yeasts are unicellular organisms from the kingdom Fungi. *Saccharomyces cerevisiae* is one species of yeast that can carry out either asexual reproduction by mitosis or sexual reproduction by meiosis.

Budding in *S. cerevisiae* is a process where a small daughter cell forms as a bud on the parent cell. The bud contains a copy of the parent cell nucleus and it eventually separates from the parent cell to form a new cell.

S. cerevisiae can exist in two forms: haploid cells or diploid cells.

- Haploid cells can be one of two different mating types: **a** and α
- Haploid cells can only mate with other haploid cells of the opposite mating type.

Fig. 3.1 shows the life cycle of *S. cerevisiae* with its asexual and sexual reproductive stages.

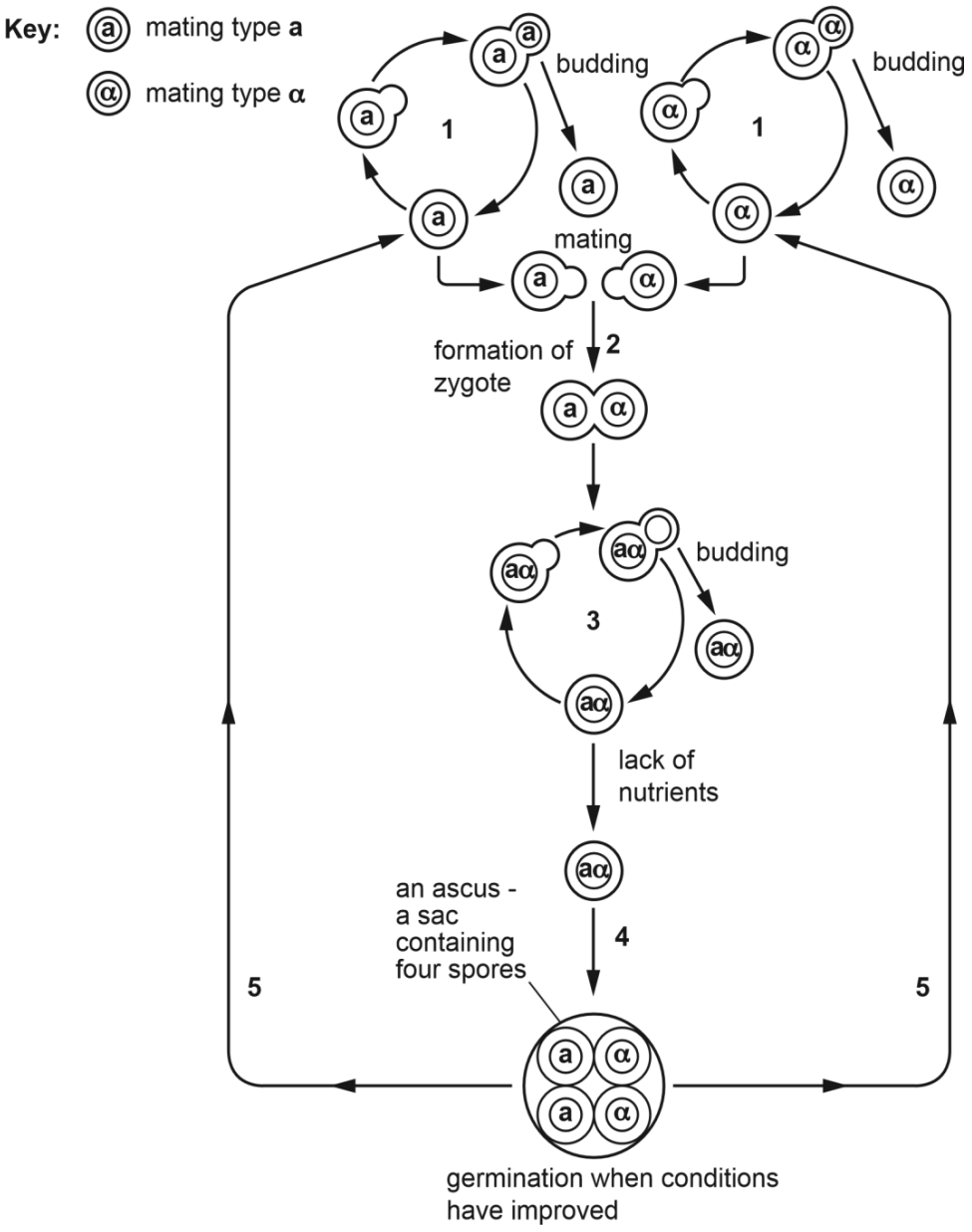

Fig. 3.1

(a) With reference to Fig. 3.1, state **one** number of the stages **1**–**5** that:

involve mitosis .....

involve meiosis .....

produces new genetic variation .....

shows only haploid cells .....

shows only diploid cells .....

[3]

(b) When there is a lack of nutrients, cells made in stage **3** will carry out stage **4** to make spores, which germinate only when conditions improve.

Suggest and explain how stage **4** is advantageous for *S. cerevisiae* in a changing environment.

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(c) Haploid and diploid cells of *S. cerevisiae* can carry out **asexual** reproduction.

Suggest why a new harmful recessive mutation may **not** have a damaging effect on:

- an asexually reproducing population of haploid cells of *S. cerevisiae*
- an asexually reproducing population of diploid cells of *S. cerevisiae*.

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…… [3]

[Total: 10]

Section B

Answer **one** question in this section.

Write your answers on the 12-page Answer Booklet provided.

Your answers 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.

4 **(a)** Describe how variation arises due to mutations, and how recessive alleles are preserved in a population. [13]

(b) Describe how anatomical and molecular homology support Darwin's theory of descent with modification. [12]

5 **(a)** Explain how genetic stability in eukaryotes is maintained at the molecular and cellular levels. [13]

(b) Describe how genetic variation increases over many generations in prokaryotes. [12]

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