VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
2021
HIGHER 2

NAME: ……

CT CLASS: ……..……

BIOLOGY 9744/03

Paper 3 Long Structured and Free-response Questions

22/09/2021

2 hour

Candidates answer on the Question Paper.
Additional Materials: Answer Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and CT class in the spaces 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.

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

Section B
Answer **one** question.
Write your answer 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.

At the end of the examination, fasten all your work securely together.
The number of marks is given in bracket [ ] at the end of each question or part question.

Question	Marks
Section A	
1	
2	
3	
Section B	
4 or 5	
Total	

This document consists of **16** printed pages.

[Turn over]

Section A starts on page 3

Section A

Answer **all** questions.

1 Drosophila are small flies in the order Diptera and family Drosophilidae. Commonly known as fruit or vinegar flies, they are often found on rotting fruit or other decaying matter. They are one of the most valuable organisms in biological research, particularly in genetics and developmental biology.

The genome of *Drosophila melanogaster* comprised of eight chromosomes (2n=8), of which two of them are sex chromosomes. Like humans, the male is the heterogametic sex. Fig. 1.1 shows the chromosomes present in a male Drosophila.

Fig 1.1

(a) (i) Circle the sex chromosomes in Fig. 1.1. [1]

(ii) Explain what is meant by "heterogametic sex".

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…….. [2]

Chromosomes contain the units of inheritance and their behavior during meiosis can be used to explain Mendel's laws of inheritance.

(b) Explain how the behavior of chromosomes during meiosis supports Mendel's law of segregation and independent assortment.

Law of segregation:

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……..……. [2]

Law of independent assortment:

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…….. [2]

Researchers studying the development of embryo in Drosophila noted the presence of mRNA coding for four different proteins: bicoid, caudal, hunchback and nanos, present in the cytoplasm of the oocyte (unfertilised egg). Before fertilisation, these maternal mRNA are not translated. Initiation of translation occurs only upon fertilisation.

(c) Describe one way in which translation of the maternal mRNA in the egg can be prevented.

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…….. [2]

Fig. 1.2 shows the development of the embryo upon fertilisation.

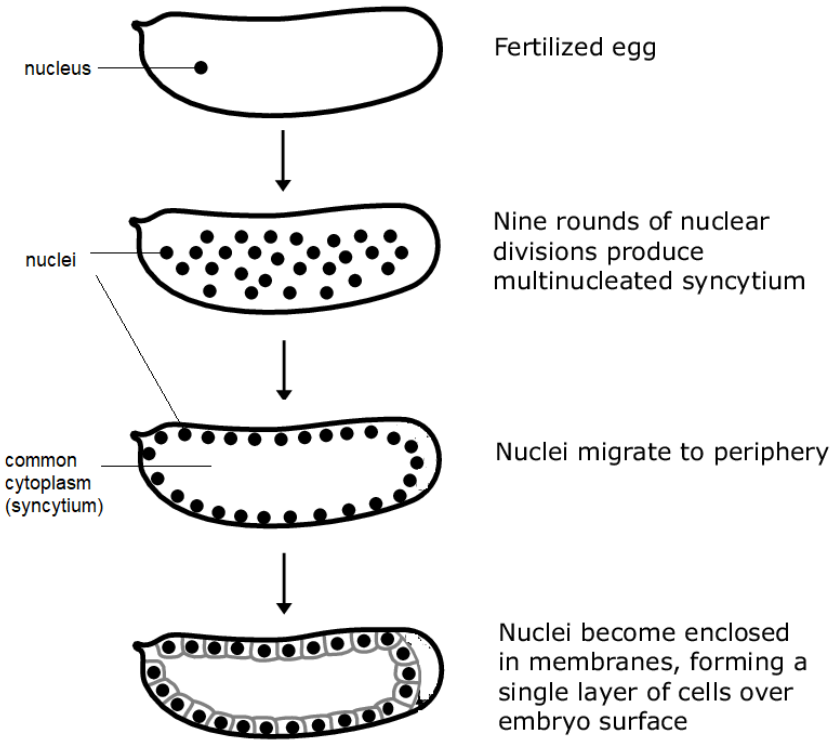

Fig. 1.2

https://www.researchgate.net/figure/Early-stages-of-embryonic-development-in-Drosophila_fig11_310995415

(d)(i) Suggest an advantage of nuclei of the early embryo sharing a common cytoplasm.

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…….. [1]

(ii) Cellularisation occurs when cell membranes are formed around each nucleus to form cells.

Explain the importance of cellularisation in the continued development of the embryo.

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…….. [2]

The maternal mRNA and their respective proteins can be found in the common cytoplasm of the embryo.

Fig 1.3 shows the concentration and distribution of the four maternal mRNA in the common cytoplasm of the fertilised egg. These mRNA are anchored to cytoskeleton present within the cytoplasm.

The distribution of the four proteins is important in the determination of the anterior-posterior (head-tail) axis of the embryo. Fig 1.4 shows the distribution and concentration of these proteins.

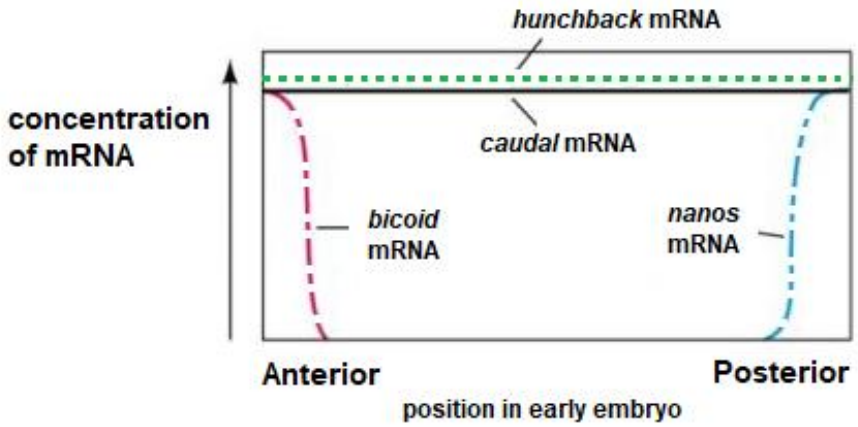

Fig. 1.3

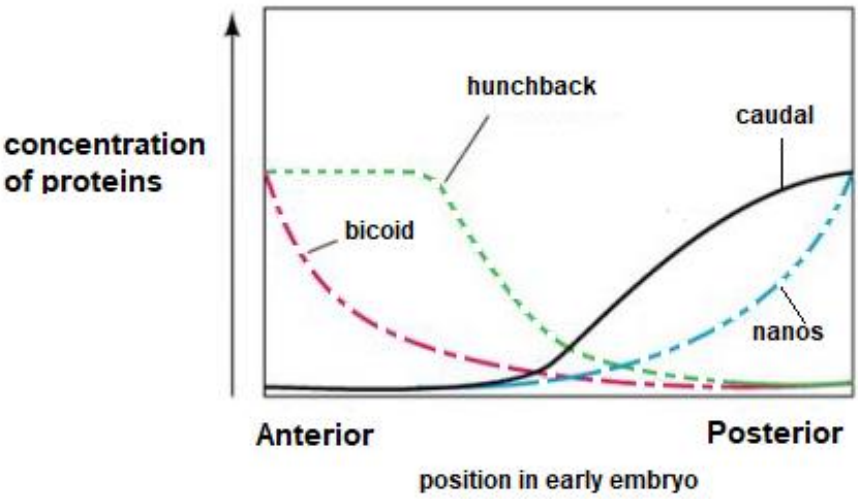

Fig. 1.4

(e) Using the information from Fig. 1.3 and 1.4,

(i) account for the distribution of bicoid and nanos proteins.

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…….. [2]

(ii) suggest explanations for the distribution of the hunchback and caudal proteins.

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…….. [3]

The bicoid protein can be transported into the nuclei where it can result in the development of specific structures (eg. head, thorax) in the anterior region of the embryo.

(f) Suggest how the bicoid protein can result in the development of specific structures in the anterior region of the embryo.

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…….. [3]

In the salivary gland of the Drosophila larvae, large chromosomes known as polytene chromosomes can be seen during development. During the formation of the polytene chromosome, paired homologous chromosomes undergo repeated divisions to form many chromatids without segregating. The newly formed chromatids remain associated lengthwise and together form a cable-like structure. These giant chromosomes possess characteristic patterns of alternating dark and light bands, which are readily observed when stained.

Fig. 1.5 shows portions of polytene chromosomes that have been stained.

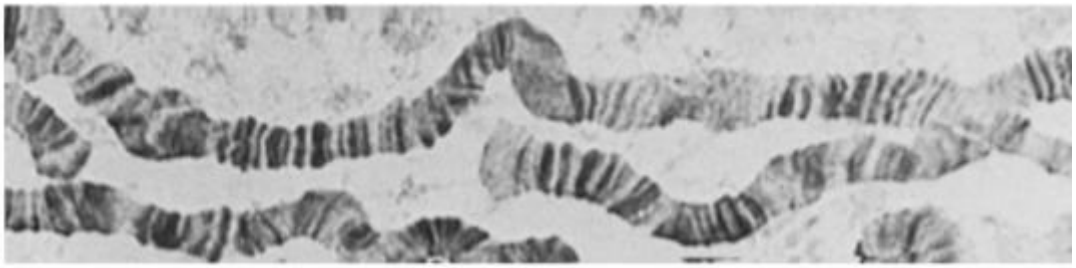

Fig 1.5

(g) (i) If each of the DNA has undergone 10 rounds of DNA replication, how many DNA molecules are there in one polytene chromosome?

…….. [1]

(ii) Explain why it is unusual for homologous chromosomes to pair up in the salivary gland.

……..

…….. [1]

(iii) Explain how repeated divisions can result in the banding pattern seen in Fig.1.5.

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…….. [3]

Scientists have labelled the banded regions of these giant chromosomes and use them to distinguish between different species of Drosophila.

(h)(i) Suggest why different species of Drosophila show different banding patterns for the same polytene chromosome.

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…….. [2]

(ii) Suggest a limitation of using polytene chromosomes to establish phylogenetic relationship.

……...

…….. [1]

[Total: 28]

Question 2 starts on page 11

2 **(a)** Fig. 2.1 shows an event occurring in a dendritic cell infected with *Mycobacterium tuberculosis* (indicated with an * in the figure). The arrowheads show this event involving several of the same organelle. B' is an enlargement of the boxed area.

Fig. 2.1

(i) Compare *Mycobacterium tuberculosis* with the structure labelled A, excluding differences in size.

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…….. [3]

(ii) With reference to Fig 2.1, briefly describe the event that is occurring in the dendritic cell infected with *Mycobacterium tuberculosis.*

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…….. [1]

An experiment is carried out using macrophages to study the effects of *M. tuberculosis* following phagocytosis. IgG-coated beads were introduced as a control for the experiment. Fig. 2.2 shows the results involving phagosomes containing either *M. tuberculosis* or IgG-coated beads.

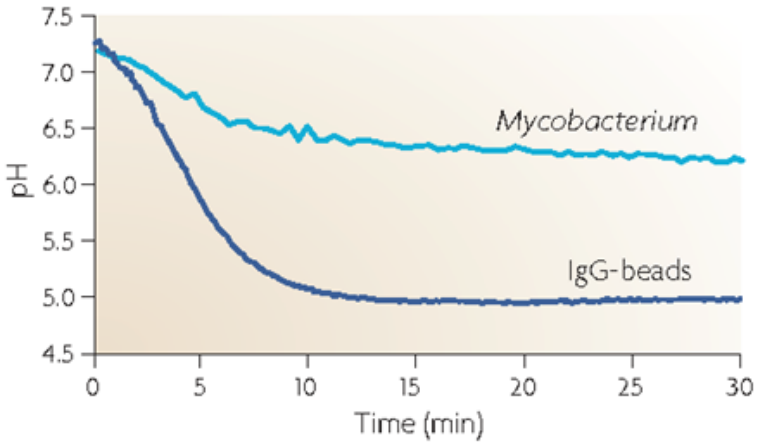

Fig 2.2

(https://media.springernature.com/full/springer-static/image/art%3A10.1038%2Fnrmicro1538/MediaObjects/41579_2007_Article_BFnrmicro1538_Fig1_HTML.jpg)

(b) Explain what happens to the IgG-coated beads when they are introduced to the macrophages.

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…….. [3]

(c) With reference to Fig. 2.2,

(i) suggest how IgG-coated beads are being used as a control in this experiment.

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…….. [2]

(ii) explain the effect of *M. tuberculosis* in macrophages following phagocytosis.

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……...

…….. [3]

[Total: 12]

3 Cytokines are secreted glycoproteins that act as intercellular messengers to control the inflammatory response by immune cells. They bind specifically to receptor tyrosine kinase on target cells to bring about specific responses.

Fig. 3.1 below shows the signalling pathway that is initiated by the binding of a cytokine to the target receptor.

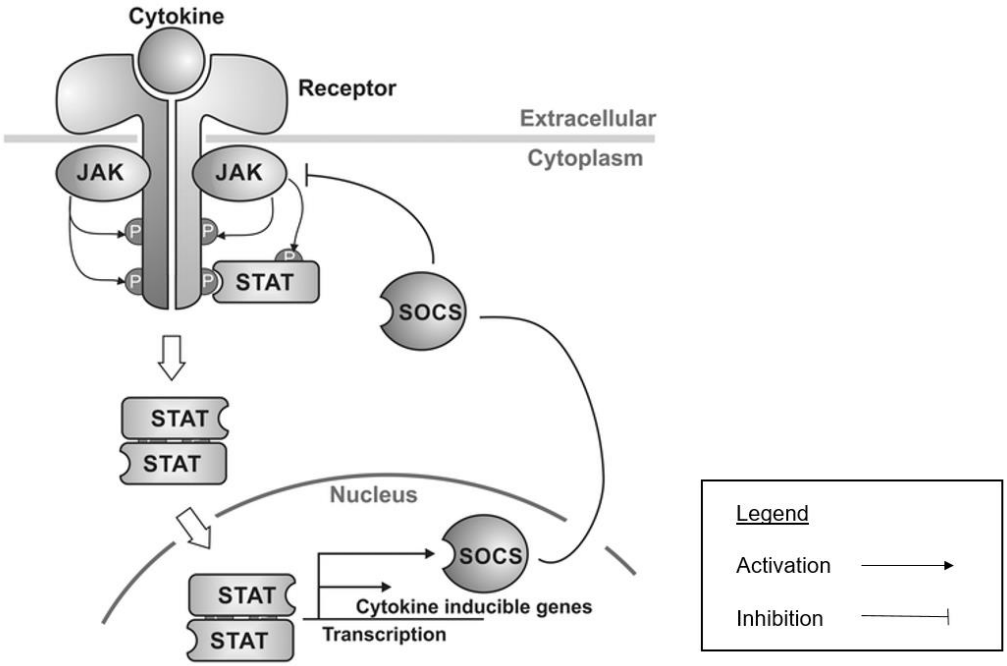

Fig. 3.1

(https://onlinelibrary.wiley.com/doi/full/10.1002/pro.3519)

(a) Name one target cell of the cytokines.

…….. [1]

(b) With reference to Fig. 3.1,

(i) explain how the structure of the receptor tyrosine kinase enables it to carry out its functions.

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……...

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…….. [3]

(ii) describe one instance in which signal is amplified in the cytokine signalling pathway.

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…….. [1]

(iii) describe two other ways in which the cytokine signalling pathway shown may be terminated, excluding the use of SOCS.

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…….. [2]

(c) Recent findings on patients suffering from certain autoimmune diseases reveal mutations in the gene coding for SOCS.

An autoimmune disease is a condition where an individual's immune system attacks its own healthy tissue.

Explain how such mutations can lead to these conditions.

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……...

……...

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…….. [3]

[Total: 10]

Section B

Answer **one** question in this section.

Write your answers in the 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)** Explain how evolution by natural selection can result in a decrease in the variation of a population and describe the various mechanisms that may increase or preserve this variation. [15]

(b) With reference to your knowledge of viral replication cycles, explain how phages can effectively eradicate bacterial infections in humans and explain the advantages and disadvantages of phage therapy over the use of antibiotics. [10]

5 **(a)** Explain the advantages of having DNA as the hereditary material instead of RNA and describe the different roles played by RNA, including stable RNA-protein complexes in the cells. [15]

(b) Many processes in cells occur in a series of steps rather than a single step. With reference to different cellular processes, explain the advantages of such an arrangement in a eukaryotic cell. [10]

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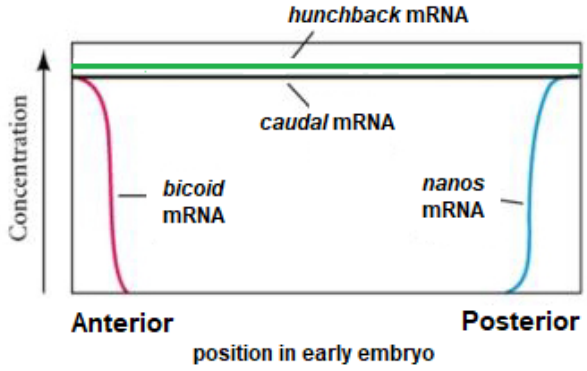

hunchback mRNA
caudal mRNA
bicoid mRNA
nanos mRNA
Concentration
Anterior
Posterior
position in early embryo

Fig 1.3

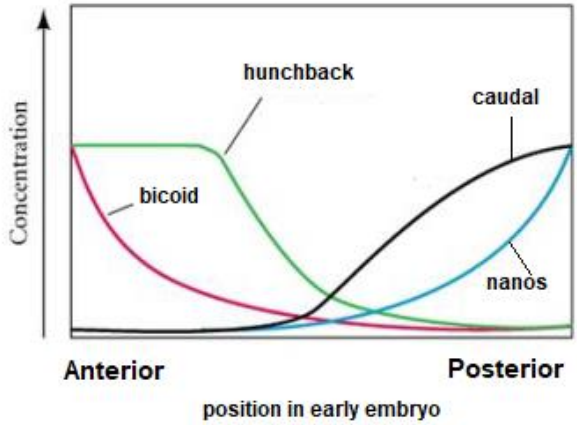
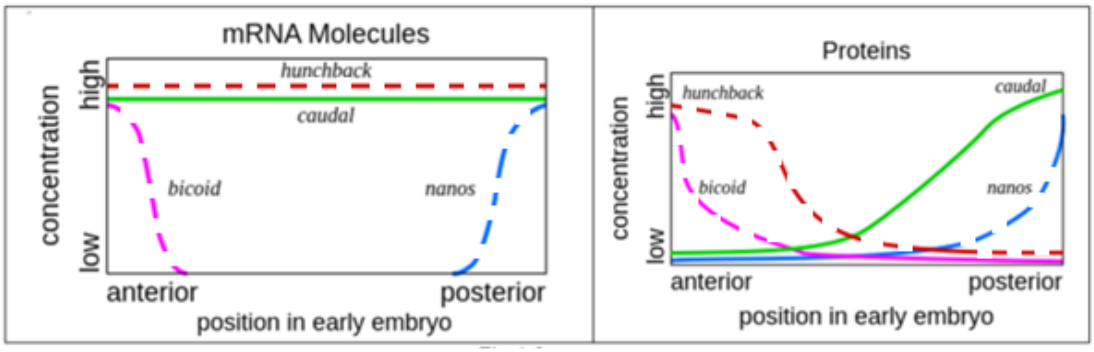

hunchback
caudal
bicoid
nanos
Concentration
Anterior
Posterior
position in early embryo

Fig 1.4


mRNA Molecules
hunchback
caudal
bicoid
nanos
concentration
high
low
anterior
posterior
position in early embryo
Proteins
hunchback
caudal
bicoid
nanos
concentration
high
low
anterior
posterior
position in early embryo