TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	

H2 BIOLOGY

9744/03

Paper 3 Long Structured and Free-response Questions

18 September 2023
2 hours

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the 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.

Section B
Answer **ONE** question.

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	
1	/ 30
2	/ 20
Section B	
3 or 4	/ 25
Total	**/ 75**

Section A

Answer all questions in this section.

1 **(a)** The pituitary gland is located in the brain of mammals. Prolactin, a hormone from the pituitary gland, stimulates cells in the mammary glands of female mammals so that the cells are able to secrete milk.

(i) State the potency of the stem cells that produce pituitary cells. [1]

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(ii) With reference to the information provided, explain how the stem cells in pituitary gland stimulate cells in the mammary gland to secrete milk. [3]

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(iii) Cells in the mammary glands that have been stimulated by prolactin need more glucose.

State **one** reason why those cells need more glucose. [1]

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(b) Female mammals produce milk to feed new-born offspring.

Secretory Immunoglobulin A (SIgA) is the main antibody found in breast milk of humans. It is secreted from IgA-producing plasma cells into cavities within the mammary glands to form milk with other components.

(i) Explain how newly synthesised SIgA in the IgA-producing plasma cells reach the cavities within the mammary glands. [4]

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(ii) The antibodies and other components in the breast milk provide immediate protection to newborns in fighting infections. However, this is not a long-term protection.

Explain why antibodies such as SIgA in breast milk will not produce long-term protection to newborns. [2]

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(c) β-catenin signalling pathway involving WNT as a ligand is important in regulating cell proliferation during mammary gland development. When WNT binds to the Frizzled receptor embedded on the cell surface membrane, β-catenin is activated which translocates into the nucleus to upregulate the transcription of target genes. Fig. 1.1 shows the signalling pathway with and without WNT.

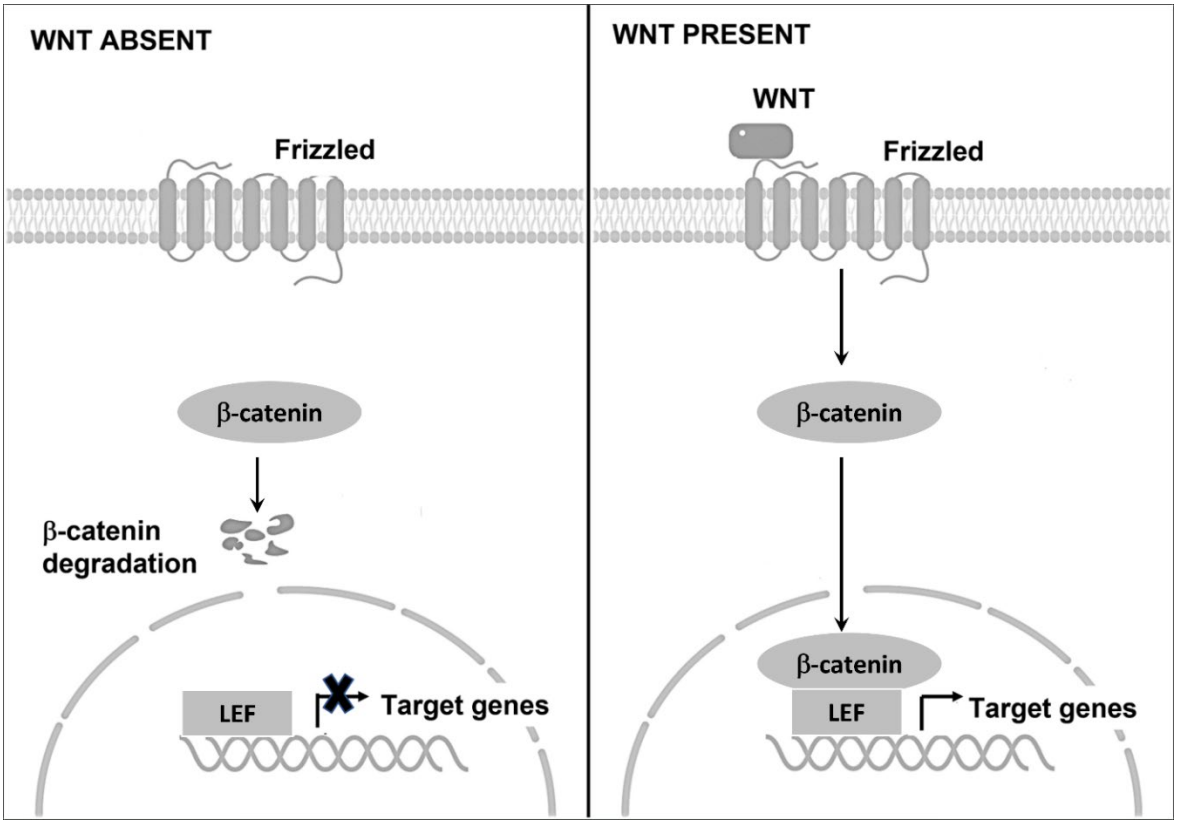

Fig. 1.1

(i) The shape of Frizzled receptor is characteristic of a particular group of transmembrane receptor proteins.

Name this group of proteins. [1]

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(ii) Suggest how β-catenin is degraded in the absence of WNT. [2]

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(iii) Cell surface membrane is made up of phospholipid molecules.

Explain why triglycerides are **not** suitable as a component of cell surface membranes. [2]

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(d) One of the target genes in WNT/β-catenin signalling pathway is *cyclin D1* gene. Fig. 1.2 shows the percentage of β-catenin activity and cyclin D1 protein level during the mitotic cell cycle of a mammary gland cell.

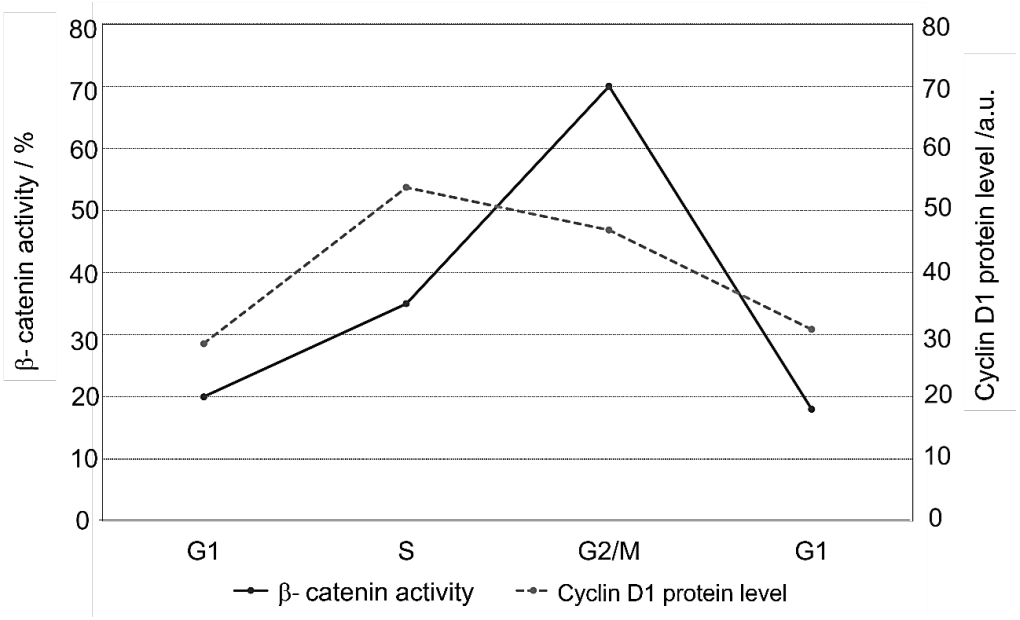

Fig. 1.2

With reference to Fig.1.1 and Fig.1.2, describe and explain the effect of β-catenin on *cyclin D1* gene expression from G1 to S **and** mitosis of mammary gland cell. [4]

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(e) The dysregulation of the β-catenin signalling pathway is frequently linked to breast cancer. A young scientist conducted an experiment to compare the amount of β-catenin protein in breast cancer cells and normal cells to determine if *β-catenin* gene expression is high in breast cancer.

(i) Explain why the amount of β-catenin protein is used as an indicator of breast cancer rather than the amount of *β-catenin* DNA. [2]

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(ii) β-catenin is encoded by the *CTNNB1* gene. While *CTNNB1* mutations are rare in breast cancer, they are found in many other types of cancer. Table 1.1 displays a mutation that is often seen in *CTNNB1*.

Table 1.1

Name of mutation	**Change in DNA**		**Change in β-catenin**	
	Nucleotide present in *CTNNB1*	Nucleotide present after mutation	Amino acid before mutation	Amino acid after mutation
K354T	Adenine (A)	Cytosine (C)	Lysine (Lys)	Threonine (Thr)

With reference to Table 1.1, explain the meaning of a gene mutation. [2]

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(f) Breast cancer is the most prevalent cancer among women in Singapore today. The age-standardised incidence rate of breast cancer per 100,000 women has significantly increased from 23.8 in 1975 to 70.7 in 2018.

(i) Calculate average annual percentage increase in age-standardised incidence rate of breast cancer from 1975 to 2018. Show your working. [2]

average annual percentage increase ……**%**

(ii) The likelihood of surviving breast cancer is largely determined by the stage at which it is identified. Stage I indicates that the cancer is small and localized within the organ where it originated, and stage IV indicates that it has spread to other areas of the body. Table 1.2 illustrates the five-year survival rate for breast cancer based on the stage of detection.

Despite the efforts to promote Singapore's national breast cancer screening program, the screening uptake rate remains low at approximately 40%.

Table 1.2

Cancer stage at detection	Five year survival rate / %
Stage I	88
Stage II	74
Stage III	41
Stage IV	15

With reference to Table 1.2, state the importance of breast cancer screening **and** suggest why breast cancer screening rate remains low in Singapore. [4]

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[Total: 30]

2 *Vibrio cholerae* is the bacterium that causes cholera by infecting intestinal epithelial cells.

The organism does not enter the cell but instead it secretes a toxin, choleragen which enter and cause damage in the cell. Choleragen is produced after *V. cholerae* has penetrated the mucus lining and attached to intestinal epithelial cells.

This toxin binds to and acts on cystic fibrosis transmembrane conductance regulator (CFTR) protein and causes large quantities of water and chloride ions to be lost from the gut epithelial cells. This results in severe diarrhoea and may lead to death if untreated.

Choleragen is composed of two subunits:

- subunit **A** consists of one polypeptide
- subunit **B** consists of five identical polypeptides
- the polypeptide in subunit **A** is different from the polypeptides in subunit **B**.

(a) Two genes, *ctxA* and *ctxB*, are needed to produce choleragen. Only one strand of the DNA forming gene *ctxA* is involved in the production of subunit **A**. Only one strand of the DNA forming gene *ctxB* is involved in the production of subunit **B**.

(i) Explain why only one strand of the DNA of each gene is involved in the production of the subunits. [2]

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(ii) *ctxA* and *ctxB* genes are observed to be transcribed in opposite directions.

Suggest why the direction of transcription of the two genes differs. [2]

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(b) CFTR protein is a channel protein that when open, allows the diffusion of chloride ions out of the epithelial cells down its concentration gradient. Chloride ions control the flow of water throughout the body, including the water that normally keeps mucus thin and slippery. If chloride ions are trapped in cells, the mucus outside the cells becomes thick and sticky, as shown in Fig. 2.1.

One of the most common causes of this defect is a mutation of the CFTR gene, $\Delta F508$, which results in a deletion of phenylalanine at position 508 of the amino acid sequence.

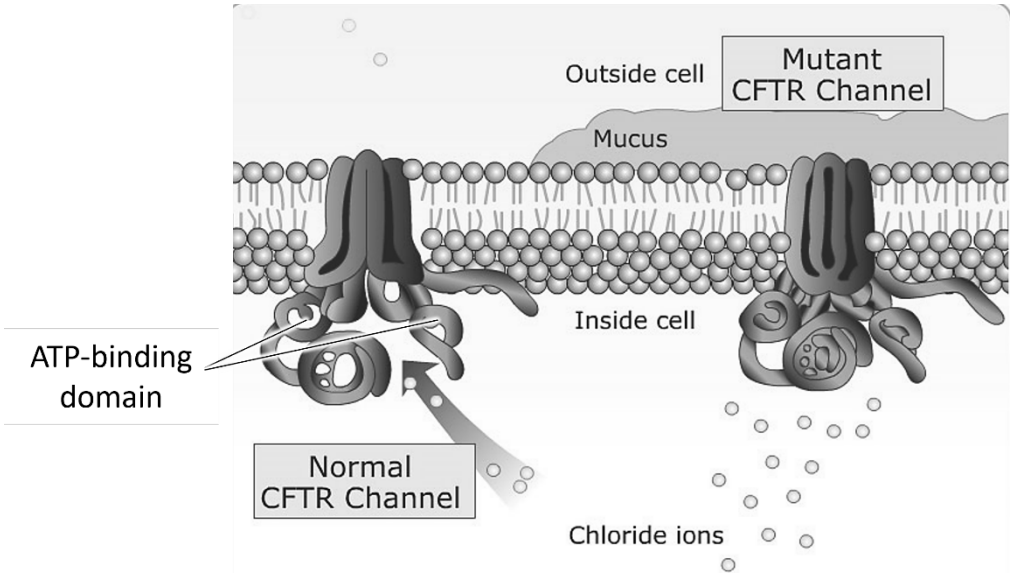

Fig. 2.1

(i) Explain how the deletion of a phenylalanine residue results in thick and sticky mucus outside the cells. [3]

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(ii) With reference to Fig. 2.1, suggest the role of ATP in opening the channel. [1]

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(c) In an experiment carried out in 1994, it was shown that when mice that were heterozygous for Δ*F508* were exposed to cholera toxin, they lost 50% less water than homozygous dominant mice also exposed to cholera toxin.

This supported a suggestion that the selective advantage of carrying the Δ*F508* allele may serve as protection from the effects of cholera.

(i) Suggest how the Δ*F508* allele might be expected to convey a selective advantage in areas of the world where cholera is common. [3]

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In 2000, a further experiment to investigate the possible link between the Δ*F508* allele and the severity of cholera in humans was conducted. To do this, the effect of prostaglandin was measured in fifteen human subjects including:

- some who had cystic fibrosis (homozygous for Δ*F508*)
- some who were carriers (heterozygous for Δ*F508*)
- a control group who did not have cystic fibrosis and did not carry Δ*F508*.

Prostaglandin is a chemical that increases water loss from epithelial cells by increasing chloride secretion through the CFTR protein.

The results are shown in Fig. 2.2.

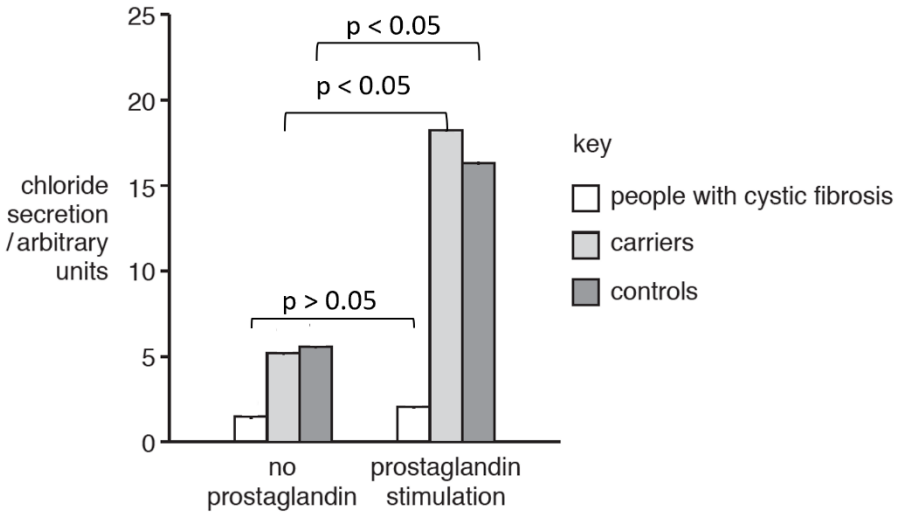

Fig. 2.2

(ii) Describe the results obtained in the study carried out in 2000. [3]

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(iii) Suggest why prostaglandin was used to increase water loss from epithelial cells in the 2000 study. [1]

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(d) Most people who have recovered from cholera rarely become ill again from the disease. In these people, antibodies have been identified that will bind either to the cholera toxin, or to the bacterial flagellum, or to the main bacterial cell.

Explain why each antibody is specific to its target. [3]

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(e) Viruses that infect bacteria are called bacteriophages. Some bacteriophages that infect the cholera pathogen cause lysis of the bacterium.

(i) Suggest what happens to the structure of a bacterial cell to cause lysis. [1]

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(ii) Some scientists believe that bacteriophages could be used to treat people who are infected with cholera.

Suggest a property of the bacteriophages that would make this possible. [1]

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[Total: 20]

Section B

Answer **ONE** question.

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

3 **(a)** Living organisms consist of diverse elements, including carbon, hydrogen, oxygen, nitrogen, and phosphorus. These elements play vital roles in upholding the continuity and viability of life.

Discuss the importance of nitrogen in living organisms. [13]

(b) The origin of viruses is a subject of extensive debate within the virology community. One hypothesis, known as the regressive hypothesis, proposes that viruses may have emerged from more complex, free-living organisms that gradually lost genetic information over time as they adopted a parasitic strategy for reproduction.

Outline the features of viruses that support regressive hypothesis **and** explain the role of viruses in evolution in living organisms. [12]

[Total: 25]

4 **(a)** Enzymes play fundamental roles in cells to maintain optimal function and to survive in its environment.

Discuss the importance of enzymes in cells, to life. [13]

(b) Explain the three modes of natural selection **and** discuss which mode(s) of selection might lead to the formation of new species, including circumstances under which this may take place. [12]

[Total: 25]

☺ END OF PAPER 3 ☺

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