VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
2024
HIGHER 2

NAME: ……

CT CLASS: ……

BIOLOGY **9744 / 03**

Paper 3 Long Structured and Free-response Questions

17/09/2024

2 hour

Candidates answer on the Question Paper.
No Additional Materials are required.

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 any **one** question in the space provided on the Question Paper.

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 bracket [ ] at the end of each question or part question.

Question	Marks
Section A	
1	
2	
3	
Section B	
Total	

This document consists of **24** printed pages.

[Turn over]

Section A

Answer **all** the questions in this section.

1 Thyroid hormones are produced and released by the thyroid gland. In humans, the thyroid gland is found in the neck below the Adam's apple. It is lined with thyroid follicular cells, also called thyrocytes, that surround a lumen.

Fig. 1.1 shows the thyroid follicular cells.

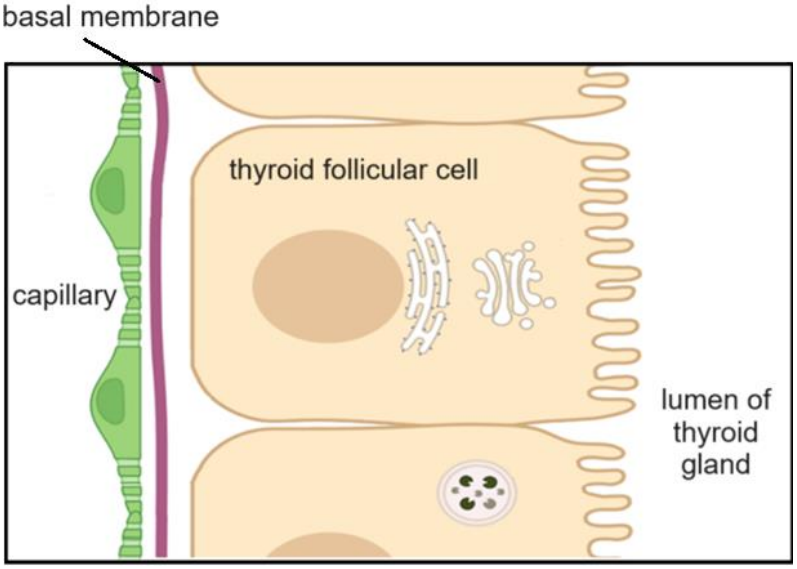

Fig. 1.1

Unlike most hormones with specific target cells or tissues, the thyroid hormones act on nearly every cell in the body and are important in regulating the basal metabolic rate of the body. They regulate the metabolism of proteins, fat and carbohydrates in cells, affecting protein synthesis and cellular respiration. They are also involved in the control of heat generation in the body and are essential for proper cell development and differentiation.

There are two types of thyroid hormones, namely triiodothyronine (T_3) and thyroxine (T_4). Their structures differ by the number of iodine present.

Fig. 1.2 shows the structure of T_3 and T_4.

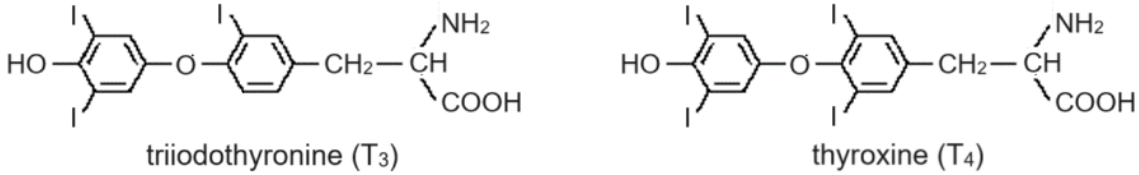

Fig. 1.2

(a) With reference to Fig. 1.1 and 1.2,

(i) suggest how thyroid hormones are able to act on nearly every cell in the body.

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……..…… [1]

(ii) compare the structure of thyroid hormones to an amino acid.

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……..…… [2]

(b) The release of thyroid hormones from the thyroid gland is regulated by other hormones released from the brain. Neurones in the hypothalamus in the brain release thyrotropin-releasing hormone (TRH), which stimulates the release of thyroid-stimulating hormone (TSH) from cells in the anterior pituitary. TSH then stimulates the release of T_3 and T_4 from the thyroid gland.

Fig. 1.3 shows the relationship between different tissues in the control of the release of thyroid hormones.

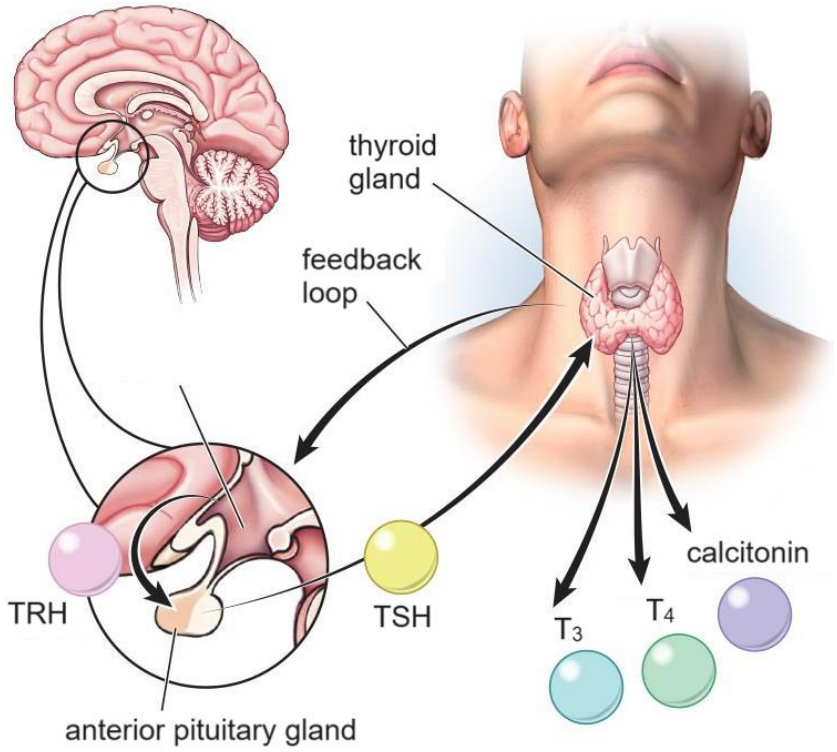

Fig. 1.3

Research was conducted to study the effect of TSH on the release of thyroid hormones from the thyroid gland. In this research, pluripotent stem cells were induced to differentiate into a culture of thyroid follicular cells. TSH was then introduced into the culture medium of this cell culture, and the amount of T_3 and T_4 released into the culture medium was measured for a period of one week.

The result of this experiment is shown in Fig. 1.4.

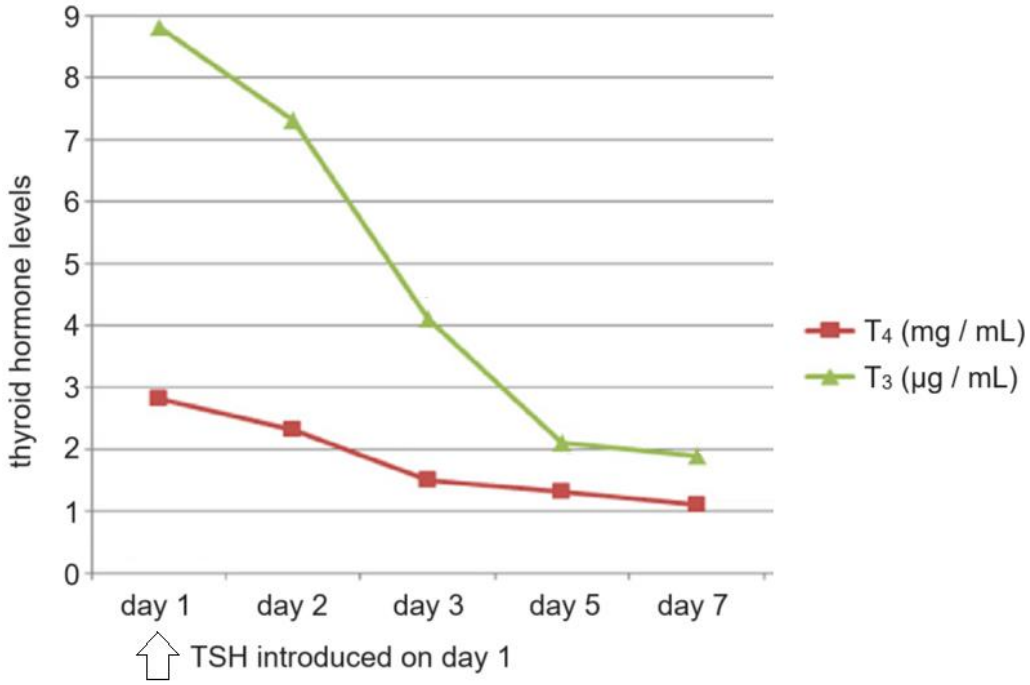

Fig. 1.4

With reference to Fig. 1.4,

(i) compare the changes in the levels of T_3 and T_4 in the cell culture medium during the week.

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…… [2]

(ii) contrast the release of thyroid hormones with the release of antibodies.

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…… [1]

Question 1 continues to page 6.

(c) The research continued and managed to discover the signalling pathways involved in the stimulation of the thyroid gland by TSH. The action of TSH on the thyroid follicular cells in the thyroid gland is shown in Fig. 1.5.

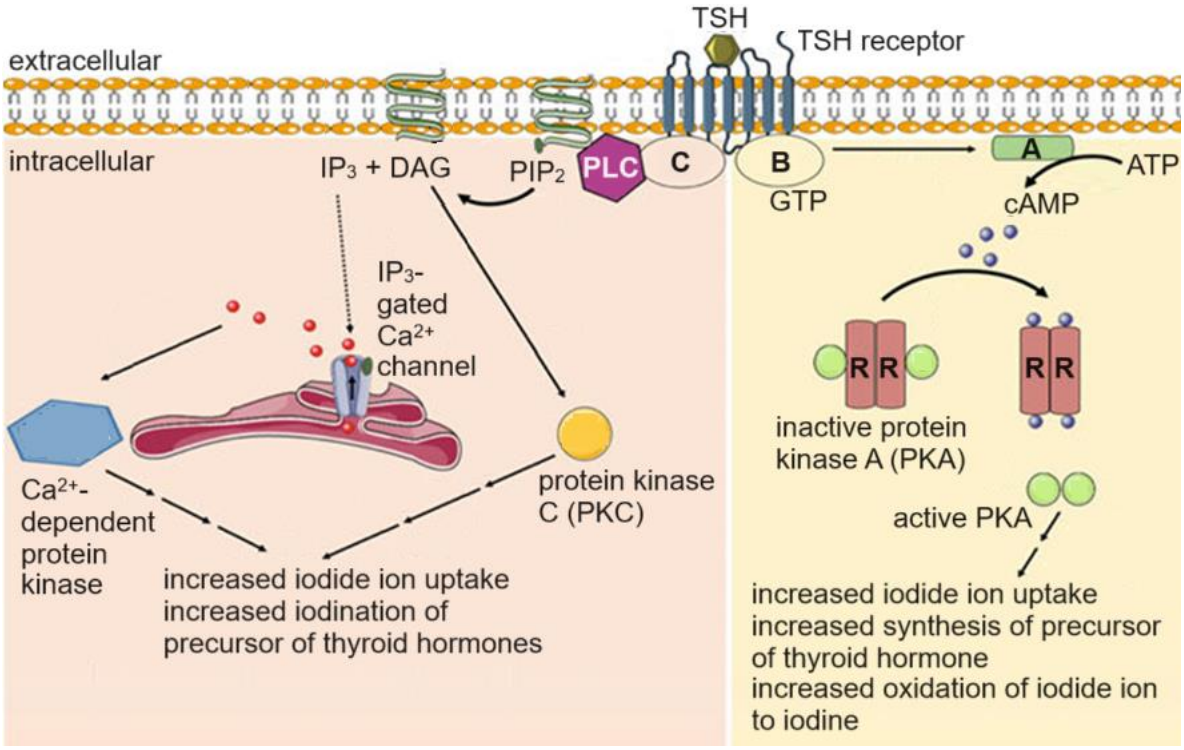

Fig. 1.5

(i) Identify the proteins labelled **A** and **B**.

A .....

B ..... [2]

(ii) Explain the significance of protein **A** in TSH signalling.

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..... [3]

(iii) Ca^{2+} ions are released from an organelle in the thyroid follicular cell when the cell is stimulated by TSH.

Describe how the structure of this organelle allows its roles in TSH signalling.

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……..…… [3]

(d) Beside the action of TRH and TSH, another regulatory mechanism of thyroid hormones is via the supply of iodine, an important component of thyroid hormones.

Most dietary iodine is reduced to iodide ions before absorption by the small intestine. The iodide ions are transported to the thyroid gland via the circulatory system and accumulated in thyroid follicular cells.

Fig. 1.6 shows the uptake of iodide ions by a thyroid follicular cell.

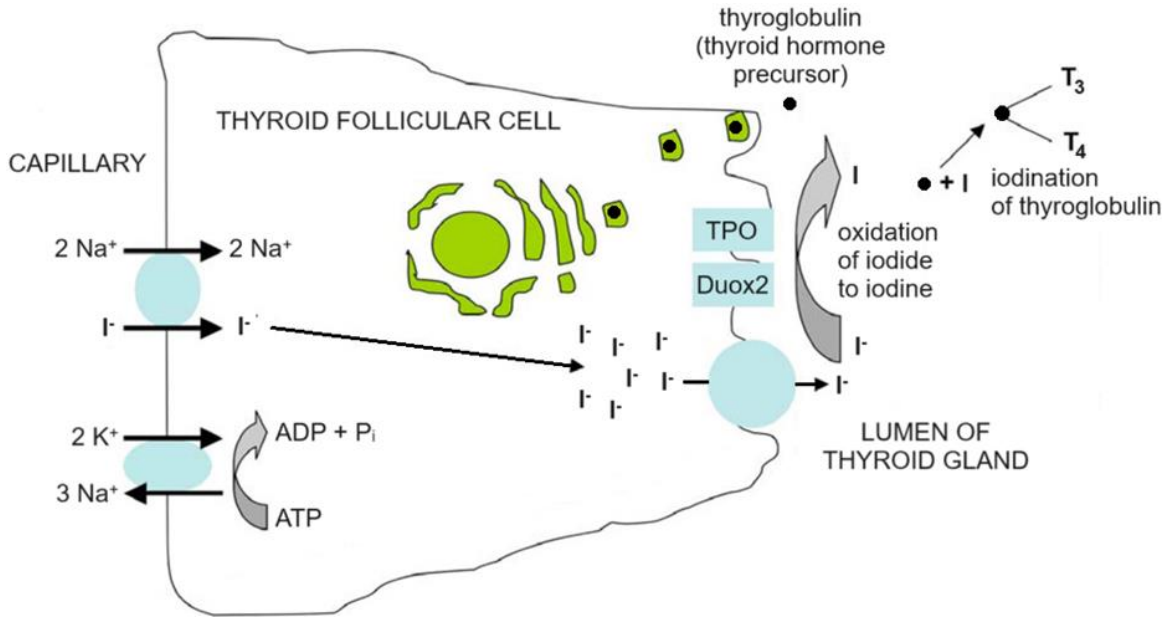

Fig. 1.6

With reference to Fig. 1.6 and your knowledge on transport across membrane,

(i) calculate the number of ATP required in the uptake of 10 mol of iodide ions into the thyroid follicular cell. Leave your answer to 3 significant figures.

Show your working in the space provided.

number of ATP required = …… mol [1]

(ii) explain the need for transport proteins in the uptake of iodide ions into the thyroid follicular cell.

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(iii) state **two** differences between the transport of iodide ions and thyroglobulin into the lumen of the thyroid gland.

feature of comparison	transport of iodide ions into thyroid gland lumen	transport of thyroglobulin into thyroid gland lumen

[2]

(e) Thyroid hormones, unlike most protein hormones, are transported into target cells and bind to intracellular receptors known as thyroid hormone receptors (TRs). TRs often form heterodimers with retinoic X receptor (RXR) and act as a transcription factor for a wide variety of genes. The dimer binds to a thyroid hormone response element (TRE) on the DNA and recruits co-repressors to repress gene expression.

Fig. 1.7 shows the action of thyroid hormone in the target cell.

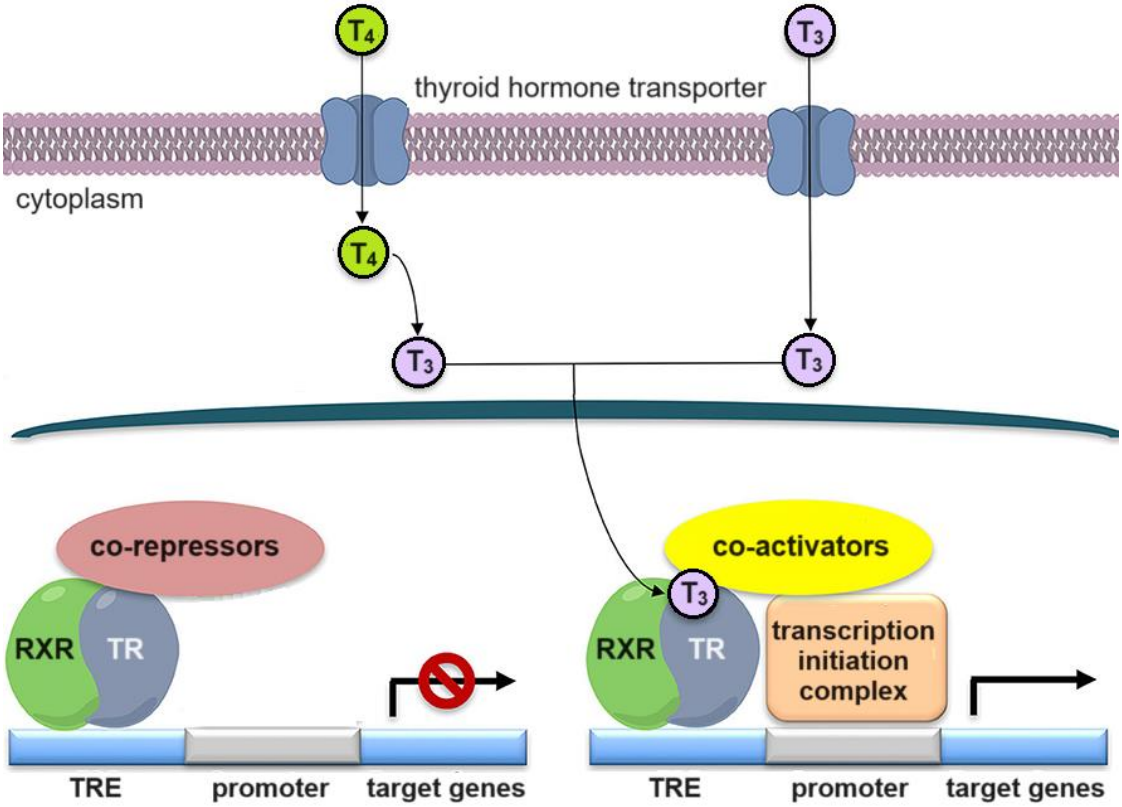

Fig. 1.7

(i) Briefly outline how T_4 is converted to T_3 in the cytoplasm.

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……..…… [1]

(ii) An example of co-repressors is histone deacetylase.

Explain how histone deacetylase represses gene expression.

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(iii) Outline how T_3 switches on gene expression after entering the target cell.

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……..…… [4]

(iv) The thyroid hormones are transported into target cells via active transport.

Suggest an advantage in the mode of transport of thyroid hormones.

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[Total: 30]

2 In the past, dieticians often advocated a diet low on fats to lose weight. Nowadays, many people are praising the benefits of the ketogenic diet that is high in fat intake but low on carbohydrate intake. Health benefits include weight loss and lowering one's risk for certain diseases.

Fig. 2.1 shows a comparison of the weight loss achieved with low-carbohydrate or low-fat diets over a two-year period.

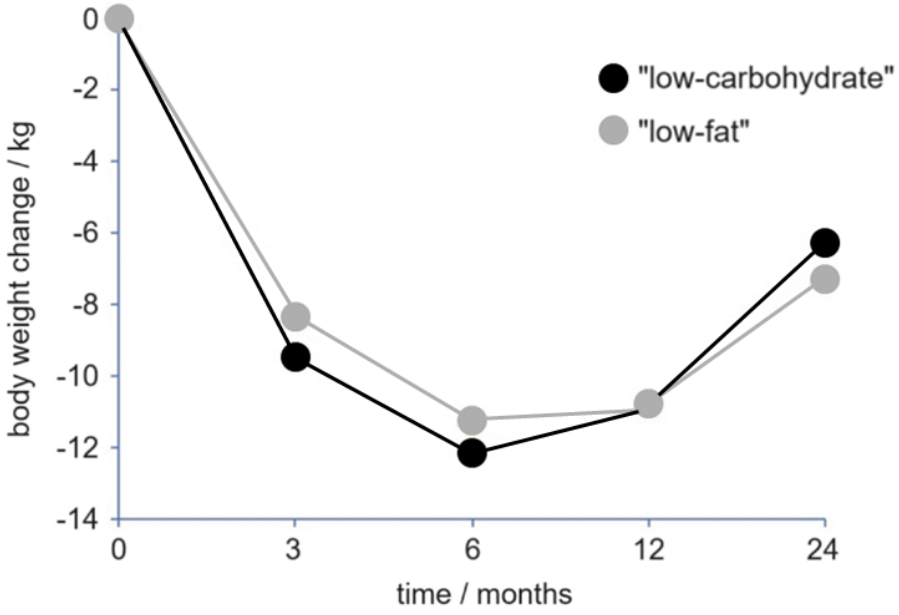

Fig. 2.1

(a) With reference to Fig. 2.1, compare the impact of weight loss of the low-carbohydrate and low-fat diets over a two-year period.

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…… [4]

(b) Fig. 2.2 shows the major pathways in insulin receptor signalling.

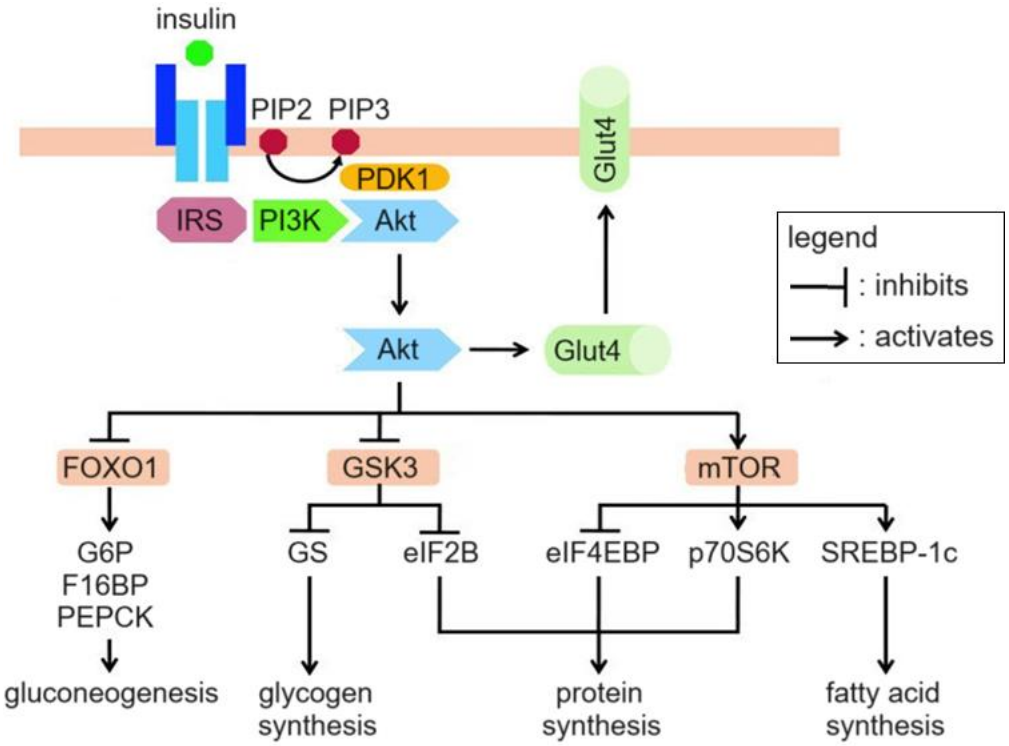

Fig. 2.2

Using Fig. 2.2 and your knowledge on glucose regulation in the body, suggest how a low-carbohydrate diet can help to facilitate weight loss.

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…… [3]

(c) The RQ value corresponds to the relative amount of CO_2 and O_2 involved in respiration and can provide information about the type(s) of substrate the body is using for energy.

Tripalmitin is a triglyceride. The chemical equation for aerobic respiration of tripalmitin is:

$$2\ C_{51}H_{98}O_6 + 145\ O_2 \longrightarrow 102\ CO_2 + 98\ H_2O$$

The formula for calculating the RQ value is:

$$RQ = \frac{\text{volume of } CO_2 \text{ liberated}}{\text{volume of } O_2 \text{ consumed}}$$

(i) Calculate the RQ value for tripalmitin. Give your answers to 2 decimal places.

Show your working in the space provided below.

[1]

(ii) Explain why the usual RQ value for respiration in humans is between 0.7 and 1.0.

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……..…… [1]

[Total: 9]

Question 3 starts on page 16.

3 Li-Fraumeni syndrome (LFS) is a rare, inherited genetic disorder that significantly increases the risk of developing various types of cancer, often at a young age, including breast cancer, sarcomas (cancers of connective tissues), brain tumours, and adrenocortical carcinoma (a rare cancer of the adrenal glands).

Fig. 3.1 shows the estimated probability of individuals with LFS being diagnosed with cancer in their lifetime when compared to normal individuals.

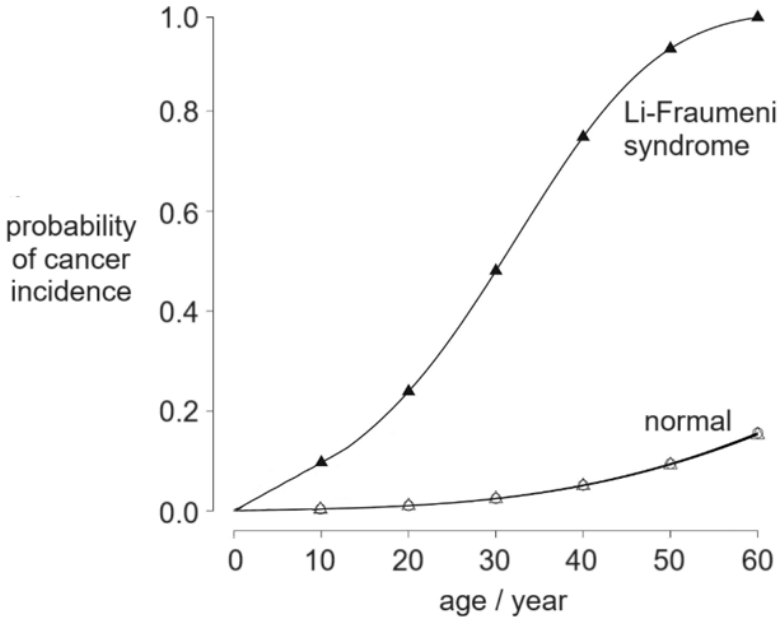

Fig. 3.1

Many individuals with LFS have a family history of multiple cancers, sometimes spanning several generations. This pattern of cancer occurrence helps in identifying the syndrome.

Research has shown that the disorder arises due to a mutation in the *p53* tumour suppressor gene occurring in germline cells.

(a) Give the evidence that supports the *p53* gene mutation occurring in germline cells and explain your answer.

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…… [1]

(b) (i) With reference to Fig. 3.1, describe how Li-Fraumeni syndrome affects an individual's probability of developing cancer.

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(ii) Using your knowledge on cancer development, explain your answer in **(b)(i)**.

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(c) Young people with LFS can lead fulfilling and relatively normal lives, but their experiences may be different from those of their peers due to the heightened risk of cancer and the necessary precautions. They often undergo regular screenings and check-ups to detect any signs of cancer early. This can mean frequent medical appointments, imaging tests, and sometimes preventive treatments.

Coping with the risks associated with LFS and the possibility of cancer can be emotionally challenging for young people with LFS. Nonetheless, these youths should stay away from less healthy coping mechanisms, such as vaping.

E-cigarette vapor contains a variety of chemicals, some of which are known to be harmful. For instance:

- Nicotine: While nicotine itself is not classified as a carcinogen, it can promote tumour growth and progression by influencing cell proliferation and survival.
- Formaldehyde: It is a known carcinogen and can be found in some e-cigarette liquids, particularly when heated to high temperatures.
- Acrolein: Another harmful compound, acrolein can irritate tissues and contribute to inflammation and oxidative stress.

Suggest how acrolein may increase the risk of cancer development.

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…… [1]

(d) Researchers explored a technique known as gene therapy to treat patients with LFS. The steps are shown in Fig. 3.2.

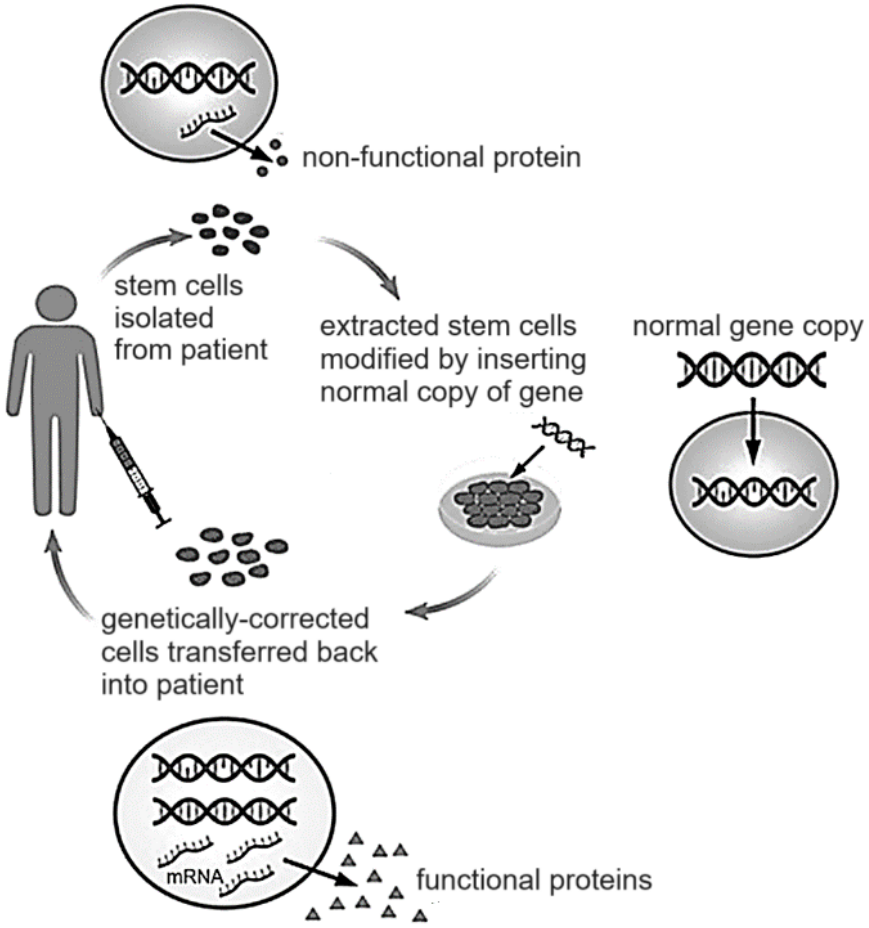

Fig. 3.2

Identify the type of stem cells extracted from the patient and describe the features of this stem cell.

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…… [3]

[Total: 11]

Section B

Answer **one** question in this section.

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.

4 Glucagon is an important protein found in most vertebrates. It functions in the regulation of glucose metabolism.

(a) Describe the roles of named RNA molecules in the synthesis of glucagon. [15]

(b) Discuss the advantages and disadvantages in the use of glucagon to determine phylogeny between species. [10]

[Total: 25]

5 The immune system consists of a complex network of organs, cells and proteins. It plays an important role in defending the body against infections by pathogens, as well as cancer.

(a) Describe the roles of named proteins in the activation of the humoral immune response. [15]

(b) Explain how viral infections may contribute to the occurrence of cancer. [10]

[Total: 25]

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