H2 ANDERSON SERANGOON JUNIOR COLLEGE
HIGHER 2

2025 JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME								
CLASS	2	5	/			INDEX NUMBER		

BIOLOGY 9744/03

Paper 3 **26 August 2025**
Long Structured and Free-response Questions **Tuesday**

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

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graph.
Do not use paper clips, highlighters, 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 spaces 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.

For Examiner's Use	
1	/ 25
2	/ 25
3 or 4	/ 25
Total	/ 75

At the end of the examination, fasten all your work securely together.

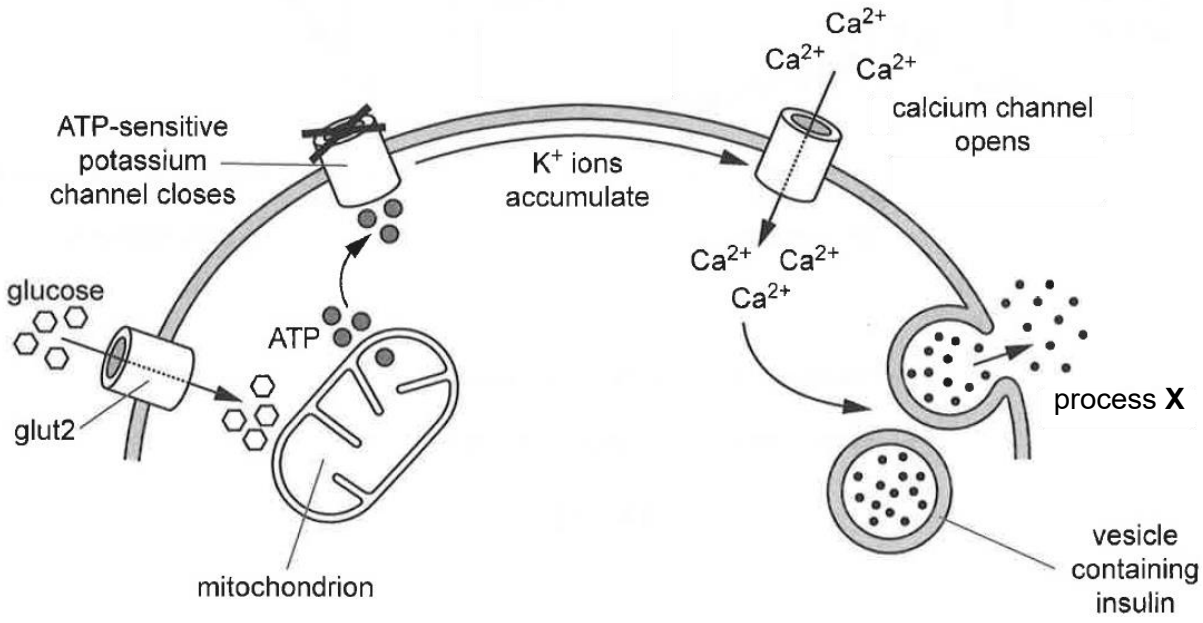
The number of marks is given in brackets [ ] at the end of each question or part question.

Section A

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

1 The prevalence of type 2 diabetes is steadily increasing. Diabetes occurs either when the pancreas fails to synthesise enough insulin or when insulin resistance develops. Insulin resistance is when the body is unable to respond to insulin.

(a) Fig. 1.1 outlines the basic mechanism involved in the release of insulin from pancreatic β cells in response to increased blood glucose concentrations.



not to scale

Fig. 1.1

(i) Fig. 1.1 contains the following substances, which are **not** given to scale:

glucose ATP Ca^{2+} insulin

Arrange the substances in order of **increasing actual** physical size.

……[1]

(ii) Glucose enters the pancreatic β cell via glut2.

Outline how glucose is used to increase ATP concentration in the cell in Fig. 1.1. In your answer, highlight specific locations in the cell.

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……[5]

(iii) Identify process **X and** explain its significance in Fig. 1.1.

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……[2]

(b) In one study, the effect of blood glucose concentration on insulin secretion was investigated in two groups of people:

- people who do **not** have diabetes
- people who have diabetes.

In the first experiment, glucose solution was given **orally** to the people in both groups. Each person was given a drink of 50 g of glucose in 400 cm^3 water. At short time intervals, blood glucose concentrations were recorded for each person, starting from 10 minutes before drinking the glucose solution (–10 minutes) up until three hours after (180 minutes).

In the second experiment, which took place several days later, the same people in both groups were given glucose solution that is **directly injected into the blood stream** throughout the whole period of the experiment (3 hours 10 minutes). The amount of glucose injected was constantly adjusted to give the same blood glucose concentrations that were recorded in the first experiment at the corresponding times. Blood glucose concentrations were recorded for each person at the same short time intervals used in the first experiment, from –10 minutes to 180 minutes.

The results for blood glucose concentration are shown in Fig. 1.2.

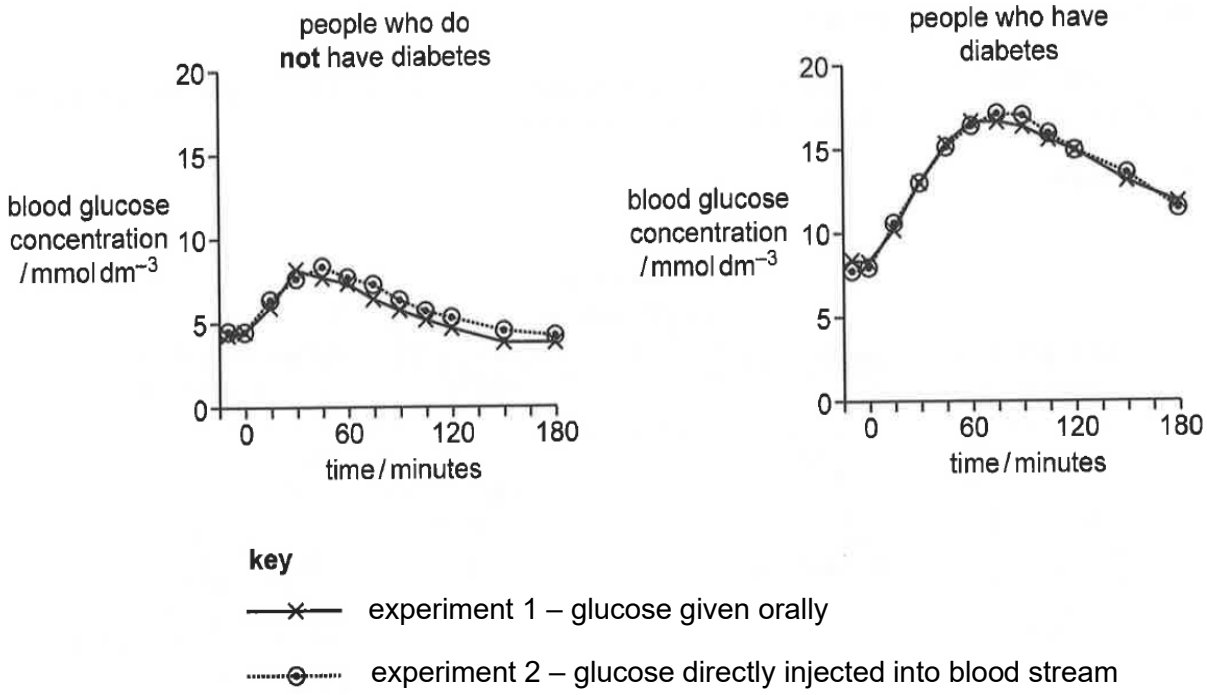

Fig. 1.2

With reference to Fig. 1.2, compare the effect of glucose given orally on the blood glucose concentration of people who do **not** have diabetes with the effect on people who have diabetes.

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……[3]

(c) Table 1.1 shows the mean rate of insulin secretion in the two groups of people in the study. It shows that the rate of insulin secretion depends partly on whether glucose is taken orally or directly injected into the blood stream.

Table 1.1

	mean rate of insulin secretion / nmol dm^{-3} min^{-1}	
	oral glucose	glucose directly injected into the blood stream
people who do **not** have diabetes	38.9	11.3
people who have diabetes	34.7	23.5

Using the data in Table 1.1, calculate the percentage change in the mean rate of insulin secretion when glucose is taken orally relative to when glucose is directly injected into the blood stream, for people who do **not** have diabetes.

Show your working in the space below.

percentage change = ……..[1]

(d) A proportion of the people in the study who have diabetes is unable to synthesise enough insulin. As a result, glucose uptake into cells is reduced and blood glucose concentrations remain high after eating.

Explain how insufficient insulin leads to reduced glucose uptake into cells.

In your answer, identify

- the specific cell surface receptor involved and
- an example of a cell which is significantly involved in glucose uptake when blood glucose concentration is high.

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……[4]

(e) The results of the study show that rates of insulin secretion are higher when glucose is given orally than when glucose is directly injected into the blood stream. This implies that blood glucose concentration is **not** the only factor responsible for controlling the rate of insulin secretion into the blood and that other mechanisms, additional to that shown in Fig. 1.1, must also act.

GIP (gastric inhibitory polypeptide) and GLP-1 (glucagon-like peptide 1) are two hormones produced by cells in the small intestine. These hormones have a role in controlling the secretion of insulin when food is ingested.

Table 1.2 compares the effects of GIP and GLP-1 in humans.

Table 1.2

process	effect of GIP on process	effect of GLP-1 on process
insulin secretion and synthesis	increases	increases
glucagon secretion	increases	decreases
pancreatic β cell apoptosis	decreases	decreases
pancreatic β cell replication	increases	increases
change in body mass	body mass decreases	body mass decreases
fat deposition	increases	no effect

To keep the effects of GIP and GLP-1 short-lived, both hormones are broken down by dipeptidyl peptidase-4 (DPP-4). As a result, most of the GIP and GLP-1 secreted from the small intestine is inactivated before reaching organs such as the pancreas.

Some people with diabetes benefit significantly from using drugs that act as DPP-4 inhibitors.

Using the information above including Table 1.2,

(i) explain why DPP-4 inhibitors could help treat diabetes.

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……[4]

(ii) suggest why the use of DPP-4 inhibitors for the treatment of diabetes may not always be beneficial.

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(f) DPP-4 is found in most cells as a transmembrane glycoprotein. However, it can also exist as a soluble glycoprotein in plasma and other body fluids.

The *DPP-4* gene has 26 exons and at least 13 different mRNA transcripts. Some of these mRNA transcripts are found in up to 40 different tissues and some tissues contain at least three different mRNA transcripts.

(i) With reference to the information above and your knowledge of proteins, compare the structures of soluble and transmembrane DPP-4.

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(ii) Suggest **two** ways in which both forms of DPP-4 can be produced from the same *DPP-4* gene.

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……..…….[2]

[Total: 25]

2 The human papillomavirus (HPV) is the primary cause of cervical cancer, with certain high-risk strains being responsible for approximately 70% of cervical cancer cases in females worldwide. HPV infections are primarily transmitted through sexual intercourse in sexually active adults and can be detected through screening.

Fig. 2.1 shows the number of cases of cervical cancer and death rate from cervical cancer in females of different ages in one year, in a particular country.

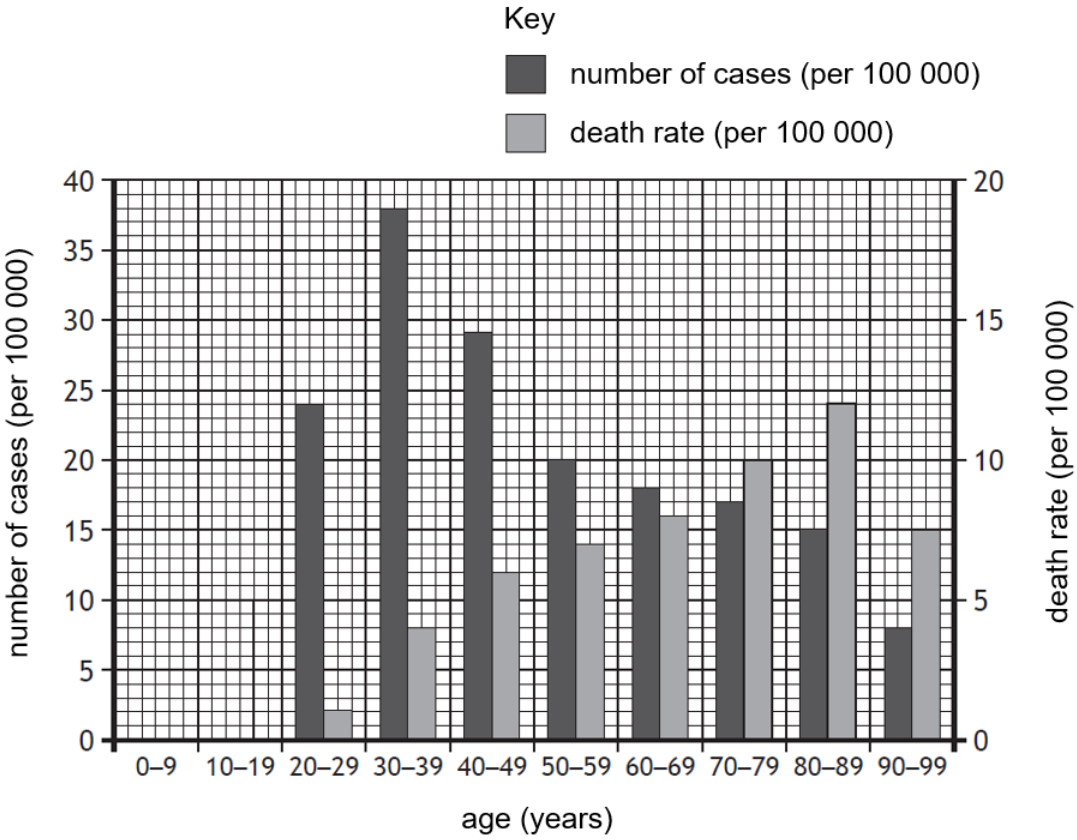

Fig. 2.1

(a) **(i)** Based on the information above including Fig. 2.1 and your own biological knowledge, describe **and** explain the number of cases of cervical cancer in females aged 0–39 years old.

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……[4]

(ii) Suggest a reason for the low number of cases of cervical cancer in females aged 90–99.

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(b) Fig. 2.2 shows the structure of the HPV.

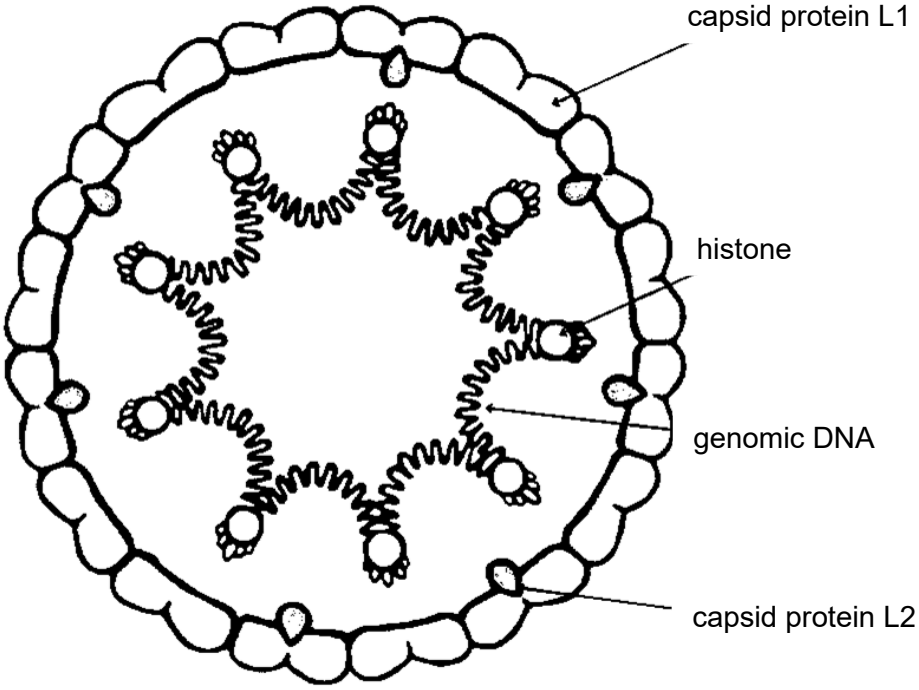

Fig. 2.2

With reference to Fig. 2.2, compare the structure of a HPV and an influenza virus.

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(c) The frequency of HPV and influenza vaccinations differ significantly for effective immunity. A single course of the HPV vaccine confers life-long immunity while influenza vaccination is usually recommended annually for immunity against the virus to be effective.

(i) Explain why influenza vaccines need to be administered annually.

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(ii) Explain how influenza vaccines can confer herd immunity.

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Question 2 continues on page 14.

(d) ASR scientists recently developed a novel HPV vaccine. They analysed levels of antibody titres as an indication of the extent of immune response.

The scientists proposed the null hypothesis:

"There is no difference between the antibody titres level in blood from people who are vaccinated and in the control group."

The scientists carried out a *t*-test to determine whether or not there was a difference between the antibody titres level in blood from people who were vaccinated and in the control group as shown in Table 2.1.

Table 2.1

group	mean antibody titre (AU/ml)	standard deviation	sample size
vaccinated	120	15	10
control	80	20	8

The number of degrees of freedom for a *t*-test is calculated by:

$$v = n_1 + n_2 - 2$$

key
v = degrees of freedom
n = sample size

(i) State the number of degrees of freedom for this *t*-test.

……..……[1]

(ii) Using the *t*-test formula provided below, calculate the *t* value.

Show your working.

$$t = \frac{\left|\bar{x}_1 - \bar{x}_2\right|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

Key to symbols
s = standard deviation*
n = sample size
$\bar{x}$ = mean

t value = ……..[1]

The critical values of *t* for the appropriate number of degrees of freedom at different probabilities are shown in Table 2.2.

Table 2.2

probability (p)	0.5	0.1	0.05	0.01	0.001
critical value	0.678	1.671	2.001	2.663	3.460

(iii) With reference to your answer in **(d)(ii)** and Table 2.2, conclude whether the vaccine produced by ASR scientists is effective in stimulating an immune response.

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(iv) Suggest a reason why your conclusion in **(d)(iii)** may not be valid.

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(e) Besides viruses, bacteria are another major group of disease-causing microorganisms that can cause mild to severe disease. Vaccines that are injected into people thus need to be tested to ensure that they are sterile (contain no live bacteria) and do not contain any endotoxins.

The pathogenic bacteria, *Chlamydia trachomatis, Escherichia coli (E. coli), Salmonella spp., Shigella spp.* have a special type of cell wall which contains endotoxins as shown in Fig. 2.3.

Endotoxins are lipopolysaccharide molecules.

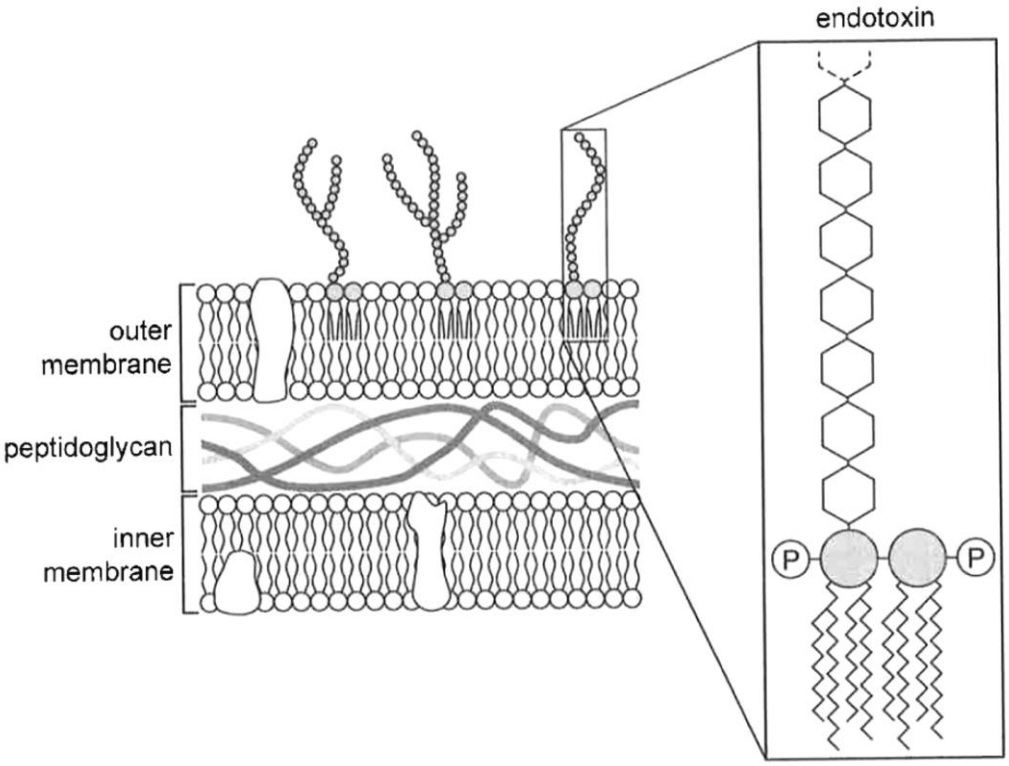

Fig. 2.3

(i) State **two** structural differences between phospholipids and the lipopolysaccharides in Fig. 2.3.

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Bacterial lipopolysaccharide (LPS) can trigger a strong innate immune response.

When LPS enters human wound fluid, it encounters a variety of innate immune proteins. These specific proteins rapidly form a protein aggregation (clump) with LPS.

(ii) Suggest an example of the innate immune proteins present in human wound fluid.

……..……[1]

The protein aggregation with LPS forms a cloudy suspension. The extent of aggregation can be assessed in two ways:

- method **1:** After the addition of LPS to the sample, measure the time taken for the cloudiness of the sample to reach a specific value for light absorbance, as measured using a spectrophotometer.

- method **2:** Use a colourless substrate that is converted to a blue product in the presence of LPS. Add the colourless substrate to the wound fluid before adding LPS. Measure the light absorbance of the reaction mixture after 10 minutes using a spectrophotometer.

(iii) Suggest a **disadvantage** for each of the two methods of assessing the extent of protein aggregation.

*method **1**:*

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*method **2**:*

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……..…….

[2]

[Total: 25]

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 sections **(a)**, **(b)**, as indicated in the question.

3 Multicellular organisms comprise many cells which perform various functions.

(a) Explain the processes which lead to cells in a multicellular organism being genetically identical and yet are able to perform different functions. [15]

(b) In humans, the diversity of cells includes mature red blood cells and plasma cells (B lymphocytes).

A student claims that a mature red blood cell has a higher protein composition relative to its lipid composition, compared to a plasma cell.

Discuss why the student's claim is valid. [10]

[Total :25]

4 **(a)** Human activities over the last few centuries have contributed to climate change through the accumulation of greenhouse gases.

Discuss the possible effects of the phenomenon above on the rate of photosynthesis of a typical C3 plant. [15]

(b) During periods of rapid environmental change, smaller plants often show greater survival rates compared to larger species.

Suggest and explain why, in a rapidly changing environment, small plants may be at an evolutionary advantage compared to large plants. [10]

[Total: 25]