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.

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.

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

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

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 represents, in outline, the basic mechanism involved in the release of insulin from pancreatic β cells in response to increased blood glucose concentrations.

not to scale

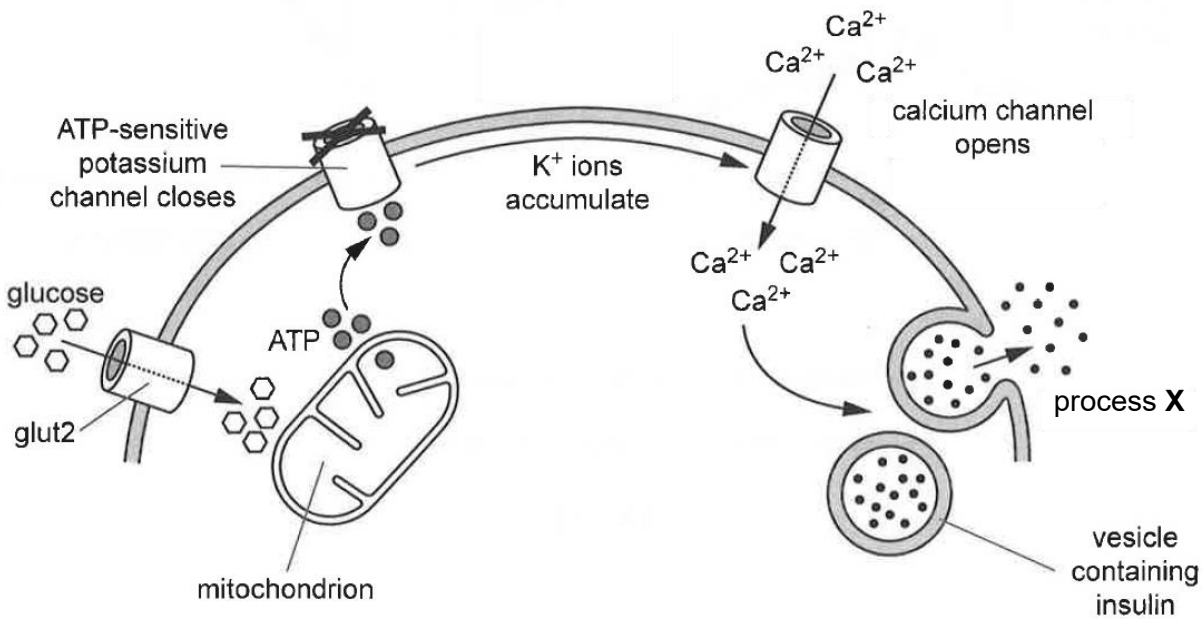

Fig. 1.1

(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]

1. **Ca^{2+}, glucose, ATP, insulin**

(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. [5]

(max 3 if at least one correct location is not given)

1. Glucose undergoes **glycolysis** in the **cytosol/ cytoplasm**
2. during which (2) ATP is produced via **substrate-level phosphorylation** *(pyruvate from glycolysis is decarboxylated during the link reaction to form acetyl-coA)*
3. **Acetyl-coA** undergoes the **Krebs cycle** in the **mitochondrial matrix**
4. during which (2) ATP is produced (per turn) via **substrate-level phosphorylation** *(award once only)*
5. **Electrons**/ **hydrogen** from carbon intermediates *(derived from glucose)* are used to **reduce NAD and FAD**/ **form NADH and $FADH_2$** (during glycolysis, link reaction and Krebs cycle)
6. and are used to produce ATP (a large amount of/ 34 ATP per glucose) during **oxidative phosphorylation** on the **inner mitochondrial membrane**
7. AVP, e.g. **ATP synthase** uses **ADP and inorganic phosphate** to make ATP, ATP leaves the mitochondrion via **carrier** protein

(iii) Identify process **X and** explain its significance in Fig. 1.1. [2]

1. **exocytosis**
2. releases a **large amount** of insulin **quickly/ simultaneously**

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). No glucose was given orally. 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.

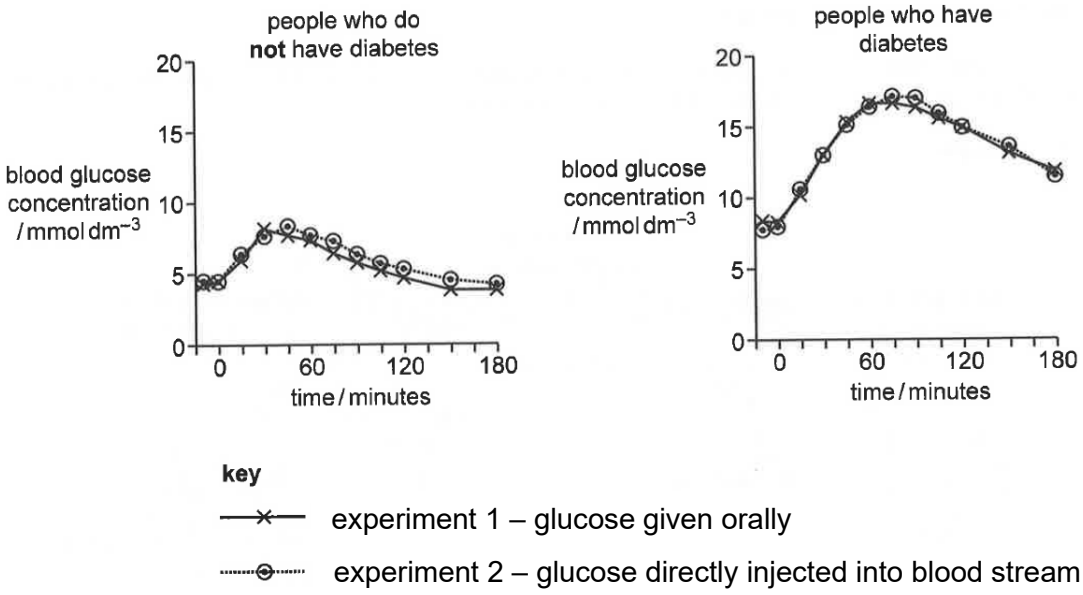

Fig. 1.2

(b) 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. [3]

1. Both led to an **increase in blood glucose concentration** followed by a (gradual) **decrease**

   (any 2)
2. peak glucose concentration in non-diabetes people is **1.6 times** *(accept: 1.5 to 2 times)* of baseline vs. significantly **higher** peak of **2.1 times** *(accept: 2 – 2.5 times)* in diabetes people
   (or quote absolute difference, i.e. 4 mmol dm^{-3} vs. higher 9 mmol dm^{-3})
3. peak glucose concentration in non-diabetes people occurred **earlier** at **30 min** vs. **75 min** in diabetes people
4. blood glucose concentration **returned to** the baseline of **5 mmol dm^{-3}** *(accept: 4)* by **180 min** in non-diabetes people vs. remained **higher** at **12 mmol dm^{-3} at 180 min** compared to the original 8 mmol dm^{-3}

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

(c) 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. [1]

percentage change for people who do not have diabetes
= (38.9 – 11.3) / 11.3 x 100%
= **244 %** (3sf)

(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. [5]

1. There are fewer insulin molecules available to bind to **tyrosine kinase receptors**
2. on the surface of fewer **liver/ muscle/ adipose cells**

Hence, there are fewer cells where (max 3)

3. receptor **dimerisation** and
4. **cross-phosphorylation of tyrosine** residues on intracellular receptor tails occur
5. leading to **a phosphorylation cascade** OR **kinases/ relay proteins phosphorylated** and hence activated
6. **vesicles** with **glucose carriers/ transporters** embedded
7. move towards the **cell surface membrane** and **fuse** with it

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.

(e) Using the information above including Table 1.2,

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

1. DPP-4 inhibitors **reduce the break down of GIP and GLP-1**
2. leading to **more active GIP and GLP-1** supplied to the **β cells of the pancreas**
3. which causes **decreased β cell apoptosis** and **increased β cell replication**, leading to **more (healthy) β cells** in the pancreas
4. more active GIP and GLP-1 also causes **increased insulin secretion and synthesis** (by the larger number of β cells), leading to **increased glucose uptake** by cells

(ii) suggest why the use of DPP-4 inhibitors for the treatment of diabetes may not always be beneficial. [1]

1. causes **decrease in body mass**/ **increase in fat deposition** + *(idea of)* undesirable for health
2. **does not treat** diabetes that is due to **insulin resistance**
3. AVP

(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. [2]

1. Both have an attached **carbohydrate chain**
2. DPP-4 as a transmembrane glycoprotein has **both hydrophilic and hydrophobic** amino acid residues on it surface but DPP4 as a soluble glycoprotein has **only hydrophilic** residues on its surface

(ii) Suggest two ways in which both forms of DPP-4 can be produced from the same *DPP-4* gene. [2]

1. **Alternative splicing** where all introns and some exons are removed, leading to **different combinations of exons** spliced together
2. **Post-translational modification** where the transmembrane/ hydrophobic region is removed/ *OWTTE* to form the soluble glycoprotein

[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.

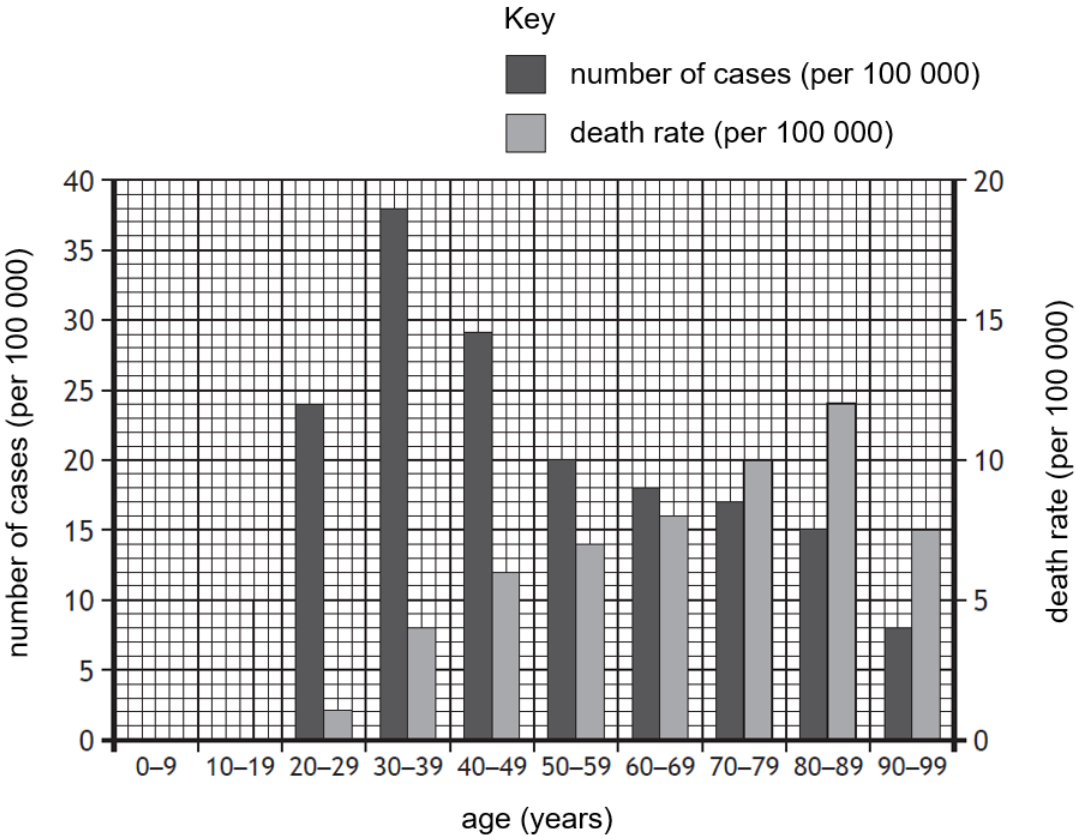

Fig. 2.1

(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. [4]

1. **[D]** No cases for 0-19 years old;
2. **[E]** as they are not sexually active yet/ no screenings (assume not yet sexually active);
3. **[D]** There are 24 cases per 100 000 for 20-29 years old females and an even higher increase to 38 number of cases per 100 000 at 30-39;
4. **[E]** as accumulation of mutation takes time/ tumour will metastasize only at later stages.

(ii) Suggest a reason for the decrease in the death rate from cervical cancer in females aged 90–99. [1]

1. Many females with cervical cancer have died before this age/ died of other causes;
   R not sexually active.

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

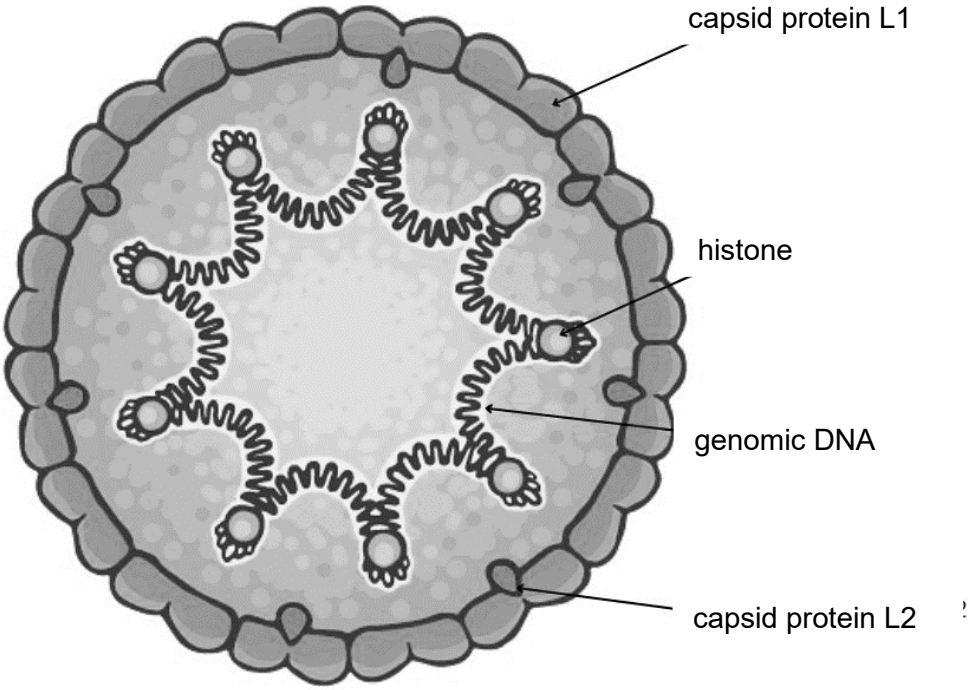

Fig. 2.2

With reference to Fig. 2.2, compare the structure of a HPV and an influenza virus. [3]

Similarities

1. The genome of both viruses are enclosed by a protein ***capsid*;*** OR
   Both viruses have a ***capsid**** which is made up of several individual protein subunits (capsomeres);

Differences:

[Max one from 2. to 6.]

2. The HPV genome is DNA, while the influenza genome is RNA;
3. The HPV DNA is double stranded, while the influenza RNA is single stranded;
4. The HPV has DNA associated with histone protein, while the influenza RNA does not associate with histone protein;
5. Circular genomic DNA vs linear RNA
6. Non-segmented DNA vs 8 RNA segments.

[Max one from 7. & 8.]

7. spherical capsid vs helical capsid head
8. The HPV has 2 types of capsid proteins, L1 and L2, while the influenza has only 1 type.

(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. [4]

1. Influenza virus's RNA genome has more mutations as RNA polymerase lacks proofreading OR HPV has a DNA genome, lesser mutations as DNA polymerase has proof reading capability.
2. Antigenic drift: The influenza virus **gradually evolve** under the selection pressure of virus-specific antibody stimulated during an infection.
3. This result in a gradual change to the **amino acid residues** in HA and NA.
4. Influenza's 8 RNA genome is also prone to Antigenic Shift: when **two or more different influenza viruses** infect a single host **cell** and the RNA genomes combine to form a new subtype having a **new surface HA or NA protein**.

(ii) Explain how influenza vaccines can confer herd immunity. [3]

1. Applies to population (not individuals).
2. Where a significant/ large proportion of the population is vaccinated
3. To protect the immune-compromised/ unvaccinated eg. elderly, children and pregnant women.
4. Fewer possible hosts to infect.

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 (number of observations)

(d) **(i)** State the number of degrees of freedom for this *t*-test. [1]

1. 10 + 8 – 2 = **16**

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

Show your working. [1]

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

Key to symbols

s* = standard deviation

n = sample size (number of observations) $\bar{x}$ = mean

Answer:

$$t = \frac{|120 - 80|}{\sqrt{\left(\frac{15^2}{10} + \frac{20^2}{8}\right)}} = \frac{40}{\sqrt{(22.5 + 50)}} = \frac{40}{\sqrt{72.5}} \approx \frac{40}{8.514} \approx \boxed{4.70}$$

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 t	0.678	1.671	2.001	2.663	3.460

(iii) With reference to your answer in **(iii)** and Table 2.2, conclude whether the vaccine produced by ASR scientists is effective in stimulating an immune response. [2]

1. With degrees of freedom ≈ 16, and t ≈ 4.70, calculated t value is larger than critical t/ the **p-value** is **less than 0.05**, indicating the **difference** is **statistically significant**.
2. The t-test shows that the vaccinated group had significantly higher antibody titres than the control group that is not due to chance. Hence the vaccine produced by ASR scientists is **effective in stimulating an immune response**.

(iv) Suggest a reason why your conclusion in **(iii)** may not be valid. [1]

1. **Small sample size** (i.e. 10 and 8) of two groups (vaccinated & control) of participants

(R: Different sample size for the vaccinated and unvaccinated.)

(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 need to be tested to make sure 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.* has a special type of cell wall which contains endotoxins as shown in Fig. 2.3.

Endotoxins are lipopolysaccharide molecules.

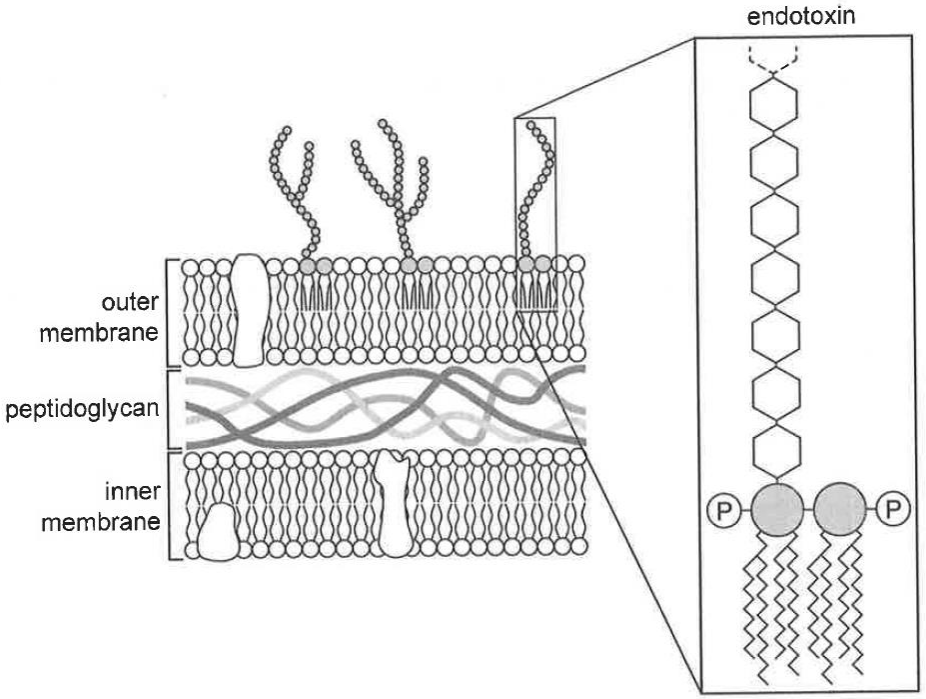

Fig. 2.3

(i) State two structural differences between phospholipids and the lipopolysaccharides in Fig. 2.3. [2]

1. Phospholipids have two fatty acid chains & LPS has 4 fatty acids chains with branching/8 chains.
2. Phospholipids have a phosphate head & LPS has 2 phosphate heads.
3. Phospholipids have none while LPS has a polysaccharide chain.

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]

1. Lysozyme/ complement proteins/ cytokines/ chemokines

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. [2]

*method **1**:*

- The time taken to reach a specific absorbance might take too long so time taken should be fixed.
- Different types of LPS from different pathogenic bacteria may have different affinity levels to bind to the proteins, thus reporting misleading quantitative levels for varying LPS types.

*method **2**:*

- Since **LPS** causes protein aggregation & therefore cloudiness, it could falsely elevate the absorbance reading of the mixture.

[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]

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.

(a)

[max 8 for MPs 1-10]
1. *ref. to* a multicellular organism developing from a single-celled **zygote**
2. via **mitosis**
3. *ref. to* genetically identical cells having the **same number and type of chromosomes**

(explain same number of chromosomes)
4. During **metaphase** of mitosis, **chromosomes** align in a **single row** at the equator, and are arranged such that each sister chromatid of a chromosome are on either side of the equator, facing opposite poles of the cell
5. During **anaphase**, **centromeres divide** and **sister chromatids are <u>equally</u> separated** into individual chromosomes/ **chromosomes are <u>equally</u> pulled apart** to opposite poles
6. When the **nuclear envelope reforms** during **telophase**, two daughter nuclei with the same number of chromosomes result

(explain same type of chromosomes)
7. During **S phase of interphase**, **<u>semi-conservative</u> DNA replication** occurs
8. where **each DNA strand** in a DNA molecule serves as a **template**
9. to synthesis a **complementary** strand *(such that two genetically identical DNA molecules result)*
10. *ref. to* two genetically identical **sister chromatids** held at centromere
11. **Crossing over also does not occur** during prophase, unlike during prophase I of meiosis

[max 8 for MPs 12-23]
12. *ref. to* stem cell **differentiation**
13. *ref. to* presence of **growth factors**/ **hormones**
14. causing **differential gene expression**/ specific genes to be switched off and others to be switched on
15. *ref. to* **DNA methylation**/ addition of methyl groups to cytosine residues
16. *ref. to* **histone modification**/ **histone acetylation**/ **histone methylation**
17. *ref. to* affecting how tightly DNA is packed, affecting gene expression
18. *ref. to* **activators** binding to **enhancers** to **increase** level of specific gene expression
19. *ref. to* **repressors** binding to **silencers** to **reduce** level of specific gene expression
20. *ref. to* post-transcriptional modification, e.g. alternative splicing
21. ref. to translational control, e.g. translation initiation factors
22. ref. to post-translational control, e.g. phosphorylation (to activate proteins), glycosylation etc
23. *ref. to* different specialised cells **expressing specific/unique set of proteins** *(hence having different structures and/or performing different functions)*

24. AVP, e.g. somatic recombination during B cell formation

QWC: at least 3 MPs each from 1 – 11, and 12 – 23

(b)

1. A mature RBC contains mostly **haemoglobin**
2. which are **quaternary** proteins/ each contains **two alpha- and two beta- chains**
3. for efficient/ maximum **transport of oxygen** around the body
4. *ref. to* RBC **lacking membrane-bound organelles**/ **nuclei**/ **endoplasmic reticulum**
5. *ref. to* **maximise space** to pack maximum amount of haemoglobin molecules
6. *ref. to* **cell surface membrane** being the only membrane/ phospholipid bilayer which the RBC has

7. A plasma cell's function is to **produce/ secrete antibodies**
8. which are **quaternary proteins**/ contain **two heavy and two light chains**
   (however, this total protein composition is comparatively lower than a RBC, as the plasma cell has a relatively higher lipid composition)
9. *ref. to* a plasma cell carrying out a high level of secretion of antibodies
10. hence has large amount of **rough endoplasmic reticulum**, where **ribosomes** synthesising antibodies are embedded/ **site of protein synthesis**
11. and large amount of **Golgi apparatus** to **chemically modify/ sort and repackage** antibodies
12. into large amount **of secretory vesicles** for **secretion/ exocytosis**
13. *ref. to* large number of **mitochondria** present to produce **ATP**
14. *ref. to* organelles involved in secretory pathway having **phospholipid bilayers**

15. AVP, e.g. enzymes involved in glycolysis found in cytoplasm of RBC/ glucose transporters found on the surface

QWC: differences in protein and lipid compositions discussed with reference to the functions of a red blood cell and a plasma cell, with at least 2 MPs each from 1 – 6 and 7 – 14

Question 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]

(a)

1. *ref. to* **carbon dioxide** as a greenhouse gas
2. increased carbon dioxide levels in the atmosphere leads to **increased rate of the Calvin cycle/ light-independent reactions**
3. **carbon dioxide fixation** occurs where **CO_2 combines with RuBP**
4. fixed by **rubisco**
5. followed by **PGA reduction** to form **G3P** involving **NADPH** and **ATP**
6. **2 G3P** combine to form **1 glucose**
7. and **RuBP regeneration** involving **ATP**
8. *ref. to* glucose polymerised to form **starch** for storage/ **cellulose** as structural support
9. *ref to.* **increased plant growth**

10. ref. to increased greenhouse gases in the atmosphere **trapping more** reflected **heat**
11. leading to **global warming**/ increased **temperature**
12. which affects **enzymes** involved in the light-dependent and light-independent reactions *(or give named example, e.g. rubisco)*
13. which could lead to **increased rate of photosynthesis** if temperature is still **below optimum temperature** (of enzyme)
14. **beyond optimum temperature**, **rate of photosynthesis decreases** significantly
15. as enzymes begin to **denature**/ weak bonds holding tertiary structure/ active site are disrupted
16. increased ambient temperature also leads to **stomata closing** to **reduce excessive water loss/ transpiration**
17. leading to **reduced carbon dioxide uptake** which would **reduce the rate of the Calvin cycle**

18. AVP, e.g. *ref. to* temperature and carbon dioxide concentration being **limiting factors** of photosynthesis

QWC: effects of increased greenhouse gases on rate of photosynthesis discussed, with at least 3 MPs each from 1 – 9, and 10 – 17

(b)

1. smaller plants tend to have **shorter life cycles**/ **shorter generation time**/ **reproduce faster**
2. *ref. to* small plants possibly producing a **large number of seeds/ spores** relative to body size
3. **form large population quickly**
4. allowing for **rapid colonisation** of an area when conditions become favourable
5. *ref. to* **out-compete other plant species** for **limited resources**
6. *ref. to* larger populations being **resistant to the impacts of genetic drift**

7. faster reproduction also leads to **more mutations** occurring, creating **new alleles**
8. and **more recombination events**/ **crossing over**/ **independent assortment** creating **new combination of alleles** (if plant undergoes sexual reproduction/ meiosis)
9. leading to **increased genetic variation** in the population/ **higher chance** of **some individuals possessing advantageous traits**
10. allowing for individuals at the best selective advantage to **survive and pass down favourable alleles** to their offspring/ next generation

11. smaller plants **require less resources** to survive/ complete life cycle
12. due to **fewer cells** required to **form the whole organism**/ **fewer respiring cells**
13. *ref. to* **higher surface area to volume ratio** for **gaseous exchange**
14. *ref. to* smaller size leading to **faster water uptake/ distribution**
15. *ref. to* individuals **occupying less space**, so that **many plants/ larger population can occupy a limited area**

16. AVP, e.g. some smaller plants are **capable of both sexual and asexual reproduction**, depending on environmental conditions

QWC: at least 3 MPs each from two areas (1 – 6, 7 – 10, 11 – 15)