TEMASEK JUNIOR COLLEGE

2024 JC2 PRELIMINARY EXAMINATION

Higher 2

BIOLOGY **9744/03**

Paper 3 Long Structured and Free Response Questio **9 SEPTEMBER 2024**

2 hours

ANSWERS

Section A

Answer **all** questions in this section.

1 Tuberculosis (TB) is an infectious disease caused by the bacterium.

(a) **Define** the term infectious disease. [1]

1. **Infectious – caused by pathogens** (bacteria/virus) **passed from infected to uninfected person**

2. **Disease – cause health problems / illness / poor health / disorder**

(b) **State** the name of the pathogenic organism which causes TB and describe its mode of transmission.

Name of organism **Mycobacterium tuberculosis** **[1]**
[1/2 mark if everything is correct but underlined together]

Mode of transmission [1]

1. **uninfected person inhales / breathes in; [1/2]**

2. **Infected person coughs / sneezes / spits and release aerosol / droplet containing the pathogen; [1/2]**

(c) One example of a defence mechanism against pathogens in the lungs involves the action of macrophages.

(i) **State** the location in the body where macrophages are **formed**. [1]

(ii) **Outline** the mode of action of a macrophage. [2]

1. **Macrophage has receptors which recognize and bind pathogens**
   OR
   macrophage has Fc receptors which recognize and bind Fc region of antibodies bound to pathogens [1/2]
2. **Take in pathogen via receptor-mediated endocytosis / phagocytosis [1/2]**
3. **Forms phagosome with pathogen and lysosome fuse and hydrolytic enzymes breaks down pathogen [1/2]**

4. **Peptide antigen presented on cell surface / act as antigen presenting cell [1]**
5. **Involved in innate immunity [1/2]**
6. **Activate adaptive immune response. [1/2]**

(iii) It is sometimes possible for the pathogenic bacteria to survive within macrophages. Suggest **one** way in which these pathogenic bacteria may survive within a macrophage.[1]

Any one [1 mark]

1. **Bacteria inhibits fusion of phagosome with lysosome**
   Note: Do not write macrophage fuse with lysosome
2. **Bacteria inhibits the proton pump that acidifies the phagolysosome**
3. **Bacteria produce inhibitors to stop lysosomal enzymes from digesting.**
4. **Bacteria form spores which is resistant to digestive enzymes**

Reject: Bacteria mutate
Reason: This is too general and vague and does not state how it can survive.

(iv) The TB bacterium has many operons in its DNA. **Suggest one** advantage to the bacterial cell in having operons. [1]

Any one [1 mark]

1 Operons allow for **rapid response** by bacteria to **environmental change**.

2 An operon consists of a **cluster** of **structural genes** that are of **related functions** which are **transcribed** at the **same time** since they are **controlled by** the **same promoter** and **operator**.

3 Allow for the **rapid synthesis of important metabolites** which are **lacking** in the environment, or the **utilisation** of **substrates** that are **present**.
OR
The **cell conserves its energy and resources** by **producing** the **necessary enzymes only** when they are **needed**.

Table 1.1 shows recent information about TB cases reported during one year in six different countries.

Table 1.1 **this is not average**

country	region	number of cases	number of cases per 100 000 population
Germany	Europe	4000	5
India	Asia	2 300 000	185
Japan	Asia	27 000	21
South Africa	Africa	490 000	981
Swaziland	Africa	15 000	1287
United Kingdom	Europe	7900	13

(d) With reference to Table 1.1, **explain** the advantage of calculating the number of cases of TB per 100 000 population rather than stating the number of cases alone. [2]

1 mark each

1. **Number of cases per 100000 shows the proportion infected in a population.**

2. **Easier to determine the severity of the problem**
   OR
   Reliable for making comparisons between different countries
   OR
   More accurate representation of the seriousness of the infection in the country
   Reject: "standardisation" or "easy comparison"
   Reason: comparing number of cases is just as easy.

3. **As countries with larger populations will usually have more cases / higher number of cases may just mean larger population of country ;**

4. **quote comparative data to support [MUST HAVE];**
   QF: any country with higher number of cases but lower number of cases per 100 000 population compared with a country with lower number of cases but higher number of cases per 100 000 population
   E.g.
   India with 2300 000 cases which is higher than Swaziland with 15 000 cases
   but
   Swaziland has 1287 number of cases per 100 000 population has higher than India with only 185 cases per 100 000 population

Antibiotics are prescribed to people who have HIV for the treatment of secondary infections such as bacterial infections.

(e) **Explain** why antibiotics are prescribed to treat secondary infections, but not for HIV infection. [2]

1 mark each

1. **Antibiotics are only effective against bacteria**
   Reject: microbes or micro-organisms instead of stating bacteria
   OR
   Antibiotics not effective against viruses.

2. **Viruses do not have cell walls / ribosomes or named enzyme that antibiotic work on**
   [must have at least 1 e.g. of the antibiotic target; RNA polymerase without qualifying what type – only 1/2]

3. **Viruses are within cells, that antibiotics cannot reach them.**

Antibiotic rifampicin is observed to bind tightly to RNA polymerase molecule **close to** its active site.
This affects the activity of the enzyme during the synthesis of RNAs, involving the action of RNA polymerase.

(f) **Suggest two ways** in which rifampicin can affect the activity of RNA polymerase. [2]

Any Two:

1. **Alters shape of / large blocks active site of RNA polymerase**
   R enters / fits into, active site as it is not competitive
   R ref. to choice of competitive or non-competitive

2. **Substrates / nucleotides cannot bind to the active site of RNA polymerase**
   OR
   Lesser enzyme-substate complex formed.

3. **Complementary base pairs cannot form / form less easily between DNA template and RNA nucleotides;**
4. **Prevents unwinding / uncoiling of DNA double helix**
5. **Prevents RNA polymerase from recognizing and binding to promoter**
6. **Prevents RNA polymerase from reading DNA template ;**
7. **Prevents RNA polymerase from joining RNA nucleotides**
8. **Prevents RNA polymerase from catalysing formation of phosphodiester bond**
9. **Prevents sigma factor from binding to RNA polymerase.**

(g) RNA polymerase is composed of five different polypeptides. Gene *rpoB* codes for one of these polypeptides known as the **β**-subunit.

- One or more mutations in a specific region of *rpoB* **gene** result in strains of TB bacteria that are resistant to rifampicin.
- In these strains, mutations often occur in two DNA triplets, in positions **526 and 531**.

Table 1.2 summarises the results of an investigation into seven rifampicin-resistant strains, **A** to **G**, that have amino acid changes for positions **526 and 531**.

Table 1.2 includes:

- the change in the **mRNA codon** for position **526** or position **531**
- the amino acid change that has occurred
- the **minimum** concentration of rifampicin required to inhibit growth of the bacterial strain (MIC)
- the number of **other** mutations occurring within the specific region of *rpoB* gene.

Table 1.2

Key
≈ approximately ⩾ greater than or equal to ⩽ less than or equal to

strain	codon involved	mRNA codon change	amino acid change	MIC / μg cm^{-3}	number of other mutations in the specific region
A	526	CAC → UAC	His → Tyr	⩽50	0
B	526	CAC → AAC	His → Asn	⩾100	1
C	526	CAC → CGC	His → Arg	≈50–75	2
D	526	CAC → CGC	His → Arg	⩾100	3
E	526	CAC → CGC	His → Arg	≈50	3
F	526	CAC → UUC	His → Phe	⩾100	3
	531	UCG → UUG	Ser → Leu		
G	526	CAC → UAC	His → Tyr	⩾100	3
	531	UCG → UUC	Ser → Phe		

With reference to Table 1.2,

(i) complete Table 1.2 to show the amino acid changes that have occurred in strains **F** and **G**; [1]

(ii) **list** the **strains** of TB bacteria that show the **greatest resistance** to rifampicin; [1]

- **B D F G [in any order]**

(iii) **suggest reasons** to explain why strains **C**, **D** and **E** show different levels of resistance to rifampicin. [2]

1. **QF: C has 2 other mutations and D and E have 3 [1/2]**

2. **Types of other mutations are different. [1/2]**
   OR
   Other mutations may result in different changes to, structure β-subunit / enzyme, and result in different levels of resistance.
   OR
   Other mutations may cause more changes to the binding site of rifampicin [1/2]
   [binding ability link back to pre-amble on page 4]

3. **QF: Strain D has highest resistance requiring ≥ 100 μgcm^{-3} of antibiotic to kill it.**
   while Strain E has lowest resistance requiring ≈ 50 μgcm^{-3} of antibiotic to kill it. [1/2]

4. **Strain D has lower binding abilities to rifampicin while strain E has higher binding abilities to rifampicin. [1/2]**
   OR
   Harder for rifampicin to bind to D than E or C.
   [binding ability link back to pre-amble on page 4]

5. **Lower resistance due to other mutations have a greater effect on RNA polymerase, leading to RNA polymerase carrying out slower rate of transcription. [1/2]**

In a different study involving HIV, it has been theorized that HIV evolved from Simian virus moving from chimpanzees and sooty mangabeys to infect humans.

Studies on a particular strain of Simian virus, SV40 has been shown to induce tumours in laboratory animals by causing cells to divide in an unregulated way.

Large T antigen (Tag) is a protein encoded by the SV40 genome. This protein is essential for SV40's tumour-forming capabilities. Tag has been shown to bind to and inactivate the tumour suppressor p53 protein.

(h) **Give one** role of p53 protein in a normal cell. [1]

- **Stimulate DNA repair / arrest/inhibit cell cycle / initiate apoptosis / programmed cell death/act as transcription factor for some genes / checks DNA for damage or length of telomeres.**

(i) **Explain how** the interaction of Tag with p53 protein would disrupt the normal control of cell division. [2]

½ mark each

1. **p53 protein cannot control the G_1 checkpoint of cell cycle.**
   R
   Cells undergo uncontrolled cell division without being stopped at the G_1 checkpoint.

2. **p53 protein cannot monitor the integrity of DNA**
   OR
   p53 protein cannot check for DNA damage and length of telomeres of chromosomes.
   OR
   p53 protein cannot detect DNA damage or cannot detect that the telomeres are too short,

3. **p53 cannot prevent the cell from entering the S phase from G_1 phase.**
   Damaged DNA will be replicated, passed to daughter cells.

4. **p53 protein cannot initiate apoptosis**
   OR
   Cannot activate genes involved in apoptosis resulting in no cell death

5. **p53 protein cannot act as a transcription factor for several genes,**
   OR
   p53 protein cannot activate the transcription of various genes

6. **Special DNA repair enzymes to repair the damaged DNA are not produced.**
   OR
   DNA is not repaired.

7. **Mutations accumulate in single cell / daughter cells.**

Human papillomavirus (HPV) is another virus that inhibits p53. HPV can cause the development of cervical intraepithelial neoplasia (CIN), which leads to cervical cancer.

A recent study in Scotland assessed the impact of vaccination against HPV on the development of CIN.

Fig. 1.1 shows the effect of HPV-vaccination on the percentage of women found to have the most severe grade of CIN.

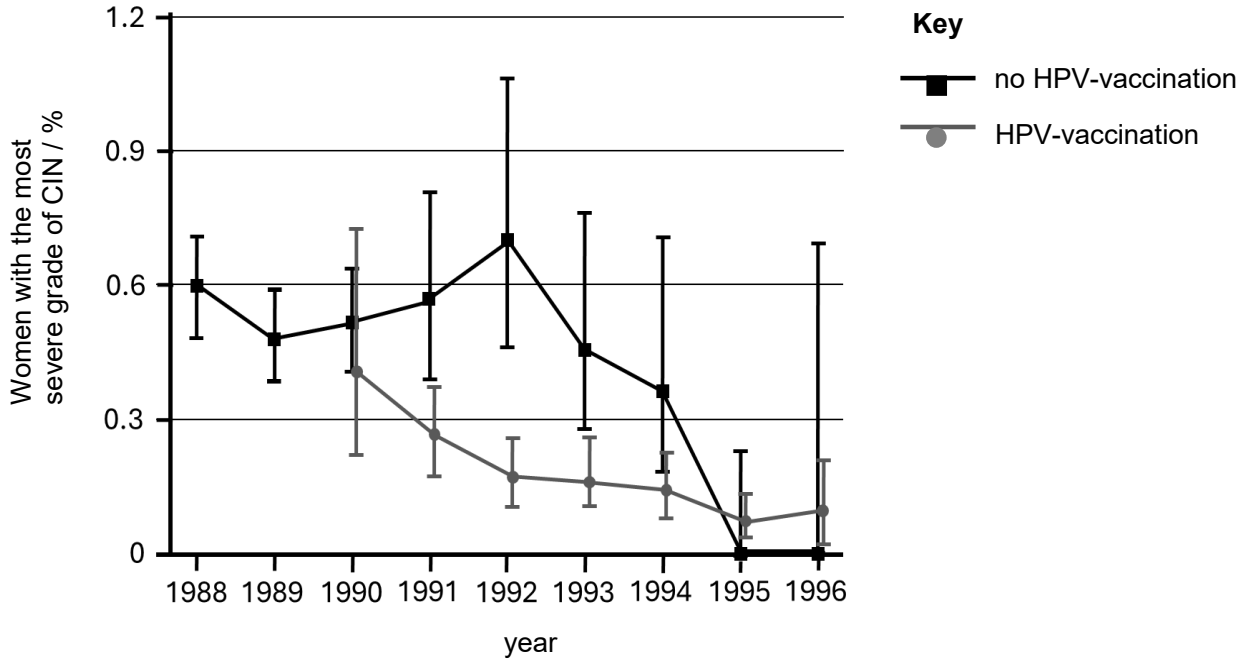


Fig. 1.1

(j) **Explain** how the data supports the suggestion that vaccination against HPV is effective in preventing development of CIN in **both** groups of women. [2]

[1/2 mark each]:

1. **From 1990 to 1996, there is a steep decrease of incidence of CIN in vaccinated women from 0.4% to 0.1%.**

2. **Herd immunity is achieved from 1992**
3. **Non-vaccinated women seemed to be protected**
4. **From 1992 to 1996, there is also a sharp decrease in incidence of CIN in non-vaccinated women from 0.7% to 0%.**
   Note: marking pt 4 mark is given ONLY if point 2 or 3 is in students' ans.

(k) Apart from vaccination, human antibodies have been used in the treatment of some forms of cancer. However, the antibodies injected into the bloodstream can only reach a small percentage of the cancer cells located at the cancerous tumour.

Scientists discovered that some of the antibodies in the blood plasma of sharks have a different structure to the human antibodies.

Fig. 1.2 shows the structure of an antibody molecule found in the blood plasma of a shark.

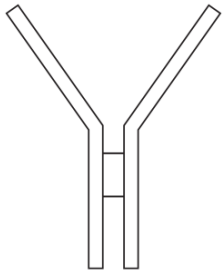


Fig. 1.2

(i) State how the quaternary structure of a human antibody molecule differs from the quaternary structure of the shark antibody molecule shown in Fig. 1.2. [1]

- **Human antibodies are made of four polypeptides while shark antibody only has 2 polypeptide chain.**
  OR
  Human antibodies contain two light chains and two heavy chains while shark antibody only has two heavy chains
  Note: only ½ mark if student only mentions present or absence of light chains.

(ii) Shark antibodies are smaller than human antibodies. Scientists are researching the possibility of injecting shark antibodies into the bloodstream to treat cancerous tumours in humans.

Suggest how using the smaller shark antibodies may be more effective in reaching a greater percentage of cancer cells than human antibodies, leading to greater success at treating cancer. [1]

any one from [1 mark each]:
Smaller shark antibodies:

1. **Easier to pass through gaps in capillary wall**
2. **so more shark antibodies enter tissue fluid (surrounding tumour cells) ;**
3. **Easier to squeeze between cancer cells to reach more cancer cells in the center of the tumour.**
4. **Bind more effectively / tightly to antigens on cancer cells.**
   Therefore, more cancer cells destroyed quickly

The presence of specific antibodies can also be used to detect diseases.

NMO is a disease that leads to damage of nerve cells in the spinal cord. A person with NMO produces anti-AQP4 antibody that attacks only these nerve cells.

Scientists measured the concentration of anti-AQP4 antibody in the blood of people with NMO. For each person, the scientists also determined the number of small bones known as vertebrae surrounding damaged nerve cells.

Each dot in the graph represents one individual in the study.

Their results are shown in Fig. 1.3.

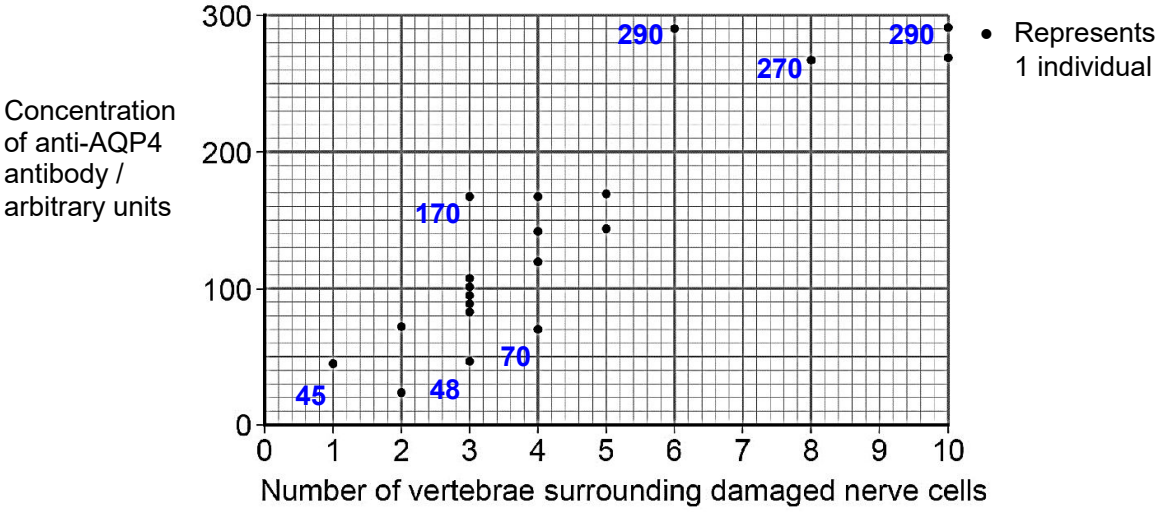


Fig. 1.3

(I) A scientist hypothesized that the concentration of anti-AQP4 antibody in a person's blood can be used to predict the number of vertebrae surrounding damaged nerve cells.

Using the information in Fig. 1.3, comment with reasons if this hypothesis is valid. [3]

[1/2 mark each]

1. **Not valid**
2. **Idea: A few individuals with different number of vertebrae surrounding damaged nerve cells but have the same concentration of anti-AQP4 antibody.**
   E.g. Individuals with 3, 4 and 5 vertebrae have the same concentration of anti-AQP4 antibody of 170 a.u.
   Note: Just need to provide 1 QF for this idea

3. **Correlation is weak / data is not reliable / not accurate.**
4. **Idea: For the same number of vertebrae, there are individuals with different concentrations of anti-AQP4 antibody**
   E.g. For 3 vertebrae , one individual has low levels of antibody of 45a.u. while another individual has 170a.u.
   Reject: 3 vertebrae have a range of antibody concentrations.
   Reason: Each dot is a different individual.
   OR
   Idea: Some individuals with low number of vertebrae, has high concentrations of anti-AQP4 antibody.
   E.g. Individual with 6 vertebrae, has higher levels of antibody of 290a.u. than another individual with 7 vertebrae of 270a.u.
   Note: Just need to provide 1 QF for this idea
5. **Small sample size of only 20 in the study.**
   OR
   Only one study was done
   OR

No statistical test done
OR
Other factors may have affected the number of vertebrae
OR
Correlation does not imply causation.

6. **Hypothesis is valid**
7. **As number of vertebrae surrounding damaged nerve cells increases from 1 to 10, the concentration of anti-AQP4 antibody increases from 45% to 290%.**
   OR
   Individual with 1 vertebra has low concentration of antibody of 45 a.u. and individual with high vertebrae number of 10 has high concentration of anti-AQP4 antibody of 290 a.u.
   Note: ALWAYS QF IV 1st

[Total: 28]

2 *Myosotis* is a genus of small flowering plants. Many different *Myosotis* species grow on the islands of New Zealand, which are an important site of *Myosotis* evolution. Lowland *Myosotis* species grow at low altitude while alpine *Myosotis* species grow at high altitude at the tops of mountains.

Fig. 2.1 shows the three largest New Zealand islands.

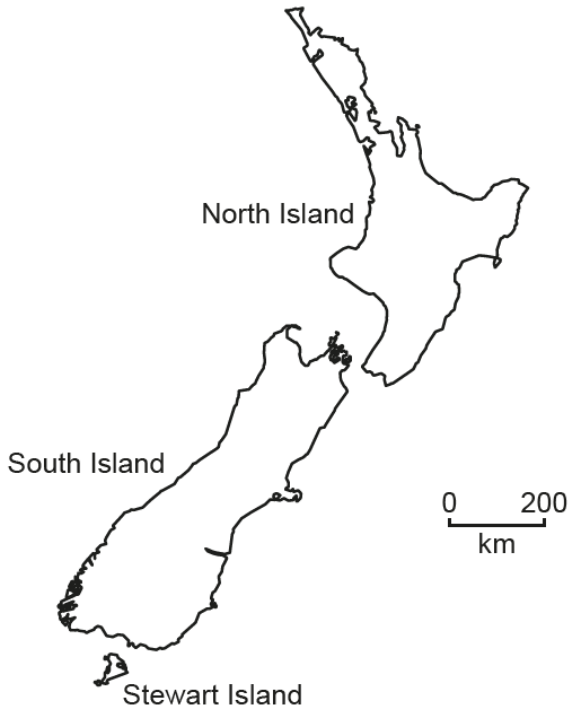


Fig. 2.1

Habitats of each island:

- North Island has mostly lowland habitat.
- South Island and Stewart Island have mountains with alpine habitats that are above the treeline.

Scientists wanted to obtain molecular data to determine the evolutionary relationships of New Zealand's *Myosotis* species. They extracted DNA from individuals of *Myosotis* species collected from three different islands in New Zealand.

DNA sequence data for three *Myosotis* species were compared. The results are described as follows:

.

1 In the alpine species *M. pygmaea*, individuals on South Island showed genetic differences from individuals of *M. pygmaea* on Stewart Island.

2 In the alpine species *M. pulvinaris*, individuals from different mountains on South Island showed genetic differences.

3 In the lowland species *M. pottsiana*, individuals from different areas of North Island showed overall genetic similarity.

(a) Discuss reasons for the results regarding the DNA sequence data of the three species. [5]

[must have]
1. Individuals of *M. pygmaea* on South Island and Stewart island are geographically isolated / separated by sea or water

[must have]
2. Individuals of *M. pulvinaris* are geographically isolated / separated by mountains

3. Different mountains and different islands with different selection pressures ;
4. Each population accumulate different mutations ;
5. Natural selection operate in each population leading to different changes in allele frequencies
6. there is no interbreeding, no gene flow between populations ;

7. genetic differences accumulate within each population / undergo independent evolutionary changes
8. can lead to allopatric speciation.

***M. pottsiana* / North Island species – genetic similarity:**
9. no geographical isolation, / lowland thus ease for cross pollination
10. interbreeding / gene flow, occurs, within / between, population(s) ;

(b) State **two** factors, other than natural selection, that **could drive genetic changes** in populations of *Myosotis*. [2]

1. **genetic drift / bottleneck / founder effect - marked as 1 point**
2. **Genetic mutation**
3. **Disruption of gene flow / no gene flow (reject gene flow)**

A large number of alpine plant species grow in the mountains of South Island. Alpine plants are defined as plants that live above the treeline, which is the height above which trees cannot grow. Many of South Island's alpine species live nowhere else in the world.

Fig. 2.2 shows two aspects of the history of South Island over the last 3.9 million years.

- The dashed line shows how the mean height of mountains in the Clyde region of South Island increased over time. The mountains in this range have a mean height of 2400 m at the present time.

- The solid line models the height of the treeline over time based on geological climate data. The treeline was higher when the climate was warmer, and the treeline was lower when the climate was colder, during ice ages.

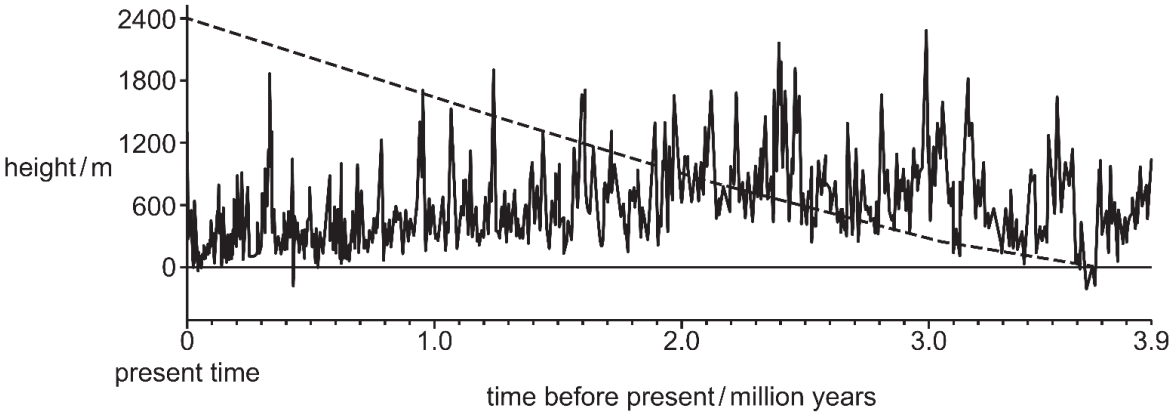


Fig. 2.2

(c) With reference to Fig. 2.2, identify with reasons the time period when South Island's alpine plant species developed. [2]

any TWO from:

1. **time period = from 0.95 million years (to present) @ 1 million years ago ;**
2. **Height of mountains <u>exceed</u> height of treeline ;**
3. **this provides alpine, habitat / region / niches ;**

(d) Describe **two** advantages of using DNA sequence data in reconstructing phylogenetic relationships. [2]

Any two

1. This / molecular method can be **<u>used for</u> <u>all living organisms.</u> <u>All</u>** living organisms **<u>have</u>** <u>nucleic acids / **DNA**</u> so valid comparisons can be made.

2. This / molecular method can be **<u>used for dead or living organisms</u>** as long as **<u>DNA is available</u>**. (Note that **NOT ALL EXTINCT animals** form fossils and **NOT ALL fossils** contained DNA. – thus careful phrasing of the answer is needed so that answer does not give idea that ALL fossils contain DNA)

3. This / molecular method is **more accurate in establishing evolutionary relationships of organisms** because it **avoids pitfalls of convergent evolution**
   - Reject: It avoids convergent evolution without stating that it is more accurate.

4a. This / molecular method is **objective and quantitative**. **Molecular data** is **converted** to **numerical form** for **statistical analysis** and **computation**. The **degree of relatedness** is **inferred** by calculating **number of nucleotide differences between species.**

4b. DNA sequences in the form of A, T, C and G are unambiguous. Thus, differences in DNA sequences between organisms can be determined **objectively**.

5. This / molecular method allows scientists to **predict the degree of relatedness** :
   - The **more recently** two species **branched from** a **common ancestor**, the **more similar their DNA** and amino acid sequences would be.

OR

   - The **number of mutations** accumulated can be used to **indicate how closely related the species** are.

OR

   - The **number of mutations** accumulated can be used as an indication of **how long ago they became separate species**.

6. This / molecular method can be used to **evaluate relationships** :
   - **Compare species** that are **morphologically very similar** (*"looks very similar"*) to ascertain whether it is due to convergent evolution or they belong to the same species or very closely related.

OR

   - **Compare species** that are **morphologically very different** (*"looks very different"*) but may only slight genetic differences. E.g. it has been determined that fungi are more closely related to animals than plants.

7. This / molecular method allows **evolutionary history** of organisms can be **traced**.
   - **rRNA genes** **changes relatively slowly,** use for **investigating earlier branching points** e.g. hundreds of millions of years ago

OR

   - **Non-coding regions** **evolves rapidly,** used for **exploring recent evolutionary events**.

8. Molecular data can be used for calibrating the molecular clock. Based on the number of differences between the DNA sequences of homologous regions, the rate of mutation may be determined.

9. Molecular data offer a large set of characters that can be analyzed. Compared to the limited number of morphological characters, each nucleotide position can be considered a character with 4 character states – A, T, C and G.

[Total: 11]

3 The β-globin gene codes for the β-globin polypeptide of haemoglobin. It has two alleles, HbA (normal) and HbS (sickle cell).

There are three possible genotypes and phenotypes.

- HbS HbS, sickle cell anaemia, a severe disease
- HbA HbS, sickle cell trait with mild or no symptoms of sickle cell anaemia
- HbA HbA, normal (healthy)

(a) Explain why the mutation in the β-globin gene cause the HbS haemoglobin to form fibres. [2]

1. **Single base substitution / Thymine replaced by adenine**

   (@ triplet code on DNA template CTC changed to CAC ; codon on RNA - GAG changed to GUG), reject T replaced by A)

2. **Glutamine with hydrophilic R group is replaced by valine with hydrophobic R group**

3. **When oxygen is low, Hb molecules form hydrophobic interactions and stick together to form fibres.**

The mutation of the β-globin gene which gives rise to sickle cell anaemia also removes a recognition site of a restriction enzyme **R**, as shown in Fig. 3.1.

Enzyme **R** cuts DNA at the sites indicated by arrows (↓). The lengths of the resulting fragments are shown in kilobases (kb).

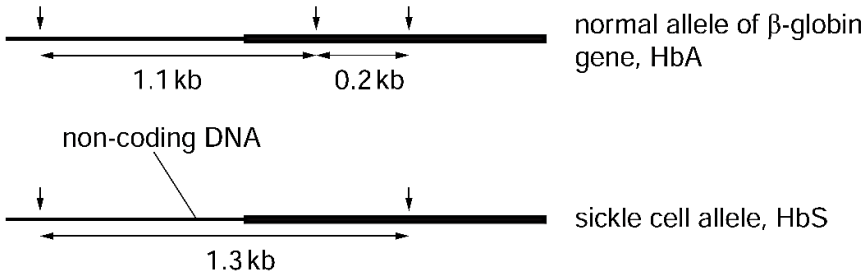


Fig. 3.1

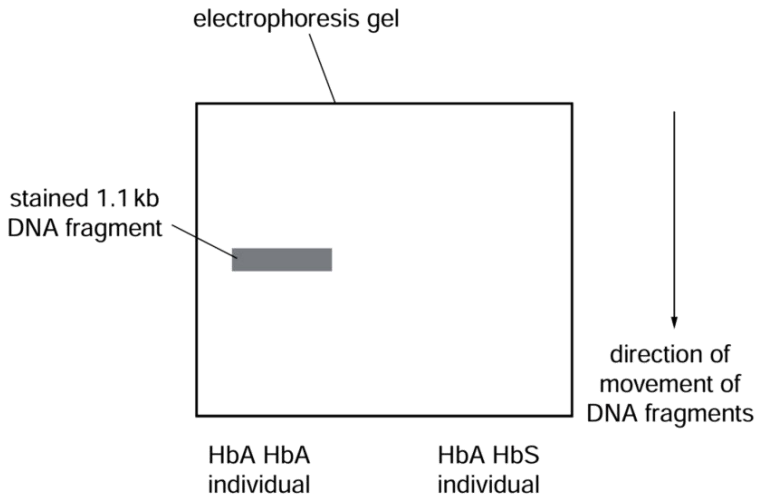


Fig. 3.2

Fig. 3.2 shows an electrophoresis gel with a DNA banding of an individual who is homozygous for the normal allele for β-globin, HbA HbA.

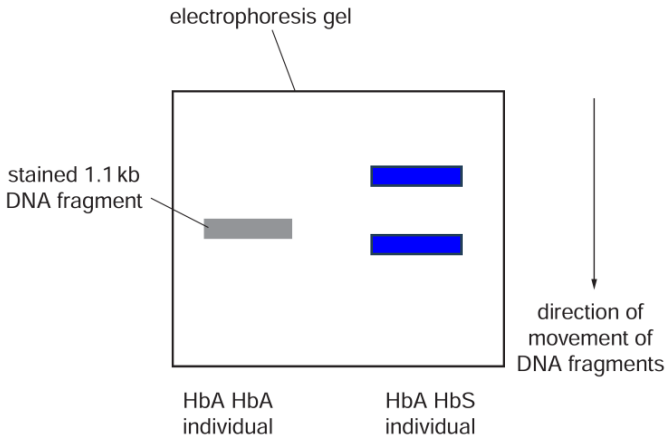
This band is the 1.1 kb fragment shown in Fig. 3.1. The location of 0.2 kb fragment is **not** shown in Fig. 3.2 due to the position of the bound radioactive probe.

(b) With reference to Fig. 3.1 and Fig. 3.2,

(i) state where the radioactive probe has bound on the normal and sickle cell allele; [1]

- **Non-coding region**
  OR
- **On to the 1.1 kb region**

(ii) complete Fig. 3.2 by drawing the DNA band that would result from an individual who is heterozygous for the sickle cell allele, HbA HbS; [1]



(iii) explain the position of the bands in **(b)(ii).** [3]

1. **Normal allele has 3 recognition sites.**
2. **The HbA allele digested with enzyme R.**
3. **results in 2 DNA fragments of 0.2kb, 1.1kb in size.**

   For the mutant HbS allele, a substitution mutation, resulted in the loss of a recognition site,
4. **Mutated HbS allele has only 2 recognition sites.**
5. **The HbS allele digested with enzyme R results in 1 DNA fragment of 1.3kb in size.**
6. **Probe only bind to the 1.1 kb and 1.3kb fragments**

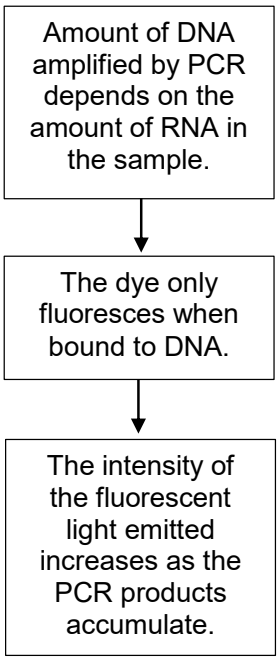
   Therefore only 2 bands at 1.1 kb and 1.3kb position.

One way to detect and measure accurately the amount of RNA in a tissue sample is by RT-PCR (reverse transcriptase-polymerase chain reaction).

RT-PCR uses a reaction mixture containing:

- the RNA sample for testing
- reverse transcriptase
- DNA nucleotides
- primers
- DNA polymerase
- fluorescent dye.

The principle behind this method is shown in Fig 3.3.



Concepts:
1. Reverse transcriptase (RNA -> cDNA)

Fig. 3.3

(c) Any DNA in the tissue sample is hydrolysed by enzymes before the sample is added to the RT-PCR reaction mixture. Suggest why this must be done before RT-PCR. [1]

1. To remove any wanted DNA present;
2. Do not want this DNA would be amplified/replicated;

Fig. 3.4 shows the results from using RT-PCR to detect RNA in two different samples, **A** and **B**.

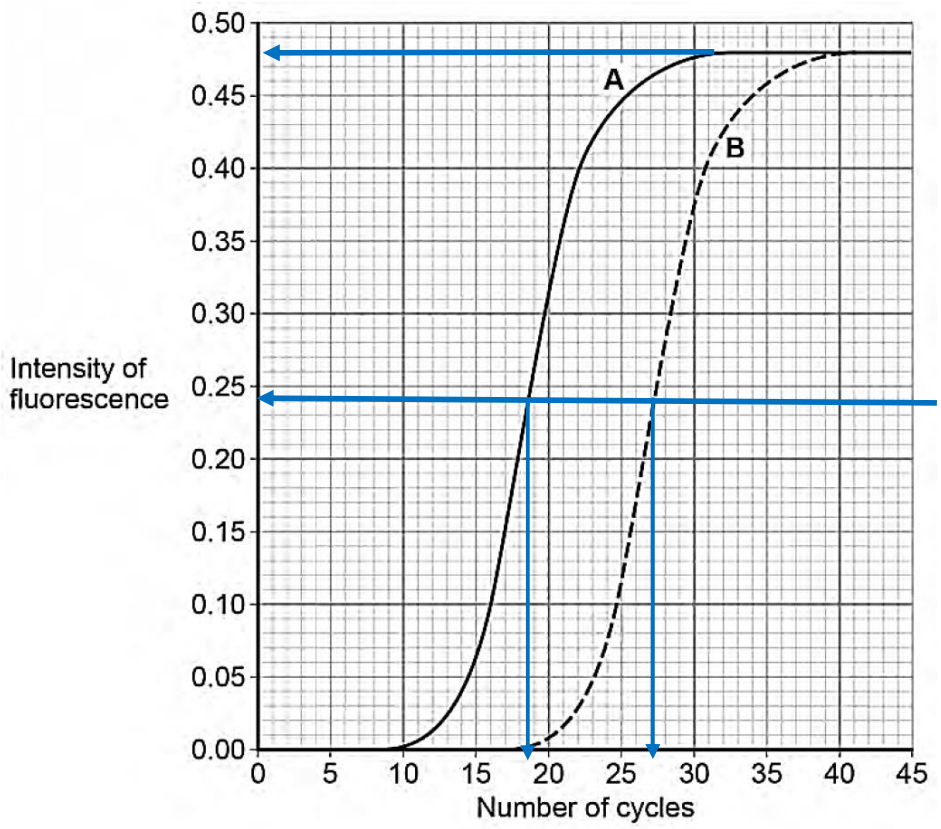


Fig. 3.4

A quantitative comparison can be made of the amount of RNA in samples **A** and **B**.

This involves determining the number of cycles required to reach 50% maximum concentration of DNA (**C**).

The amount of RNA in a sample can be measured as: 1 ÷ **C**

(d) Use the information in Fig. 3.4 to calculate the the RNA content in sample **A** and RNA content in sample **B**. Give your answer to **three significant figures.**

Note: Working not required

Accept
Sample A: 1/18, 1/18.5, 1/19
Sample B: 1/27, 1/27.5

Sample **A** **0.0541**

Sample **B** **0.0370** [1]

(e) Suggest **one** reason why DNA replication stops in the polymerase chain reaction. [1]

- **Primers/nucleotides used up as the reaction proceed.**
- **Limited primers/nucleotides left as the reaction proceed.**
  Accept: DNA polymerase (eventually)denatures

(f) Scientists have used the RT-PCR method to detect the presence of different RNA viruses in patients suffering from respiratory diseases.

Explain why a variety of different primers is required for this procedure. [1]

1. **RNA of different viruses have different base sequences;**
2. **Different complementary primers required;**

[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 **(a)** Using named examples, distinguish between inducible and repressible systems of regulation in a prokaryote and explain how the inducible regulation allows the bacteria to respond to varying concentrations of lactose. [12]

QWC:
1. **Paragraph (P)**
2. **Differences addressed + named examples (D)**
3. **Lac operon addressed (L)**

Max 5

Inducible system of regulation	Repressible system of regulation	
1. **Lac operon**	2. **Trp operon**	
3a. An inducible operon is one where it is **usually turned off** **3b. but can be stimulated / switched on (induced)** when an **inducer allolactose** binds allosterically to its regulatory protein.	4a. A repressible operon is one where its transcription is **usually turned on** 4b. **but can be inhibited (repressed)** when the **co-repressor tryptophan** binds allosterically to its regulatory protein.	3a & 4a **[1]** 3b & 4b **[1]**

5. **Regulatory gene** (upstream to the operon) **codes for** an **active repressor**	5. **Regulatory gene** (upstream to the operon) **codes for** an **inactive repressor**	**[1]**
6. If the **inducer is absent,** the **repressor** (**active**) binds to the operator and transcription is **turned off** **OR** If the **inducer is present,** the **inactive repressor cannot bind** to the **operator** and transcription is **turned on.**	6. If the **corepressor is absent**, the **repressor** (**inactive**) cannot bind to operator and transcription is **turned on.** **OR** If the **corepressor is present,** the **active repressor binds** to the **operator** and transcription is **turned off.**	**[1]**
7. **Involves an inducer** to cause the **operon** to be **switched on**	7. **Does not involve an inducer** for the operon to be switched on	**[1]**
8. **Does not require a co-repressor** to bind to the repressor in order to change it to an active conformation.	8. **Involves a co-repressor** to **bind** to the **repressor** to **change** it to **active conformation**.	**[1]**
9. Involves **both negative** and **positive control**. OR Involves **negative** and **positive control and catabolite repression.**	9. Involves **only negative control**.	**[1]**
11. The **repressor** is **inactive** when the **inducer binds.**	11. The **repressor** is **inactive without** the **co-repressor binding** to it.	**[1]**
12. The **gene products** are involved in **catabolic reactions**.	12. The **gene products** are involved in **anabolic reactions**.	**[1]**
13. It is an **inducible operon with inducible genes** OR The **inducible genes code** for **inducible enzymes**	13. It is a **repressible operon with repressible genes** OR The **repressible genes code** for **repressible enzymes**	**[1]**

Max 6

When lactose is present in the environment.

14. A **membrane protein**, ***lac* permease transports lactose** from the **outside into** the **cell**.
15. **Allolactose** is **formed** when **lactose** enters the cell and is **cleaved / converted by β-galactosidase**.

16. **Allolactose binds** to the **lac repressor** and **changes** it to the **inactive** **[MUST HAVE]** **conformation**.
17. It is now **unable** to **bind** to the **operator**.
18. The *lac* operon is "**switched on**" OR **negative control is removed.**
19. **RNA polymerase** is able to **bind** to the **promoter** to **transcribe** the genes of the *lac* operon.
20. β-**galactosidase**, **lac permease** and **β-galactoside transacetylase** are **produced.**
21. **β-galactosidase** will **hydrolyse lactose into glucose and galactose**.
22. A **small amount** of **lactose** result in a **small amount of glucose formed**
23. As **amount of lactose increases** (being transported in), lac operon stay **switched on for a longer period of time**, and **more glucose** will be **formed**.
24. **When glucose increase,** this will cause the **cAMP concentration to decrease**.
25. Without cAMP, **catabolite activator protein (CAP) changes to its inactive conformation** and **disengages from** the **CAP-binding site**.
26. As a result, the *Lac* operon is **not transcribed even though lactose was present** OR catabolite repression.

27. When the **levels of glucose decreases** as it is used up by the cell for respiration
28. The levels of **cAMP increases** which **binds** to the allosteric site on **CAP** which changes toan **active shape**

29. Inactive CAP and **binds** to the **CAP-binding site** upstream of the lac promoter.
30. The **attachment** of **CAP bends** the **DNA**, which makes it **easier** for **RNA polymerase** to **bind** to the **promoter**.
31. The Lac operon genes are **transcribed** at a **high rate** as long as lactose is present OR presence of positive control.

(b) With reference to examples, describe the effect of climate change on the relationship between living organisms. [13]

QWC:

1. **at least 3 different types of living organisms (3)**
2. **mention the relationship between living organisms, at least once. (LO)**
3. **Paragraphing (P)**

Effects of climate change [1/2 each effect]	Impact on living organisms [1/2]	How does the impact affect other organisms (relationship) [1/2]
A. Increased in temperature (max 7m for this category)	1. Animals / insects move to areas/ waters that are cooler.	a. competition with other species for food and other resources b. ecological disruptions as predators become separated from their preys/loss of biodiversity c. lead to loss/extinction of certain species

	2. some insects not being able to finish the developmental cycle 3. affect metabolic / respiratory enzymes, increase / speed up life cycles of bees	a. drop in predator and increase in food source of these insects
	4. Higher temperature and increasing drought will affect various ecosystems that the Monarchs butterflies rely on as they migrate.	a. asynchronous with flowering seasons affecting reproduction of plants.
	5. plants gradually shift upwards to a higher altitude and latitude where temperature is lower.	a. Lower altitude pests may move to higher latitudes, causing new problems for farmer's crops b. reduces the breeding area for many birds and the grazing areas for land animals.
	6. Plants that are already at high altitude/latitude will not have cooler regions to migrate to, as such, they could go extinct;	a. Reduce food source for primary consumers.
	7. Insects are cold-blooded, migration of insects to higher altitude/latitudes which is cooler. 8. increases the metabolism rate of mosquitoes, and this hastens the life cycle of mosquitoes. 9. More feeding on flower nectar by male mosquito 10. Shorten developmental time of mosquito increases its survival rate as egg, larvae and pupae are less susceptible to predators, diseases and parasitism 11. Reduce extrinsic incubation period of virus	a. Increased feeding on human blood by female mosquito b. virus reproductive cycle shortened -> infective earlier c. Overall lead to increase in transmission of dengue or malaria in human.
B. Increase in greenhouse gases (CH_4, CO_2)	1. Due to increase in CO_2 level. C3 plants, increase rate of photosynthesis thus increase plant growth (C3 plants)	a. Increased food source for other organisms.

	2. Enhance the growth of aquatic plants (e.g. seagrasses) and algae due to a higher concentration of CO_2 which increases their rate of photosynthesis.	b. Algal bloom on the ocean's surface prevents sunlight from reaching the aquatic plants. They are unable to photosynthesise, resulting in death. The decomposition process depletes oxygen levels in the water, causing other aquatic organisms to die.
C. Melting of sea ice / ice sheets	1. loss of habitats for algae and plankton and polar bears. 2. Reduce hunting grounds for polar bears. 3. Reduce resting platforms thus lead to overall decrease in polar bear population.	a. decrease population of ice algae will affect the population of zooplankton that feed on ice algae; which is in turn eaten by cod, and in turn eaten by seals, overall reduction in population of cod and seals (food for other living organisms). b. will affect the other organism, causing imbalance within the ecosystem at artic.
D. Ocean acidification	1. Affected calcifying organisms (e.g. corals, planktons, shellfishes and molluscs). -> have a weaker shell and do not grow well in lower pH, hence threatening their survival and reproduction. Corals have a symbiotic relationship with zooxanthellae. 2. The corals will expel the symbiotic photosynthetic algae, zooxanthellae, that live within their tissues, resulting in coral bleaching.	a. reduce food sources for marine organisms. b. loss of habitats for marine organisms c. reduce food sources for marine organisms.
E. Melting of ice caps / glacier / ice bergs leading to increase sea levels	1. Increased flow of seawater into estuaries, increasing salinity content of freshwater streams, thus affecting the animals and plants in the streams.	a. Has implications on organisms living there (e.g. decrease in freshwater fish species, increase in saltwater fish species).
F. Extreme weather conditions (heavy rainfall/flood)	1. soil erosion and rising sea levels may result in the loss of habitats to animals and plants. [optional: e.g. disappearance of the Bengal tigers' mangrove forest	a. Removal of top predator will result in increased numbers of preys population / imbalance food web.

	habitat, thus threatening their survival.]	
G. Extreme weather conditions (droughts)	1. Decrease in population of milkweed plant, which Monarch butterflies rely on as a breeding ground 2. Decrease in population of nectar-heavy wildflowers, which Monarch butterflies rely on as a food source;	a. Decrease of butterflies might affect pollination of some flowers, and affect population of animals that preyed on the butterflies / caterpillars.
H. Melting of permafrost	1. Dormant / ancient bacteria and viruses that were trapped in frozen organic matter, ice and permafrost are now exposed. 3.	a. transmitted to cause disease in living organisms.

Max 7m for category A.
Max 3m for categories B – G.

Markers comments:
1. **This is a very open question, thus mainly idea marking.**
2. **Recommend format of answer: First describe the specific effect of climate change, followed by the impact of the effect on living organism (animals/plants/coral reefs/algae/insects etc) -> followed by describing the how does the change in those living organisms affect the other living organisms (reflecting the relationship between various organisms.)**
3. **Students did quite well for this part.**

[Total: 25]

5 **(a)** Explain how the structures of polysaccharides in plants allow them to carry out their functions.
[12]

QWC:
1. **Paragraphing (P)**
2. **Must have both polysaccharides (2P)**
3. **At least 1 S-F r/s each (sf)**

Starch [1/2m], Max 6 marks

Function (1/2m each)

1. **Major storage** in plants.
2. **Can be easily hydrolyse to glucose** when required.

Structural features of starch in relation to its function:

Structural features (1/2m each)	Significance and contribution to function (correct match -1/2m each)
1. It is a **large molecule** made up of many **α-glucose** residues.	a. It is **insoluble** in water and thus **prevented from diffusing out** of cells. b. It can be **stored in large amounts without having any great effect on water potential** of cells.
2. Helical structure of amylose and amylopectin form **compact structures.**	a. **Storage** of **large amounts of glucose** within a fixed volume. b. Starch molecules accumulate to form **starch grains**.
3. It is a **highly branched structure**.	a. Many **free ends** for **enzymes** to **bind** and **hydrolyse starch**. b. **More glucose** can be **released** at a **faster rate**.

Cellulose [1/2m each], Max 6marks

A. Function [1/2m each]

1. found in all **plant cell walls**
2. **structural support** for the plant.

B. Structural features of cellulose in relation to its function:

Structural features (1/2m each)	Significance and contribution to function (correct match -1/2m each)
1. **Alternate β-glucose molecules rotated at 180° to each other** to form **β(1-4) glycosidic bonds**, resulting in **straight chains**. 2. **Hydroxyl groups project outwards** from each chain.	a. Both features **allow for many H-bond cross-links** can be formed between **neighbouring cellulose chains**, thus b. conferring **high tensile strength.**
3. **Cellulose chains associate** into **bundles** of **microfibrils**, which **combine** to form **macrofibrils**.	a. Contributes to **high tensile strength**. b. Cellulose cell wall **prevents cells from bursting** when water molecules enter by osmosis when placed in a medium of **higher water potential**.
4. Presence of **large inter-molecular spaces** between **macrofibrils**.	a. Allows the cellulose layers (cell wall) to be **permeable** to water and solutes.
5. It is a **large molecule**.	a. Makes cellulose **insoluble** in water, making it a **suitable structural polysaccharide**.

Markers comments:
1. **Note this is quite an easy question.**
2. **Must match correctly structure – function.**
3. **Need to be clear in describing the structures.**
4. **NOTE: Glycogen is NOT found in PLANTS.**

(b) Describe the molecular structure of the plasma membrane and with named examples, explain the role of membranes involved in transport of substances involving a plant cell and its organelles. [13]

[STRUCTURE OF MEMBRANE] [Max 3]

1. **Membrane is a phospholipid bilayer.**

2. **a. Hydrophilic phosphate heads of phospholipids face / outwards aqueous exterior and interior of cell / organelle.**
   b. Hydrophobic fatty acid tails of phospholipids sandwiched between hydrophilic phosphate heads.

3. **a. Intrinsic / Integral proteins**
   b. embedded in membrane.

4. **a. Extrinsic / Peripheral proteins**
   b. attached loosely to membrane (on either side).

5. **a. Glycoproteins and glycolipids in the**
   b. outer layer of phospholipid bilayer.

6. **a. Cholesterol**
   b. between phospholipids / –OH group interacts with phosphate heads & hydrocarbon skeleton interacts with fatty acid tails of phospholipids

7. **Fatty acid tails of the phospholipids can be saturated or unsaturated.**

8. **a. Membranes are asymmetric in structure:**
   b. The outer and inner layers of membrane differ in composition and function.

ROLES IN MEMBRANES INVOLVED IN TRANSPORT IN ORGANELLES OF PLANT CELLS]

[Award generic ideas only once if mentioned again in various organelles]

G1 **All plasma membranes are partially permeable.**

G2 **The phospholipid bilayer form a hydrophobic boundary OR have a hydrophobic core.**

G3 **Non-polar and small molecules can diffuse directly across the membrane.**

G4 **Polar molecules and charged ions cannot diffuse directly across, require hydrophilic channel to diffuse across the membrane.**

G5 **Water molecules are polar but small, therefore a small number of water molecules can move directly across the membrane via osmosis.**

G6 **Large number of water molecules can move across hydrohilic channel of aquaporin via osmosis.**

G7 Active transport OR ion pump transport ions can across the membrane against concentration gradient and energy from ATP.

G8 Cell surface membrane is fluid and can invaginate to form phagocytic vesicles to take in solid particles.
OR
Cell surface membrane is fluid and can invaginate to form pinocytic vesicles to take in liquid particle.
OR
Cell surface membrane is fluid and after virus or bacteria bind to the cell surface receptor, membrane invaginate to carry out receptor-mediated endocytosis.

[Chloroplast Membranes] [Max 2]

1a. Outer membrane of chloroplast contains transport proteins / channel proteins to
1b. allows water-soluble molecules to enter intermembrane space

2a. Thylakoid membrane has electron carriers
2b. to transport / transfer electron to final electron acceptor / NADP.
2c. to pump H^+ from stroma into thylakoid space.

3a. thylakoid membrane has ATP synthase with hydrophilic channel
3b. allow H^+ to diffuse from thylakoid space into stroma so that energy released for ATP synthesis

4a. thylakoid membrane is impermeable to H^+ [SAME as G4]
4b. to create a steep proton gradient for chemiosmosis.

[Mitochondria Membranes] [Max 2]

5a. Outer membrane of mitochondria contains transport proteins known as porins
5b. that allow water-soluble molecules to enter intermembrane space

6a. Inner membrane has electron carriers
6b. to transport / transfer electron to final electron acceptor / O_2.
6c. to pump H^+ from matrix into intermembrane space.

7a. Inner membrane has ATP synthase with hydrophilic channel
7b. allow H^+ to diffuse from intermembrane space into matrix which releases energy for ATP synthesis by ATP synthase.

8a. Inner membrane is impermeable to H^+ ions
8b. which allows a steep proton gradient to be created.

[Nucleus Envelope] – Max 1

9a. Membrane of nucleus has nuclear pore complexes (which surround nuclear pores)

9b. control movement of water-soluble substances between nucleus and cytoplasm. [Accept if following examples are given]
OR
9b. Entry of free DNA and RNA nucleotides, RNA polymerase, Transcription Factors
OR
9b. Exit of mature mRNA, tRNA, ribosomal subunits

[Rough Endoplasmic Reticulum Membrane] – Max 1
10. rER membrane has receptor protein to provide channel for polypeptide to enter lumen of rER as protein synthesis proceeds / OWTTE.

11a. rER membrane forms ER vesicles which bud off
11b. to transport proteins to Golgi apparatus / OWTTE.

[Golgi apparatus Membrane] – Max 1
12a. GA membrane forms secretory vesicles
12b. to transport substances to cell surface membrane for exocytosis
OR
vesicles move to the center of plant cell to transport material for formation of new cell plate.

[Lysosome Membrane] – Max 1
13. lysosome membrane has proton pump to actively transport H+ into the lysosome to maintain low pH.

[Smooth Endoplasmic Reticulum Membrane] – Max 1
14a. Formation of ER vesicles that
14b. to package and transport lipids and carbohydrates to Golgi apparatus / OWTTE.

[Secretory vesicle Membrane] – Max 1
15a. Gogi vesicle membrane form secretory vesicles
15b. to transport substances to cell surface membrane for exocytosis / secretion.

QWC
1. P: Separate paragraphs (P)
You should have many separate paragraphs.
Do not just have 2 big paragraphs.
You can even have different paragraphs -
2. M – described structure of membrane.
3. 3O – role of membrane in 3 organelles.

[Total: 25]