H

TEMASEK JUNIOR COLLEGE

2023 JC2 PRELIMINARY EXAMINATION

Higher 2

TEMASEK JUNIOR COLLEGE

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER				

BIOLOGY 9744/03

Paper 3 Long Structured and Free Response Questions **12 SEPTEMBER 2023**

PART I **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your Center number, index number and name in the spaces at the top of this page.
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Section A
Answer **all** questions in the spaces provided on the Question Paper.

Section B
Answer any **one** question in 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 any working or if you do not use appropriate units.

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

For Examiner's Use	
1	/ 29
2	/ 11
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4 / 5	/ 25

Answer **all** questions in this section.

1 There are a variety of infectious diseases that can affect humans.

(a) Explain what is meant by an infectious disease. [2]

Infectious Diseases Part III Lecture Notes p.2

1. **[Infectious] Infectious diseases are caused by pathogens *(A: bacteria, viruses, fungi, protozoa)* that can spread from one organism / host to another (i.e. transmissible, communicable). [1]**

2. **[Disease] The pathogens cause damage or injury to the host that impairs the normal function of the body. [1]**

(b) The human immunodeficiency virus (HIV) causes the infectious disease known as autoimmune deficiency syndrome (AIDS).

(i) Compare the structures of HIV and a typical bacterium. [2]

Similarities:

1. **Both have genetic material.**
2. **Both have phospholipid bilayer (envelope for HIV, cell membrane of bacteria)**
3. **Both have glycoproteins.**
4. **Both do not have membrane-bound organelles.**

Differences:

Feature	HIV	Bacteria
1. Genetic material	Linear, single stranded (+) RNA	Circular, double-stranded DNA
2. Presence of peptidoglycan cell wall	No	Yes
3. Presence of reverse transcriptase / HIV integrase / HIV protease (Any 1)	Yes	No
4. Presence of ribosomes	No	Yes
5. Presence of plasmid	No	Yes
6. Presence of flagellum	No	Yes

HIV can integrate its genome into the host cell chromosome, thus forming a provirus. The provirus may remain transcriptionally silent for decades.

(ii) Suggest and explain **one** way in which the provirus can remain transcriptionally silent. [3]

Any one modification

1. **DNA methylation [1]**
2. **Causes DNA to bind more tightly to histones and nucleosomes to pack tightly [1]**
3. **Transcription factors and RNA polymerase cannot access promoter and HIV genes are not expressed [1]**

4. **Histone deacetylation [1]**
5. **Causes DNA to bind more tightly to histones and nucleosomes to pack tightly [1]**
6. **Transcription factors and RNA polymerase cannot access promoter and HIV genes are not expressed [1]**

7. **Binding of repressor to silencers / one of the viral gene codes for a repressor [1]**
8. **Slow down / prevent formation of transcription initiation complex [1]**

9. **Block activator from binding to enhancer / bind to activator to prevent activator from binding to enhancer / interact with proteins at TIC to make it more difficult for TIC assembly / recruit histone deacetylase for DNA to bind more tightly to histone [1]**

10. **Integrates itself into heterochromatin [1]**

The HIV/AIDS pandemic has had a very large impact on life expectancy in many African countries.

Table 1.1 shows the average life expectancy of individuals without and with HIV/AIDS and the percentage of the population tested positive for HIV in five African countries.

Table 1.1

country	average life expectancy / years		percentage of population tested positive for HIV / %
	without HIV/AIDS	with HIV/AIDS	
Botswana	72.4	33.9	35.8
Côte d'Ivoire	55.6	42.8	10.8
Kenya	65.6	45.5	14.0
South Africa	66.3	48.8	19.9
Zimbabwe	69.0	40.2	25.1

(iii) Using the data shown in Table 1.1, calculate the percentage decrease in average life expectancy for patients with HIV/AIDS in Zimbabwe.

Show your working and give your answer to the nearest whole number.

1. **Correct calculation of decrease in average life expectancy: 69.0 – 40.2 = 28.8 [1/2]**
2. **Correct substitution of values into formula [1/2]**
3. **Correct answer: [1]**

$$\frac{28.8}{69.0} \times 100\% = 42\%$$

percentage decrease: **42** % [2]
(-1/2 if not to nearest whole number)

(iv) After studying the data in Table 1.1, a student concluded that:

"The higher the percentage of population tested positive for HIV, the greater the decrease in life expectancy with HIV / AIDS".

With reference to Table 1.1, discuss the validity of the student's conclusion. [2]

Valid (any 1):

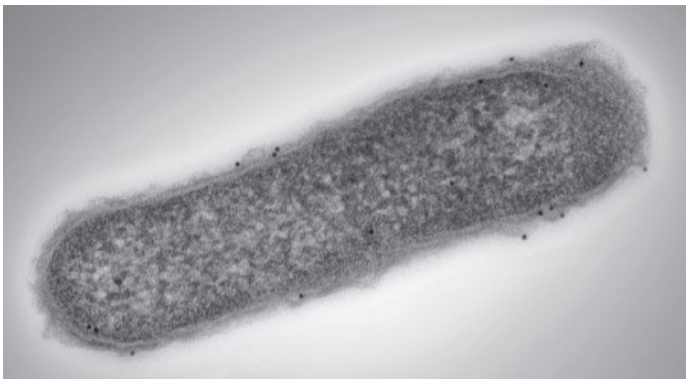
1. **Botswana has the highest percentage of population tested positive for HIV (35.8%) and has the greatest decrease in life expectancy with HIV/AIDS, from 72.4 years to 33.9 years, a decrease of 38.5 years.**
2. **Cote d'Ivoire has the lowest percentage of population tested positive for HIV (10.8%) and has the least decrease in life expectancy with HIV/AIDS, from 55.6 years to 42.8 years, a decrease of 12.8 years.**

Not valid:

3. **While South Africa has a higher percentage of population with HIV (19.9%) compared to Kenya (14.0%), the decrease in life expectancy is lower in South Africa, 66.3 years to 48.8 years (decrease of 17.5 years) than Kenya, 65.6 years to 45.5 years (decrease of 20.1 years).**

(c) Another common infectious disease in developing nations is cholera. Cholera is caused by consuming food or water contaminated with a bacterium called *Vibrio cholerae*.

Fig. 1.1 shows a transmission electron micrograph of *Vibrio cholerae*.



×30 000

Fig. 1.1

The symptoms of cholera are caused by the protein, cholaregen.

Choleragen is a protein made up of six polypeptides:

- a single copy of a polypeptide known as the **A** subunit that includes an extended alpha helix
- five polypeptides that together make the **B** subunit.

The **B** subunit of choleragen binds to a cell surface membrane component, known as GM1, of an intestinal epithelial cell. The complete choleragen protein then enters the cell by endocytosis. Once inside the cell, the **A** subunit of the protein acts as an enzyme, disrupting normal functions of the cell.

(i) List the levels of protein structure present in choleragen. [1]

Primary, secondary, tertiary, quaternary [all for 1]

Fig. 1.2 shows the *ctxAB* operon which contains the structural genes that code for choleragen.

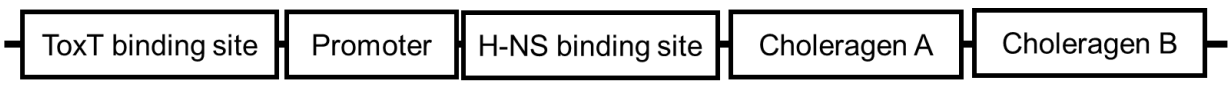


Fig. 1.2

H-NS and ToxT are proteins that are coded for by separate regulatory genes found upstream of the operon.

It is found that:

- high levels of H-NS would reduce the expression of the operon,
- high levels of ToxT would increase the expression of the operon,
- the operon has similar regulation as *lac* operon.

(ii) State the role of H-NS and ToxT proteins in the regulation of *ctxAB* operon. [2]

H-NS: **repressor protein**

ToxT: **activator protein**

(iii) In the laboratory, it is possible to produce a form of choleragen consisting of only **B** subunit as a vaccine against cholera.

Suggest why **B** subunit, rather than **A** subunit, is used in the production of the vaccine. [1]

Any 1

1. **B subunit is the portion that binds to cell, thus antibodies that target B subunit will prevents binding of choleragen to cell thus prevent entry to cell**
2. **B subunit is safer as it does not disrupt the normal functioning of the cell.**
3. **B subunit is larger, so more likely to stimulate immune response**

Infection by *V. cholerae* causes severe watery diarrhea, which leads to dehydration (loss of water and ions) and even death if untreated.

Fig. 1.3 shows the signaling pathway activated by choleragen.

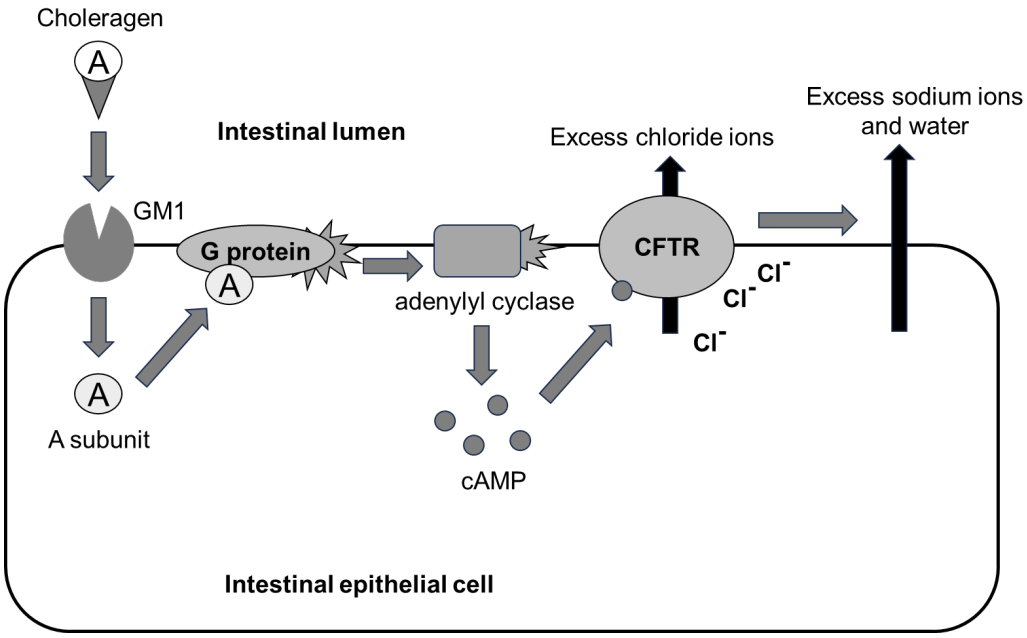


Fig. 1.3

(iv) With reference to Fig. 1.3, outline how choleragen **A** subunit can result in diarrhea after chloragen binds to receptor GM1. [3]

1. **Choleragen will bind and cause the activation of G protein**
2. **Activated G protein activates adenylate cyclase, which forms cAMP.**
3. **cAMP binds to CFTR protein,**
4. **causing excess chloride ions to be transported out of the intestinal epithelial cell/ into the intestinal lumen**
5. **Excess sodium ions and water**
6. **moves out of the intestinal epithelial cell into the intestinal lumen, leading to diarrhoea. (Award once, point 4 or 6)**

(d) Measles is a highly contagious, serious disease caused by the measles virus. The virus is normally spread through direct contact and through the air when an infected person coughs or sneezes. Nine out of ten people who are not immune will become infected when they share living space with an infected person.

The measles-containing vaccine (MCV) was developed in 1963 and is extremely effective at preventing the disease. Fig. 1.4 shows the global annual reported cases of measles and MCV coverage from 1980 to 2009. Immunization coverage refers to the percentage of population who receive one or more vaccines of interest in relation to the overall population.

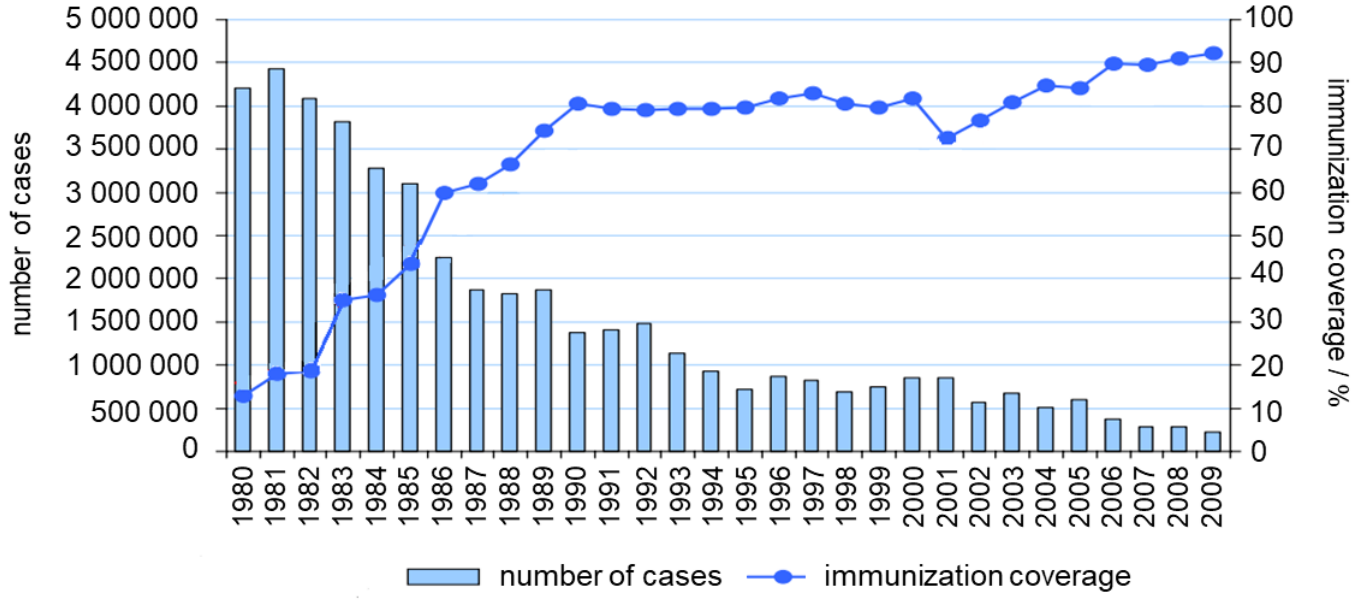


Fig. 1.4

(i) Comment on the relationship between immunization coverage and number of global annual reported cases. [1]

Generally, as immunization coverage increased from 20% to 90%, the number of cases decreased from 4, 500, 000 in 1981 to close to 0 in 2009.

(ii) With reference to Fig. 1.4, evaluate if the changes in global annual cases can be attributed to the changes in immunization coverage. [2]

Yes:

1. **QF decrease in cases, increase in coverage / high coverage, low cases**
2. **Vaccination gives rise to herd immunity where more individuals are immune and are less likely to infect other individuals who are not vaccinated.**

OR

No:

3. **QF decrease in cases, no increase in coverage**
4. **Improvement in sanitary hygiene and living conditions can contribute to decreased transmission. / AVP**

[1] – yes/no
[1/2] – relevant evidence (QF)
[1/2] – explanation

(e) Other than infectious diseases, human health can also be affected by other lifestyle diseases. Type II diabetes is a common lifestyle disease and is caused by dysregulation of insulin. Insulin is a peptide hormone secreted by the pancreas. It triggers a different cell signalling pathway and cellular response from choleragen.

The binding of insulin to the insulin receptor found on target cells such as muscle cells, triggers specific responses that eventually helps to lower the blood glucose levels.

In some diabetics, the insulin receptors are mutated and do not allow insulin to bind.

(i) Explain how a mutation to the gene coding for the insulin receptor can affect blood glucose levels. [3]

1. **Mutation to gene of insulin receptor results in different coding / nucleotide sequence.**
2. **Different amino acid sequence / primary structure in the insulin receptor polypeptide chain**
3. **Different folding / conformation of the insulin receptor**
4. **Insulin binding site of the insulin receptor will not be complementary in shape to the shape of insulin**
5. **Therefore signalling transduction pathway will not be activated**
6. **Glucose will not be taken up into the cell, resulting in high blood glucose levels / blood glucose levels cannot reduce.**

The hormone insulin is synthesised in the beta cells of the pancreas as preproinsulin.

Preproinsulin is non-functional and has to undergo post-translational modification to form the functional insulin that is secreted out of the cell.

Fig. 1.6 shows the process of post-translational modification to form the functional insulin.

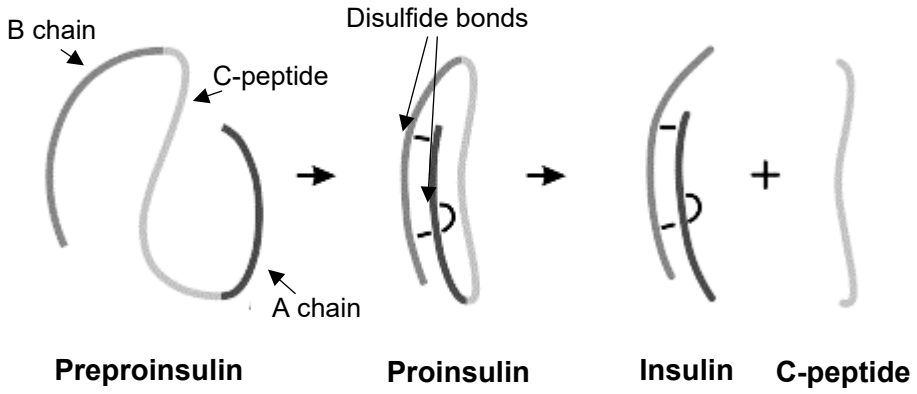


Fig. 1.6

(ii) With reference to Fig. 1.6, describe how post-translational modification of preproinsulin can give rise to the functional insulin. [3]

1. **Preproinsulin folds such that A chain and B chain are adjacent to each other**
2. **Disulfide bonds are formed between A and B chain, forming proinsulin**
3. **C-peptide is cleaved / hydrolysed / removed from proinsulin, resulting in the functional insulin**

C-peptide will be released into the bloodstream together with the insulin hormone. The C-peptide does not serve any function, but they are useful for monitoring the levels of functioning beta cells in people with diabetes.

(iii) Predict the level of C-peptide in people with lesser number of functioning beta cells. Give a reason for your prediction. [2]

1. **Low level of C-peptide [1]**
2. **People with lesser functioning beta cells will synthesize low quantity of insulin, hence lesser C-peptide will be removed and released into the blood stream. [1]**

End of Paper 3 [Part I]

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2	/ 11
3	/ 10

2 Competition between genetically similar species of bird may lead to changes in one or more characteristics. One characteristic that results from this kind of selection is differences in the beaks. Researchers studied the beak lengths of two species of warblers. Fig. 2.1 shows the beak length of Pine Warblers (*Dendroica pinus*) and yellow-throated Warbles (*Dendroica dominica*) from three geographically isolated areas in USA.

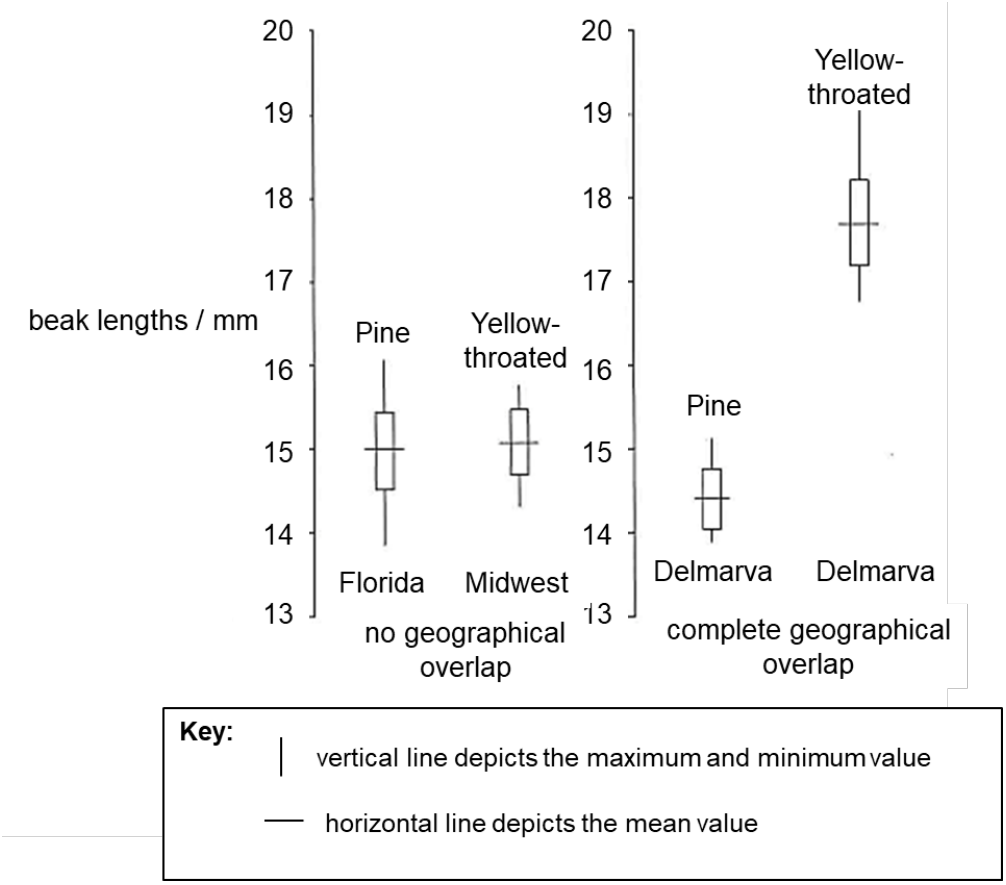

Fig. 2.1

(a) Complete **Table 2.1** to show the classification of one of the species of warbler. [2]

Table 2.1

kingdom	Animalia
phylum	Chordata
class	Aves
order	Passeriformes
family	Parulidae
genus	Dendroica
species	*Dendroica pinus*

(b) (i) Identify the species with the shortest mean beak length. [1]

Pine Warblers/Dendroica pinus (of Delmarva)

(ii) Determine the difference in the mean beak length of the two populations of Yellow-throated Warbles in Midwest and Delmarva. [1]

2.6 mm (accept answers in the range of **2.5mm** to **2.7mm**)

(iii) Compare the range of variation in beak length of the Yellow-throated Warbles in Midwest to the beak length of the Yellow-throated Warbles in Delmarva. [1]

Yellow-throated Warblers have a **bigger range** / **greater variation** (of beak length) in **Delmarva than in Midwest** (accept numerical values)

(c) Describe how the researchers could determine whether two warblers are of the same species. [2]

1. By **Biological Species Concept**, **interbreed both birds**;
2. If same species, offspring will **viable and fertile**;

OR

1. Apply the **Genetic species concept**; obtain **DNA samples from both birds.**
2. **Compare DNA sequences** (of common genes). If same species, DNA sequences would be **identical / highly similar**.

(d) Suggest an advantage for the longer beaks of Yellow-throated Warblers in Delmarva. [1]

Allows them to eat other foods / changes feeding behavior / ref to accessing food from hard-to-reach places (e.g., gaps in the tree barks, etc). This reduces competition with Pine Warblers.

R: Defense / ease of getting food.

(e) Using the Yellow-throated Warblers as an example, outline the concept of allopatric speciation. [3]

1. Allopatric speciation occurs between **populations that are geographically isolated** / live in different areas.
2. Hence, **no interbreeding /no gene flow** between the populations.
3. **Natural selection** works on **each population independently.**
   (Note: "Populations" should be mentioned at least once).

4. Competition with the Pine Warbler only occurs in Delmarva,
5. where the Pine Warbler acts as selective pressure on the Yellow-throated Warbler.

6. Over time, the gene pool of the Yellow-throated Warblers in the two places diverge such that they become **two species** / unable to interbreed to produce viable and fertile offspring / OTTWE (Idea that Yellow-throated Warbler populations become different species.)

[Total: 11]

3 The area over which the Arctic ice sheet extends varies throughout the year. Fig. 3.1 shows the variation in the extent of the Arctic ice sheet for the months of July to November for the years 1979 and 2009.

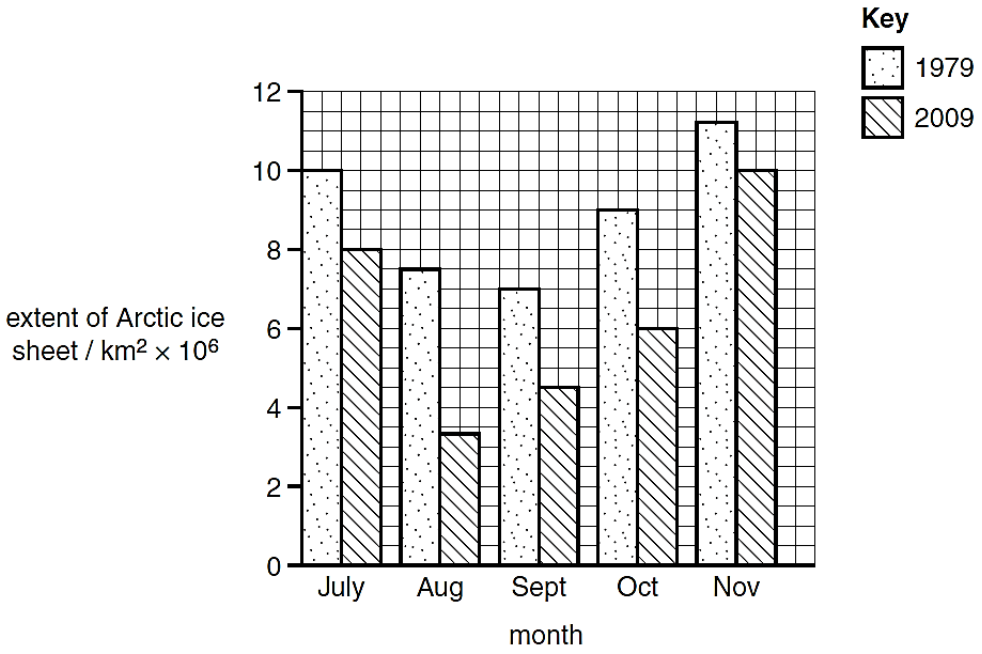

Fig. 3.1

(a) Suggest reasons for the reduction in the Arctic ice sheets from 1979 to 2009. [3]

1. **Increased rate of deforestation / clearing of forest / reduction of carbon sink [1]**
   OR
   Increased burning of fossil fuels / energy consumption for homes, industries or transport [1]
   OR
   Increased rearing of livestock [1]

2. **Increase in concentration of greenhouses gases (carbon dioxide, methane) in the atmosphere results in more heat trapped, [1]**
3. **hence resulting in an increase in air, land and/ or sea temperature, [1/2]**
4. **leading to the melting of Arctic ice sheets / decrease in snowfall / ice sheets forms slower. [1/2]**

(b) The polar bear, *Ursus maritimus*, moves across the Arctic ice sheet to hunt prey such as seals. When seals surface to breathe at cone-shaped breathing holes on the sea ice, a hunting polar bear which is waiting by the breathing hole will smack the head of the seal with both of its front paws to stun it, before biting and dragging the seal onto the ice. This method of still-hunting minimizes energy consumption and is the most successful strategy of hunting.

In 2008 the government of the USA classified *U. maritimus* as an endangered species because it is under the threat of extinction.

Suggest how climate change could have caused *U. maritimus* to become an endangered species. [2]

1. **Global warming in the Arctic resulted in melting sea ice**
2. **and reduction in extent of ice sheets / loss of habitat for both seals and polar bears.**

3. **It also leads to more [i.e. initial stage] / less or bigger breathing holes [i.e. later stages when the ice melts and the breathing holes fuse]**
   OR
   The seals migrate to other cooler places / no longer breathe at breathing holes,

4. **therefore the polar bears are unable to still-hunt seals (only source of food) / use other hunting strategies that increases energy consumption, hence they starve and die.**

Climate change also affects plants.

Plants can be categorized based on the way they photosynthesize. Most plants are C3 plants because their first photosynthetic product is a three carbon compound. Examples of C3 plants include barley, oats, potato, rice, and wheat commonly grown in temperate regions.

On the other hand, C4 plants produce a four-carbon compound as their first photosynthetic product. Examples of C4 plants are common grass crops of tropical regions, such as maize, millet, sorghum and sugarcane.

The rate of carbon dioxide uptake at a range of carbon dioxide concentrations by barley, a C3 plant, and sugar cane, a C4 plant, were compared at two temperatures.

The results of the experiment are presented in Fig. 3.2.

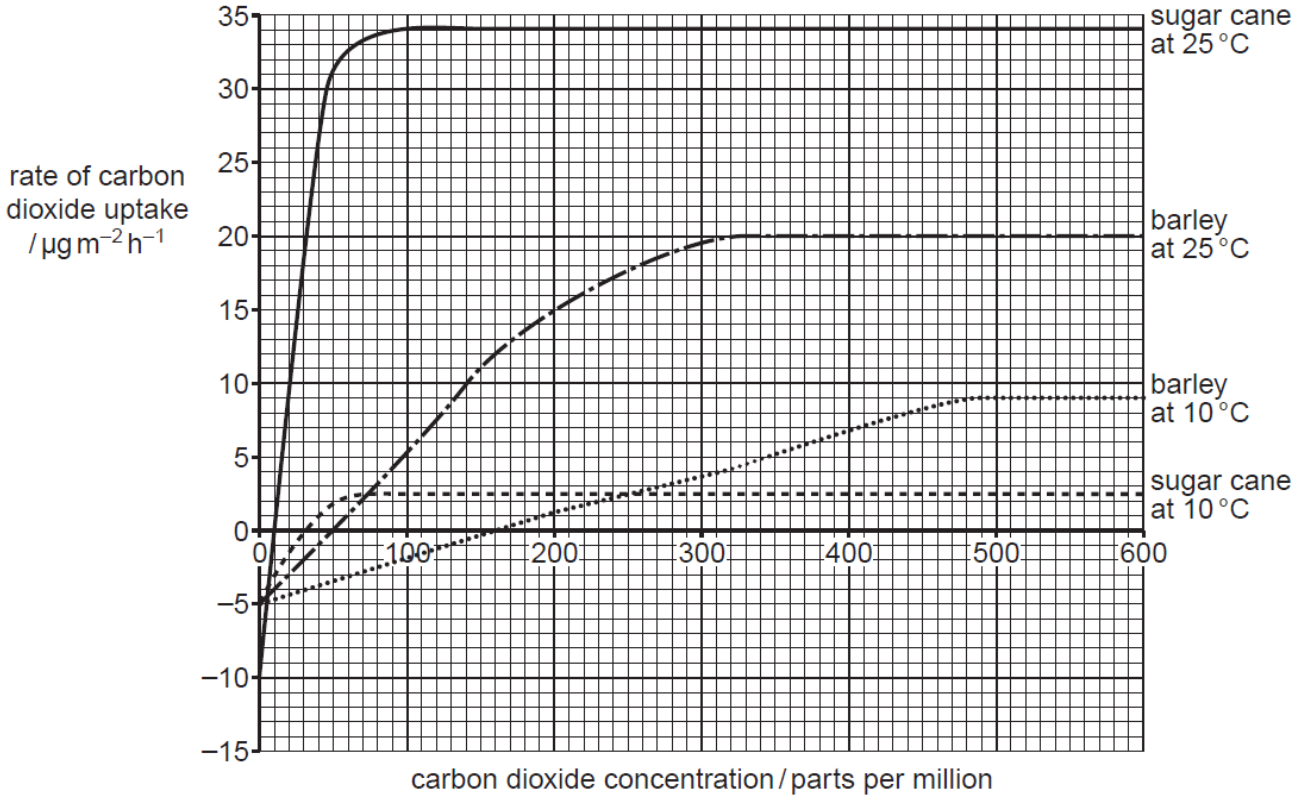

Fig. 3.2

The current carbon dioxide concentration in the atmosphere is more than 400 parts per million and it is likely to increase in the future. It is widely believed that the carbon dioxide concentration of the atmosphere affects the global mean surface temperature which in turn changes rainfall patterns.

Different types of crops require different amounts of water for optimal growth. Table 3.1 shows the mass of water each crop absorbs in a week for optimal growth regarding three C3 and three C4 plants which are important crops. Crops that absorb more water tend to grow better in regions with higher rainfall.

Table 3.1

crop	mass of water absorbed in a week / g
rice **C3**	682
potato **C3**	575
wheat **C3**	542
maize **C4**	350
millet **C4**	285
sorghum **C4**	204

(c) With reference to Fig. 3.2 and Table 3.1, discuss the likely impact of the predicted changes in carbon dioxide concentration, global temperatures and rainfall patterns on the global distribution of C3 and C4 plants. [3]

1. **Increased in carbon dioxide concentration will likely increase temperature.**

2. **At high carbon dioxide concentration of 500 parts per million and high temperature of 25°C, the rate of photosynthesis for C4 plants / sugar cane at 34 $\mu gm^{-2}h^{-1}$ is HIGHER than that of C3 plants/ barley at 20 $\mu gm^{-2}h^{-1}$. [1]**
   [Accept: Maximum rate of photosynthesis. Reject: Peak]
   [Accept: Any high value of carbon dioxide concentration more than 400 ppm]

3. **Hence, both plants will grow well, but C4 plants are better adapted than C3 plants in hotter areas and their population will likely increase/ OWTTE.**
   [Accept: Reference to latitude (tropical / temperate)]

4. **Increased temperatures may result in lower rainfall in some places.**
   [Accept: Higher rainfall]
5. **C4 plants absorb between 204 to 350g of water which is LESS than C3 plants between 542 and 682g. [1]**
   Reject: average values
6. **Hence, C4 plants are better adapted than C3 plants in drier areas and their population will likely increase / OWTTE.**

7. **[Additional] However, predicted change in temperature over the next century is only small, therefore it may not make a lot of difference.**

Climate change potentially affects the spread of diseases. Fig. 3.3 shows the worldwide distribution of dengue.

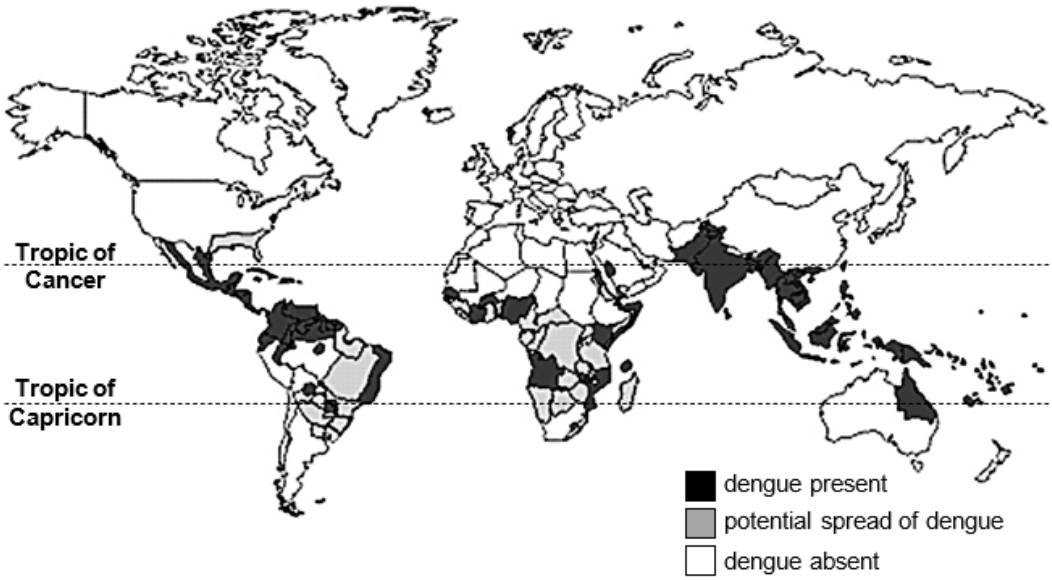

Fig. 3.3

Unlike dengue, influenza is found across the whole world.

(d) Explain why dengue shows the distribution pattern shown in Fig. 3.3, but influenza is found everywhere. [2]

1. **Dengue is vector-borne disease (i.e. caused by dengue virus and transmits / reproduces within *Aedes* mosquito) [1/2]**
2. **which lives within the Tropics of Cancer and Capricorn [1]**
   OR
   hot and humid areas (at temperatures above 20°C) at a favourable temperature range for breeding / reproduction of mosquitoes,
3. **whereas influenza is an air-borne disease / transmitted by respiratory droplets / coughing / sneezing, [1/2]**
4. **and it is not limited by the range of the vector (i.e. hot and humid conditions) to be transmitted / spread to other parts of the world by infected travelers. [1/2]**
5. **[Additional] Mosquitoes are prevalent in tropical region due to poor / non-existent mosquito control programmes/ OWTTE. [1/2]**
6. **[Additional] Mosquitoes may also be resistant to insecticides. [1/2]**

[Total: 10]

End of Paper 3 [Part II]

H

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Section B	
Essay **4* / 5*** **circle*	**/ 25**

Section B

4 (a) Outline the mitotic cell cycle and describe how this process could develop into one that results in cancerous cells instead. [10]

A. Mitosis (max 5 – 1 m each)

1. G1 phase is where cell synthesizes RNA, enzymes and proteins for growth
2. DNA is replicated during S phase of interphase.
3. G2 phase – proteins synthesis / formation of new organelles / centrosome duplicates.
   (Note: G1, G2 and S phases are all part of interphase)

4. 1m Mention of Prophase, Metaphase, Anaphase, Telophase (PMAT) in the correct sequence

5. During prophase, chromatin fibres condense, centrosomes migrate to opposite poles, nuclear envelope breaks down, spindle fibres extend from each pole.
   (Award ½ for any 2 processes mentioned)

6. During metaphase, spindle fibres connect to kinetochore at the centromere [1/2] and chromosomes arrange themselves in a single row at the metaphase plate / equator [1/2].

7. During anaphase, the centromere divides, and the sister chromatids of each chromosome, separate and move to opposite poles of the spindle. The spindle fibres shorten.

8. During telophase, sister chromatids reach the respective poles of the cell and become chromosomes of the daughter cells, chromosomes uncoil to become chromatin fibres, nuclear envelope reforms, nucleolus reappears. Spindle fibre breaks down.
   (Award ½ for any 2 processes mentioned)

9. Cytokinesis occurs, where a cleavage furrow is formed in animal cells which eventually separates to form 2 genetically identical daughter cells [1/2]or where a cell plate is formed in plant cells which eventually separates the 2 daughter cells [1/2].

B. Development of cancer (max 5)

1. One named carcinogen
   e.g. ionising radiations such as UV radiation [1/2] can increase chances of gene mutations [1/2]
2. As DNA is replicated, several independent mutations [1/2] must be present in a single cell. [1/2]

Effects of mutation that will occur during interphase:

3. Mutations include a loss of function mutation of both alleles / copies of tumor suppressor genes [1/2] e.g. *p53* gene involved in controlling of cell cycle OR initiate apoptosis OR maintaining stability by stopping cells at G1 checkpoint [1/2]

4. Gain in function mutation in one of proto-oncogenes into oncogenes, [1/2] e.g. *ras* gene which will be hyperactive and continues to transmit signal to divide even in the absence of a growth factor; [1/2]
5. Gain in function mutation, or mutation causing the activation of telomerase gene [1/2] allows for the cell to divide excessively without triggering apoptosis, OR overcome the end replication problem in normal cell replication i.e. Hayflick limit; [1/2]
6. Gain in function mutation, or mutation causing the activation of angiogenesis [1/2] and hence supply the tumour with blood containing nutrients needed for growth [1/2];

7. Loss of function mutation / mutations causing the inactivation of genes involved in cell-to-cell adhesion / recognition [1/2], allowing for metastasis i.e. cancer cells escape from tumor, circulate in the blood and lymph and invade / spread to other areas of body; [1/2]
8. Accumulation of these mutations allow the cancerous cells to replicate bypassing the G1 and G2 checkpoints of cell cycle, resulting in uncontrolled cell division; (accept M if included)
9. AVP; related to the development of cancer

QWC
P: Paragraph
Q: Address mitosis + at least one point of cancer development

(b) Describe how genetic stability in eukaryotes is maintained at the molecular, cellular and population levels. [15]

Molecular level (max 7)

M1. Genetic stability at molecular level means maintaining same DNA sequence in daughter cells and parental cells;
M2. In order to have identical copies of DNA as parent cell before nuclear division, DNA is first replicated during S phase of interphase via semi-conservative replication;
M3. Each parental strand of double stranded DNA act as template;
M4. To synthesise daughter strand following complementary base pairing;
M5. Where nitrogenous base adenine forms 2 hydrogen bonds with thymine, guanine forms 3 hydrogen bonds with cytosine and vice versa
M6. Complementary base pairing between purine and pyrimidine bases ensures constant width of 2.0 nm which stabilises structure
M7. Each DNA molecule formed consists of one parental template with a daughter strand/newly synthesized strand;
M8. DNA polymerase proof-reads newly synthesised region where if there is an incorrect DNA nucleotide is added, it will remove and replace with correct nucleotide. This is to ensure accuracy of DNA sequence;
M9. Numerous hydrogen bonds of DNA / Antiparallel strands increases stability of the molecule / holds two chains together;
M10. Hydrophobic interactions between stacked nitrogenous bases stabilise structure
M11. Deoxyribose sugar is resistant to hydrolysis / less chemically reactive which maintains DNA sequence
M12. Strong phosphodiester bonds between adjacent nucleotides stabilise double helix structure
M13. Telomeres at the ends of chromosomes prevent the loss of genetic information with each round of DNA replication;

AVP: Concept of packing of DNA

Cellular level (max 6)

C1. Genetic stability at cellular level means maintaining same number and type of chromosomes in daughter and parental cells;

Role of cell cycle:

C2. During prophase, genetically identical sister chromatids condense to allow for separation;
Note: student must mention the idea of genetically identical (hence maintaining genetic stability) instead of simply stating "chromosomes condense" which is describing the process.
C3. During metaphase, chromosomes arrange themselves along metaphase plate/at equator;

C4. During anaphase, centromere divides and spindle fibres shortens;
C5. During anaphase, genetically identical sister chromatids are separated and move to opposite poles;

C6. Mitosis thus ensures equal distribution of identical sister chromatids to daughter cells;

Role of checkpoints:

C7. Cell cycle is regulated at checkpoints [1/2]
C8. Ensure that proper conditions are achieved before proceeding to the next stage of the cell cycle.
C9. Ensure that incomplete or damaged DNA are not replicated and passed on.
C10. The main checkpoints are G_1, G_2 and M checkpoints;
C11. At G1/G2 checkpoint, when there is DNA damage, cell cycle is halted so that there is enough time for cell to repair its damaged DNA;
C12. At M checkpoint, cell division is arrested at metaphase if any chromosomes are not attached to the spindle fibres.
C13. Cells with telomeres at critical length do not go through any further cell divisions.

Population level (max 3)

P1. Genetic stability at population level means maintaining same frequency of alleles in the population;
P2. Genetic stability occurs when there is no change in allele frequency, hence no major evolutionary forces such as natural selection, mutation, gene flow, genetic drift and sexual selection.
P3. Constant unchanging environment leads to no change in selection pressure.
P4. natural selection selects for the same favourable alleles: hence allele frequency will NOT increase and contribute to genetic stability.
P5. NO gene flow: there is NO transfer of alleles from one population to another through eg: migration
P6. NO genetic drift / bottleneck effect / founders' effect: there is NO change in allele frequency due to chance events
P7. Random mating: In sexually-reproducing populations, individuals DO NOT preferentially choose mates thus there is random mixing of gametes and genetic stability occurs. So random mating contributes to genetic stability, whereas non-random mating does not.
P8. NO mutation, new alleles are NOT generated and genetic stability occurs.

P9. More prevalent in asexually reproducing populations where there is no fusion of (genetically-different) gametes, genetically identical offspring.
P10. Meiosis produces haploid cells (reductive division).
P11. This allows the diploid state to be restored upon fusion of gametes during fertilisation;

QWC:
P: paragraphing
Q: at least one correct mark point from each of the three categories (molecular, cellular, population).

[Total: 25]

5 (a) Despite selection pressures selecting for certain phenotypes, some phenotypes continue to persist in a population.

Explain how both genetic and environmental factors contribute to phenotypic expressions in eukaryotes and suggest how phenotypes which are **selected against** could be preserved in a population. [15]

A. Genetic factors (max 6)

1. **Genes that are expressed are transcribed and translated into proteins which directly affects or phenotypes as many of these proteins are involved in metabolic processes.**

2. **Different forms / sequences of the same genes, alleles, determine the type of protein synthesised and therefore variation of phenotype expressed.**

3. **Most eukaryotes are diploid organisms that have two sets of chromosomes each containing the same gene; hence every cell of a eukaryote contains at least 2 copies of genes at each gene locus.**

4. **In a heterozygote with one dominant and one recessive allele for the same gene, the expression of the dominant allele masks that of the recessive allele.**
5. **Some genes could exhibit co-dominance, where both alleles are expressed equally in a heterozygote and neither masks the other, e.g. I^A and I^B alleles for blood type.**
6. **Some genes could exhibit incomplete dominance where the heterozygote exhibits a phenotype that is intermediate between the two homozygous forms.**

7. **Some phenotypes can be controlled by multiple genes, such phenotypes are typically in a continuous variation.**

8. **Phenotypes that are controlled by more than one gene can exhibit epistasis, where the expression of one gene is masked by the expression of another gene.**

9. **AVP; phenotype can also be affected by (a) control elements and (b) genes coding for transcription factors that change the expression of genes when they are mutated.**

B. Environmental factors (max 3)

1. **Environment can also contribute to phenotypic expressions by affecting the proteins within organisms such as through temperature, food, chemicals (at least 1 example demonstrated, max 2);**
   a) **e.g. bee larvae and diet**
   b) **e.g. Himalayan rabbits**

2. **Hence both environment and genetic factors contribute to phenotypic expressions via the proteins that determine the phenotype, and environmental factors can influence the degree of expression of certain genes e.g. genetically identical twins with different weight / skin tan**
3. **The more genes are involved in the phenotypic expression of a trait, the greater the influence of environment on the phenotypic expression. *(Idea: multiple gene inheritance, influenced by env, effect of each gene is small / additive)***

C. Preservation of phenotypes selected against (max 6)

Diploidy

1. **Heterozygotes of diploid organisms can carry recessive alleles that are not expressed and hence, not subjected to selection pressure.**
2. **Allows recessive alleles that are selected against to remain in the gene pool.**

3. **These alleles are still being passed down to offspring and persist in the population.**

Heterozygote advantage

4. **Heterozygous individuals may have a greater ability to survive and reproduce than homozygous recessive individuals.**
5. **Although homozygous recessive phenotype is selected against, recessive alleles are preserved and recessive phenotypes may be expressed in the next generation.**
6. **(sickle cell anemia example – 1m)**

Frequency dependent selection

7. **Phenotype that is selected for becomes selected against when it is too common [1/2]**
8. **Phenotype that was selected against becomes selected for [1/2]**
9. **Frequency of both phenotypes oscillate over time, ensuring that both phenotypes continue to persist in the population.**

AVP:
Masking by mutations in non-coding sequences

10. **Mutations could occur in regulatory sequences (mainly enhancers) which stops the expression of genes that code for phenotype that is selected against.**
11. **These genes that are being passed down could then be expressed again upon re-activation of the regulatory genes / other mutations that allows expression.**

Masking by environment factors

12. **Some phenotypes that are selected against could be countered by environmental factors such as food / medication**
    a. **e.g. deficiency in certain essential nutrients in the body that can be substituted by diet / medication**
    b. **e.g. insulin deficiency being substituted by insulin injection that allows one to not be affected by diabetes**

QWC:
P: Paragraphing
Q: Addressed 1 point from each category

(b) In eukaryotes, a mutation in the DNA can give rise to a new allele. In prokaryotes, a mutation in the DNA may give rise to a new gene with a novel function.

Outline how the allele frequency and the new gene frequency can increase in both eukaryotic and prokaryotic populations respectively. [10]

prokaryotes

1. **from parent to offspring via binary fission;**
2. **Semi-conservative DNA replication ensures offspring are genetically identical to parents;**
3. **Transformation: Competent cell transformed during uptake of foreign DNA containing the new gene;**
4. **Transduction: With help of bacteriophages, a piece of bacteria host DNA containing the new gene and insert into recipient bacteria during subsequent infection;**
5. **During conjugation when a F^+ bacteria transfers the new gene found on the F plasmid, to an F^- bacteria;**
6. **Naming of process for points 3 – 5: Transformation / transduction / conjugation**
   [1] – all 3 processes
   [1/2] – 2 processes

eukaryotes

7. **Mutation of the gene / new allele should be in a gamete;**
8. **Fertilization / random fusion of gametes [1/2]**
9. **allows the allele to be passed on to offspring; [1/2]**

Natural Selection (award once ONLY for both prok and euk)

10. natural selection occurs [1/2]
11. new / different / change in selection pressure [1/2]
12. individual with mutated gene / allele is selected for / selective advantage [1/2]
13. survive and reproduce at a higher rate to produce viable offspring [1/2]
14. pass new gene / allele to offspring [1/2]

15. genetic drift [1/2]
16. founder's effect [1/2]
17. small number of individuals start a new population in a new habitat, frequency of the new allele increases because of the smaller gene pool.
18. Bottleneck effect [1/2]
19. Catastrophic event occurred resulting in a small number of individuals left in the population, frequency of new allele increases because of smaller gene pool.

QWC:
P: Paragraphing
Q: Prok + Euk + NS

[Total: 25]

End of Paper 3 [Part III]