Victoria Junior College
Biology Department
2023 H2 Preliminary Exams Paper 3 Proposed answers

Marking abbreviations:
A: Accept, R: Reject, BOD: benefit of doubt, AW: alternative wording, AVP: Any valid point, NAQ: not answering question, ECF: error carried forward

Question 1

Cells can respond to their environment through **regulating the expression of certain genes**. Unicellular **eukaryotes** such as yeasts respond to changes in the glucose concentration in the environment.

Glucose is the preferred carbon source for *Saccharomyces cerevisiae* (Baker's yeasts) which metabolizes glucose by a purely glycolytic process (fermentation), producing ethanol even under aerobic conditions. Presence of glucose represses the uptake and metabolism of other carbon sources eg. galactose, maltose. When the glucose has been consumed, the cell switches to **aerobic** metabolism of the ethanol.

(a) (i) State the difference in the number of ATP produced from one molecule of glucose between fermentation and aerobic respiration. [1]

- 30 ATP;

(ii) Suggest why yeast cells undergo fermentation even in the presence of oxygen. [2]

- (idea of) Take advantage of the high glucose concentration quickly taking up glucose from the environment due to competition from other yeast cells;
- (idea of ethanol as a reserve) when glucose is depleted, yeast can then fully oxidise ethanol to obtain ATP; (R: directly lift from text without further explanation)
- So that repression on other carbon sources eg. galactose (monosaccharide) and maltose (disaccharide) is removed;
- ATP produced via fermentation is faster as it involves fewer steps compared to complete oxidation;
- AVP

(b) Several components of the signalling pathway involved in glucose repression have been identified. These are shown in Fig.1.2. **Snf1 is a protein kinase** and **binding of Mig1 to the promoter interferes with the binding of other proteins.**

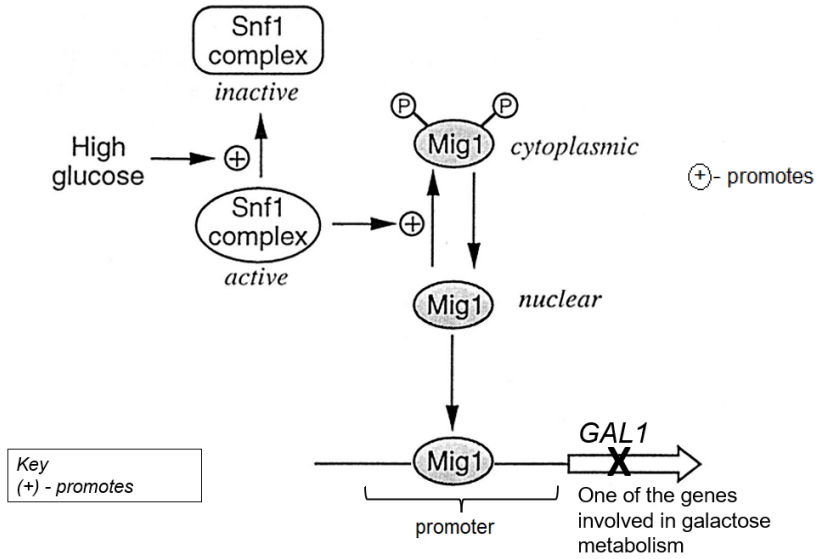

Fig 1.2

(i) With reference to the information given in Fig 1.2, explain how the presence of glucose in the **environment** is able to bring about the repression of *GAL1* gene. [4]

1. Glucose taken up by **facilitated diffusion** via transport/channel proteins into cytoplasm;
2. Presence of glucose/ High glucose **inactivates the Snf1 protein kinase;** resulting in Mig1 **not being phosphorylated** (A: cytoplasmic Mig1 dephosphorylate) and;
3. Mig1 enters the nucleus, and binds to the **promoter** of GAL1;
4. **Preventing the attachment** of other transcription factors and RNA polymerase, prevents the assembly of transcription initiation complex and no transcription of GAL1gene;

Mig1 binds to **promoter** sites with these features:

- 17 base pairs long
- Includes a region of five repeating adenine-thymine pairs
- Includes a region of six repeating cytosine-guanine pairs

Promoter sites to which Mig1 binds are known as Mig1-binding promoter sites.

(ii) Explain how Mig1 recognizes and binds to these sites. [2]

- Mig1 has a **DNA binding domain;**
- that has a specific **3D conformation** which is **complementary in shape** (and charge) to the base sequence of the binding sites;
  R: complementary base pairing

Scientists analysed the yeast genome to look for DNA that matches the features shown by of Mig1-binding promoter site. Analysis of **four chromosomes** revealed the presence of 26 Mig1-binding promoter sites.

yeast chromosome	number of Mig1-binding promoter sites
A	1
B	9
C	2
D	14

Table 1.1

Since five different enzymes coded by five different genes are required for galactose metabolism, the expected number for of Mig1-binding promoter sites for an individual diploid yeast is 10.

(iii) Explain why the expected number of Mig1-binding sites is 10. [2]

1. Since yeast is a eukaryote, **every gene would have its own promoter** => 5 genes – 5 promoters/ 5 Mig1-promoter binding sites;
   R: 5 genes 5 Mig1-promoter binding sites without explanation (in bold)
2. A diploid cell will have chromosomes occurring in pairs – homologous chromosomes/ 2 copies of each gene on homologous chromosomes and hence the number is 2x5 = 10;

(iv) Suggest reasons for the difference in the number of Mig1-binding promoter sites seen in Table 1.1 and the expected number. [2]

Note: Difference: Total number of Mig1-binding promoter sites is 26 for the 4 chromosomes, much larger than the expected 10/ idea of more than the number of genes involved in galactose metabolism and only 4 chromosomes are shown;

Possible reasons: [Any 2]
- Mig1 regulates genes involved in other pathways;
- There could be several copies of the five genes;
- Some galactose genes are found on the same chromosome – because only 4 chromosomes analysed;

(c) Changes in gene regulation was also observed in Aedes mosquitoes infected with dengue virus.

Scientists carried out experiments to study how the mosquitoes respond to the presence of dengue virus (DENV) after a blood meal.

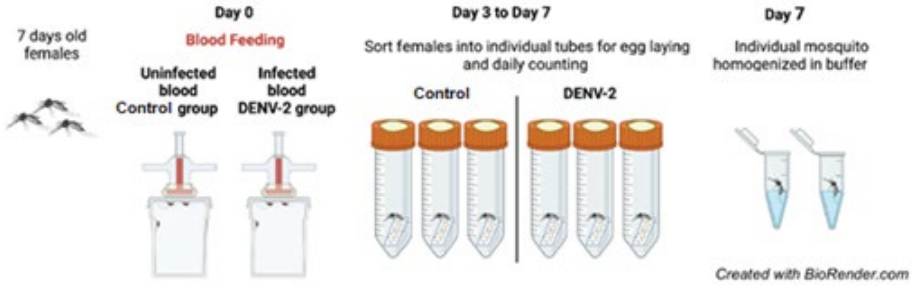

Fig 1.2 Experimental setup
Source: https://pubmed.ncbi.nlm.nih.gov/35814655/

(i) Explain the **importance** of the control group in this experiment.[2]

1. Show that any **changes in gene expression/ fecundity** between the control and experimental group;
2. Is due to the **dengue virus** present in the experimental group;
3. control sets the baseline for the level of gene expression in the ovary for the uninfected group, for comparison with the experimental;

Fig 1.3 shows the fecundity (number of eggs laid per mosquito) for the two groups of female mosquitoes.

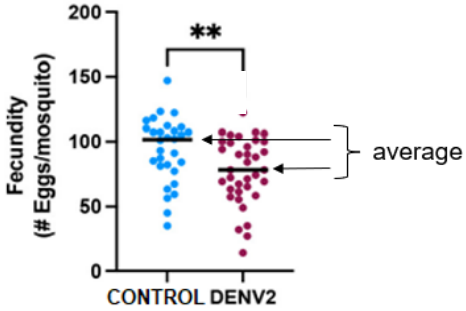

Fig 1.3
(**) – indicates that the $p < 0.05$

(ii) Suggest two reasons for the variation seen in the fecundity of the individual mosquitoes **within** each group. [2]

Any two of the following:
For both groups

1. Differences in the **genetic makeup** of the mosquitoes resulting in them having different combination of alleles that determine the number eggs laid;
   A: Additive gene effects
2. Since female mosquitoes need to take a blood meal before they can lay eggs, differences in the **amount of blood** taken up by each mosquito can result in different amounts of nutrients available for egg laying;
3. The mosquitoes are of different ages 7-10 days. There might be a differences in the fertility of the mosquitoes based on age;
   (Note: the positive relationship is seen more for body size than age)

For experimental group:

4. different amount of blood taken up will mean different amount of the **viruses (**taken up), and this would affect the extent of infection in the mosquitoes;
   different ability of the immune systems of the mosquitoes to overcome the infection as more nutrients and energy will be directed to fighting the infection/production of antibodies and less for egg laying;

5. AVP;

A study of the ovaries obtained from the infected mosquitoes showed the cells infected with the dengue virus exhibit **reduced**

- cytochrome c oxidase activity
- synthesis of ribosomal proteins
- RNA binding to proteins

(iii) Based on the information provided, explain the difference in the fecundity between the two groups of mosquitoes in Fig. 1.3. [4]

1. Difference: Overall reduction in fecundity of the mosquitoes infected with Denv2- average of 75 eggs/mosquito compared to 100 eggs/mosquito in control;
2. Reduced cytochrome c oxidase activity leads to decrease ATP production for the synthesis of protein/ reduce energy required for egg production;
3. Reduced synthesis of ribosomal proteins leads to a decrease in ribosomes synthesis, resulting in less protein involved in egg production will be translated;

4. Reduced RNA binding to proteins leads to less rRNA associating with ribosomal proteins, less ribosomes will be formed and less protein synthesis;

(d) Two genes were found to be upregulated in the infected mosquitoes.

To investigate the role of these two genes (*Oatp*, *amd*), scientists carried out further studies using mosquito cell culture. Three cell cultures were set up, one for control and two experimental.

In each experimental group, small interfering RNA (siRNA) specific to the mRNA produced by the gene is introduced into the cell culture.

Table 1.2 summarises the treatment for the control and experimental groups.

Setup	siRNA added
Control	None
Experiment 1 (E1)	specific for mRNA of *Oatp*
Experiment 2 (E2)	specific for mRNA of *amd*

Table 1.2

Fig 1.4 shows the sequence of events occurring in the cells after the introduction of siRNA.

(i) With reference to Fig. 1.4, explain how siRNA can affect the expression of a gene. [2]

- siRNA binds to a specific sequence on the mRNA of a gene by complementary base pairing;
- This results in the mRNA being fragmented by the enzyme RNAase in the protein complex and no translation / no protein product formed, resulting in gene being silenced/ no gene expression;

The cells in both the control and experimental groups were then infected with the dengue virus. The number of copies of dengue RNA was then determined 24 hours post infection. The results are shown in Fig 1.5.

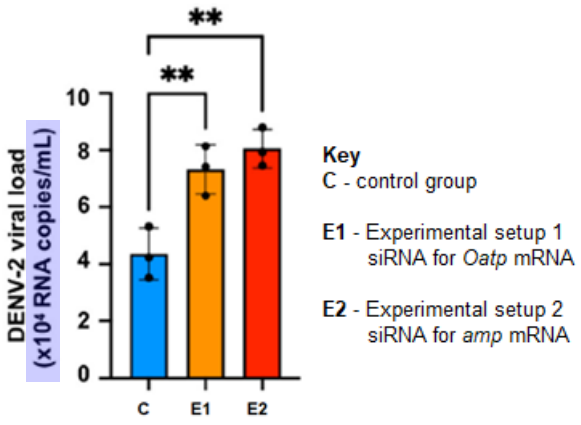

Fig. 1.5 (**) – indicates that the $p < 0.01$

(ii) With reference to Fig. 1.4 and 1.5, state a possible function of the two genes (*Oatp* and *amp*). Explain your answer. [3]

- The two genes code for proteins that are involved in inhibiting viral replication/ immune response/removal of the viruses (any 1 - idea of);

- Higher viral load of $7x10^4$ RNA copies/mL for E1 and $8x10^4$ RNA copies/mL for E2 compared to $4x10^4$ RNA copies/mL for Control (QV);
- as siRNA for *Oatp* and *amd* mRNA causes no production of the proteins resulting in more viral replication/ less immune response against virus (idea of link between data and function);

(e) Diseases caused by viruses such as dengue fever, Covid-19, have caused significant concerns to humans. Medication such as antibiotics are not effective against viruses. Viruses are so unique that they are not even grouped into any of the three domains – Eukarya, Bacteria and Archaea which **encompasses all life on earth**. Members of these three domains are either **unicellular or multicellular**.

Justify why dengue virus should not be classified into any of these domains. [3]

[Any 3 below]

Main concept: How viruses challenge the cell theory and the concept of living organisms.

Must have to get full marks: Either one below

CA: Cells are the smallest and most basic unit of life;

NLA: Viruses exhibit borderline of being living and non-living/ exhibit both living and non-living characteristics/ non-living characteristics;

Cell theory:
- Viruses are not made up of cells/ acellular/ non-cellular, they are made up of just proteins and DNA/ RNA;
- Viruses do not have any organelles and cytoplasm;
- Viruses are smaller and more basic than cells (Accept only when CA is stated);

Concept of living/non-living
- Exhibit *living characteristics* only if they infect a host + an example of living characteristic (eg. Viruses contain genes and can undergo spontaneous mutation/ allow evolution)
- Outside of the host, they cannot reproduce (on their own) as they lack the cellular machinery to synthesise nucleic acids or proteins using building blocks like amino acids, nucleotides, etc;
  Or they can only reproduce when they infect a host cells and make use of the host cellular machinery to reproduce;
- They do not carry out metabolism on their own as they are unable to generate usable forms of energy such as ATP;
- They do not have any sensory components or response mechanisms on their own;
- They do not have any internal mechanism to maintain homeostasis. The lack of cytoplasm also means a lack of internal environment to be maintained;

2 Cervical cancer occurs in the neck of the uterus.

Scientists investigated the link between cervical cancer and infection with some types of Human Papilloma Virus (HPV).

Fig. 2.1 shows the frequency of five different types of HPV in women who had cervical cancer.

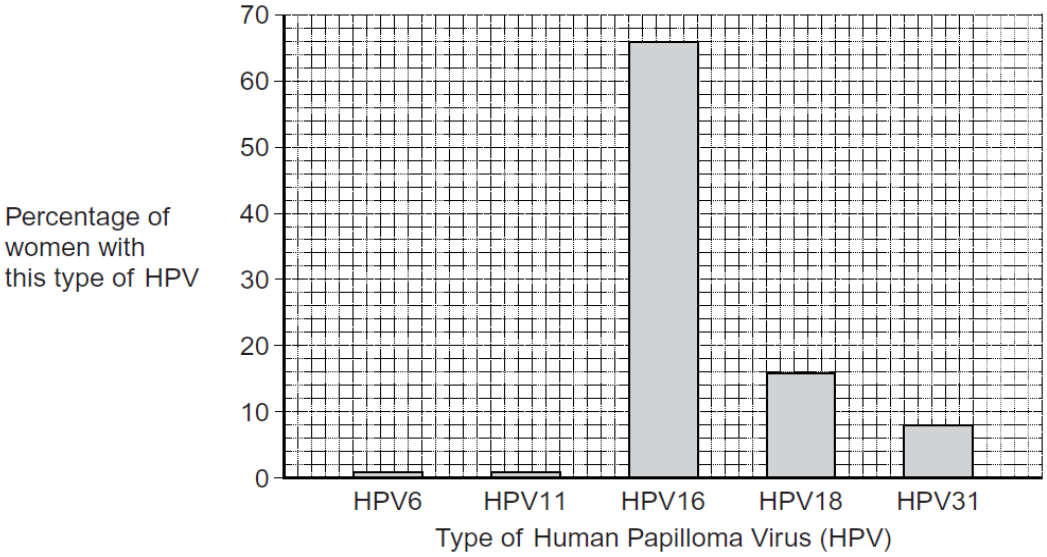

Fig. 2.1

(a) A local newspaper published an article about cervical cancer with the headline 'HPV causes cervical cancer'.

Evaluate this claim based on the data shown on Fig. 2.1. [3]

1. Claim supported by 66% (92%) women with cervical cancer have HPV16 (HPV);
   Reject: 66% women with HPV 16 have cervical cancer as this emphasises that not all women with HPV will develop cervical cancer; many will clear the infection without any cancerous changes. However, in the study, all the women had cervical cancer, so the data shows the prevalence of HPV in women with cervical cancer.
2. Claim not supported as only 1% women with cervical cancer have HPV 6/ 11;
3. HPV infection does not mean causation because could be caused by another factor / example given: genetics, lifestyle, and immune system health / may be due to coincidence (for HPV 6/ 11);
4. Neutral/ AVP
   no control group / did not study HPV in healthy women / did not study all HPV types / having cancer may increase susceptibility to HPV / does not add up to 100% / not all women with cancer have HPV / individual may have more than one HPV type/ etc;

Accept: minor errors in reading HPV frequencies from graph

When HPV16 infects a cervical cell, its genome integrates into the host genome. Fig. 2.2 shows the sequence of events leading to the development of HPV-related cervical cancer.

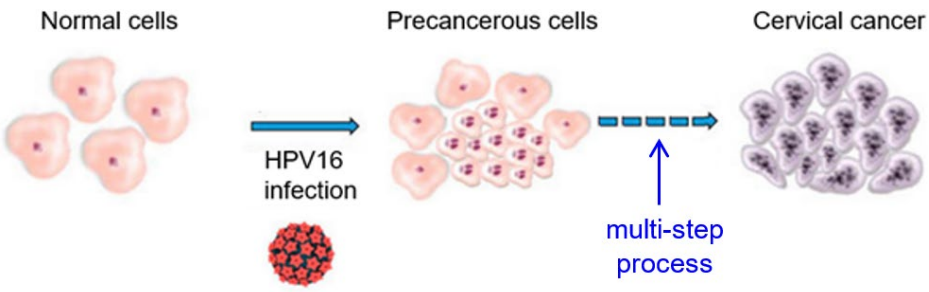

Fig. 2.2

(b) Suggest how HPV16 infection may cause the development of HPV-related cervical cancer. [4]

1. HPV DNA integrates into host chromosome, causes a gain-in-function mutation of protooncogene to oncogene / loss-of-function mutation of tumour suppressor genes / mutations in genes controlling cell cycle / AW;
2. lead to change / distortion in shape/ smaller size and/ or loss of contact inhibition of precancerous cells;
3. Increasing number of precancerous cells lead to larger number of infectious virus particles to be produced and released to infect more surrounding cells;
4. Cervical cancer is a multi-step process taking several years leading to uncontrolled division of cells / formation of tumours;
5. involving accumulation of several mutations in genes controlling cell cycle/ at least one gain in function mutation of proto-oncogenes, and several loss of function mutation of tumour suppressor genes;

(c) A vaccine can be used to produce immunity to HPV.

(i) Describe how memory cells are important in this process. [3]

- Memory cells produced / remain / stored (from vaccination)/ AW;
- (When individual) comes into contact with virus / antigen (again), rapid / secondary / greater response;
- Many or more antibodies produced to destroy virus / antigen before it can cause harm / symptoms / cancer/ AW;

Some doctors suggested offering the vaccine to young men.

(ii) Explain the advantage of vaccinating young men as well as young women. [2]

1. HPV destroyed in males (accept vaccinated individuals) / prevents males being carriers of HPV;
2. Prevents males passing on HPV (to unvaccinated females)
3. HPV may cause (other) cancers in males/ protect against (other) cancers in males;

Question 3

North America is home to diverse migratory bird species that travel long distances between their breeding grounds in the north and wintering grounds in the south. One such migratory bird species is the American robin, a widespread bird across North America. During the winter season, the robins will migrate from the northern region of Canada to the southern region to seek for their food source – caterpillars.

Over the years, climate changes have affected the population of American robins, affecting their migration pattern and possibly impacting their survival.

Figure 3.1 below shows the average global temperature over the years.

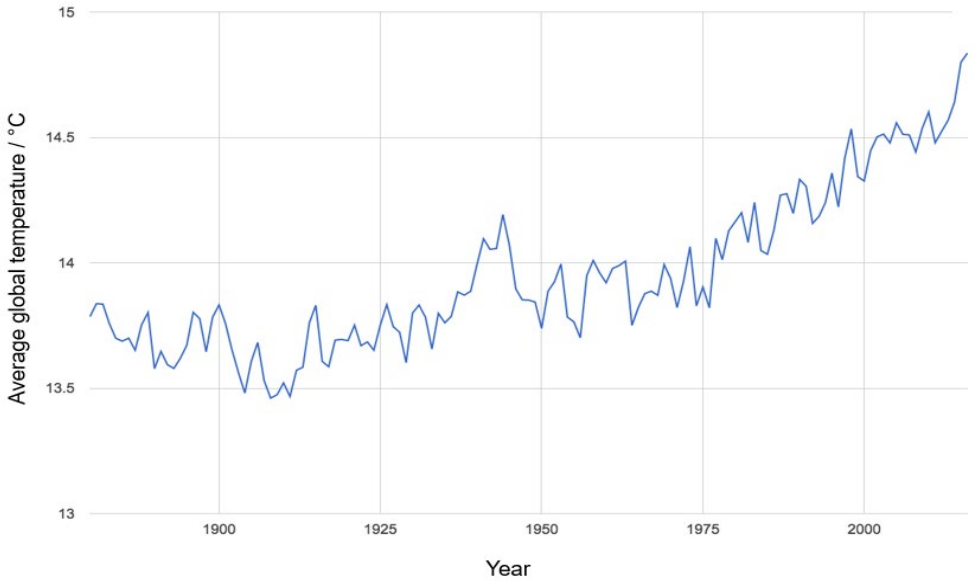

Figure 3.1

Figure 3.2 shows the migration period of the robins from north Canada to south Canada in 1950 and 2000 while Figure 3.3 shows the period where there is great abundance of caterpillars in south Canada in 1950 and 2000.

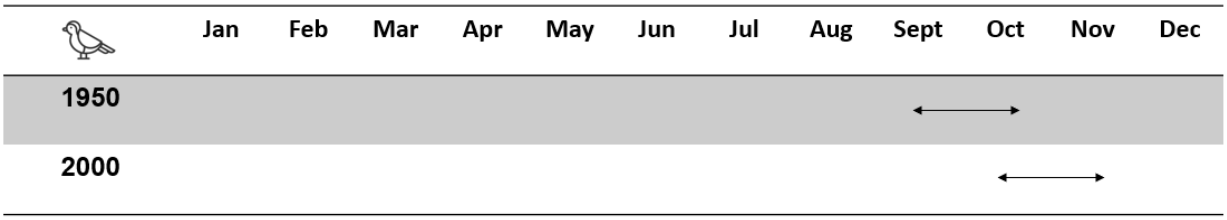

Figure 3.2

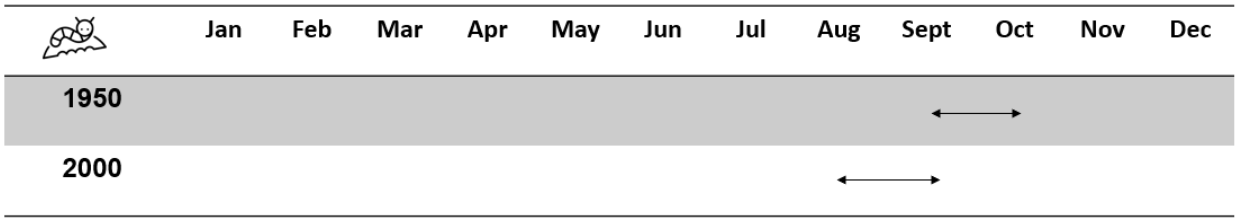

Figure 3.3

Climate change has been said to affect the American robins migratory phenology.

(a) Explain what is meant by the term “phenology”. [1]

- Phenology refers to **the timing of events** over the **annual cycle** of animals.

(b) With reference to Fig. 3.1 and 3.2, describe and explain how climate change has caused the change in the migration pattern. [3]

1. From 1950-2000 there was an increase in global average temperature (QV) due to global warming.
2. The migration of the robin was delayed from September to October in 1950 to October to November in 2000.
3. This can be due to warmer winter/delayed offset of winter because of which delays the departure of the robin from southern Canada
4. As there is still availability of food source.

(c) Explain why caterpillars are found in abundance earlier as shown in Figure 3.3. [2]

- The increase in global temperature can increase the metabolic rate of the insect.
- This can result in the shortening of developmental time of the insect, resulting in caterpillars emerging from the egg much earlier.

(d) Discuss how changes shown in Fig. 3.2 and Fig. 3.3 can impact the American robins. [4]

1. The robins migrate later while the caterpillars are in abundance earlier.
2. This results in the lack of food source for robins as they arrive at south Canada
3. The lack of food source can results in reduced viability of the robins as south Canada
4. Robins might need to fly further south to find a region with food source
5. Robins might need to find other food sources in the region in order to survive
   AVP

Section B Essay answers

4(a) Discuss the importance of transmembrane proteins in glucose regulation and metabolism. [15]

1. In the regulation of blood glucose concentration**, insulin** is released when the **blood glucose concentration is above the norm** while **glucagon** is released when the **blood concentration is below the norm**.

2. Insulin then binds to the **receptor tyrosine kinase** on the muscle/liver cells, which is a transmembrane receptor/protein

3. Upon ligand binding, there is a **conformational change** to the receptor results in its **activation**.

4. **Cross phosphorylation** of the RTK occurs which results in subsequent signal transduction process/ activates other relay proteins to elicit cellular responses

5. Vesicles that contain the **glucose carrier**, also a transmembrane protein, can **move and fuse with the cell surface membrane**

6. This transmembrane protein can help to **facilitate the increase in glucose uptake** into the cell via **facilitated diffusion** which helps to reduce the blood glucose concentration.

7. This can stimulate glycogenesis/glycolysis/glucokinase/glycogen synthetase or inhibit glyogenolysis/ glycogen phosphorylase

8. **Glucagon will bind to the G protein coupled receptors which is a transmembrane** protein and activate it through a conformational change.

9. **G protein will be activated** which will then activate the **adenylyl cyclase** which is also a transmembrane protein.

10. Adenylyl cyclase is important for the **conversion of ATP into second messenger cAMP.**

11. cAMP will activate **protein kinase A** and bring about responses to increase the blood glucose concentration

12. It will stimulate glucogensis/glycogenolysis/ glycogen phosphorylase/ inhibits glycogen synthetase

13. In cellular respiration, glucose will undergo **glycolysis, link reaction and Krebs cycle to produce reduced NAD and FAD.**

14. . A **transmembrane protein (pyruvate translocase)** is responsible for the **uptake of pyruvate** which is formed from glycolysis into the mitochondrion.

15. In **oxidative phosphorylation, electron carriers** are embedded on **the inner mitochondrion membrane.**

16. As electrons are passed down these electron carriers of progressively lower energy, energy is released to pump protons from matrix to intermembrane space to create a **proton motive force.**

17. **ATP synthase** a transmembrane protein in the inner mitochondrion membrane allows for **protons to diffuse down its electrochemical gradient** into the matrix to synthesise ATP.
QWC: Cover Insulin, glucagon signaling pathway and cellular respiration.

4(b) The human gut microbiome refers to the full array of microorganisms living in the gastrointestinal tract. These microorganisms include fungi, bacteria and viruses. These groups of microorganisms are dynamic and change in response to a host of environmental factors such as diet, exercise and other exposures.

Explain how the community of viruses and bacteria can facilitate phenotypic alterations of a bacterium resulting in its survival in an antibiotic rich gut environment. [10]

Introduction [Max-2m]

1. To cause phenotypic alterations, the characteristic must be encoded by gene;
2. Resistance is encoded by a gene found in R plasmid/DNA from donor/ DNA from environment contain **antibiotic resistance** gene which allows bacteria to survive;
3. Results in changes in the bacteria's **genotype and phenotype**;
4. Can acquire via **Horizontal gene transfer** involving mechanisms such as transformation, transduction and conjugation;

Mechanisms

Transformation (Max 3)

5. [What] Transformation is the process by which a (naked foreign) DNA molecule/ plasmid (genetic material) is taken up from the surrounding external environment;
6. Source of DNA: dead bacteria that release their DNA into the environment;
7. Taken up and integrated into the bacterium's genome/chromosome via homologous recombination/ crossing over with a homologous region;
   (Note plasmid need not be integrated into the bacteria DNA)
8. thus resulting in the change of recipient bacterial cell's genotype/ bacterium can now express this new gene that it has acquired; (Note introduction: no double awarding)
   Or
   If fragment of DNA codes for antibiotic resistance, the bacterium would now be antibiotic resistant/ be able to survive in an antibiotic environment;

Transduction (Max 3)

9. [What] Transduction is the process by which DNA is transferred from one bacterial cell (donor) to another (recipient)/ between bacteria by **bacteriophages;**
10. Generalized transduction:
    Main idea: Random piece of DNA /**bacteria host cell's degraded DNA** from the first bacterium is packaged into new phages during assembly of new phages and integrated into the second bacterium's/ recipient cell genome via homologous recombination when the phages infect a second host; (homologous recombination – mark once only)
11. Specialised transduction
    When the **prophage/ integrated viral DNA is improperly excised,** resulting in the gene coding for resistance, that is adjacent to the prophage being cut along with it and the gene can be incorporated into the next host bacterium genome;

12. Relate lysis of bacterial cells to the release of gene coding for resistance being found in the environment;

Conjugation (Max 3)

13. Conjugation is the process by which bacterial cells make **direct contact** with each other and DNA/genetic material is directly transferred from one donor cell to the another recipient cell;;
    Or describe as below
14. The **F^+ cell/** DNA donor/(1 bacterium to another) forms a temporary cytoplasmic mating bridge (also known as conjugation tube or mating bridge) with the F^- cell/ recipient cell through which direct DNA transfer occurs;
15. (Idea of the transferred plasmid becoming double stranded) the single stranded F plasmid that is transferred to the recipient cell replicates/ both single stranded F plasmid in the 2 bacteria cells replicate to form double stranded F plasmid;

(**Accept R plasmid** as these plasmids can contain genes that promote conjugation.)
Reject this point if F or R plasmid not mentioned anywhere in the answer.

QWC: answers must include at least 2 different mechanisms of horizontal gene transfer that must include viruses and bacteria. (1m)

5(a) Explain the normal functions of blood stem cells and discuss how the cells they differentiated into work together to provide effective immune responses against pathogens. [15]

A: Normal Functions of Blood Stem Cells

- Blood stem cells are multipotent stem cells that reside in the bone marrow;
- capable of mitotic cell division and renewing themselves for long periods/ long term self-renewal;
- undifferentiated cells with no tissue-specific structures or functions with the capacity to differentiate/ give rise to specialised cell types e.g., all the immune cells, other blood cells like red blood cells (RBCs) and platelet-producing cells known as megakaryocytes under appropriate conditions;
- play a vital role in maintaining the constant supply of various blood cell types within the body/ AW;
- ability to differentiate into two main lineages, lymphoid and myeloid stem cells;
- Myeloid stem cell may differentiate to give rise to cells such as monocytes, macrophages, neutrophils, basophils, eosinophils, erythrocytes (red blood cells) and platelets (any 3);
- lymphoid stem cell may differentiate to give rise to cells such as T cells, B cells and natural killer cells;
- Which differentiation path the cell takes is regulated by cytokines and / or hormones;

B: Innate Immune System and Cell Functions

- Cells of the innate immune system provides the next line of defence against infection/ cellular defence if pathogens successfully penetrate the body's first defence/ enter the body;
- Innate immune cells express cell-surface receptors that recognise molecules (antigens) associated with a broad class of pathogens;
- Neutrophils are rapidly mobilised to enter the sites of infection to remove pathogens via phagocytosis and kill pathogens by releasing microcidal molecules;
- Macrophages, derived from monocytes, kill and remove pathogens via phagocytosis and release cytokines to cause inflammation;
- Dendritic cells ingest pathogens via phagocytosis and are professional antigen presenting cells to activate the adaptive immune system;
- Eosinophils are involved mainly in immune response against parasitic worms and other intestinal parasites;

Accept: Natural killer cells kill infected cells which expressed molecules on their surfaces that act as stress signals recognised by the natural killer cells;
Reject: Basophils and mast cells because more involved in allergic reactions.

C: Link between innate and adaptive immune systems

- Innate immune cells provide an initial rapid response to limit pathogen spread;
- Antigen presenting cells / any named APCs (after phagocytosis and enzymatic digestion of pathogens) display digested antigen peptide fragments on their cell surface/ facilitate the activation of adaptive immune responses through antigen presentation;
- The displayed antigen fragments is specifically recognised by helper T cells of the adaptive immune system, resulting in their activation;
- leading to a more targeted and potent attack on the pathogen/ AW;

D: Adaptive Immune System and Cell Functions

- Adaptive immune system is highly specific to the particular pathogen that induced it;

- involves lymphocytes/ B and T cells which defence against pathogens that managed to evade or overcome innate immunity;
- Helper T cells stimulate B cells and cytotoxic T cells, enhancing their responses/ function to regulate activities of other immune cells via the secretion of cytokines;
- Cytotoxic T cells function to identify and kill abnormal cells in the body / reference to targeting infected host cells and eliminate them;
- B / plasma cells produce antibodies that can neutralise pathogens and mark them for destruction/ other ways to combat pathogens (any 1);
- memory B cells and memory T cells are generated during the primary immune response and provide long-lasting immunity / ensure a faster and more effective reaction upon re-exposure to the same pathogen;

Accept: reference to naïve T and B cells and their activation;

QWC: 1 mark (at least 1 from parts A-D)

5(b) "Mutations are necessary for survival." Using named examples, discuss the validity of this statement. [10]

Introduction/Definition of terms [D]

- A gene mutation is a change in the nucleotide /base sequence in **DNA***;
- Depends on the **type of mutation** (substitution, addition, deletion) and **location of mutation (coding vs non-coding)**;

Overall marking guideline	What is the mutation? **1m each bullet** What is the effect of this mutation? What is the impact of mutation on survival/fitness	Valid/ not valid
Immune system (Individual)	1. Somatic hyper-mutation as random point mutations that occur in the variable regions/ VDJ gene segments of the heavy chains and VJ gene segments of the light chain when activated B cells undergo clonal expansion; R: mutations in the heavy and light chain because this includes the constant region of the heavy chain; 2. Some of these mutations increase the binding affinity of the antibody for its epitope /increase affinity maturation to pathogen/epitope 3. (idea of) resulting in better /more effective protection against the pathogen/ more effectively removed/ clear infection etc	Valid Survival of the individual
Evolution (Population) 4m max	1. Mutation is the **source of all new alleles**/ genetic variation in a population, resulting in variation in phenotypes /new phenotypes; **2.** Genetic variation produced by mutations is the **raw material for natural selection;** 3. Important for **survival of species** when **environment changes**/ adaptability of species; 4. As different environment exerts different selective pressures/ selects for different phenotype;	Survival of the population/ species
Genetic diseases Eg. Sickle cell anaemia 5m max of if include individual and	1. a **single base substitution** where Thymine replaced by adenine (template) results in glutamic acid being replaced by valine; 2. Haemoglobin forms insoluble fibers/ppt out of solution at low oxygen concentrations; 3. causing RBC to sickle, blocking circulation /supply of oxygen to vital organs, obstruct blood vessels, spleen enlargement and damage; RBC more fragile and haemolyse more easily; (name any 2 effects but the effects must affect survivability)	Not valid Individual come down with disease

population levels	4. a **single base substitution** where Thymine replaced by adenine (template) results in glutamic acid being replaced by valine; (Award once only) 5. **Heterozygote advantage** at places with **malaria/** heterozygotes are selected for at places with malaria; Or Presence of malaria selects for individuals with genotype Hb^AHb^S; 6. Advantage of heterozygotes over both homozygotes HbAHbA – suffers from malaria, HbSHbS – suffers from sickle cell anaemia, HbAHbS – only normal RBC are affected but not the sickle cell type;	Valid at population level – places with malaria
Cancer	1. Loss of function mutation in tumor suppressor genes will result in inability to inhibit cell cycle, repair damaged DNA and promote apoptosis; 2. Gain of function mutation in protooncogene (resulting in production of oncogene] will result in overexpression of proteins/growth factors OR production of hyperactive proteins etc that promotes cell growth and division/ overproduction of ras protein/constitutively active; Must have some idea of the increase cell division, not just overstimulate cell cycle 3. Accumulation of mutations in several TSG and at least one protooncogene results in dysregulation of cell cycle/ loss of cell cycle checkpoints and cells divide out of control, resulting in cancer; Accumulation of mutations of critical genes controlling cell cycle….	Not valid Decrease survivability of the individual
AVP Others 2m max	• Mutation in the non-coding region eg. **introns** – no effect as introns will be removed during post transcriptional modification; • Substitution mutation that results in the same amino acid being coded for/ Silent mutation due to degeneracy of the genetic code;	Not valid – no effect
AVP	• Viruses mutating – antigenic drift resulting in changes to 3D conformation of the viral glycoproteins; • Viruses escape host immune mechanism and hence can continue to propagate or for humans – repeated infections;	Valid – virus perspective Not valid – human perspective
Down's syndrome	• Non-disjunction of chromosome 21 or 22 / failure of chromosomes to separate either in meiosis I or II/ during meiosis; • Examples of symptoms that confer disadvantage: Mental retardation, **lower than average life-span** due to heart defects, susceptibility to respiratory infection and developing leukaemia and Alzheimer's disease; most are sexually undeveloped and sterile;	Valid

QWC: Have examples to support both valid and not valid stand