

VICTORIA JUNIOR COLLEGE
BIOLOGY DEPARTMENT
JC2 PRELIMINARY EXAMINATIONS 2017
HIGHER 1 8755
PAPER 2



1

- (a) (i) Identify organelle A. Support your answer with one observable feature, other than vesicles, shown in Fig 1.

Golgi body/ golgi apparatus;;
A stack of membranes with swollen ends;;

- (ii) Describe the differences in the role of the vesicles that fuse with the forming face and the vesicles that are formed at the maturing face. [4]

Box C: [2m]

- vesicles contain proteins and/or lipids;
- transported from rER and sER;
- that will undergo chemical **modification** within the golgi body;
- **examples** of modification: glycolysation, phosphorylation etc

Box B: [2m]

- Packaging and transport function: Vesicles containing modified products will be transported to the cell membrane;
- where they **fuse** and **release** the products to the outside of the cell
- via **exocytosis**;

- (b) Explain how the lack of E3A expression can lead to a disruption in the structure and function of the Golgi apparatus.

- Lack of gene expression means that the enzyme E3A is not **produced/** transcribed and translated;;
- Proteins that are tagged by ubiquitin, are meant for **degradation**;;
- These proteins are either **damaged/abnormal/excess**;;
- Removal of these proteins help to maintain the normal functions of the GA (idea of);; (A: reverse argument)

- (c) Explain the importance of membrane-bound organelles in allowing the increase in size of eukaryotic cells. [3]

- Increases in the size of a cell is only possible if it can meet the increases in **nutrient and energy** demands;;
- Membrane-bound organelles allows **compartmentation and specialisation**;;
- All the enzymes and substrates involved are located in one place;

- allows the setting up of an environment that is **optimal** to the functioning of the enzymes;
 - and increase **efficiency** of metabolic processes;
- (A: named example with the same idea eg. mitochondria that increases efficiency of respiration)

[Total: 11]

2

(a) (i) Structures R and Q are two different biomolecules that make up a typical chromosome. Identify structures R and Q. [1]

- R – DNA; Q – (histone) proteins;

(ii) State two structural differences between R and Q. [2]

- Type of bonds – Q contains peptide bond while R contains phosphodiester bonds
- Type of monomers – Q consists of amino acids while R consists of nucleotides
- Shape – Q is globular, compact while R has double helical shape
- AVP

(iii) With reference to Fig 2, discuss the significance of the interaction between R and Q in eukaryotes. [2]

- Ref large size of eukaryotic genome / ref length of eukaryote DNA molecule;
- R (DNA) is wrapped / wound around Q (proteins);
- to allow tight packing of the DNA molecule;
- To enable it to fit into a small space eg. nucleus of a cell;

(b) (i) Suggest how the kinetochore proteins is able to bind specifically to the centromeric sequences. [2]

- Ref specific **DNA sequences** of centromere constitute a **specific 3D shape**;;
- Which is complementary to the shape of the binding site for the kinetochore;;

(ii) Explain the consequences to the cell if the kinetochore protein is unable to bind successfully to the centromere during cellular division. [2]

- Spindle fibres **unable to attach properly** to each chromosomes;
- **Non-disjunction**;
- **Unequal separation** of chromosomes to each daughter cells;
- Idea of daughter cells may not be viable;

(iii) Suggest what would happen to a chromosome if a mutation causes it to contain more than one centromeric sequence. [1]

- It may fragment / break into pieces when different spindle fibres become attached to the same chromosome and pull it apart;; AVP;;

3 (a)

(i) Using Fig 3.1, explain what is meant by “a homologous feature”. [2]

- A structure with a common evolutionary origin / evidence that different species share a **common ancestor**;;
- that have been modified to adapt to a particular environment seen in different species / descent with modification to serve different functions;;

(ii) Explain how this provides evidence in support of Darwin’s theory of natural selection. [4]

- Forelimbs of different species show the **same basic plan** in terms of the arrangement of bones;;
- Provides evidence that **vertebrates** share a **common ancestor**;;
- Basic plan has been structurally **modified** through **natural selection**;;/ **descent with modification** has occurred in different species/ trait held by a common ancestor evolves into different variations over time;;
- which allows the limb to adapt to a certain method of locomotion (e.g. flying, swimming, etc.) in a particular environment;;/ adapt to different selective pressures in different environments;;

(b) DNA from the fossil material of these birds were extracted and amplified. State the name of the technique used and outline the major steps involved. [3]

- Polymerase chain reaction (PCR);;
- Major steps of PCR;;
30 3-step cycle: Denaturation (95°C), Annealing (45-55°C) and Extension (72°C)
- require dNTPs, ATP, Taq polymerase, forward and reverse primers;;

(c) State two advantages of using molecular data over morphological data to establish relationships between different vertebrates. [2]

- All forms of life use the same genetic language of **DNA and RNA and the genetic code** is universal;
- Even dissimilar organisms share genes inherited from a common ancestor;
- Hence, molecular data can be used to compare across all organisms, even microscopic organisms, some of which like amoeba can **change shape** and difficult to categorise based on morphology;;
- Adults and young may also appear different and hence making morphological comparisons challenging;;
- Convergent evolution resulting in organisms from different ancestral lineages sharing similar morphological features will make morphological comparisons difficult too;;

[2max]

4

(a) Describe how GM salmon is produced in the laboratory [4]

- *What?*
- *Gene of interest : Growth hormone from Chinook*
- *How?*
- *Technicality of GMO : Microinjection/ Electroporation*
- *Recombinant DNA plus Promoter from Ocean pout introduced to target species of salmon*
- *Selection and breeding of GM salmon*
- *Why?*
- *GM salmon with growth hormone can feed and grow continuously, so bigger*

GM salmon

Recombinant DNA

- Antifreeze promoter from an Ocean pout
- Growth hormone gene from a Pacific Chinook salmon
- Fusing of a strong gene promoter such as the ocean pout antifreeze promoter leads to enhancement in the expression of the gene construct
- The recombinant DNA is then introduced into fertilized eggs of Atlantic salmon

There are two methods to modify salmon eggs to produce GM salmon:

(1 Mark awarded for ANY ONE method)

- **Microinjection** – foreign gene was microinjected into the cytoplasm of one-to-four cell embryos

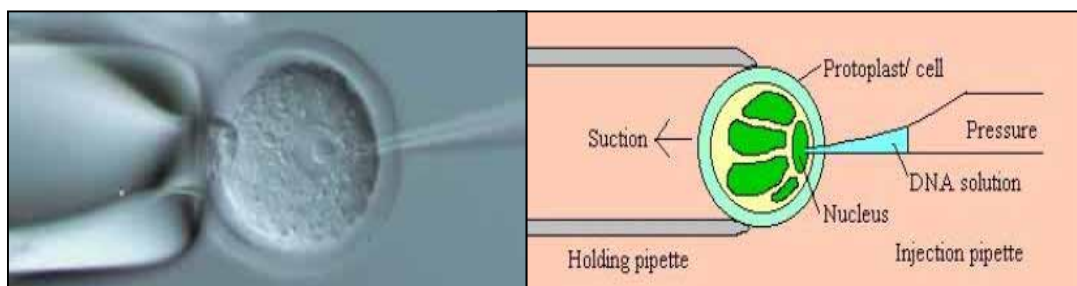


Figure 10: Techniques in production of GM salmon – (a) Microinjection

http://nims.umdni.edu/departments/cell_biology_and_molecular_medicine/images/microinjection3.jpg

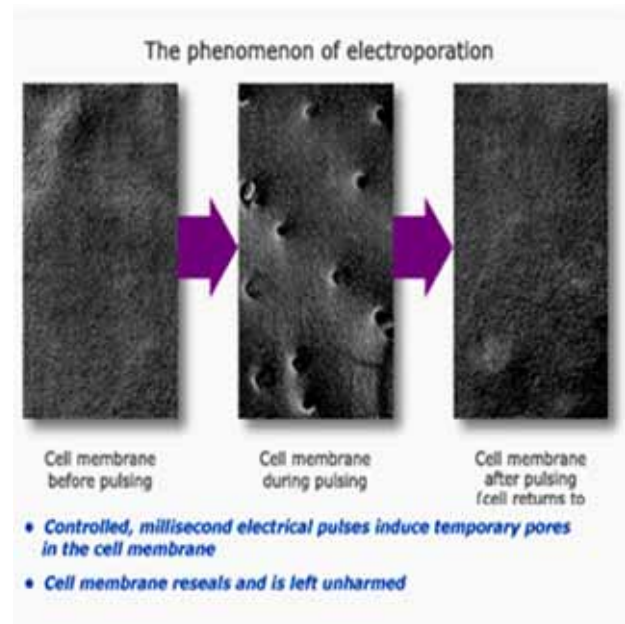
OR

- **Electroporation** – involves placing the eggs in a buffer solution containing DNA and applying short electrical pulses to create transient openings of the

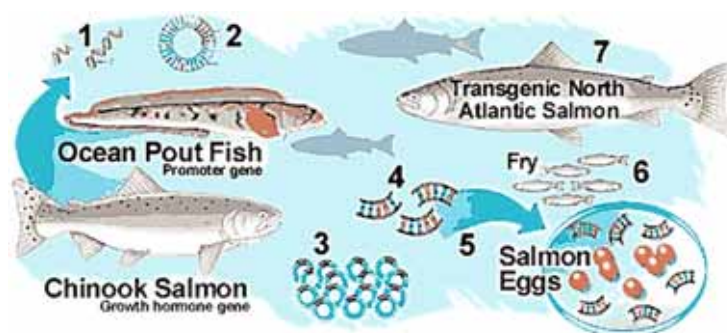
cell membrane, allowing the transfer of genetic material from solution into the cell



Figure 11: Techniques in production of GM salmon – (b) Electroporation
http://www.inovio.com/images/IMG_electroporation.gif



- Subsequent selection and breeding led to development of the genetically modified salmon
- Due to the **year-round production** of growth hormone (due to the antifreeze promoter), this allows for **continuous feeding and growth** of the GM salmon.
- The GM salmon is able to grow quicker in size while feeding more efficiently (less feed is consumed to reach a larger size)



Producing a GM salmon

[4 max]

- (b) Describe briefly the advantages of farming GM salmon (AquAdvantage) over normal salmon [2]
- GM salmon showed a **faster growth rate** than standard salmon

- Lesser resources need to farm the GM salmon

It reached 500g within 250 days compared to standard salmon that took 450 days for the same weight gain (allow similar comparisons for other quoted values at 1000/2000/4000g);; OR

GM salmon grew bigger than standard salmon, reaching 6000g by 700th day but even with another 150 days of growing, at 850 days, standard salmon reached only 4000g in weight;;

- (c) There are many public concerns about the impact of Genetically modified organisms on the natural ecosystems. The following chart shows the results of an experiment conducted by Biotech companies who made GM salmon. Explain why public worries on GMO could actually be unfounded. [2]

- Although GM salmon grew over twice bigger than non-GM salmon at 300mm in the hatchery;
- GM salmon remained roughly the same size, if not, only slight larger at 130mm compared to 100mm in a simulated natural environment;;
- This shows that GM salmon, even if released into the wild, might not have a higher survival fitness and outcompete the wild non-GM salmon by outgrowing them;;
- Hence it is safe to farm and even release them into natural ecosystems;

ESQ

- 5 (a) Using methylene blue, describe an experiment to study the effects of different concentrations of glucose on the enzyme catalysed reactions in respiring yeast cells. Explain the scientific theory behind the design of your experiment. [8]

- Aerobic respiration involves the stages of glycolysis, link reaction, Krebs cycle and the Electron transport chain;
- As respiration process occurs, hydrogen atom are released which instead of being taken up by the usual **coenzymes like NAD**; or **FAD**;
- will now reduce Methylene blue as it is an effective hydrogen acceptor;
- This is indicated by a colour change in Methylene blue from blue to colourless;
- The rate at which this colour change occurs can thus be used to measure the rate of respiration of the yeast cells;
- Higher concentrations of glucose will take longer to process and thus a slower colour change

[3]

Experimental method

(General idea of the various steps in bold)

1. **Prepare five concentrations of glucose, ranging from 0.5%, 1%, 2% 5% and 10% from a stock solution;;**
2. **Label six boiling tubes A – G;**
3. Starting from the 10% stock solution, add equal volumes of distilled water and glucose to make 10cm³ of solution;;
4. Dilute each new solution made with equal volumes of distilled water and continue until all the five different concentrations of glucose are prepared, after which placing each tube in a rack;
5. **Into each tube add 3 drops of Methylene blue;**
6. **Add 5cm³ yeast solution to each tube noting the time;**
7. **Shake each tube to mix the contents and place back into the rack;**
8. **Do not disturb the tubes again but note the time taken for the blue colour to disappear from each tube;**
9. Repeat step 1-8 with replicates;

[5 max]

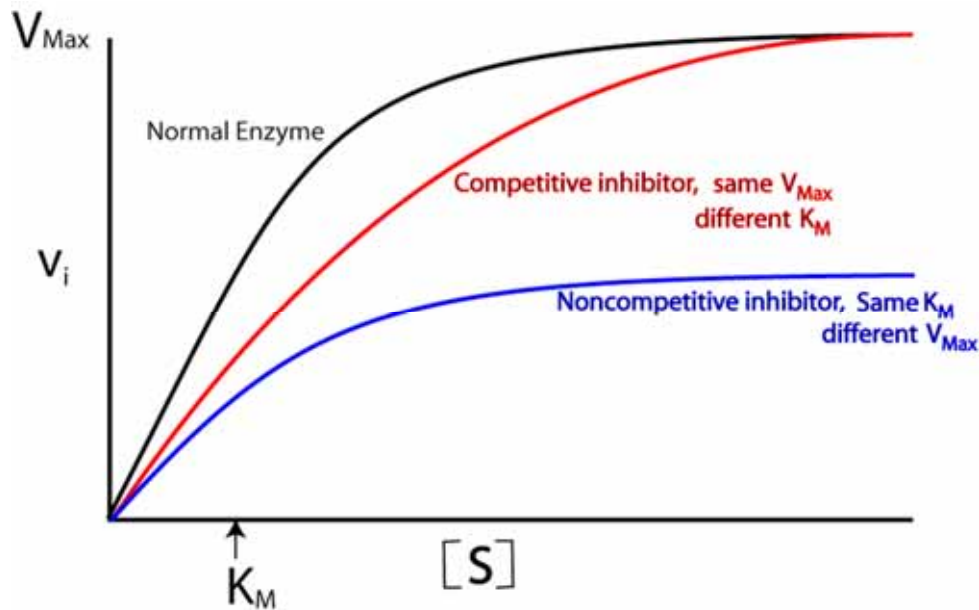
- (b) A small amount of inhibitor is added to reaction mixture, explain how you would go about determining the mode of action of this inhibitor. [8]

Competitive inhibition (CI) (4max)

- Addition of a small amount of competitive inhibitor will have an impact on the lower concentrations of glucose;;
- At low substrate concentrations, CI molecules who have similar shapes to the original substrates, in this case glucose molecules, will compete for the active sites on the yeast enzymes;;
- Forming enzyme-inhibitor complexes instead of enzyme –substrate complexes;;
- This is because CI can also show affinity to the active sites but will have no enzymatic product at the end of the binding;;
- This results in a slower overall rate of enzymatic reaction;
- At higher substrate concentrations, say > 2%, the impact of adding CI is reduced by the presence of many more substrate molecules which result in a similar K_{max} achieved for the enzymatic reaction. K_m is changed;;

Non-competitive inhibition (NCI) (4max)

- Addition of NCI will have an impact on the V_{max} and hence overall rate of reaction regardless of the substrate concentration;
- NCI molecules will probably bind to a site other than the active site, often called an allosteric site;;
- This alters the overall 3D conformation of the enzyme and hence changes the shape and configuration of the active site;;
- This prevents binding by the original substrates like glucose and hence no formation of enzyme-substrate complexes is possible;;
- Depending on the concentration of NCI added, V_{max} will be lowered but K_m remains;;



- (c) Using a named example, explain the normal function of stem cells in a living organism. [4]

Blood stem cell (haematopoietic stem cells);;

- Haematopoietic stem cells are **multipotent cells** with the ability to differentiate into the different **blood cells** and **immune cells**;;
- Major sources of haematopoietic stem cells include adult **bone marrow** and **umbilical cord blood**;;
- All the various types of blood cells are produced in the **bone marrow**, particularly in the ribs, vertebrae, breastbone and pelvis. These cells arise from a single type of cells called a **hematopoietic stem cell** (an adult multipotent stem cell);
- Umbilical cord blood is **human blood from the placenta and umbilical cord** that is rich in hematopoietic stem cells. The **haematopoietic stem cells** in the umbilical cord blood can be used to generate blood and immune cells;

OR

Embryonic stem cells;;

- **Pluripotent** stem cells derived from a group of cells called the inner cell mass, which is part of the early (4 – 5 day) embryo called the blastocyst;; **Pluripotency** refers to the ability to differentiate into almost any cell type to form any organ or type of cell;;
- Self-renewal- embryonic stem cells are “immortal”, i.e. these cells can **reproduce indefinitely** (can grow and divide for long periods in an undifferentiated state);;
 - Gives rise to cells from all three embryonic germ layers, ectoderm, mesoderm and endoderm;;

6 (a) Explain how the structural features of the cell membrane enable it to transport materials in and out of the cell [9]

- The cell membrane serves as boundary of cell;
- Selectively permeable to regulate movements of substances in and out;;
- Made up of mostly lipids (phospholipids and cholesterol), proteins and carbohydrates;;
- Phospholipid is most abundant, consists of two non-polar hydrocarbon chains and one polar phosphate head, phosphate molecules orientate to form a lipid bilayer;;
- Hydrophilic polar heads face the aqueous environment while the hydrophobic hydrocarbon tails face inwards and form a hydrophobic core within the lipid bilayer;;
- Only non-polar substances, like O_2 and CO_2 can move freely across the lipid bilayer via simple diffusion;
- Embedded within the lipid bilayers are protein carriers and protein channels which transport polar substances (eg glucose) and charged particles (eg ions) across the membrane;;
- These transport proteins are made up of both hydrophilic and hydrophobic amino acids;;
- The hydrophobic regions interact with the hydrophobic core of the lipid bilayer;
- The hydrophilic regions interact with the substances to be transported across;
- Pore of channel protein made of hydrophilic amino acids to allow ions to flow through down their concentration gradient via facilitated diffusion;;
- Ions like Na^+/K^+ will be transported against their concentration gradient via Na^+/K^+ pumps with the energy provided by ATP;;
- Conformational change in transport proteins allow substances to be moved across the membrane via facilitated diffusion or active transport;;
- Bulk transport can also take place with infolding of region of the plasma membrane which later pinches off to form a vesicle;
- Endocytosis allow larger substances to enter the cell enclosed within a membrane bound vesicle;
- Ref to pinocytosis (cell drinking) and phagocytosis (cell eating);
- Exocytosis is the secretion of substances out of the cell;
- Involves formation of vesicles from the Golgi apparatus;
- Secretory vesicles containing substances (digestive enzymes, peptide hormones) pinches from the trans face of the GA and migrates to the cell surface;
- The membrane of the secretory vesicle fuses with the plasma membrane and the contents are released out of the cell;

[9 max]

(b) Explain the significance of having double membranes in organelles like mitochondria and chloroplasts [5]

- Double membranes allow the compartmentalisation of space;;

- Creates the inner membrane space in mitochondria and thylakoid space in chloroplasts for the storage of protons (H^+ ions);;
- This is necessary for the build-up of a proton gradient that is the proton motive force behind the process of chemiosmosis that makes energy in the form of ATP;
- Increase in the surface area for **spatial arrangement** of reaction and attachment of components of the electron transport chain (ETC);;
- Without the inner membrane, the series of redox reactions occurring down the ETC as electrons are being passed on to the final electron acceptor will not be possible;;
- The creation of the matrix and stroma spaces in the mitochondria and chloroplasts respectively with the membrane segregation also allow separate reactions to occur and hence facilitate their **regulation** and control in cellular respiration and photosynthesis;;
- Double membranes also serve as evidence of the endosymbiont theory;
- Such inner membranes might have been derived from the ancestral cell membrane of the organelles who used to be free living while the outer membrane are remnants of the host cell membrane upon phagocytosis;

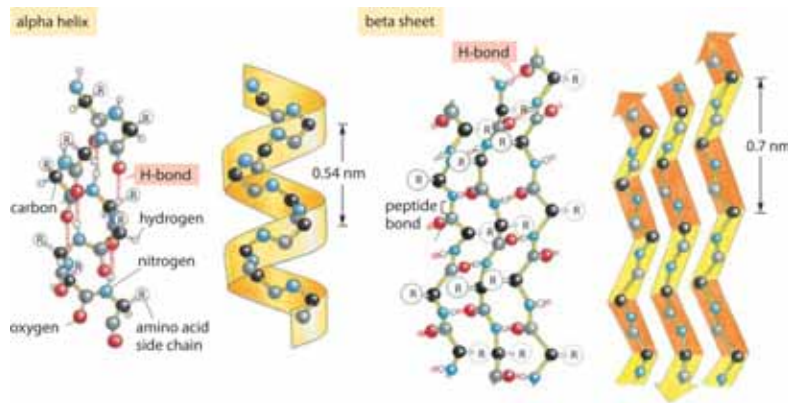
[5max]

(c) Outline the role of hydrogen bonds in biomolecules. [6]

Carbohydrates

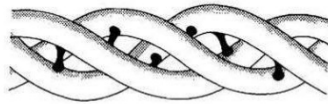
- In amylase, hydrogen bonds serve to stabilise the helical structure
- In starch and glycogen, hydrogen bonds with water molecules form a hydration shell that resulted in a partially soluble polysaccharide that can be approached and digested by hydrophilic enzymes;;
- In cellulose, the hydrogen atoms form **hydrogen bonds** with oxygen atoms in the same glucose molecule and other neighbouring glucose molecules;
- While these hydrogen bonds are individually weak, due to the large numbers of -OH groups, collectively they develop massive tensile strength;
- Also, between 60-70 cellulose molecules become tightly cross linked to form bundles called **microfibrils**, which are in turn held together in bundles called **fibres** by further hydrogen bonding, making the entire structure even stronger;;

Proteins



- Secondary structures like **alpha helix** and **beta pleated sheets** stabilised by H bonds;;
- At tertiary levels and above, a globular protein have non-polar, hydrophobic R groups point into the centre of the molecule, making them **water soluble**, since water clusters around their outward facing hydrophilic groups, but water cannot get into the molecule;;
- However, proteins that form long strands are known as **fibrous** proteins, and are mostly **insoluble** with hydrophobic R groups facing outwards;;
- **Interchain H bonds** within the triple helical structure of each tropocollagen, due to presence of many glycine residues, result in strong, tight coil with **high tensile strength**;;

❖ Hydrogen bonds between the residues stabilise the 3d structure of the tropocollagen.



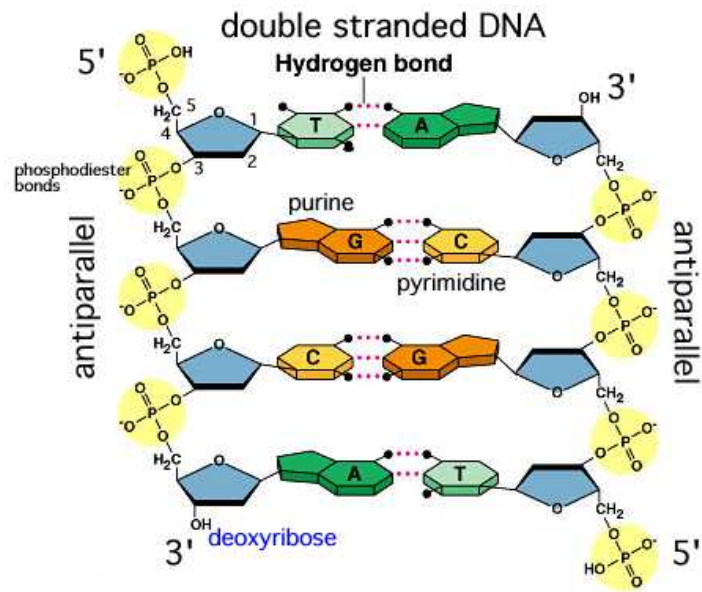
- ❖ Covalent bonds form between tropocollagen molecules which stabilise the collagen fibre.
- ❖ Steric repulsion between proline and hydroxyproline side chain stabilise the whole helix of collagen.

Lipids

- Lack of hydrophilic components within lipid structures meant that it will not form H bonds with water molecules and hence will be insoluble in water, important as storage material or to provide buoyancy and insulation;;

DNA

- H bonds between nitrogenous bases of nucleotides in double helix DNA structure helps to stabilise it and maintain same width throughout;;



[6 max]