2016 VJC H1 Biology Prelim Answer

1 **Fig. 1.1** below shows part of a eukaryotic cell viewed under the microscope.

Fig. 1.1

(a) State two membrane-bound organelles that can be identified in **Fig. 1.1** and briefly describe their functions. [2]

- **Rough endoplasmic reticulum** [1/2]
  - Site of **synthesis and transport of proteins** [1/2]

- **Mitochondria** [1/2]
  - **Aerobic respiration** to produce ATP [1/2]

(bi) Describe the fluid mosaic model of membrane structure. [2]

- The membrane consists of 2 layers of phospholipids with **proteins scattered in a patchwork arrangement** within the bilayer [1/2]
- The **phospholipids exhibit lateral movement** within their own monolayer [1/2]

(bii) Explain the significance of the membrane in oxidative phosphorylation. [3]

- For **attachment of electron carriers** to form the electron transport chain [1/2]
  - Ref. to electron carriers arranged in **decreasing energy level** [1/2]
  - Ref. to **pumping of H^+ from matrix to intermembrane space** [1/2]

- Membrane **impermeable to H^+** [1/2]
  - **High H^+ concentration** in the intermembrane space [1/2]
  - Setting up the **proton motive force** [1/2]

- For **attachment of ATP synthase** [1/2]
  - Allows **chemiosmosis of H^+** down its concentration gradient into matrix [1/2]
  - Energy used to add inorganic phosphate to ADP to **form ATP** [1/2]

(c) Outline the roles of carbohydrates on the cell surface membrane. [3]

- Found on **glycoproteins** and **glycolipids** [1/2]
- Form a layer known as **glycocalyx** [1/2]

- **Cell communications** [1/2]
  - Cell surface identity marker for **recognition of cell type** [1/2]

- **Adhesion to neighbouring cells** for tissue formation [1/2]

- **Stabilise membrane structure** [1/2]
  - Ref. to carbohydrates being **hydrophilic** [1/2]
  - Form **hydrogen bonds** with aqueous extracellular environment [1/2]

2 There have been many breakthroughs in stem cell research in recent years. It has been discovered that stem cells are involved in the replacement of worn-out cells and repair of damaged tissues. Further research is being conducted to better understand the mechanism involved in controlling the behaviour of stem cells in order to better manipulate them to treat various diseases and disorders.

(a) State the type of stem cells involved in the replacement of worn-out cells and repair of damaged tissues, and describe the unique properties of this type of stem cells. [2]

- **Adult stem cells** [1/2]
- **Undifferentiated cells** found in differentiated tissues [1/2]
- **Multipotent** → Able to **differentiate into a limited range of cell types** [1/2]
- Able to **undergo mitotic cell division for self-renewal** [1/2]

(b) Stem cells undergo cell division to produce genetically identical daughter cells. **Fig. 2.1** shows two cells, each at a different stage of cell division.

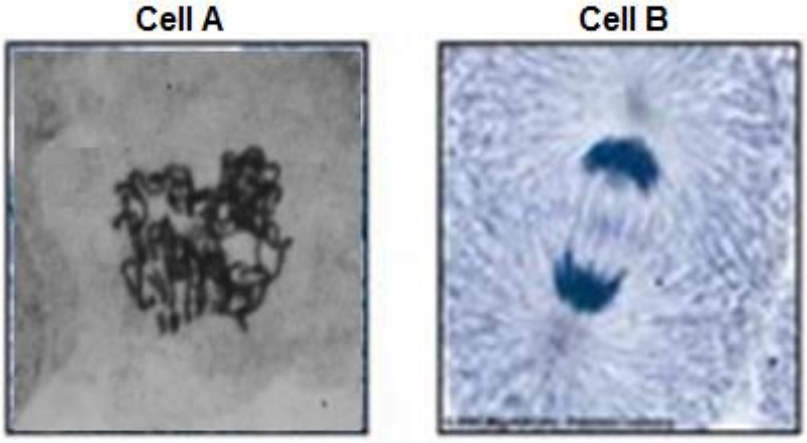


Fig. 2.1

With reference to **Fig. 2.1**,

(i) state the stages of cell division in **Cell A** and **Cell B**. [1]

- **Prophase** (cell A) and **anaphase** (cell B) [1]

(ii) describe how DNA is packaged in **Cell A**. [3]

- Each DNA molecule is in the form of a **double helix** [1/2]
- Which is **wound around histone proteins** [1/2]
- Into **nucleosomes** [1/2]
- Forming **chromatin** threads [1/2]
- Which is then **condensed into chromosomes** [1/2]
- With **2 sister chromatids** joined together [1/2]
- At the **centromere** [1/2]

(iii) explain how a **named** protein allows for the process in **Cell B**. [2]

- **Tubulin** [1/2]
- Which is the subunit that **forms spindle fibres** [1/2]
- Which are **attached to the chromosomes at the centromere** [1/2]
- **Shortening of spindle fibres** pull the sister chromatids to opposite poles [1/2]

(c) Outline how checkpoints allow the normal mitotic cell cycle to be regulated, preventing cancer. [2]

- Ensure that **cell cycle proceeds only when the previous stage is completed** [1/2]
- E.g. **G2/M checkpoint** ensures **accurate DNA replication** [1/2]
- **Cell cycle can be halted** when mistakes arise [1/2]
- Thus **preventing the accumulation of mutations** [1/2]

3 (a) Explain why variation is important in selection. [2]

- **Genetic variation** results in **variation in phenotype** between individuals in a population [1/2]
- Giving rise to **different reproductive success** between individuals [1/2]
- Under a particular **selective pressure** [1/2]
- Individuals with the advantageous variation are **selected for** [1/2]

(b) Calvin cycle is an enzymatic process that occurs as part of photosynthesis. One of the enzymes involved is ribulose bisphosphate carboxylase (Rubisco). It was discovered that the gene coding for Rubisco has many different alleles, each coding for an enzyme with slight variations in the 3D structure. This gives rise to different rates of Calvin cycle in different conditions.

Explain how different alleles give rise to variations in Rubisco structure. [3]

- Different alleles have **different DNA nucleotide sequence** [1/2]
- Due to **gene mutations** [1/2]
- Each allele results in a **different mRNA sequence** after transcription [1/2]
- Thus a **different amino acid sequence / primary structure** after translation [1/2]
- Which **affects folding** of the polypeptide [1/2]
- Giving rise to **different 3D conformation** in the **tertiary structure** [1/2]

(c) **Fig. 3.1** shows the effect of increasing temperature on the activity of two variations of Rubisco. **Rubisco C** is obtained from a species of coniferous tree found in Canada, while **Rubisco S** is obtained from a species of cactus found in the Sahara Desert.

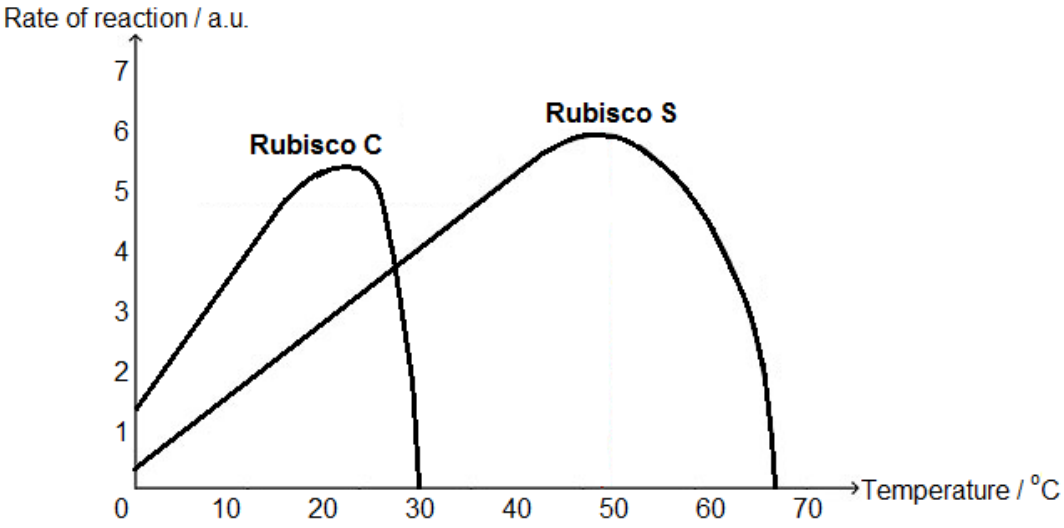


Fig. 3.1

(i) With reference to **Fig. 3.1**, compare the effect of temperature on the two enzymes. [3]

- Rate of reaction increases at a faster rate when temperature increases for Rubisco C compared to Rubisco S + Q.V. [1]
- Maximum rate of reaction is achieved at a lower temperature for Rubisco C compared to Rubisco S + Q.V. [1]
- The maximum rate of reaction at the respective optimum temperature is lower for Rubisco C compared to Rubisco S + Q.V. [1]
- Enzyme denaturation occurs at a lower temperature for for Rubisco C compared to Rubisco S + Q.V. [1]

(ii) Suggest how genetic engineering can be carried out to produce coniferous trees that can adapt to rising temperatures due to global warming. [2]

- **Obtain the allele for Rubisco S** from the cactus found in Sahara Desert [1/2]
- **Introduce the allele into the nuclei of cells** obtained from the coniferous tree [1/2]
- Via the use of **agrobacteria / gene gun / microinjection** [1/2]
- Carry out **plant cloning** with the transformed plant cells to obtain coniferous trees expressing Rubisco S [1/2]

4 A male mouse with long tail was mated with a female mouse with no tail. All the male offspring had no tail but all the female offspring had bent tail.

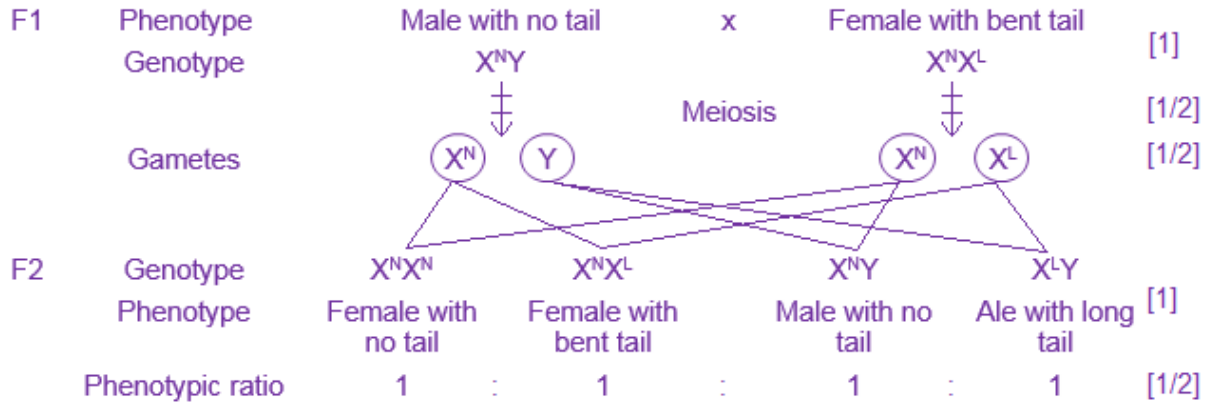
Another male mouse with no tail was then mated with a female mouse with long tail. All the male offspring had long tail but all the female offspring had bent tail.

A male offspring from the first cross was mated with a female offspring from the second cross. The proportion of different offspring is listed below.

Male F2 with long tail	23
Male F2 with no tail	27
Female F2 with bent tail	21
Female F2 with no tail	25

(i) Draw a genetic diagram to deduce the expected phenotypic ratio of the above cross. [4]

Legend:
X^L – Allele for long tail
X^N – Allele for no tail [1/2]



(ii) Is it possible for a male mouse to have a bent tail? Explain your answer. [2]

- Not possible [1/2]
- The bent tail phenotype is a **sex-linked codominant trait** [1/2]
- Due to the **heterozygous genotype of X^NX^L** [1/2]
- Males **only have 1 X chromosome** thus cannot be heterozygous [1/2]

(iii) Explain why the observed F2 numbers do not match the expected phenotypic ratio exactly. [1]

- The observed numbers do not match the 1:1:1:1 ratio due to **sampling errors that arise by chance** [1]

(b) The gene involved in the above study was obtained from mice and cloned into a bacterial plasmid, which is then used to transform viable *E. coli* cells.

Compare between two **named** methods of selecting transformed bacteria with recombinant plasmid. [3]

Named methods	• Replica plating [1/2]	• Blue-white screening [1/2]
Selection markers in plasmid	• 2 antibiotics resistant genes [1/2]	• 1 antibiotics resistant gene and 1 LacZ gene [1/2]
Number of agar plates required	• 2 plates with different antibiotics [1/2]	• 1 plate with antibiotics and Xgal [1/2]
Identification of transformed cells with recombinant plasmid	• Colonies that grow on the 1st plate but not the other [1/2]	• White colonies [1/2]

5 (a) Describe the process of DNA replication. [10]

- **Helicase** binds to **origin of replication** [1/2]
- **Breaks complementary base pairing** between complementary bases [1/2]
- **Unwinds** and separates the double stranded DNA [1/2]
- To form a **replication bubble** [1/2]
- **Single-stranded binding proteins** bind to single-stranded DNA to keep them separated and stabilise the replication bubble [1/2]

- Each strand of DNA serves as a **template strand** for **semi-conservative DNA replication** [1/2]
- **Primase** synthesises a short **RNA primer** complementary to the DNA templates [1/2]
- RNA primers bind to DNA templates through **complementary base pairing** [1/2]
- RNA primers provide the **free 3' OH ends** required by **DNA polymerase III** for elongation of growing DNA strands [1/2]
- **Free DNA nucleotides** bind to the single-stranded template strands by **complementary base pairing** [1/2]
- **DNA polymerase III** catalyses the formation of **phosphodiester bonds** between adjacent DNA nucleotides [1/2]
- In the **5' to 3' direction with respect to the growing DNA strands** [1/2]

- Elongation of the **leading strand** is **continuous towards the replication fork** [1/2]
- Elongation of the **lagging strand** is **discontinuous away from the replication fork** [1/2]
- In the form of **Okazaki fragments** [1/2]
- The **RNA primers are excised and replaced** by complementary DNA nucleotides by **DNA polymerase I** [1/2]
- **DNA ligase** catalyses the formation of **phosphodiester bonds** between **Okazaki fragments** [1/2]

- **2 identical DNA molecules** are formed [1/2]
- Each containing **1 parental DNA strand and 1 newly synthesised DNA strand** [1/2]
- Ref. to **semi-conservative replication** [1/2]

(b) Explain the mode of action of pyruvate decarboxylase. [6]

- Pyruvate decarboxylase catalyses the breakdown of **pyruvate to ethanal and carbon dioxide** [1]
- It has an **active site** [1/2]
- That has a **specific shape complementary to the shape of pyruvate** [1/2]
- Pyruvate binds to the active site [1/2]
- To form the **enzyme-substrate complex** [1/2]
- This causes a **change in enzyme conformation** [1/2]
- Enabling the substrate to **fit more snugly** into the active site [1/2]
- Ref. to **induced-fit hypothesis** [1/2]
- This **lowers the activation energy** of the reaction [1/2]
  - As the bond to be broken is put under physical stress [1/2]
  - Ref. to R groups of catalytic residues which may affect the charges on the substrate [1/2]
- Thus **increasing the rate** of breakdown of pyruvate [1/2]
- The enzyme molecule **remains unchanged** when the reaction is complete and the products have left the active site [1/2]

(c) Discuss the social implications of genetically modified animals. [4]

- Consumption of genetically modified animals **may affect health of consumers** [1]
  - Genes introduced to make the GM animals may code for **potential allergens** [1/2]
  - Resulting in allergic reaction in consumers of GM animals [1/2]
  - Genes introduced to make the GM animals may code for a **strong growth hormone / increase cell division** [1/2]
  - Consumption of these GM animals may potential cause cancer [1/2]
- The genetically modified animals may **affect the environment** if released into the wild [1]
  - GM animals **may outcompete** the wild animals [1/2]
  - Affecting the number of animals in the wild population [1/2]
  - Genes introduced to make the GM animals may be **disadvantageous** in the wild [1/2]
  - Mating of GM animals mate with the wild animals of the same species, these genes will be introduced into the gene pool of the wild populations [1/2]

6 (a) Outline the process of Calvin cycle. [10]

- Occurs in the **stroma of chloroplast** [1]
- Consists of 3 stages – **Carbon dioxide uptake, carbon reduction and regeneration of RuBP** [1]
- Produce **sugars, NADP and ADP** [1]

- **Carbon dioxide** is **added** to **ribulose bisphosphate (RuBP)** [1]
  - Catalysed by **RuBP carboxylase** [1/2]
  - To form an **unstable 6C compound** [1/2]
  - Which is broken down into **2 molecules of glycerate-3-phosphate (GP)** [1/2]
- GP is **reduced** to **glyceraldehyde-3-phosphate / triose phosphate (TP)** [1]
  - Using energy and reducing power provided by **ATP** and **reduced NADP** [1/2]
  - Which are produced in the **light reaction / photophosphorylation** [1/2]
- 2 TP combines to form **glucose** [1]
- The remaining TP stay in the Calvin cycle to **regenerate RuBP** [1]
  - Using energy provided by **ATP** [1/2]
  - Which are produced in the **light reaction / photophosphorylation** [1/2]
- The RuBP regenerated accepts another carbon dioxide [1/2]
- Continuing the cycle [1/2]
- NADP and ADP produced due to usage of reduced NADP and ATP are used in the light reaction / photophosphorylation [1]

(b) Explain the mode of action of RNA polymerase. [6]

- RNA polymerase catalyses the formation of **phosphodiester bonds between RNA nucleotides** [1]
  - In the **5' to 3' direction with respect to the growing chain** [1/2]
- It has an **active site** [1/2]
- That has a **specific shape complementary to the shape of RNA nucleotides** [1/2]
- RNA nucleotides binds to the active site [1/2]
- To form the **enzyme-substrate complex** [1/2]
- This causes a **change in enzyme conformation** [1/2]
- Enabling the substrate to **fit more snugly** into the active site [1/2]
- Ref. to **induced-fit hypothesis** [1/2]
- This **lowers the activation energy** of the reaction [1/2]
  - As the substrate are put in the correct orientation [1/2]
  - Ref. to R groups of catalytic residues which may affect the charges on the substrate [1/2]
- Thus **increasing the rate** of formation of phosphodiester bonds [1/2]
- The enzyme molecule **remains unchanged** when the reaction is complete and the products have left the active site [1/2]

(c) Discuss the ethical implications of genetically modified plants. [4]

- Religious groups may not agree with the **genetic manipulation of plants** [1]
  - Tamper with nature / play God [1/2]

- Concerns regarding companies **patenting genetically modified plants** [1]
  - Viewing plant lives as objects [1/2]
  - Farmers have to depend on these companies for seeds [1/2]

- Some religious groups may have **dietary restrictions against genetically modified plants** [1]
  - Genes introduced to make the GM plants may originate from animals unacceptable to some religions [1/2]