Victoria Junior College
Biology Department
2023 Prelims H2 Paper 2 – Proposed Answers

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

1 The cell surface membrane regulates the movement of different substances via different mechanisms.

Table 1.1 shows the results from an investigation to determine how two different drugs A and B enter animal cells.

Table 1.1

concentration of drug **A** in container / arbitrary units	concentration of drug **A** inside the cells after 5 minutes / arbitrary units	concentration of drug **B** in container / arbitrary units	concentration of drug **B** inside the cells after 5 minutes / arbitrary units
0	0	0	0
5	5	5	4
10	10	10	7
15	15	15	11
20	19	20	13
25	24	25	13

Cells which did not contain either drug were placed into separate containers. Different concentrations of each drug were added and after 5 minutes, the drug concentration in the cells was measured.

(a) Based on the data shown in Table 1.1,

(i) state the chemical nature of drugs A and B [1]

- A is lipid soluble/hydrophobic whereas B is polar/hydrophilic;

(ii) explain the difference between the transport of drugs A and B. [3]

- Data to support differences: Concentration of the drug A inside the cells matches/similar to the external concentration while for drug B, as external concentration increases, the internal concentration also increases but reaches a plateau;
- Drug A enters by simple diffusion whereas B enters via facilitated diffusion;
  OR
  Drug A diffuses across the phospholipid bilayer/ hydrophobic core of cell membrane into cell, but B requires carrier/ channel proteins to enter cell;
- A: moves down concentration gradient from outside of the cell into the cell until equilibrium is reached;
- B: (Idea of) the number of carrier/ channel proteins on cell membrane are fixed/ saturated;

(b) Viruses make use of certain properties of the cell membrane to facilitate its own release from the host cell. Fig. 1.1 shows such a process.

(i) Explain clearly how the structure of the cell membrane facilitates this process. [3]

- Phospholipid bilayer structure of the cell membrane provides fluidity/ lateral movement within their own monolayer;
- Phospholipids held by weak hydrophobic interactions between the hydrocarbon tails of the phospholipids;
- allowing the cell surface membrane to change its shape / be pushed outwards – budding;
- (idea of) allowing viral glycoproteins to be embedded in cell surface membrane as exit points;

(ii) Contrast the process seen in Fig 1.1 with the process in which HIV virus enters the host cell. [2]

Process shown in Fig 1.1	Process which HIV virus enters the host cells
[Any 2 of the following] • Budding involving evagination of host cell surface membrane • Involves removal/ loss of cell membrane; • Involves viral glycoproteins on cell surface membrane as exit points for budding	• Fusion of viral envelope with host cell surface membrane; • Addition/ gain of cell membrane; • gp120 on viral envelope binding to CD4 receptor on cell surface membrane;

R: Budding vs no budding, fusion vs no fusion, loss vs no loss of membrane, etc. – when there is *an equivalent process*, students should describe the difference in that feature.

2 **(a)** Starch molecules are the main storage molecules in many types of cereal grain, such as the grain of the barley plant. When the seed inside a barley grain germinates, enzymes are synthesised to catalyse the hydrolysis of the starch molecules.

(i) Starch is a mixture of two different molecules.

Name these **two** molecules. [1]

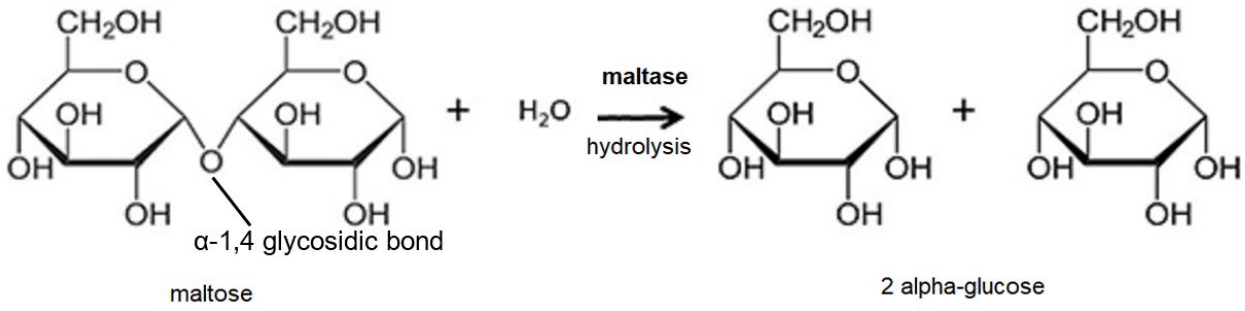
- Amylose and amylopectin;

(ii) Describe two features that allow the starch to be a good storage molecule. [2]

Any 2:
- Can be coiled and folded into compact shape, maximising storage space/ AW;
- Can be easily hydrolysed to (α-)glucose (R: energy) when they are required by enzymes/ amylase breaking glycosidic bonds/ to produce large amount of energy in respiration;
- Has large size which makes it insoluble in water so will not affect the water potential of cell;
- AVP

(b) In the space below, draw the molecular structure of maltose and show how it can be catalysed by maltase to produce glucose molecules. [3]

Diagram includes the following:
- Maltose drawn correctly with 1,4 glycosidic bond labelled;
- Water molecule being added and/ or name the process as hydrolysis;
- Products drawn correctly, two alpha glucose;



When producing sugar syrups, there are advantages in using enzymes extracted from microorganisms.

For example, some enzymes extracted from microorganisms are heat stable. Heat-stable enzymes are used to increase productivity because the reactions can be carried out at higher temperatures.

(c) Suggest one other advantage of using enzymes obtained from microorganisms, rather than enzymes extracted from barley seeds, in the production of sugar syrups. [1]

Any **one** valid suggestion;
- e.g. easier to extract
- idea that microorganisms can be cultured in large quantities and produce large amounts of enzyme
- higher rate of reaction
- active over a greater temperature range

(d) Fig. 2.2 is a graph showing how the activity of α-amylase extracted from barley seeds changes as the temperature increases from 10 °C to 66 °C.

(i) Explain the effect of temperature on the activity of α-amylase extracted from barley seeds, as shown in Fig. 2.2. [3]

*Any **three** from:*

1. increase in temperature from 10 to 48 °C, increases kinetic energy of, molecules / substrate and enzyme **;**
   A moving around faster
2. (increase in temperature) increases rate of, successful/ effective collisions between enzyme and substrate / enzyme–substrate complex formation / substrate binding to active site **;**
   OR
   at 48 °C (47 or 49) ref. to, optimum temperature / maximum enzyme activity / active sites binding substrate at maximum capacity / AW **;**
3. (at temperatures higher than optimum) ref. to denaturation / loss of shape of active site **(**and decrease in activity**) ;**
4. AVP **;** e.g. weaker / hydrogen/ ionic, bonds break (and ref. to denaturation)
   R disulfide bond – covalent bond, strong not easily broken by high temperature

(ii) Sketch on Fig. 2.2 the curve that would be obtained using the heat stable α-amylase enzyme extracted from microorganisms. [2]

- optimum / peak / max activity / at 100% and to right of original **;**
- line beyond optimum must be to right and, reach vertical axis at 50% or below / reach horizontal axis **;**

Example:

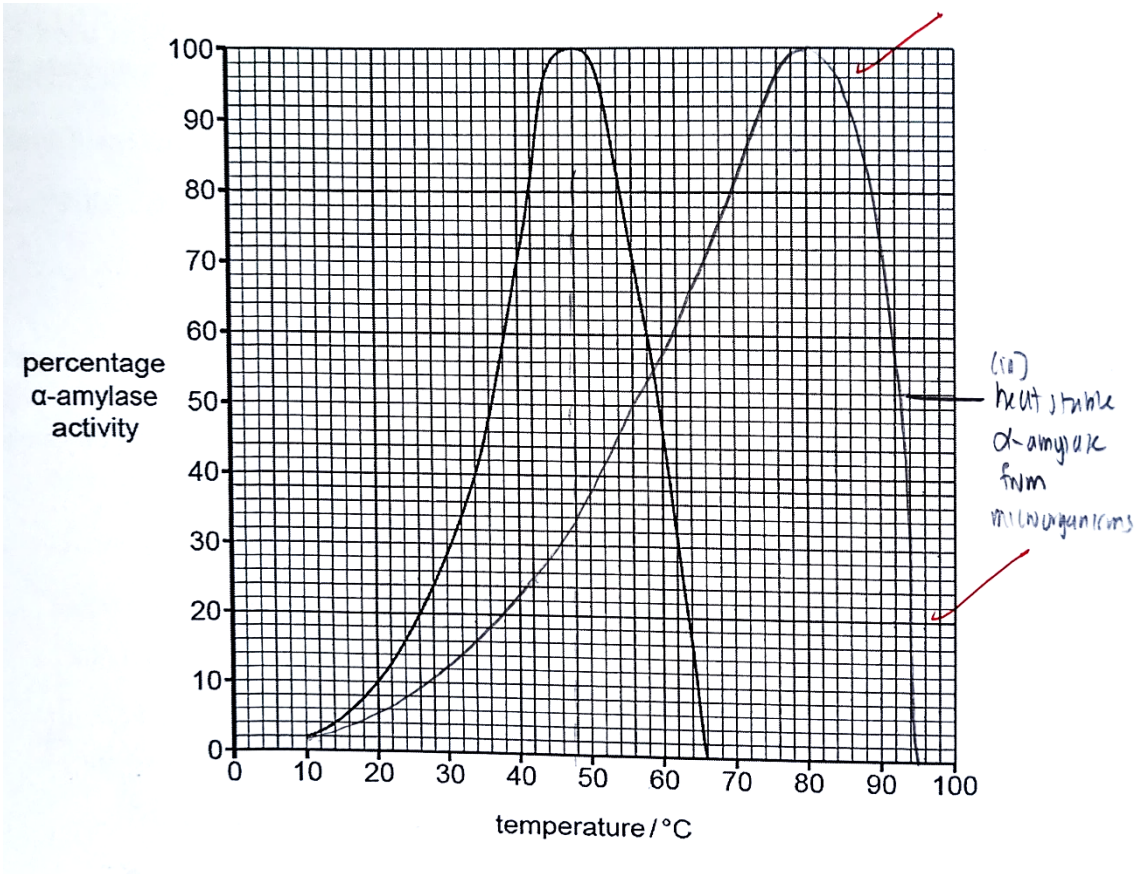


Fig. 2.2

3 Collagen is present in large quantities in connective tissue and provides tendons and ligaments with tensile strength. Fig. 3.1 below shows how tropocollagen molecules is organised in collagen.

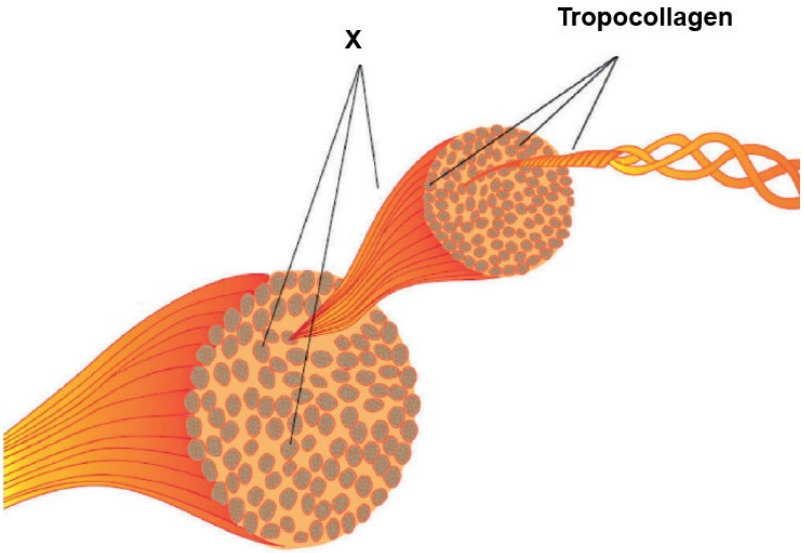


Fig. 3.1

(a) Identify structure X and explain how it allows collagen to serve a structural role. [3]

1. X is **collagen fibril**
2. **Staggered arrangement** of tropocollagen within the collagen fibril **eliminates areas of weakness;**
3. **Covalent cross-links** between the tropocollagen to strengthen the structure, contributing to **high tensile strength**;
4. **Aggregation** of collagen fibrils into **collagen fibres,** contribute **to high tensile strength**

(b) Each of the three polypeptide in the tropocollagen is a kinked helix whereas in another macromolecule, cellulose, each chain is a straight chain.

(i) Explain how the kinked helix in tropocollagen and the straight chain in cellulose contribute to high tensile strength. [3]

1. Both kinked helix and cellulose are **strand-like structures which provide high/more surface area** for crosslinking/ hydrogen bonds formation.
2. Kinked helix allows the three polypeptide to **wind more tightly around each other** and thus require more force to break them.
3. Straight chain in cellulose allows most **hydroxyl groups** of the glucose residues to **project in all directions for interchain H bonds formation**

(ii) Explain how the arrangement of monomers in tropocollagen and cellulose results in their respective shapes.[3]

1. Monomer of tropocollagen is amino acid and beta glucose for cellulose.
2. Tropocollagen: Repeated sequence of Gly-X-Y or amino acid sequence with every 3rd amino acid as glycine results in kinked helix
3. Cellulose: Alternate beta glucose rotated 180 degrees results in straight chain

4 (a) Fig. 4.1 shows the process of translation.

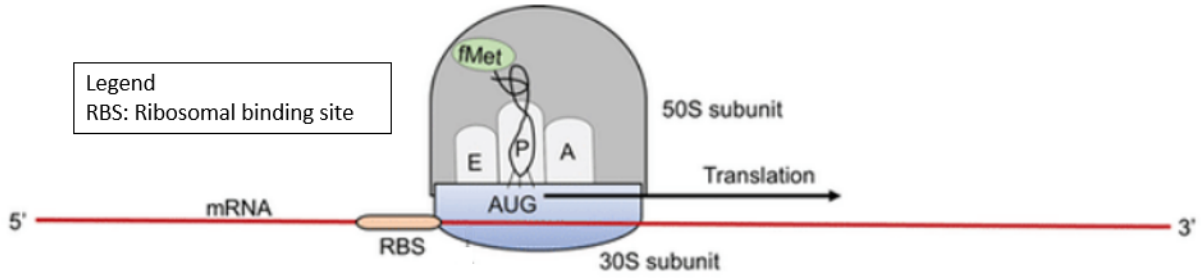


Fig. 4.1

(i) State the evidences shown in Figure 4.1 which support that this process occurs in prokaryotes. [3]

1. Presence of 60S and 40S ribosomal subunits instead of 50S and 30S;
2. Initiator tRNA contains methionine instead of formyl-met;
3. Presence of 5' cap and poly A tail on the mRNA;
4. Ribosome in the eukaryote binds to the 5'UTR of the mRNA whereas ribosome of prokaryotes bind to Shine-Dalgarno sequence;

(ii) Briefly describe the process that has to occur for the entire polypeptide to be translated. [4]

1. The corresponding aminoacyl-tRNA for the next codon binds to the mRNA at the A site of the ribosome via complementary base pairing.
2. Peptide bond forms between the amino acid / peptide on the tRNA in the P site and the amino acid on the tRNA in the A site, catalysed by peptidyl transferase
3. the ribosome moves three nucleotides /1 codon down the mRNA in the 5' to 3' direction with respect to the mRNA;
4. initator tRNA (without the fmet) is now in the E site, the tRNA with the peptide attached is in the P site, leaving the A site empty for a new corresponding aminoacyl-tRNA;
5. the process repeats until the ribosome reaches a stop codon and the A site accepts a protein called the release factor which hydrolyses the polypeptide from the tRNA

(b) Fig. 4.2 shows an electron micrograph of the translation process in a human epithelial cell.

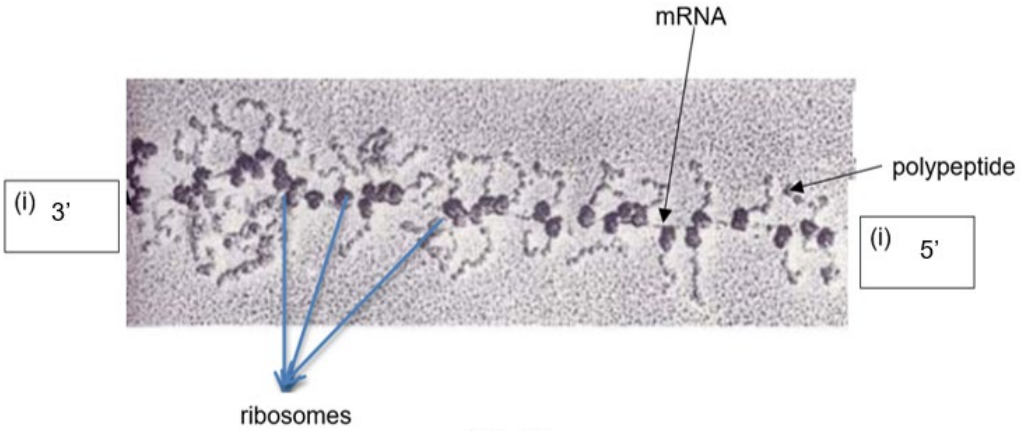


Fig. 4.2

With reference to Fig. 4.2,

(i) label the ends of the mRNA strand in the boxes provided. [1]

(ii) state the significance of the structure shown. [1]

- increase the rate of production of proteins;

5 (a) Fig. 5.1 shows a cell from the testis of a locust undergoing nuclear division.

(i) Identify the stage shown in Fig 5.1. [1]

- Prophase I of meiosis;

(ii) Explain the significance of this stage in the formation of the products. [4]

1. **Crossing over** between non-sister chromatids of homologous chromosomes at the chiasmata;
2. Where there is physically breaking and rejoining of corresponding sections of the **non-sister chromatids of homologous chromosomes;**
3. Resulting in gametes (products) with new combinations of alleles/ producing **genetically variable** gametes/ different linkage groups;

4. Chiasmata hold the two homologous chromosomes together and allow them to be aligned **across the equator** during **metaphase I**;
5. Ensuring their separation to opposite poles during anaphase I for the production of gametes with haploid number of chromosomes/ gametes with different combinations of maternal and paternal chromosomes;

(b) Uncontrolled mitosis can cause cancer in humans.

With reference to Fig 5.2,

(i) describe the effects of Paclitaxel on the mitotic cell cycle.[2]

- increasing Paclitaxel concentration from 5 nmol dm^{-3} to 50 nmol dm^{-3}, increases the percentage of cells in stages of mitosis from 5 to 38;
- but decreases the ratio of number of cells in anaphase to cells in metaphase from 0.25 to 0.07;

(ii) suggest an explanation for the effect of Paclitaxel. [3]

- Paclitaxel prevents depolymerisation of the microtubules/ disassembly of the spindle fibers;
- which are important for the separation of sister chromatids to opposite poles during anaphase;
- [explain for decrease ratio] hence more cells remained in metaphase stage;
- [explain for increase percentage] but cancer cells continue to proceed to mitosis but stalled at metaphase;

6 The bacterium, *Escherichia coli*, can use glucose or disaccharides, such as lactose, in its metabolism. Lactose needs to be hydrolysed by the enzyme β-galactosidase to form glucose and galactose, which can then be used by *E. coli*.

The production of β-galactosidase is controlled by a length of DNA called the *lac* operon.

(a) Explain the term operon. [2]

- An operon consists of a cluster of structural genes, coding for proteins with related functions - for the breakdown of lactose;
- These structural genes are under the control of the same promoter and operator;

(b) In an investigation into the growth of *E. coli*, a sample of the bacterium was grown in a medium that contained limited concentrations of glucose and lactose. The population size of *E. coli* was measured at regular intervals.

Fig. 6.1 shows the population growth curve obtained for this investigation.

(i) Describe **and** suggest reasons for the population growth curve shown in Fig. 6.1. [3]

1. population increases, then levels off, increases, then levels off / AW **;**

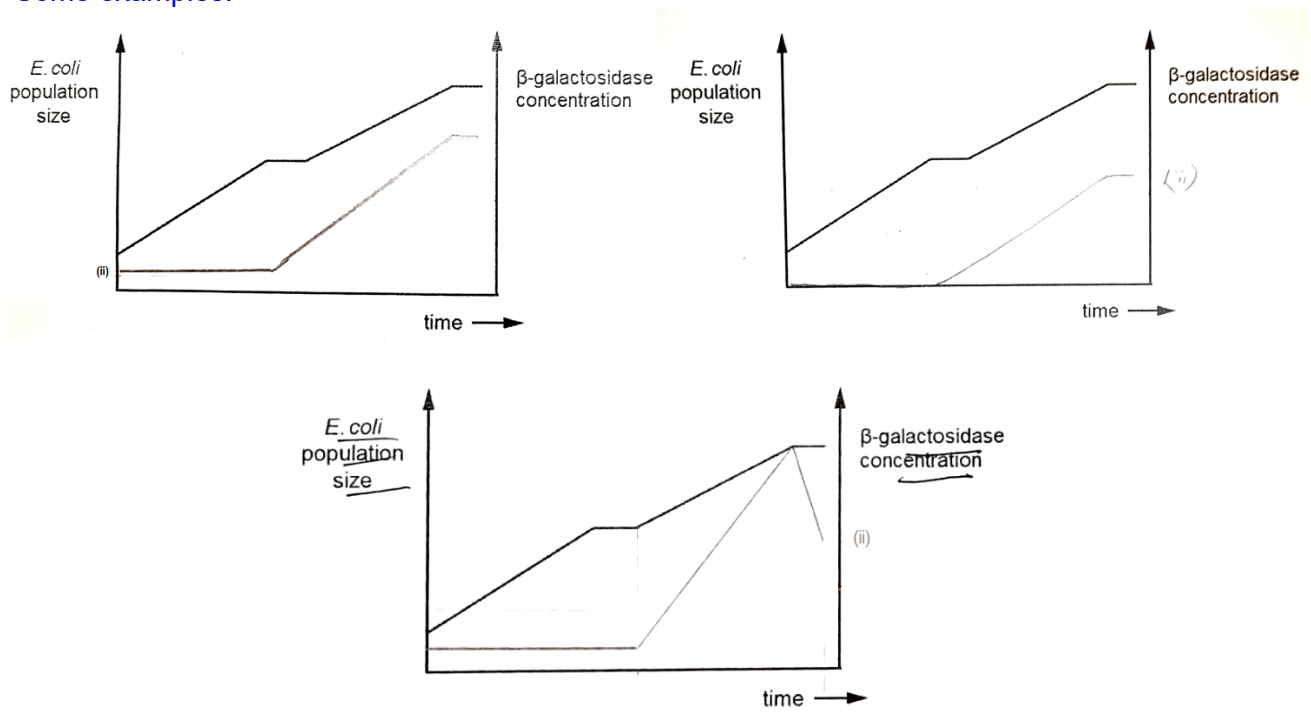
Any **two** from:

2. (first increase) preferential use of glucose for respiration to produce energy for increase in population size/ cell division/ binary fission**;**
3. (first levelling off) glucose depleted and switching of substrate to lactose which takes time;
4. (second increase) lactose hydrolysed / broken down, into, glucose / galactose for respiration until it is depleted/ run out;

(ii) Sketch in Fig. 6.1 the change in β-galactosidase enzyme concentration over the same time period. [1]

- low concentration until plateau, start increase during the first plateau, maximum when reached second plateau, can show decrease during second plateau;

Some examples:



(iii) Provide an explanation for your answer in **(ii)**. [4]

1. Low level of β-galactosidase concentration because of catabolite repression in the presence of glucose/ described;

Increased β-galactosidase concentration due to depletion of glucose

2. presence of lactose, allollactose binds to *lac* repressor, inactivating it so that it does not bind to operator;
3. cAMP concentration increases so cAMP binds to CAP and the cAMP-CAP complex binds to the CAP binding site
4. (enhances) the binding of the RNA polymerase to promoter increase expression of lacZ gene;

5. Levelling off of β-galactosidase concentration due to lactose used up, active repressor binds to operator switching/ turning off *lac* operon;

OR

β-galactosidase concentration drops due to lactose used up, β-galactosidase is not required and thus degraded;

(c) β-galactosidase is also found in human cells.

Describe how the regulation of this gene differ from that in E. coli. [2]

	Human cells	*E. coli*
1. coordinated expression;	regulation of expression is by its own promoter	regulation of expression is controlled with other structural genes within the *lac* operon
2. Regulation at transcriptional level;	a variety of mechanisms for gene regulation at transcriptional level, including transcription factors, enhancers, silencers, and chromatin remodelling. OR any mechanism described compared with *E. coli*	regulated by a repressor protein binding to operator (proximal to gene) which can be inactivated in the presence of lactose
3. Regulatory Complexity;	mechanisms and complexity of regulation are much greater in human cells allowing for fine-tuning of gene expression, which is critical for multicellular organisms. OR Gene can be regulated at post-transcriptional, translational and post-translational level in human cells while only regulated at transcriptional level for *E.coli*.	

7 The Labrador is a breed of domestic dog. Its fur coat can be chocolate, black and yellow.

In Labradors, TYRP1 is a gene that codes for the fur colour. In this gene locus, it has two alleles, B and b.

- The dominant allele, B, codes for an enzyme that will result in the production of melanin, leading to black fur.
- The recessive allele, b will code for another enzyme that results in the production of a brown form of melanin, leading to chocolate fur.

Another gene, MC1R, interacts with TYRP1. In this gene locus, it also has two alleles, E and e.

- The dominant allele E, allows for the alleles of TYRP1 to be expressed.
- The recessive allele e, prevents the alleles of TYRP1 from being expressed.
- When there is no melanin produced, the Labrador will have yellow fur.

(a) Explain the terms *locus* and *dominant* allele. [2]

- Locus: refers to the **position** occupied by the gene on the **chromosome;**
- Dominant: Allele whose characteristic is expressed in the **phenotype** even in the presence of an alternative allele;

(b) A test cross of a female with a black male Labrador resulted in offspring with all three phenotypes. Construct a genetic diagram to explain the results of the cross. [5]

Parental Phenotype; **Black male** **Yellow female**

Parental Genotype; **BbEe** **bbee**

Gametes;

Punnett Square

	BE	**Be**	**bE**	**Be**
be	**BbEe**	**Bbee**	**bbEe**	**Bbee**

F1 genotype; **BbEe** **bbEe** **_ _ ee**

F1 phenotype (and ratio); **1 Black** **1 Chocolate** **2 Yellow**

Marking point:
- Correct phenotype and genotype of each parent ;;
- Correct gametes produced for each parents (in circle);
- Correct F1 genotype;
- Correct corresponding F1 phenotype with ratio;

(c) While the fur colour of Labradors is due to epistasis, the fur colour of rabbits is due to multiple alleles. Distinguish between the inheritance of fur colour in Labrador and rabbit. [2]

- For epistasis, two genes are involved whereas only one gene involved in multiple alleles.
- For epistasis, each gene has two different alleles (recessive or dominant) whereas for multiple alleles, there can be more that two alleles involved.

8 Respiration and photosynthesis are vastly different processes but they share similarities in terms of having triose phosphate(TP) as one of the intermediates as well as the use of coenzymes.

(a)(i) Describe two similarities in how Triose phosphate is formed in respiration and photosynthesis. [2]

1. Produced from the breakdown/hydrolysis of 6 carbon compound;
2. ATP is required for their synthesis;
3. Enzymes are involved;

(ii) Describe the role played by the coenzyme involved in photosynthesis. [2]

1. Coenzyme is NADP and it accepts electrons from the electron transport chain and combines with proton/H+ to form reduced NADP;
2. It is then used to reduce GP to form TP in Calvin cycle;

Fig. 8.1 shows some of the components involved in respiration in a Gram negative bacterium. Gram negative bacteria have two cell membranes.

Some bacteria can undergo aerobic respiration in the same way as eukaryotic cells. However, Link reaction and Krebs cycle occur in the cytoplasm.

(a) With reference to Fig. 8.1, suggest how the proton pumps present on the inner membrane serve as a link between the respiratory processes in the cytoplasm and the synthesis of ATP. [4]

1. Reduced NAD from glycolysis, Link reaction and reduced NAD and FAD from Krebs cycle;
2. pass their electrons to the electron transport carriers on the inner membrane which are arranged at decreasing enery level;
3. energy released is harnessed to pump protons/hydrogen ions across from the cytoplasm to periplasmic space via the bacterial proton pumps resulting in a higher H+ concentration in the periplasmic space/ resuts in a proton motive force;
4. H+ diffuse through the ATP synthase, resulting in the production of ATP from ADP and Pi;

9 Cats are members of the Felidae family. Two genera of Felidae are *Leopardus* and *Panthera*.

The genus *Leopardus* consists of species of wild cats that are small and spotted. In 2013, researchers investigated the evolution of *Leopardus tigrinus* in South America.

The cats in population **A** have a lighter coat colour and a different pattern of spots from the cats in population **B**. Fig. 9.1 shows the locations in South America of two populations of. *L. tigrinus*, population **A** and population **B**.

With more compelling data uncovered by the researchers, Population **B** has now been reclassified as a new species, *L. guttulus*.

(a) With reference to Fig. 9.1 and the information given above, explain why the two populations can be considered as separate species. [3]

1. They are occupying **different niches** as they live in different habitats, with population A living in grassland and desert habitats while B in forest habitats;
2. They also have **different morphological features** with population A have a lighter coat colour and a different pattern of spots from the cats in population B;
3. The two populations are found in different locality, with **no overlaps in the region** that they are found;
4. The barriers between the 2 populations reflect **no interbreeding** thus **reproductive isolation**;

Fig. 9.2 shows the tail lengths and weights of the two species of wild cats.

(b) Discuss how the information in Fig. 9.1 and Fig. 9.2 shows how both micro-evolution and macro-evolution may have contributed to the evolution of the wild cats. [4]

Microevolution [2max]
1. Different region/locality (give examples) has different **selection pressures**
2. Variant (give specific example) with selective advantage will be **selected for** leading **to change in allele frequency** which is microevolution
3. This is reflected by the **range of values** in tail length and weight (quote values) in each population

Macroevolution [2max]
1. There is **no gene flow** between the two populations because of **reproductive isolation**;
2. Each population adapted to the conditions in their respective habitats;
3. **Accumulated mutations independently** so that over time, **distinct gene pools form/ speciation** which is macroevolution;

(c) The researchers obtained extensive sequence data for three homologous genes from mtDNA, Y chromosome and X chromosome. From these data, the molecular phylogenetic relationships of cats of the genus Leopardus in South America are established.

Fig. 9.3 shows the family tree of South American cats, including *L. tigrinus* and *L. guttulus*.

(i) Describe how polymerase chain reaction (PCR) can be used to isolate homologous genes. [3]

- **denature** the double stranded DNA at **95 ^{0}C** to form **single strands**;
- **annealing** at 60 ^{0}C with the use of **forward and reverse primers to flank the gene of interest** at opposite ends
- **extension** of complementary strand at **72 ^{0}C,** catalysed by **Taq polymerase;**

(ii) Describe **and** explain **one** characteristic of mtDNA that makes it more useful than using X chromosome to provide evidence of evolution. [2]

*any **one pair** from:*
1 large quantity in the cell **;**
2 (so) easier to, extract / amplify, DNA for testing **;**
or
3 small genome size **;**
4 (so) easier to locate specific section of DNA to test **;**
or
5 mtDNA is, a single copy of DNA / not paired alleles / haploid **;**
6 (so) only mutation causes it to change **;**
or
7 inherited maternally **;**
8 (so) all mtDNA sections are shared between all members (of maternal) family **;**
or
9 mutation rate is higher / no enzymes to repair mutations **;**
10 (so)more choice of suitable sections of mtDNA to test / more accurate time estimate **;**
Or
11 circular
12 less likely to degrade over time

10 COVID-19 is respiratory disease. The cells of the airway epithelium are the first line of defence against the pathogen.

(a) Describe how the cells of the airway epithelium provide the first line of defence against the pathogen. [3]

1. healthy airway epithelium maintains an impermeable physical barrier to viral entry through cell–cell barriers
2. Mechanical defence occurs through the combination of mucus production by secretory cells which trapped the pathogen, preventing them from entering the cells;
3. And cilia to move the mucus with the trapped pathogen out of the from the respiratory tract/ towards the mouth so that pathogen can be killed by the acid condition in the stomach;
4. airway epithelial cells can release antimicrobial defensins that can prevent viruses from entering their target cells;
5. AVP: provide a physical / mechanical barrier that expels the pathogen via cilia and induced coughing

Early signs of COVID-19 infection include a fever, a sore throat, headache.

(b) Explain how the COVID-19 virus may cause these symptoms. [2]

1. Virus stimulates/ activates innate/ non-specific immune response/ immune cells (e.g. dendritic cells);
2. Resulting in cytokines and chemokines being released by (alveolar) macrophages;
3. Which increased permeability of blood vessels resulting in inflammation, causing the sore throat and headache;
4. Pyrogen released by activated macrophages leads to rise in systemic body temperature resulting in fever; (A: protein from liver leads to increase in temperature.)

11 India has been facing freshwater shortage issues for decades. Climate change has further exacerbated the situation, making water scarcity a persistent and pressing issue in India.

Fig. 11.1 below shows the water demand and supply in India over the years. Researchers have also predicted the trend of water demand/supply in 2030.

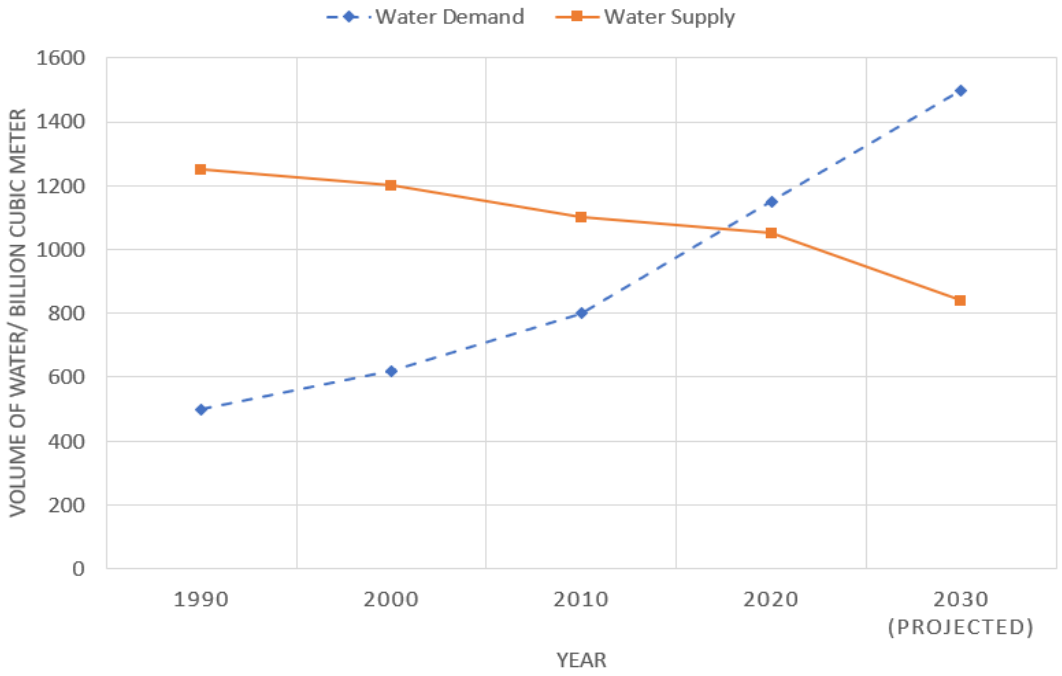


Fig. 11.1

(a) With reference to Figure 11.1, describe the water scarcity situation from Year 2000 to Year 2020. [3]

1. [general trend] The water scarcity situation worsen from Year 2000 to Year 2020;
2. From year 2000-2010, though the water supply exceeded the water demand, the difference between them is getting smaller;
3. [QV] Water supply exceeds demand by 580 billion cubic meter in year 2000 to 300 billion cubic meter in year 2010
4. In year 2020, the water demand of 1150 billion cubic meter, has exceeded the water supply of 1090 billion cubic meter, making the water scarcity situation pressing.

(b) Explain how climate change can result in the projected water supply in Year 2030. [2]

1. Increase in global temperature/global warming results in **excessive evaporation**, drying up reservoir/water storage facilities
2. The **shrinking of glacier** results in **reduction of meltwater** supplies
3. Alter **precipitation patterns** and hydrological systems in many regions can result in **droughts** and thus reducing water supply.