Section A

Answer **all** the questions in this section.

1 (a) List three structural features of E. coli that are visible in Fig. 1.1 [3]

1. Ribosomes
2. Circular DNA
3. (Peptidoglycan) Cell wall
4. Cell surface membrane

(b) For one of the structural features listed in (a), state a detail of this feature that is characteristic of a bacterial cell. [1]

1. Ribosomes – 70s ribosomes in bacteria

2. DNA - circular DNA that is double stranded
   OR
   DNA molecule is not associated with histone but other histone-like protein molecules.

3. Cell wall – Made up of ***peptidoglycan**** ~~polymers~~

4. Cell surface membrane - Phospholipid bilayer with electron transport chains and ATP synthase are embedded to produce ATP

(c) Describe what happens to the genome of bacteria during binary fission. [2]

1. Bacterial genome which is made of DNA replicates by ***semi-conservative replication****
2. DNA is unzipped by breaking hydrogen bonds between bases of the 2 strands
3. each parental strand serves as a template for synthesis of daughter strands
4. free deoxyribonucleotides complementary base pair with bases on the parental /template strand
5. ***DNA polymerase**** forms ***phosphodiester bonds**** between adjacent deoxyribonucleotides

(d) Describe how the generation time and mean mass of an individual bacterial cell changes with nutrient availability, as shown in Table 1.1. [2]

1. As nutrient availability increased from low to high, the generation time decreased from 100 to 24 minutes (quote data);
2. And mean mass of individual bacterial cells increased from 150×10^{-15} g to 870×10^{-15} g (quote data).

(e) Suggest an explanation for the effect of decreasing nutrient availability on the generation time of these bacteria, as shown in Table 1.1. [2]

Name nutrient + Effect of a lack of these nutrients on named cell processes

1. With low or no glucose, the bacteria will be unable to carry out aerobic respiration to generate sufficient levels of ATP
2. Hence the bacterial cells will have insufficient energy required for cell division/binary fission and hence take a longer generation time

OR

1. Certain essential amino acids, which cannot be produced by the bacterial cells, need to be taken up from the environment
2. Without which the bacterial cells will be unable to synthesize important bacterial proteins for growth, and hence require a longer generation time

AVP

[Total: 10]

2 **(a)** Name the monomers that join to form a cellulose molecule. [1]

β-glucose monomers

(b) Name the covalent bond between two of these monomers in a cellulose molecule and describe how this bond is formed. [3]

1. ***β(1-4) glycosidic bond****
2. The glycosidic bond forms between C1 of one ***β glucose**** monomer and C4 of another ***β glucose**** monomer;
3. ***Condensation**** reaction joining two β glucose residues with ***removal of one water**** molecule;
4. Reaction is catalysed by ***enzymes*;***

(c) Explain how the molecular structure of cellulose is related to the high tensile strength of the cellulose cell walls of plants. [3]

1. Adjacent ***β glucose**** monomers are ***rotated 180°**** with respect to each other cellulose
2. Forming a ***straight**** chain/molecule and is able to lie ***parallel**** to other cellulose chains;
3. ***Hydroxyl groups**** project outwards from each molecule, allowing extensive ***hydrogen bonding**** between adjacent chains, forming ***microfibrils**** with ***high tensile strength**** that make up the cell wall

(d) Suggest why cellulose must be synthesised at the cell surface membrane and **not** inside the cell. [3]

1. Cellulose is a macromolecule found outside the cell as part of the cell wall and therefore easier to simply deposit it there.
2. Cellulose molecule may be too large to pass through cell membrane if it has to be transported to the exterior of the cell.
3. Cellulose is insoluble in the hydrophobic core of the phospholipid, and is hence synthesized at the cell surface membrane and transported out of the cell

[Total:10]

3 **(a)** Explain why transcription and translation are able to occur simultaneously in a bacterial cell such as *E. coli*. [2]

1. *E.coli* is a prokaryotic cell that does not contain a membrane bound nucleus/nuclear envelope. Hence as soon as the mRNA is transcribed the ribosomes can attach to the mRNA and translation can be carried out;

2. Also, unlike eukaryotic cells, DNA that is transcribed to mRNA in prokaryotic cells need not undergo post-transcriptional modification and hence transcription and translation can occur simultaneously;

(b) Identify structures **A**, **B** and **C**, as shown in Fig. 3.2. [3]

A: DNA double helix

B: mRNA/messenger RNA

C: polypeptide

(c) Describe how structure **D** is different from structure **E.** [2]

1. Structure D, the ribosome is made of rRNA and protein while structure E, the RNA polymerase is only made up of protein;
2. Structure D is made up of 2 subunits while structure E is a single molecule (based on the diagram;
3. Structure D, has an active site that is made of rRNA while structure E, has an active site that is made up of protein;

(d) List three ways in which the process of transcription is different from the process of translation. [3]

	Transcription	Translation
Location	Occurs in ***nucleus**** of eukaryotes	Occurs on ***ribosomes**** in cytoplasm / rough endoplasmic reticulum
Process	DNA used as ***template**** in synthesis of mRNA	mRNA used as ***template**** in synthesis of polypeptide
Enzymes that joins monomers	Enzyme ***RNA polymerase**** links ribonucleotides	***Peptidyl transferase**** on ribosome joins amino acids
Linkages	Ribonucleotides linked by ***phosphodiester bonds**** to form mRNA	Amino acids linked by ***peptide bonds**** to produce polypeptide
Product	Single-stranded mRNA	Polypeptide
Direction read	DNA template read from a 3' to 5' direction	mRNA read from 5' to 3' direction

[Total: 10]

4 **(a)** Identify structures **X, Y** and **Z** on Fig. 4.1. [3]

X: (Icosahedral) Capsid head

Y: (contractile) Tail sheath

Z: Tail fibre

(b) With reference to Fig. 4.1, outline how the T4 phage viral genome is replicated. [3]

1. Inside the cell, the T4 bacteriophage DNA is immediately transcribed to synthesise messenger RNA using the host RNA polymerase
2. Phage enzymes coded by the phage genome takes over the bacterium's macromolecular (protein, RNA, DNA) synthesising machinery for its own use.
3. The phage uses the host cell's nucleotides and DNA polymerase to synthesise many copies of phage DNA.

(c) Describe the two main differences between the energy requirements of the reproductive cycle of a T4 phage and the energy requirements of the reproductive cycle of an influenza virus, as shown in Table 4.1.

Suggest an explanation for each of the two differences. [4]

difference 1 and explanation:

1. T4 phage requires much higher energy, of 200 a.u., than influenza virus, of 10 a.u. for genome replication
2. T4 could require more energy due to the larger size of the viral genome required to be replicated
   OR
   T4 viral DNA could require more energy to replicate due it being double stranded
   OR
   T4 requires more energy to degrade host cell DNA to synthesize viral DNA as opposed to influenza virus which synthesizes viral mRNA in animal host cell using existing ribonucleotides

difference 2 and explanation:
1. T4 phage requires lesser/no energy/0 a.u for viral exit, as compared to influenza virus, requiring 300 a.u. for viral exit.
2. T4 viral gene codes for lysozyme which causes host bacterial cell wall to lyse and release bacteriophages, thus not requiring energy. However the influenza virus will need to bud off from host cell and acquire host membrane, thus requiring more energy

[Total: 10]

5 **(a)** Describe the gene mutation shown in row 1. [2]
1. A single ***base substitution****
2. From thymine to adenine

(b) Describe how the gene mutation shown in row 1 leads to the change in row 3. [3]
1. The change in the nucleotide / base sequence in ***DNA**** from thymine to adenine
2. Results in a change in sequence of the mRNA, and a change in ***codon****
3. Change from GAG coding for amino acid glutamate to GUG which codes for valine

(c) Explain how the change in row 3 affects the haemoglobin molecule. [3]
1. ***Hydrophilic**** charged ***glutamic acid**** is replaced by ***hydrophobic****, non-polar ***valine*;***
2. ***This changes the primary, secondary and tertiary structure**** because the way polypeptide chain folds is affected by change in ***R groups**** and bonds formed;
3. At low O_2 concentrations, loss of O_2 from ***HbS**** results in an unusual conformational change that causes a ***hydrophobic patch to stick out;***
4. This hydrophobic patch attaches to a hydrophobic patch on another HbS causing them to crystallise / ***polymerise*** into insoluble ***fibers*;***

(d) Explain how this change to haemoglobin results in the symptoms of sickle cell anaemia when oxygen concentration is low. [2]
1. Long insoluble ***HbS fibers*** within ***red blood cell*** causes its shape to be distorted from a normal biconcave shape to a ***sickle**** shape;
2. Sickle red blood cells are more fragile resulting in them having a ***shorter life span***, results in ***shortage of red blood cells*** and poor ***oxygen transport*** resulting in anaemia;
3. Sickle-shaped red blood cells, being pointed and elongated, may also get lodged in small ***blood vessels*** (capillaries) and therefore interfere with blood circulation. This may result in ***organ damage;***

[Total: 10]

6 **(b)** A queen bee that is heterozygous for both genes is crossed with a drone that has the recessive allele for both genes. After fertilisation, the queen bee is able to lay both fertilised and unfertilised eggs.

Fig. 6.1 shows all possible male and female offspring of this queen bee.

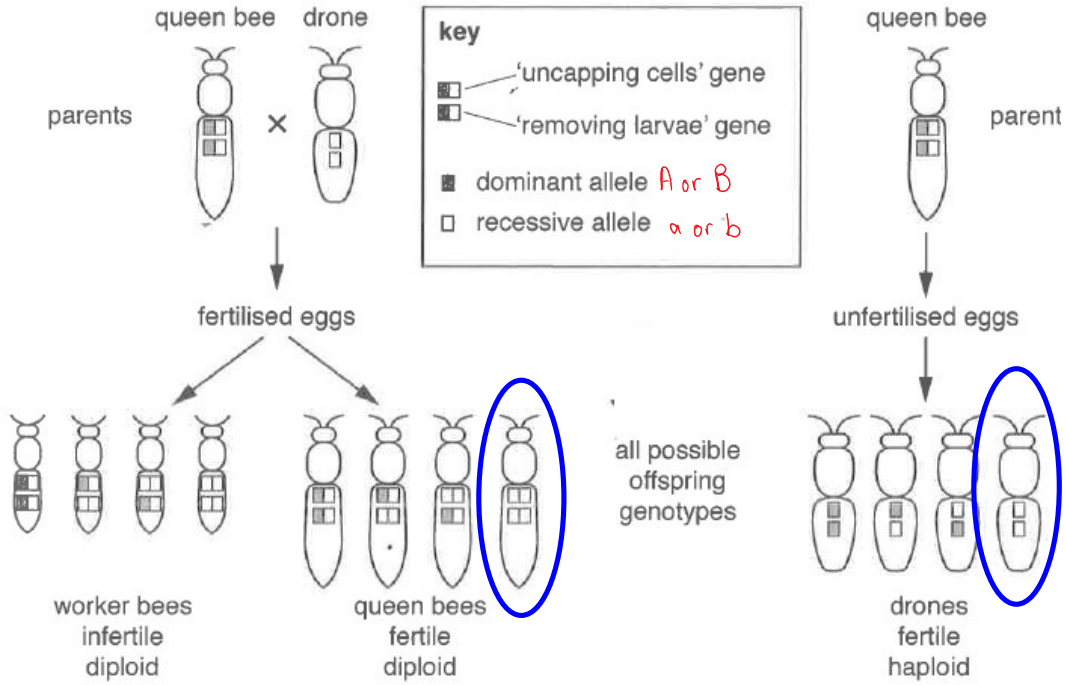


Fig. 6.1

(a) Draw genetic diagrams to explain the results shown in Fig. 6.1 for the:

(i) Male offspring

Parental phenotype: Fertile female

Parental genotype: AaBb

Gametes: (AB) (Ab) (aB) (ab)

Offspring genotype: AB, Ab, aB, ab

Offspring phenotype: All fertile males (drone)

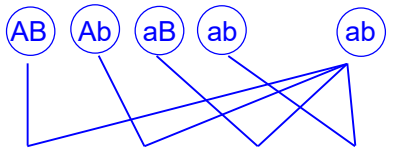
[2]

(ii) Female offspring

Parental phenotype: Fertile female (queen) X Fertile male (drone)

Parental genotype: AaBb X ab

Gametes: AB Ab aB ab ab



Offspring genotype: AaBb Aabb aaBb aabb

Offspring phenotype: All female

[3]

(b) It is possible to selectively breed western honey bees so that all worker bees in a hive display the 'uncapping cells' behaviour and the 'removing larvae' behaviour.

Circle two of the offspring on Fig. 6.1 to identify which bees should be used in a cross to ensure that all worker bees in the next generation show both of these behaviours to reduce disease. [2]

See Fig. 6.1 – Thinking: One fertile queen bee, one fertile drone. Both must result in homozygous recessive offspring.

(c) Explain how the environment determines whether fertilised eggs develop into queen bees or worker bees. [3]

1. Diet of the larvae determines if it develops into queen bee or worker bee
2. Larvae fed ***royal jelly****, a protein-rich secretion from young worker bee will develop into a queen bee.
3. Chemicals in royal jelly trigger expression of genes involved in the development of ovaries and reproductive organs.
4. Larvae fed a nectar and pollen will develop into worker bee.

[Total: 10]

7 **(a)** Describe the role of oxygen in aerobic respiration. [3]

1. Oxygen is ***final electron acceptor**** at the end of ***electron transport chain****, where it will combine with electrons and protons to form water (accept: $2e^- + 2H^+ + \frac{1}{2}O_2 \rightarrow H_2O$);
2. By removing electrons, oxygen re-oxidises electron transport chain so that ***NADH**** and ***$FADH_2$**** can continue to donate electrons to the chain, thereby allowing ***oxidative phosphorylation**** to continue to produce ***ATP****;
3. This allows ***regeneration**** of ***NAD^+**** and ***FAD**** allowing them to pick up more electrons and protons from ***glycolysis****, ***link reaction**** and ***Krebs cycle**** to keep them going;

(b) In yeast cells, less glucose is required to maintain cell metabolism under aerobic conditions than under anaerobic conditions.

Explain why. [3]

1. Under aerobic conditions, complete breakdown of glucose produces ***38 ATP**** molecules per glucose molecule as compared to ***2 ATP**** molecules in anaerobic respiration;
   OR
   under anaerobic conditions, 19 glucose molecules will be needed to generate same amount of energy that 1 glucose molecule can yield under aerobic conditions;

2. Under aerobic conditions, ***link reaction**** and ***Krebs cycle**** produce ***NADH**** that will be oxidised and hence regenerated by the ***electron transport chain**** during ***oxidative phosphorylation****, generating additional ATP;

3. However, under anaerobic conditions, glycolysis only produces a ***net of 2 ATP molecules**** for each glucose molecule oxidized and ***NAD+**** and is only regenerated through fermentation processes to allow only ***glycolysis**** to continue.

(c) With reference to Fig. 7.1, describe the effect of a high concentration of ATP on PFK activity. [2]

1. High levels of ATP slows down / inhibits PFK activity (as the graph is below the graph represented by low ATP);
2. This inhibition is most pronounced at lower substrate concentrations; at 0.5mmol/dm3 substrate conc, PFK activity at 3 au and for high ATP conc vs PFK activity at 47au at low ATP conc
3. this inhibition is overcome by high substrate concentrations;

(NB: despite the observation in points 2 & 3, do note that ATP is NOT a competitive inhibitor, since PFK is an allosteric enzyme - meaning that ATP would be binding to an allosteric site)

(d) Using the information in Fig. 7.1 and your subject knowledge, suggest a mechanism to explain how ATP controls the rate of glycolysis. [3]

1. (low levels of ATP promote PFK activity); When ***ATP**** levels are high, it will bind to allosteric site of PFK;
2. This alters 3-D ***conformation**** of enzyme's ***active site****, such that its substrate is no longer ***complementary in shape and charge**** to active site, and this stabilizes the inactive conformation of PFK which will have a lower affinity for substrate;
3. resulting in a decrease in rate of glycolysis due to end-product inhibition;

[Total: 11]

8 **(a)** Describe how the blood insulin concentration changes after administering insulin orally, as shown in Fig. 8.1. [2]

1. From 0 minute to 9 hours, the blood insulin concentration increase gradually from 4 milliunits dm^{-3} to 64 milliunits dm^{-3}
2. From 9 hours to 25 hours, the blood insulin concentration decrease gradually from 64 milliunits dm^{-3} to 12 milliunits dm^{-3}

(b) Explain how Fig. 8.1 and Fig. 8.2 provide evidence that insulin controls blood glucose concentration. [2]

1. Ref to inverse relationship between concentration of insulin and blood glucose concentration
2. After oral administration of insulin, the insulin concentration increases from from 4 milliunits dm^{-3} at 0 hours to 64 milliunits dm^{-3} at 9 hours and this results in a decrease in blood glucose concentration from 400 mg dm^{-3} at 0 hours to 100 mg dm^{-3} at 9 hours

3. When insulin concentration decreases from from 64 milliunits dm^{-3} to 12 milliunits dm^{-3} and this results in a increase in blood glucose concentration from 100 mg dm^{-3} at 9 hours to 320 mg dm^{-3} at 7 hours

   Accept if student quota data from injected insulin.

(c) Suggest **two** advantages of using orally administered insulin in treating diabetes. [2]

1. Does not require injection of insulin, thus lessen pain for patients / decreases the risk of infections due to injections.
2. Has longer lasting effects thus keeping the blood glucose level lower for a longer period of time.

(d) Explain how the binding of insulin to the insulin tyrosine kinase receptor triggers a response in the target cell that reduces the blood glucose concentration. [3]

1. Conformational change in the intracellular domain of receptor results in activation of intrinsic tyrosine kinase;
2. Intrinsic tyrosine kinase activity of each subunit in the intracellular domain cross-phosphorylates /autophosphorylates the ***tyrosine**** residues on the other subunit;
3. Other relay proteins inside the target cell will be able to bind to the phosphorylated tyrosine residues and become activated themselves;
4. This will enable the signal to be transduced within the cell until an appropriate cellular response is reached.

Cellular responses include :

5. Increase the number of glucose transporters (GLUT4) on the plasma membrane;
6. increasing the permeability of the plasma membrane to glucose to increase uptake of glucose from the blood by these cells, causing blood glucose concentration to drop;
7. increased activation of the enzyme glycogen synthase, which catalyses the synthesis of glycogen

9 **(a)** Describe briefly why these four ecomorphs have such different adaptations despite all the species of *Anolis* lizards in these ecomorphs being closely related. [3]

1. Random mutations which resulted in new alleles as well as sexual reproduction;

2. meant that there was ***variation**** in size, leg length, size of toepads, tail length and colour in the population of lizards;

3. The different habitats/environments had different niches with had different ***selection pressures****, + (Give at least one context specific explanation)

   - large toe pads of canopy ectomorphs increases surface area for them to cling to canopy regions of the tree or to glide to escape from predators or source for more food;
   - possibly the availability of insects (food) in different sections of the tree;
   - presence of ground-based predators that the lizards need to escape from resulted in selection of different leg lengths;
   - possibly the different size and colour of lizards allowed them to be better camouflaged and they could hide from predators/ catch prey more easily;

4. The lizards that were best adapted to a particular habitat/ part of the tree survived were selected for and survived and reproduced and passed on their ***alleles**** their offspring; R: genes

5. Over time frequency of alleles responsible for the various favourable adaptations in the 11 species of lizard, increased resulting in the 4 ecomorphs with different adaptations;

(b) Explain how the data in Fig. 9.1 and Fig. 9.2 provide evidence for:

(i) allopatric speciation [2]

1. The 3 Carribean islands are ***geographically isolated**** as they are surrounded by water that acts as a physical barrier that prevented interbreeding. This resulted in the ***disruption of gene flow****;
2. The islands due to their differing habitats / environments/ niches, presented ***different selection pressures**** ;
3. that resulted in ancestral lizards with the best adapted size/leg length/tail length as seen in Fig.9.1, surviving and reproducing which eventually led to different ***reproductively isolated**** species in the 3 different islands over time as seen in Fig 9.2;

(ii) sympatric speciation [2]

1. A ***reproductive barrier**** formed in the ancestral lizards of the twig and canopy ectomorphs that lived in the trees (as seen in Fig.9.1) which ***disrupted gene flow**** and prevented interbreeding between the two subpopulations;
2. In Jamaica, the 2 sub populations evolved independently and the best adapted survived and reproduced until the differences between them became so great that speciation occurred (as seen in Fig.9.2) leading to the formation of the twig and canopy ectomorphs;

(c) On the smallest Caribbean islands, severe storms can wipe out the existing populations of *Anolis* lizards. When small numbers of *Anolis* lizards recolonise these islands, only slight changes in leg length occur within their populations over time.

Outline how the evolution of *Anolis* lizards on the larger Caribbean islands differs from the evolution of *Anolis* lizards on the smallest islands. [3]

1. Since severe storms can wipe out entire lizard populations on the smallest islands, the small number of pioneers that later recolonize these islands are not likely to carry all the alleles present in the source population and hence have a smaller gene pool compared to the lizards from the larger Carribean islands;
2. Thus over time, the smallest islands, will have a population of lizards with some alleles being over represented and other alleles being under represented or not represented at all;
3. As a result, there will be reduced genetic variation in the smaller islands due to genetic drift, and hence less changes in leg lengths will occur in these populations over time;

[Total: 10]

10 **(a)** Using the data in Fig. 10.1 and Fig. 10.2, explain why the invasion of sea urchins into Tasmanian kelp forests is a recent phenomenon. [2]

1. Sea Urchin density increases sharply from 0 to 0.9m^{-2} as August sea temperature increase from 12 to 12.5^{o}C (from Fig 10.2).
2. Sharp increase in August Sea Temperature from 12 to 12.5 ^{o}C occurs from only recently from 1983 to 2010

(b) Using the information provided throughout the whole of this question, describe **and** explain the likely impact of climate change on Tasmanian kelp forests. [3]

1. Increase in sea temperature will result in an increase sea urchin density,
2. sea urchin which will graze on kelp, leading to decrease in percentage kelp cover
3. decrease % kelp cover will lead to decrease in marine species and biodiversity
4. quote values : Increase temperature above from to 12^{o}C to 12.5^{o}C results in sharp increase in sea urchin density from 0 to 0.9m^{-2}, will results in decrease in percentage kelp cover from 100% to ard 20%

[Total: 5]

11 **(a)** With reference to Fig. 11.1, deduce the difference between the actions of bactericidal and bacteriostatic antibiotics. [2]

1. From 0 to 5 hours, the number of bacteria per cm^3 in sample treated with tetracycline remained constant at 10^7 indicating that it is bacteriostatic, preventing further replication of bacteria by binary fission.

2. From 0 to 5 hours, the number of bacteria per cm^3 in sample treated with penicillin decreases from 10^7 to 10^2 indicating that it is bacteriocidal, killing the bacterial thus reducing the number of bacteria per cm^3

(b) Describe the effect of penicillin on the number of bacteria per cm^3, as shown in Fig. 11.1. [2]

1. Treatment with penicillin decreases the number of bacteria per cm^3 of sample
2. From 0 to 4 hours, the number of bacteria per cm^3 in sample treated with penicillin decreases from 10^7 to 10^2
3. From 4 to 5 hours, the number of bacteria per cm^3 plateau/does not decrease further

(c) Name the site of action of penicillin in bacterial cells. [1]

Bacteria peptidoglycan cell wall

[Total: 5]