STRUCTURED QUESTIONS

Question 1

(a) Describe the role of *haem* group in haemoglobin. [2]

1. Haem group in haemoglobin consists of an iron ion held in a porphyrin ring structure
2. Ref to iron ion bind with oxygen

(b) Discuss the advantages of having four subunits in haemoglobin. [3]

1. Binding of four oxygen molecules per haemoglobin results in increased oxygen carrying capacity
2. Ref to cooperative binding
3. Change in 3D conformation in one subunit results in changes in 3D conformation of the other subunits

(c) Explain how the differences in haemoglobin structure of the Greylag and Andean geese contribute to their different oxygen affinities. [4]

1. Ref to different amino acid sequence in the for Greylag goose and Andean goose haemoglobin
2. Different R-groups interactions results in the different specific 3D conformation
3. Haem groups are more exposed to bind to oxygen in Andean goose
4. Ref to different subunit interactions and different extend of cooperativity

[Total: 9]

Question 2

(a) Distinguish between the helical structures shown in regions **X** and **Y**. [2]

1. The helix in region X is single-stranded but the helix in region Y is double-stranded
2. Hydrogen bonds are formed between amine (-NH) and carbonyl (-CO) groups along the polypeptide backbone in region X but hydrogen bonds are formed between complementary bases on the two DNA strands in region Y
3. Helix in region X makes one complete turn every 3.6 amino acids but helix in region Y makes one complete turn every 10 base-pairs

(b) Describe the roles of DNA polymerase in the S phase of the cell cycle. [2]

1. DNA polymerase holds the DNA template and deoxyribonucleoside triphosphates / deoxyribonucleotides close together in the correct orientation
2. DNA polymerase catalyses the formation of phosphodiester bond between 5' phosphate group of an incoming dNTP and the 3' hydroxyl group of the growing daughter strand
3. DNA polymerase catalyses the formation of a daughter DNA strand that is complementary to the parental DNA strand

4. DNA polymerase removes the RNA primer and replaces it with dNTPs.
5. DNA polymerase proofreads and removes mismatched bases / nucleotides on the newly-synthesised daughter DNA strands

(c) ddCTP was added to a DNA replication reaction in large excess over the concentration of deoxycytidine triphosphates (dCTP).

Explain how the addition of ddCTP would affect DNA replication. [4]

1. Daughter strands would be synthesised until the first guanine base (G) encountered in parental / template strand
2. ddCTP is incorporated into daughter strands instead of dCTP and extension of daughter strand terminated / stops
3. Since ddCTP has a similar shape / 3D conformation to dCTP and ddCTP is added to DNA replication reaction in large excess over dCTP
4. ddCTP outcompetes dCTP for the active site of DNA polymerase and forms phosphodiester bond with 3' hydroxyl group of daughter strand
5. Since ddCTP lacks 3' hydroxyl group on the pentose, the incorporated ddC nucleotide cannot form phosphodiester bond with incoming dNTPs

(d) ddCTP is used in DNA sequencing reactions to determine the DNA base sequence. In such reactions, ddCTP is added at 10% the concentration of the dCTP.

Suggest how ddCTP facilitates the determination of DNA base sequence. [2]

1. 1 in 10 chance of ddCTP being incorporated whenever a G is encountered on the template strand
2. A population of DNA fragments of different sizes will be synthesised
3. From the lengths of DNA fragments, one can deduce the position of the G nucleotides on the template strand

[Total: 10]

Question 3

(a) With reference to Fig. 3.1,

(i) suggest why structure **C**, the first viral enzyme involved in the reproductive cycle of HTLV- 1, is crucial in its classification as a retrovirus. [1]

Structure C which is enzyme reverse transcriptase synthesizes a DNA intermediate

(ii) describe the roles of structures **A** and **B** in the reproductive cycle of HTLV-1 in $CD4^+$ T cells. [2]

1. Structure A binds to $CD4^+$ receptor to facilitate fusion of membranes for the release of viral contents into host T cell
2. Structure B serves as a template to form viral DNA for integration into host T cell genome

(b) Suggest how HTLV-1 infection could lead to the onset of T-cell leukemia. [1]

Idea of insertional mutagenesis

(c) With reference to Fig. 3.2 and 3.3,

(i) identify the time period(s) which correspond(s) to this late stage of HIV reproductive cycle shown in Fig. 3.3. [1]

X and Z

(ii) describe what happens during this stage of HIV reproductive cycle. [3]

1. Newly assembled immature HIV are budding off from the host T cell, acquiring host cell membrane as viral envelope
2. This is evident from the sharp increase of HIV RNA copies per ml plasma from Week 0 to 6 and Year 9 to 11

(iii) suggest how infection by HIV could cause diseases in time period **Z**. [2]

Failure of HIV patients' immune system as evident from the mass destruction of $CD4^+$ T cells by Year 11 could potentially leads to life-threatening infections

[Total: 10]

Question 4

(a) (i) State whether the *AFP* gene is found in the euchromatic or heterochromatic region in the nucleus of a foetal cell. [1]

Euchromatin / euchromatic region

(ii) Explain your answer in **(a)(i)**. [3]

1. Euchromatin is highly de-condensensed
2. allows RNA polymerase to bind
3. resulting in expression of AFP protein

(b) (i) Explain how chromatin remodelling can lead to a significant decrease in cellular *AFP* mRNA upon birth. [2]

1. Deacetylation of histone tails catalysed by histone deacetylases
2. hence, the chromatin structure becomes more compact
3. prevents access of RNA polymerase to AFP gene

(ii) Explain how cellular AFP proteins declines in the absence of *AFP* mRNA. [2]

1. Ubiquitin binds to and marks existing AFP proteins
2. Proteasome binds to ubiquitinated protein and degrades it

(c) State one limitation of using AFP as a biomarker in the detection of liver cancer. [1]

AFP protein is found in blood serum during liver regeneration and this may result in misdiagnosis for liver cancer

[Total: 9]

Question 5

(a) Describe how structures **P** differ from structures **Q**. [2]

1. structures Pare genetically identical while structures Q are not genetically identical
2. structures P are derived from a single parent where structures Q are derived from both parents / ref. to maternal and paternal

(b) **(i)** Draw a genetic diagram to explain the results of the test cross for plant **B**. [4]

F1 phenotype	normal leaves, few spines on fruit		heart-shaped leaves, many spines on fruit	
F1 genotype	$\frac{H\ f}{h\ F}$	**x**	$\frac{h\ f}{h\ f}$	
Gametes	(H f) (h F) (h f) (h F)		(h f)	

		male gametes			
		(H f)	(h F)	(H F)	(h f)
female gametes	(h f)	$\frac{H\ f}{h\ f}$	$\frac{h\ F}{h\ f}$	$\frac{H\ F}{h\ f}$	$\frac{h\ f}{h\ f}$
	phenotypes	normal leaves, many spines	heart-shaped leaves, few spines	normal leaves, few spines	heart-shaped leaves, many spines

ii) Account for the different test cross results obtained from plants **A** and **B**. [2]

1. ref. to coupling arrangement in plants A
2. ref. to repulsion arrangement in plant B
3. having different allelic arrangements on their chromosomes / produces gametes with different allelic combinations

(c) **(i)** Explain how the distance between two linked genes on a chromosome can affect the products of meiosis. [2]

1. Ref. to when 2 linked genes are located far apart, chances of crossing over between non-sister chromatids
2. to produce recombinant gametes / new combination of alleles / recombinant chromatids in gametes

(ii) Given that the loci for leaf shape and number of spines in plant **A** are 32.6 map units apart, complete Table 5.2 to show the expected proportions of progeny in each phenotype. [1]

Table 5.2

phenotype	expected proportion / %
heart-shaped leaves and many spines	33.7
normal-shaped leaves and many spines	16.3
heart-shaped leaves and few spines	16.3
normal-shaped leaves and few spines	33.7

(iii) Suggest why the observed numbers recorded for plant **A** in Table 5.1 do not exactly match the expected proportions. [1]

1. sample size is too small
2. random fertilisation of gametes
3. Ref. to chance events

[Total: 12]

Question 6

(a) **(i)** Account for the trends shown by the distribution of the two types of bacteria after six months.

[3]

1. Aerobic bacteria decrease with depthfrom mean number of bacteria per gram of stored soil of 12.5×10^7 to 0.9×10^7
2. Anaerobic bacteria increase with depth from mean number of bacteria per gram of stored soil of 0.6×10^7 to 8.8×10^7
3. Oxygen content of soil decreases with depth as aerobic bacteria requires oxygen for respiration
5. Less oxygen available as the final electron acceptor in ETC, decrease in ATP synthesis

(ii) Describe how aerobic bacteria are structurally adapted for cellular respiration. [2]

1. Presence of cytoplasmic membranes in aerobic bacteria. Hence, increase surface area
2. For more embedding of electron transport chain and ATP synthase to allow electron transfer / to drive oxidative phosphorylation of ADP to ATP

(b) (i) State with evidence from Fig. 6.1 which depth, A or B, were samples taken from a greater depth. [2]

1. Depth B
2. Bacteria in samples taken from depth B shows a lowered mean dehydrogenase activity with 1.5 to 2.4 au compared to 3.2 to 5.7 au in samples taken from depth A

(ii) Explain the roles of dehydrogenase in Krebs cycle of the aerobic bacteria. [2]

1. ref to substrate and ref oxidation / loss of protons and electrons
2. ref to reduction of coenzyme NAD and FAD and formation of NADH and $FADH_2$

[Total: 9]

Question 7

(a) Describe the role membranes in maintaining resting membrane potential. [2]

1. Hydrophobic lipid bilayer prevents movement of ions across the membrane
2. Thus allow buildup of ion gradient/ membrane potential
3. Membrane is embedded with Na^+/ K^+ pumps which pump 3 Na^+ out and 2 K^+ into cells to establish membrane potential

(bi) State the site of action of muscarine. [1]

Binding site of receptor on postsynaptic membrane (R: synaptic cleft)

(bii) Describe how muscarine changes the resting membrane potential when it binds to the muscarinic M1 receptor. [2]

1. Muscarine binding activates G-protein resulting in activation of phospholipase C/ formation of IP3
2. IP3 binds and triggers release of Ca^{2+} from ER resulting in depolarisation of the cell

(ci) Explain how ion channels cause a change in membrane potential after Y. [2]

1. Voltage-gated Na^+ channels close preventing influx of Na^+
2. Voltage-gated K^+ channels open allowing efflux of K^+

(cii) Explain how the graph in Fig. 7.2 would differ if acetylcholine was added together with muscarine at X. [3]

1. There would be greater number of action potentials/ shorter delay before first action potential/ more frequent or less intervals between peaks
2. Ref to spatial summation
3. As both muscarine and acetylcholine induce excitatory post synaptic potentials which result in greater depolarisation

[Total: 10]

Question 8

(a)(i) State the name given to the process in which only a certain percentage of adult foxes were chosen by humans to breed in each generation. [1]

Artificial selection / selective breeding

(ii) Compare the process in **(a)(i)** and natural selection. [2]

1. Both result in changes in allelic and genotype frequencies in the gene pool of the population
2. Man exerts the selection pressure in artificial selection while environment acts as the selection pressure in natural selection

(iii) Suggest why 20% of the female foxes were used for breeding but only 5% of the male foxes. [1]

1. Males can father many offspring / mate several females while females can produce only a few offspring
2. More females than males are needed to maintain numbers for each generation

(b) Explain how the percentage of foxes in elite class increases with increasing number of generations as shown in Table 8.2. [3]

1. Artificial selection allowed the elite foxes to be bred together
2. resulting in passing of allele(s) for tameness to offspring
3. With time, more foxes possess the allele(s) for tameness resulting in an increase in percentage of foxes in elite class from 18% to 75% going from generation 10 to 35

(c) Suggest how two different types of reproductive isolating mechanisms allowed dogs to evolve separately from wolves. [2]

1. Habitat / geographic isolation where wolves avoid human settlements / dogs confined by humans, so they never come in contact with each other
2. Behavioural isolation where there are differences in courtship behaviour
3. Mechanical isolation where incompatible genitalia prevent interbreeding
4. Gametic isolation where gametes fail to unite with each other
5. Seasonal / temporal isolation due to different breeding seasons
6. Hybrid inviability where hybrids are produced but fail to develop to maturity
7. Hybrid infertility where hybrids failed to produce functional gametes
8. Hybrid breakdown where F1 hybrids are fertile but the F2 generation fails to develop or are infertile

(d) Justify if the hypothesis that the golden jackal is more closely related to the domesticated dog than the grey wolf is correct. [2]

1. The hypothesis is incorrect
2. Dog and grey wolf have 2 nucleotide differences while golden jackal and dog have 4 nucleotide differences
3. This indicates that the dog has a greater degree of homology in DNA sequence with grey wolf than with golden jackal

[Total: 11]

FREE RESPONSE QUESTION

Question 9

(a) Describe the structure of a bacterial chromosome. [6]

1. Small in size
2. Circular double-stranded DNA molecule
3. Supercoiled via association with positively-charged histone-like proteins
4. Not enclosed by nuclear membrane but aggregated in nucleoid
5. Has a single origin of replication
6. Genes grouped into operons

(b) Explain the significance of genetic exchange in bacteria. [6]

1. Transformation, a recipient cell takes up small fragments of naked DNA from the surrounding environment
2. Transduction, bacteriophages carry bacterial genes from their first host cell / donor to their second host cell / recipient due to errors in the phage reproductive cycle
3. Homologous recombination of the donor DNA fragment takes place with a homologous section of the recipient cell's chromosome
4. Conjugation where direct contact / cytoplasmic bridge between donor and recipient cells results in transfer of F factor
5. These processes allow for genetic recombination, resulting in genetic variation in bacterial populations
6. This is essential for natural selection, selective advantage / differential survival and reproduction / better adapted to environment
7. Transfer of beneficial genes such as antibiotic resistance

(c) Outline the differences between prokaryotic control of gene expression with the eukaryotic model. [8]

		PROKARYOTIC	EUKARYOTIC
Control of transcription	Site of action	1a RNA Polymerase binds to the -10 Pribnow box	1b TFIID binds to the -25 TATA box to recruit RNA polymerase
	Level of control	2a Lack of complex regulation due to small number of regulatory sequences	2b Complex regulation of transcription due to presence of numerous regulatory sequences
	Regulation of gene expression	3a Binding of a repressor protein to operator OR Binding of activator protein to specific sequence (e.g CAP binding site)	3b Binding of repressor protein to silencer sequence OR Binding of activator protein to enhancer sequence

	Structural genes	4a Several structural genes under the control of a single promoter	4b Only one structural gene under control of each promoter
	Termination of transcription	5a Termination occurs in a rho - dependent or rho -independent manner	5b Termination occurs at the termination/ polyadenylation sequence following the transcription unit
Post transcriptional control	Post transcriptional control	6a There is no post transcriptional control since transcription and translation occur simultaneously	6b Post-transcriptional control enables modification for control of mRNA products formed
Control of translation	Nature of mRNA	7a Each mRNA is polycistronic / possessing multiple Shine-Dalgarno sequences, start and stop codons	7b Each mRNA is monocistronic/ able to give rise to a single polypeptide with a single ribosome-binding site, start and stop codon
	Type of ribosome	8a Ribosome is 70S, comprising 30S and 50S subunits	8b Ribosome is 80S, comprising 40S and 60S subunits
Post-translational modification	Post-translational modification	9a Occurs to only a very limited extent in prokaryotes	9b Multiple post-translational modifications occur, including cleavage, and addition of non-protein components

Question 10

(a) Describe the homeostatic regulation of blood glucose concentration. [8]

1. Set point of blood glucose level is 90mg/100 ml of blood, regulated by the negative feedback system

2. An increase in blood glucose concentration above set point
3. insulin is secreted by β cell of the pancreas
4. insulin decreases / down-regulates blood glucose levels by
    a. promoting uptake of glucose into cells
    b. promoting glycolysis
    c. promoting glycogenesis
    d. inhibition of gluconeogenesis
    e. inhibition of lipolysis

5. An decrease in blood glucose concentration below set point
6. Glucagon is secreted by α cell of the pancreas
7. Glucagon increases / up-regulates blood glucose concentration by
    a. promoting glycogenolysis
    b. stimulating gluconeogenesis
    c. stimulates lipolysis

(b) Outline the differences between a named proto-oncogene and a named tumour suppressor gene in their contribution to cancer. [8]

PROTO-ONCOGENE	TUMOUR SUPPRESSOR GENE
1a. *Ras* is a proto-oncogene	1b. *p53* is a tumour suppressor gene
2a. Ras protein is a G protein	2b. p53 protein is a transcription factor
3a. Ref. to role of Ras in cell signalling cascade	3b. ref. to role of p53 in cell cycle suppression / DNA repair
4a. *Ras* undergoes gain of function mutation	4b. *p53* undergoes loss of function mutation
5a. Mutation in only one Ras allele is required	5b. Mutation in both p53 alleles are required
6a. Hyperactive Ras protein	6b. Non-functional p53 protein
7a. remains bound to GTP even in the absence of growth factor	7b. cannot bind to the enhancer
8a. The cascade of protein kinases is always triggered	8b. Failure to upregulate transcription of genes involved in cell cycle suppression / apoptosis and DNA repair
9a. There is overstimulation of the cell cycle / excessive cell division	9b. There is no / reduced suppression of cell cycle

(c) Explain the advantages of having a cell signalling system in multicellular organism. [4]

1a. Signal amplification
1b. Allows for small number of extracellular signal molecules to produce a large cellular response from target cell

2a. Multi-step
2b. Provide more opportunities for coordination
2c. and regulation of cellular responses

3a. Contribute to the specificity of cellular response / cell signalling
3b. conferred by the same specific combination of signalling / relay proteins in a cell