QUESTION 1

(a) Describe one feature visible in Fig. 1.1 that identifies the amoeba as a eukaryotic organism.[1]

1 it contains a true nucleus / a membrane bound nucleus / membrane bound organelle like the food containing vacuole

(b)(i) Explain how the structure of the contractile membrane enables it to perform its function. [4]

1 presence of protein pumps / carriers for ions embedded on the contractile vacuole membrane
2 allow for active transport / pumping of ions into the lumen of contractile vacuole
3 resulting in the solute potential of the lumen being high / the lumen of the vacuole being of more negative water potential than the cytoplasm
4 so that excess water can enter the contractile vacuole by osmosis and expelled from the cell by exocytosis

5 presence of hydrophobic core of phospholipid bilayer / membrane
6 results in the membrane of contractile vacuole being impermeable to ions
7 allows accumulation of ions in the / prevents ions from leaving the lumen of the contractile vacuole so that solute potential of the lumen is high
8 so that excess water can enter the contractile vacuole by osmosis and expelled from the cell by exocytosis

9 contractile vacuole is made by phospholipids that form a bilayer / phospholipid bilayer
10 presence of weak hydrophobic interactions between fatty acid tails of the phospholipids / within the hydrophobic core
11 allow for membrane fluidity
12 that helps in fusion of the contractile vacuole with the cell surface membrane for exocytosis of water

13 presence of water channels / aquaporin embedded on the contractile vacuole membrane
14 allow for facilitated diffusion of water into the lumen of the contractile vacuole
15 so that excess water can enter the contractile vacuole by osmosis and expelled from the cell by exocytosis ref. to water moving from region of less negative water potential to region of more negative water potential

16 ref. to fluidity of the membrane allows for fusion of many small vesicles to the contractile vacuole to allow the vacuole to expand / increase in size

(ii) Explain how organelles of the endomembrane system are involved in the synthesis of proteins embedded within the membranes of contractile vacuoles. [4]

1 mRNA coding for proteins are translated by rough endoplasmic reticulum (RER) bound ribosomes forming polypeptides

2 movement of polypeptide into lumen of RER is halted when the polypeptide is midway through and the polypeptide continues to fold, resulting in a protein that is embedded in RER membrane

3 Transport vesicles with such proteins bud off the RER

4 these vesicles migrate to and fuse with cis face of Golgi apparatus (GA) where chemical modification occurs

5 GA releases these as vesicles that remain in the cytoplasm to serve as contractile vacuole / secretory vesicles containing these enzymes migrate to and fuse with contractile vacuoles

[Total: 9]

QUESTION 2

(a) State the level of protein structure found in β-keratin. [1]

secondary

(b) With reference to Fig. 2.1, describe features of keratin structure that contribute to its stability. [4]

1 β-keratin polypeptide + (Anti-parallel) β-pleated sheets + numerous intrachain hydrogen bonding between C=O and N-H groups of neighbouring segments

2 in a β -keratin dimer, there are two covalent / disulfide bonds between two β-keratin polypeptides

3 in a β -keratin fibril, there are two covalent/disulfide bonds between β-keratin dimers

4 in a β -keratin fibre, there are numerous / extensive disulfide bonds between neighbouring / adjacent β-keratin fibrils

5 disulfide / covalent bonds being, strong / not overcome by temperature / pH

(c) Keratinase is a type of protease that catalyse the hydrolysis of α-keratin and β-keratin. Many proteases are able to hydrolyse more than one type of protein.

Explain why it is possible for a protease to act on different types of protein. [3]

1 induced-fit hypothesis

2 substrates / proteins with similar 3D conformation / shape being able to fit / bind active site of enzyme

3 active site changes its 3D conformation slightly to fit the substrate more firmly/snugly

4 R groups of catalytic amino acids are brought into close proximity to the chemical bonds to be broken

5 straining of chemical bonds

[Total: 8]

QUESTION 3

(a)(i) Name molecules **A** and **B**. [2]

A - messenger RNA
B - aminoacyl tRNA

(ii) With reference to molecules **A** and **B**, discuss the role of hydrogen bonds in translation. [2]

1a hydrogen bonds between complementary segments of the tRNA
1b stabilising the 3D conformation of tRNA / tRNA folds into a specific 3D conformation for binding to specific aminoacyl tRNA synthetase

2a hydrogen bonds between anti-codon and codon
2b giving rise to specificity of amino acid residues added to the polypeptide

3a hydrogen bonds between tRNA and rRNA
3b holding it in the A-site and P-site

(b) Describe the differences between transcription and DNA replication. [3]

1 RNA polymerase vs DNA polymerase as the catalyst
2 transcription produces RNA while DNA replication produces DNA daughter strands
3 only one of the two DNA strands is used as template for transcription while both strands are used as template for DNA replication
4 type of monomers being different
5 transcription starting at promoter while DNA replication begins at origin of replication
6 transcription copies selected genes while DNA replication copies the whole DNA / genome
7 RNA polymerase unwinding and unzipping DNA double helix in transcription vs helicase in DNA replication
8 RNA being synthesised continuously in transcription while lagging strand is synthesised discontinuously in DNA replication
9 RNA primers needed to provide free 3'OH group for DNA polymerase to extend in DNA replication but not needed in transcription
10 transcription being unidirectional vs DNA replication being bidirectional
11 proof reading

(c) Explain how carbovir triphosphate may prevent the synthesis of viral DNA. [3]

1 absence of free 3' OH group when carbovir triphosphate is added to a growing chain

2 DNA polymerase cannot form phosphodiester bond between incoming free deoxyribonucleotide and growing strand

3 complete (viral) DNA not made / chain does not elongate / no more nucleotides added
4 similar shape to, substrate / (activated / phosphorylated) nucleotide + acts as a competitive inhibitor
5 any further detail of how, inhibitor / carbovir triphosphate, may act
6 proofreading mechanism

[Total: 10]

QUESTION 4

(a) Identify structures **A** to **D**. [2]

A: viral envelope
B: RNA
C: nucleoproteins / RNA-binding proteins
D: glycoprotein

(b) State the **origins** of structures A and D. [1]

Structure A is from previous host cell and structure D is from virus ;

(c) Both coronaviruses and influenza viruses rely on a similar class of enzyme for their replication processes.

Describe how the coronavirus produces viral progenies after entry into host cells. [4]

1 viral replicase / RNA-dependent RNA polymerase

2 copies negative sense RNA as a template to synthesise positive sense RNA

3 positive sense RNA is used to synthesise negative sense RNA / viral genome

4 positive sense RNA is translated in the cytoplasm to synthesise viral proteins

5 which is packaged into new viral particles

(d) Suggest **how** viruses such as SARS-CoV can potentially result in an **outbreak*** of **new** viral diseases. [3]

1 Antigenic shift + reassortment of viral genome

2 with that of a different antigenic type results in the formation of new strain

3 ref. to spread of viruses from one host species to another

4 Antigenic drift + gradual accumulation of minor mutations

5 results in changes to the genes for the glycoprotein receptors

6 ref. to existing viruses with high mutation rate as replication of nucleic acid does not involve proofreading

[Total: 10]

QUESTION 5

(a) Describe how gene expression in eukaryotes can be downregulated at the chromatin level. [3]

A1 deacetylation of acetylated lysine residues in histone tails

A2 lysine residues regaining their positive charges resulting in an increase in the affinity of the histone complex for DNA

A3 preventing binding of RNA polymerases to the promoter

M1 DNA methylation catalysed by DNA methyltransferases

M2 changes in 3D conformation of DNA

M3 preventing binding of RNA polymerases to the promoter

(b) Explain why RNA cannot act as a template for PCR amplification. [2]

1 RNA being single-stranded

2 Taq polymerase needing double-stranded templates

3 PCR uses a set of two primers thus two strands are needed for both primers to bind regions flanking gene of interest

4 if RNA is used as template unidirectional extension of 1 primer means the specific sequence to be amplified cannot be marked out

5 conformation of (active site of) Taq polymerase is complementary to DNA but not RNA

6 RNA is unstable and will degrade upon heating

(c) With reference to Fig. 5.2, outline how gel electrophoresis and nucleic acid hybridisation can be used to investigate the nature of genetic diseases **X** and **Y**. [4]

1 gel electrophoresis separating PCR products by size

2 use of probes complementary to gene of interest

3 thicker band for individual suffering from disease X, indicating increased expression of gene of interest/ increased amount of gene product

4 no band for individual suffering from disease Y, indicating no expression of gene of interest / no gene product

(d) Suggest why comparison of the gene expression profiles of healthy and diseased individuals might be insufficient to help researchers understand the nature of the disease. [1]

cDNA profiles cannot provide information on post-translational regulation / cause/ origin of disease / how disease is inherited

[Total: 10]

QUESTION 6

(a) Describe how dysregulation of any of these checkpoints may lead to cancer. [2]

1 any of the three checkpoints and refer to the respective consequences

2 rate of cell division far exceeding rate of cell death / uncontrolled cell division of cells, that may lead to cancer

(b) With reference to Fig. 6.1, explain why HCC development is a multi-step process. [5]

1 gradual accumulation of independent mutations in cancer-critical genes in a single cell lineage

2 loss-of-function mutation in tumour suppressor genes, *TP53, ARID1* and *RB1*

3 gain-in-function mutation in proto-oncogene, *CTNNB1*

4 Increase percentage of cells with mutations in *TERT* promoter from 5% in Stage C to Stage E

5 switching on the telomerase gene producing telomerase to maintain the telomere length, cancer cells evade replicative cell senescence

6 In Stage E, metastasis occurs with new secondary tumours

(c) Outline the differences between the malignant cells in Stage **E**, with the cells in Stage **C** in Fig. 6.1 . [2]

1 cells in Stage E with atypical/ irregular shape, compared to cells in Stage C with regular shape

2 cells in Stage E undergoing higher rate of cell division/ mitosis compared to cells in stage C

3 cells in Stage E with variable/ irregular sizes, compared to cells in Stage C with regular/ uniform sizes

4 cells in Stage E with bigger nuclei/ nuclei with variable sizes, compared to the cells in Stage C with regular sizes

(d) Identify one causative factor that may lead to HCC. [1]

1 excessive drinking of alcohol

2 Polycyclic aromatic hydrocarbons in cigarette and tobacco smoke / ionising radiation / ultraviolet radiation

[Total: 10]

QUESTION 7

(a) State what is meant by the term *autosomal* in this context. [1]

ref. to genes not located on sex chromosome

(b)(i) With reference to the observed test cross results in Table 7.1, deduce the phenotypes of the two pure-breeding fruit flies used to produce the F_1 generation. [2]

1 wild type body and vestigial wings
2 ebony body and wild type wings

(ii) Explain your answers to **(b)(i)**. [2]

1 ref. to greater numbers of parental phenotypes / fewer numbers of recombinants

2 ref. to genes being linked

(iii) Draw a genetic diagram to show the observed test cross results in Table 7.1. [4]

F1 test cross	wild type body and wings				ebony body and vestigial wings	
genotypes	$\frac{Ab}{aB}$			×	$\frac{ab}{ab}$	
gametes	Ab	aB	AB	ab	ab	

random fertilization

		male gametes			
		Ab	aB	AB	ab
female gametes	ab	$\frac{Ab}{ab}$	$\frac{aB}{ab}$	$\frac{AB}{ab}$	$\frac{ab}{ab}$
offspring phenotype		wild type body and vestigial wings	ebony body and wild type wings	wild type body and wings	ebony body and vestigial wings
observed number of offspring		2768	2843	842	855
		parental		recombinants	

(c)(i) Calculate the expected number of each phenotype if the two genes are on **different** autosomes. Write your answers in Table 7.1. [1]

1827 for each of the 4 phenotypes

(ii) Explain how the value of χ^2 and Table 7.2 can be used to assess the significance of the difference between the observed results and the expected numbers in Table 7.1. [3]

1 correct comparison of χ^2_{calc} and χ^2_{crit}

2 significant difference between observed and expected results

3 any valid explanation / observation for difference

[Total: 13]

QUESTION 8

(a) Use letter **A** or letter **B** from Fig. 8.1 to complete Table 8.1 to show the location where the substrates or products are used or produced. [2]

Table 8.1

substrate or product	**location**
oxygen produced	A
carbon dioxide used	B
reduced NADP used	B
hexose produced	B

(b) With reference to Fig. 8.2,

(i) describe **and** explain the effect of CO_2 concentration on the rate of CO_2 fixation shown by the **wild type** plants. [4]

1a CO_2 concentration being the limiting factor

1b as CO_2 concentration increases from 60 mg m^{-3} CO_2 to 1200 mg m^{-3} CO_2, rate of fixation of CO_2 increases from 1 μmol CO_2 m^{-2} s^{-1} to 42 μmol CO_2 m^{-2} s^{-1}

2a CO_2 concentration not being the limiting factor

2b as CO_2 concentration increases from 1200 mg m^{-3} CO_2 to 1900 mg m^{-3} CO_2, rate of fixation of CO_2 remains constant at 42 μmol CO_2 m^{-2} s^{-1}

(ii) suggest explanations for the differences in the rate of CO_2 fixation between wild type plants and Sox4 plants. [3]

1 maximum rate of fixation of CO_2 being higher in Sox4 at 47 μmol CO_2 m^{-2} s^{-1} compared with wild type at 42 μmol CO_2 m^{-2} s^{-1}

2 Sox4 having more SBPase / ora, resulting in faster regeneration of RuBP

3 more RuBP being fixed with CO_2

(c) Research has shown that the mean plant biomass of Sox4 plants is 37% higher compared with wild type plants.

Suggest why Sox4 plants has a higher mean plant biomass compared with wild type plants. [1]

more glyceraldehyde-3-phosphate (GALP) / triose phosphate (TP) made by Calvin cycle, resulting in more starch / lipid, for storage / more cellulose, for cell walls / more amino acids / proteins, for growth

[Total: 10]

QUESTION 9

(a) Explain how the three subspecies of tiger on the Sunda Islands formed. [4]

1 ref. to geographical isolation

2 no gene flow / breeding, between populations (on the different islands)

3 different, selection pressures / environmental conditions (on the different islands)

4 different mutations occur (on the different islands)

5 some mutations make individuals better adapted through natural selection

6 those individuals, survive / reproduce

7 pass on advantageous alleles to successive / many generations

8 change in allelic frequencies in the gene pool of each population

9 over time the 3 populations of tigers accumulate phenotypic divergence but insufficient reproductive isolation mechanisms

(b) Explain why specific primers were used for the tiger mtDNA sections. [2]

1 bind to complementary base sequences in mtDNA

2 only amplify specific mtDNA sections

3 mtDNA section, differences / similarities, used to assess how closely related the subspecies

(c) Suggest **and** explain **one** characteristic of mtDNA that makes it more useful than using nuclear DNA to provide evidence of evolution. [2]

1 large quantity in the cell,
2 so easier to, extract / amplify, DNA for testing

3 mtDNA is a single copy of DNA
4 so only mutation causes it to change

(d) Suggest **two** reasons why *P. t. balica* and *P. t. sondaica* became extinct. [2]

1 massive / severe / extensive (deaths) reduction in population size

2 rate of reproduction / reproductive success is much slower than rate of death

3 inbreeding depression / small gene pool leads to less genetic variation / reduced fitness and inability to adapt to new environmental selection pressures

[Total: 10]

QUESTION 10

(a) Explain why *Mycobacterium tuberculosis* (MTB) is only detected at later stages of infection.[2]

1 MTB escaping phagocytosis, by preventing the fusion of the phagosome with lysosomes

2 MTB remaining inside macrophages, forming tubercles / granulomas

3 detecting MTB upon rupture of tubercles during later stages of infection

(b)(i) With *reference* to Fig. 10.1, explain why MTB-specific antibody responses are usually undetectable during the early phase of infection, but detectable as the infection progresses to active TB. [2]

1 low bacterial cell count at early phase of infection, B cells not activated / antibodies not produced to detectable levels

2 increasing bacterial cell count as infection progresses to active TB, B cell activation / clonal expansion to produce sufficient antibodies to be detected

3 antigen can only be detected during active TB (when MTB are released from ruptured tubercules)

(ii) Suggest why IFN-γ would be a better indicator for identification of individuals at risk of developing active contagious TB.

1 IFN-γ is detected shortly after infection / prior to active TB, allowing for early treatment

[Total: 5]

QUESTION 11

(a) With reference to Fig. 11.1, compare the effects of climate warming on the biodiversity in tropical and temperate regions. [3]

1 greater reductions in biodiversity in tropical regions compared to temperate regions

2 quoting of relevant supporting data from Fig. 11.1

OR

3 temperate regions could have positive change / increase in biodiversity, compared to tropical regions which are mainly negative

4 quoting of relevant supporting data from Fig. 11.1

(b) Suggest possible reasons for the difference in **(a)**. [2]

1 greater proportion of/larger number of/more species are near their upper tolerable temperature limit/optimum temperature/tolerable range, in tropical regions

2 poleward shift of species to keep to within their tolerable range

[Total: 5]