HWA CHONG INSTITUTION (COLLEGE SECTION)
2023 JC2 9744 H2 BIOLOGY
PRELIMINARY EXAMINATIONS PAPER 3 MARK SCHEME

QUESTION 1

(a) During the last ice age an ice sheet separated southern and northern populations of *R. tarandus* in North America.

(i) Indicate on Fig. 1.2 with an "X" a possible location of the ice sheet formed during the last ice age. [1]

any location where there is an overlap in range between subspecies BGS and WS

(ii) Explain how this ice sheet affected the evolution of *R. tarandus* to result in the two different subspecies. [3]

1 ref. to geographical isolation
2 ref. to no gene flow between populations
3 ref. to adaptation to environment

(b) Assess the relative importance of natural selection and genetic drift in producing the different body sizes of the two subspecies of reindeer. [2]

1 genetic drift is more important
2 ref. to any valid justification

(c) Interbreeding has occurred between individuals of the two subspecies which now live in the area previously covered by the ice sheet.
Comment on how the hybrid populations compare to the pure subspecies in terms of genetic variation and potential to adapt to climate change. [2]

1 ref. to hybrid populations with more genetic variation
2 ref. to hybrid populations with more potential to adapt to climate change

(d) Table 1.1 in page 2 suggests that the subspecies **WS** is mainly non-migratory whereas subspecies **BGS** is primarily migratory.
Explain how the data shown in Fig. 1.3 supports the above suggestion. [3]

1 ref. to subspecies BGS having low index of seasonal range overlap
2 ref. to subspecies WS having high index of seasonal range overlap
3 ref. to link between index of seasonal range overlap and migratory / non-migratory behaviour

(e) Outline how molecular techniques could be used to test the hypothesis that migratory behaviour in reindeer has a genetic basis. [3]

1 ref. to obtaining DNA
2 ref. to testing both subspecies BGS and WS
3 ref. to use relevant molecular techniques e.g. gel electrophoresis / DNA fingerprinting and compare results to see genetic differences

(f) Discuss the importance of the trends observed in Fig. 1.4 for long-distance migratory animals. [4]

1 ref. to energy expenditure inversely proportional to duration of activity
2 ref. to correct supporting data from Fig. 1.4
3 ref. to increase in both muscle aerobic capacity and fatty acid transport in long-distance migratory animals
4 ref. to correct supporting data from Fig. 1.4

(g) **(i)** Calculate the net number of ATP molecules produced from the complete oxidation of one molecule of 16-carbon palmitoyl CoA. Show your answer clearly in the space provided below. [2]

1 ref. to correct working
2 129

(ii) Suggest why fatty acids can only be respired under aerobic conditions. [2]

1 ref. to fatty acids converted to acetyl coA
2 ref. to role of oxygen in aerobic respiration

(h) The Hardy-Weinberg principle states that allele frequencies remain constant from generation to generation.
Explain **two** reasons why this would not apply to the gene pools of species in fragments **P**, **Q** and **R**. [2]

1 ref. to small population size
2 ref. to genetic drift

(i) List fragments **P**, **Q** and **R** in order of risk of species extinction, from most to least. Explain your answer. [3]

1 most risk – Q P R – least risk (A: P Q R)
2 ref. to ease / difficulty of gene flow with main population
3 ref. to correct supporting info from Fig. 1.6

(j) Assuming edge effects extend 35 m into each habitat patch, calculate the percentage of the fragment influenced by the edge effects for the second largest patch.
Show your working clearly and write your answer in the space in Fig. 1.7. [1]

41.2%

(k) Describe the trend in the data and suggest how human activities could affect an abiotic factor that would differ in the area affected by edge effects. [2]

1 ref. to correct trend from data
2 ref. to relevant human activities affecting relevant abiotic factor

[Total: 30]

QUESTION 2

(a) Suggest how glycoproteins **H** and **F** enable the entry of nucleoprotein and viral polymerase into the host cell. [2]

1 Ref to H binding to sialic-acid containing receptors
2 Ref to F allowing fusion of viral envelope with endosome / lysosome

(b) Rubella virus contains a single positive sense RNA strand as the genetic material.
Suggest how the positive sense RNA strand of rubella virus is utilised in making progeny virus. [2]

1 Ref to viral polymerase converting positive sense RNA to eventually more copies of positive sense RNA
2 Ref to positive sense RNA template for translation of viral proteins

(c)(i) Describe how activated B lymphocytes producing IgM would start to produce IgG a few weeks after infection. [2]

1 Ref to class switching
2 Ref to heavy chain constant region of IgM being changed to that of IgG

(c)(ii) Using information provided throughout the whole of this question, assess the role of these three classes of antibodies in the immune response to the rubella virus. [4]

1 IgM is produced early in response to virus thus have a role in agglutination of viruses
2 IgA produced early in response and secreted in tears or mucus can cause agglutination, opsonization neutralisation
3 IgG persist in the body to provides sustained immunity to virus
4 IgG can cross placenta, + ref to provide immunity to the fetus

[Total: 10]

QUESTION 3

(a)(i) Name the type of variation shown in Fig. 2.2. [1]

continuous

(a)(ii) Suggest and explain how genes and the environment contribute to variation in IPD in humans. [3]

1 Ref. to multiple genes
2 Act on the phenotype in an additive manner
3 Ref. to description of the cumulative effect of varying environmental factors acting on different genotypes / AW

(b)(i) State the term that is used to describe a gene, such as *PAX3*, that controls the expression of other genes **and** suggest how the PAX3 protein controls the expression of other genes. [3]

1 Regulatory gene
2 Gene codes for transcription factor
3 that binds to DNA / promoter

(b)(ii) Suggest how knowledge of the *PAX3* gene helps scientists explain how humans and chimpanzees are very different in facial structure, even though they have very similar DNA. [3]

1 Ref. to one gene contributing to big phenotypic effect
2 Ref. to *PAX3* controls other genes
3 Ref. to different levels of gene expression

[Total: 10]

QUESTION 4

The metabolism of a eukaryotic cell is tightly regulated by enzymes. Some of these enzymes interact with additional non-protein components such as inorganic ions, coenzymes and prosthetic groups.

(a) Describe the mode of action of enzymes and explain how enzyme activity can be regulated in a eukaryotic cell. [15]

any nine for mode of action:

M1 ref. to active site having a specific 3D conformation

M2 ref. to binding amino acid residues that hold the substrates in position

M3 ref. to catalytic amino acid residues that are involved in the making or breaking of chemical bonds

M4 ref. to enzymes speeding up a chemical reaction by lowering the activation energy

M5 ref. to enzymes and substrates colliding in the correct orientation

M6 ref. to formation of enzyme-substrate complex

M7 ref. to catalytic amino acid residues causing a strain on the bonds in the substrates

M8 ref. to active site providing a microenvironment to make or break covalent bonds

M9 ref. to product being released from the active site and enzyme being reused to take up another substrate

M10 ref. to lock and key hypothesis, in which only substrates that are exactly complementary can bind to the active site

M11 ref. to induced fit hypothesis, in which the active site is not exact complementary conformation to the substrate before binding

M12 ref. to a change in the 3D conformation of the active site being induced, thus moulding the active site into a precise conformation

any five for regulation:

R1 ref. to competitive inhibitor resembling the substrate in structure and can to bind to active site

R2 ref. to non-competitive inhibitor <u>not</u> resembling the substrate in structure and thus binds to a site other active site to cause a change in the 3D conformation

R3 ref. to allosteric inhibitor binding to allosteric site to stabilise the inactive form of the enzyme

R4 ref. to reducing the frequency of effective collisions

R5 ref. to association of apoenzyme with cofactor that facilitates the binding of the substrate to the enzyme

R6 ref. to post-translational modifications such as phosphorylation of kinases

Cell cycles are tightly regulated at various checkpoints. The development of cancer is a multi-step process comprising gene mutations that cause cells to bypass cell cycle checkpoints.

(b) Discuss how gene mutations contribute to the development of cancer in a cell lineage. [10]

any nine:

1 ref. to cancer as a disease that results when cells divide excessively

2 ref. to accumulation of mutations

3 ref. to development of cancer as a multi-step process

4 ref. to gain in function mutation of proto-oncogenes resulting in increased expression of oncogenic protein(s) / expression of variant protein(s)

5 ref. to loss of function mutation of tumour suppressor genes resulting in decreased expression of tumour suppressor proteins / expression of non-functional protein
6 ref. to dysregulation of cell cycle checkpoints
7 resulting in uncontrolled cell division
8 ref. to mutations in genes regulating apoptosis
9 ref. to mutations in genes regulating angiogenesis
10 ref. to mutation in genes regulating metastasis

[Total: 25]

Question 5

Photosynthesis nourishes almost all of the living world directly or indirectly, as the path of the food chain is traced from plants up through animals.

(a) Describe how plants harness light energy to drive the synthesis of organic compounds and suggest how photosynthesis is necessary to sustain life. [15]

Describe light-dependent stage [L] [max 6]

1 Ref to light striking a pigment molecule in light harvesting complex of PSI / II
2 Ref to resonance energy transfer, from one pigment molecule to another within LHC
3 Ref to electron in special chlorophyll *a* / P680 molecules becoming photoexcited
4 Ref to electron captured by the primary electron acceptor in the reaction centre
5 Ref to photolysis of water, to replenish electron deficit from the reaction centre of PSII
6 Ref to electron passing through the electron transport chain, from PSII to PSI
7 Ref to free energy released being used to pump protons against a concentration gradient from the stroma into the thylakoid space
8 Ref to diffusion of H^+, down the proton gradient, through ATP synthase complex, driving ATP synthesis
9 via chemiosmosis
10 Ref to electron from PSII replenishing electron deficit in PSI
11 Ref to excited electron from PSI's primary electron acceptor being passed down a second ETC
12 Ref to NADP as the final electron acceptor, forming NADPH

Light-independent stage [D] [max 5]

carbon fixation

1 Ref to carbon dioxide (1C) being fixed with RuBP (5C), catalysed by RUBISCO
2 forming an unstable 6-carbon intermediate that breaks down spontaneously to form two molecules of phosphoglyceric acid PGA (3C)

reduction of PGA

3 Each molecule of PGA (3C) is phosphorylated by ATP, forming 1,3-bisphosphoglycerate (3C)
4 Ref to NADPH, as the reducing power to form triose phosphate (TP) (3C)

regeneration of RuBP

5 Ref to every 3 turns of Calvin Cycle forming 6 molecules of TP (3C)
6 For every 3 turns of Calvin Cycle, 1 net TP (3C) is synthesised from six molecules of TP (3C)
7 Remaining five molecules of TP (3C) are used, to regenerate three molecules of RuBP (5C) used in carbon fixation
8 using 3 molecules of ATP
9 For every 6 turns of the Calvin Cycle, 1 glucose (6C) is synthesized
10 Ref to number of carbon atoms for various intermediates in Calvin cycle

Photosynthesis sustaining life [S] [max 3]

1 Ref to plants as primary producers of the food chain
2 Ref to plants being directly nourished by sunlight as they are photoautotrophs
3 Ref to food chain
4 Ref to glucose used as respiratory substrate for synthesis of ATP
5 Ref to oxygen as by-product of photosynthesis necessary for aerobic respiration
6 Ref to ATP required for metabolic processes / respiration / cell division / transport etc
7 Ref to plants as carbon sinks, keeping atmospheric carbon dioxide within reasonable limits

Global food insecurity has been rising due in large part to anthropogenic climate change.

(b) Discuss the consequences to the global food supply of increased environmental stress resulting from climate change. [10]

General points [G] (max 2)

1 Anthropogenic climate change has led to increased temperature and more extreme weather conditions
2 Ref. to a decrease in quality / quantity of food
3 Ref to food insecurity because of demand exceeding supply for food

Any seven

Effects on plant crops [P]

1 Heat stress may leads to decrease in crop yield because the increase in temperature may be beyond the temperature tolerance levels of the plants, and result in death of plants
2 Water stress (drought) may lead to potential decrease in efficiency of photosynthesis as stomata close to prevent wilting, limiting CO_2 concentration for carbon fixation
3 Increase in temperature might also lead to expansion of range for some insect pests which may decrease yield if they destroy crops
4 Range shifts of weeds may lead to increased competition and affect crop yield
5 Ref to lack of pollinators

Effects on livestock / fisheries [A]

1 Some crops are food for livestock, so will be indirectly impacted by the decrease in crop yields
2 Death of livestock from, drought (lack of water) / overheating
3 Increased susceptibility to diseases
4 Changes to behavior of the animals

Loss of genetic diversity for food [D]

1 Wild crop relatives should be maintained as potential food sources
2 However, these wild crop relatives may go extinct if they are unable to adapt to the extreme weather conditions
3 This leads to decrease in food security which is guarantee of adequate, safe, reliable food supply

[Total: 25]