Victoria Junior College
2018 H2 Biology Prelim Paper 2
Answer

1 In eukaryotic cells, the degradation of mRNA is an essential part of the regulation of gene expression. It can be controlled in response to developmental, environmental, and metabolic signals. mRNA hydrolysis is catalysed by numerous types of nucleases, such as the endonuclease Ribonuclease A (RNAse A), shown in Fig. 1.1.

(a) Using a labelled and annotated diagram, illustrate the hydrolysis of the bond catalysed by RNAase. [3]
(A monomer has been drawn for you.)

- Accurate drawing of mRNA strand, at least 2 nucleotides (using symbols);;
- Accurate drawing of phosphodiester linkage + label;;
- Water;
- Hydrolysis ;
- Accurate drawing of correct number of nucleotides after hydrolysis;

Fig 1.1B shows two important catalytic residues within the active site of RNAse A, which are His12 and His119.

(b) Explain how these two histidines, which are in position 12 and 119 of the 124 amino acid sequence, are brought together in the active site of the enzyme. [3]

- Primary structure (number, type and sequence of amino acid)determines how the polypeptide chain folds upon itself;;
- interactions between R groups of amino acids not located close to one another on the primary structure ;
- To form the tertiary structure with a compact globular 3D structure;
- Bringing faraway amino acids together within the active site;

(c) Predict how the catalytic activity of RNAse would be affected if both histidines were replaced by phenylalanines. [2]

- Histidine has an R-group that is polar whereas phenylalanine has an R-group that is non-polar;;
- This causes the change in the interaction between the catalytic residues and the substrate at the active site; therefore; RNAase catalytic activity will be greatly reduced / lost;;

2 (a) Based on your understanding of penicillin and with reference to Fig. 2.1,

(i) deduce whether penicillin is more effective against gram-positive or gram-negative bacteria. [1] Gram positive;;

(ii) suggest a reason for your answer in (a)(i). [3]

- Penicillin binds irreversibly to the enzyme DD-transpeptidase;;
- which is responsible for the catalysis of cross-link formation within the peptidoglycan cell wall;;
-

- Gram positive bacteria have thicker peptidoglycan cell wall hence more affected than Gram negative bacteria;;

- Penicillin is a hydrophilic molecule;
- Unable to pass through the hydrophobic core of outer membrane;
- Gram positive bacteria has no outer membrane hence allowing penicillin easier access to the peptidoglycan cell wall;;

(bi) Outline how the bacterium produces an efflux pump from a gene on a plasmid. [4]

- RNA polymerase binds to the promoter;
- catalyses phosphodiester bonds between ribonucleotides
- transcribes mRNA from DNA template strand;
- mRNA binds to small ribosomal unit of 70S ribosome;
- and undergoes simultaneous translation;
- Idea of triplet code;
- peptidyl transferase; catalyses formation of peptide bonds;
- between amino acids carried by tRNA on ribosomal A and P sites;
- Formation of efflux pump polypeptide;
- folds to form tertiary structure;

(ii) Describe one similarity between the bacteria efflux pump and the glucagon receptor that is important to their function. [1]

- Both are transmembrane proteins that span the membrane;;
- The transmembrane sections of both proteins have hydrophobic amino acid residues that can form hydrophobic interactions with the hydrophobic core of the phospholipid bilayer;;

(iii) Suggest two ways the structure of the bacterial efflux pump is different from an insulin receptor involved in blood glucose regulation. [4]

	RTK	Efflux pump
Number of transmembrane regions	• One transmembrane section;;	• 2 transmembrane section;;
Important binding domains	• Extracellular domain binds to insulin hormone;;	• Intracellular region binds to antibiotic to pump it out of the cell;;
Shape of active protein	• Active receptor is made of 2 subunits that have dimerised;;	• Efflux pump is a channel protein with a central hydrophilic core that allows hydrophilic molecules like antibiotics to pass though;;
Presence of enzyme	• Contain tyrosine kinase for cross phosphorylation of tyrosine residues on cytoplasmic domains	• No tyrosine kinase in cytoplasm domain

3 Telomeres have a nucleotide sequence that is repeated as many as 2000 times. This repetition is shown in Fig. 3.1. Attached to the DNA of the telomere are protein units.

(a) (i) What sequence of bases is repeated in the complementary polynucleotide shown in Fig. 3.1? [1]

- AATCCC / adenine adenine thymine cytosine cytosine cytosine;; (first 6)

(ii) Suggest one reason for the presence of protein units in the telomere. [1]

- Protect the DNA from degradation;;
- Prevent binding of transcription factors and RNA polymerase to the DNA;;
- Enables homologous chromosomes to pair during meiosis;;
- AVP;;

(b) In the past, repeating sequences were referred to as "junk DNA". Explain why the term "junk DNA" is misleading in the context of telomere. [2]

- "Junk" implies no, function / purpose;; ora
- Repeating sequences of telomeres serve to protect genes from being eroded via successive rounds of replication, maintain the integrity of chromosomal end, and limit the lifespan of cells;;

(c) The repetitive base sequence of telomere DNA is an example of a non-coding base sequence.

Explain what is meant by non-coding. [1]

- Not transcribed to form a product (protein / polypeptide / amino acid sequence);;

(d) A study of individual telomere lengths and its correlation with age is shown in Fig. 3.2.

Account for the trend line shown in Fig. 3.2. [4]

1. Increase in age from 20 to 70, decrease in telomere length from 7.8 kb to 6.5 kb;
2. More, cell division / generations of cells / mitosis / replication;
3. Loss of, telomere / DNA / nucleotides / part of chromosome, at each replication;
4. Due to end replication problem;
5. During DNA replication, when the last RNA primer is removed / excised;
6. At the 3' end of parental template strand / 5'end of daughter strand, it is not replaced by corresponding DNA sequence;
7. As DNA polymerase cannot add new nucleotides; without an existing 3'OH end;
8. Idea of resulting daughter DNA strand being shorter than the parental DNA strand;

[Total: 9]

4 **(a)** Explain why ATP is regarded as the universal energy currency in organisms. [2]

- Found in all organisms;;
- Loss of phosphate / hydrolysis, leads to, energy release / release of 30.5 kJ (per mole);;
- ADP + Pi → ATP / reversible reaction;;
- Small / water soluble, so can move around cell;;
- Link between energy yielding and energy requiring reactions / AW;;
- Example of use e.g. active transport / muscle contraction / Calvin cycle / protein synthesis;;

(b) Studies on cancer cells found that fast-growing cancer cells require much more energy than normal cells, which explains the much higher rate of glucose uptake into cancer cells. However, it is also found that, unlike normal cells, the higher glucose uptake reduces oxygen uptake into cancer cells. This respiratory inhibition is known the Crabtree effect. It is proposed that this is due to more mitochondrial damages in cancer cells.

(i) Besides the need for more energy for cell division, explain the process how cancer cells utilise glucose at a much higher rate than normal cells to produce energy. [3]

- Ref. to anaerobic respiration;;
- Ref. to glycolysis producing 2 net ATP;;
- Pyruvate acting as the alternative hydrogen acceptor to regenerate NAD;;

(ii) Compare the differences between respiration in cancer cells and yeast cells. [2]

	Cancer cells	**Yeast cells**
Type of fermentation;;	• Lactate fermentation	• Alcoholic fermentation
Products (besides ATP);;	• Lactate / Lactic acid	• Ethanol and carbon dioxide
Enzyme(s) involved;;	• Lactate dehydrogenase	• Pyruvate decarboxylase and alcohol dehydrogenase

[Total: 7]

5 *lac* operon consists of a promoter, an operator, a catabolite activator protein (CAP) binding site and structural genes such as lacZ which codes for β-galactosidase, an inducible enzyme. The operon switches on or off depending on the type of carbon source present.

(a) Define the term "inducible enzyme", with respect to β-galactosidase. [1]

- Synthesis of β-galactosidase can be stimulated when lactose is available;;

Feature	**Inducible system**	**Repressible system**
Example	• *lac* operon	• *trp* operon

Characteristics	• Expression of the structural genes is switched on in the presence of the substrate e.g. lactose • Substrate binds to and inactivates the repressor	• Expression of the structural genes is switched off in the presence of the end product e.g. tryptophan • End product serves as the co-repressor, binds to and activates the repressor
Product	• Inducible enzymes which catalyse the uptake and metabolism of lactose ➢ β-galactosidase, lactose permease, galactoside transacetylase	• 5 repressible enzymes which catalyse the biosynthesis of tryptophan

(b) An experiment was conducted to determine the identity of Substance X and Substance Y. Both substances are known to have an effect on the expression of β-galactosidase in *Escherichia coli*. Substance X was added after 10 minutes, Substance Y was added after 20 minutes and both substances X and Y were added after 30 minutes. The results are shown in Fig. 5.1.

With reference to Fig. 5.1,

(i) suggest the identities for Substance X and Substance Y. [2]

- Substance X: cAMP;;
- Substance Y: Lactose / Allolactose;;

(ii) explain how the expression levels of β-galactosidase are affected by Substance X and Substance Y between 10 minutes to 40 minutes. [5]

- From 10 minutes to 20 minutes, the amount of β-galactosidase remained constant at 0.1mg;;
- This is because even with the presence of Substance X/cAMP, the *lac* operon is off due to the absence of lactose;;
- From 20 minutes to 30 minutes, the amount of β-galactosidase increased slightly from 0.1mg to 1.0mg;;
- Substance Y / Lactose /.Allolactose binds to the repressor, making the repressor inactive → RNA polymerase can bind to promoter, the *lac* operon is on, but rate of transcription is low;;
- From 30 minutes to 40 minutes, the amount of β-galactosidase increased greatly from 1.0mg to 9.0mg;;
- Substance Y/Lactose/Allolactose binds to the repressor, hence the *lac* operon is on. Substance X/Glucose/cAMP binds and activates CAP. Binding of cAMP-CAP complex to CAP binding site facilitates binding of RNA polymerase at the promoter, resulting in a high rate of transcription;;

(c) In another experiment, the *trp* operon and the *lac* operon of a bacteria cell were made to fuse together. The fusion process is illustrated in Fig. 5.2.

Suggest the condition(s) needed for β-galactosidase to be expressed in this strain of bacteria that carries the fused operon. Explain your answer. [4]

- Only when tryptophan is absent;;
- Fusion of trp and lac operon means that the genes in the *lac* operon are now under the control of the regulatory region of the *trp* operon;;
- In the absence of tryptophan, the repressor is inactive and is therefore unable to bind to the operator;;
- RNA polymerase is able to bind to the promoter and transcribe lacZ genes that encode β-galactosidase;;

[Total: 12]

6 Some hormones circulating in the blood are able to trigger transcription within a cell, even though they are unable to enter the cell. Phosphatases and kinases then take part in cell activities that eventually result in genes switching on and transcription beginning.

(a) Suggest why the hormones, referred to in the passage, are unable to enter the cell. [2]

- Hormones are protein / peptide;
- Too large to cross membrane;
- Hydrophilic / water soluble; A not, hydrophobic / lipid soluble
- Unable to pass through hydrophobic core / AW, of phospholipid bilayer;

(b) Use the information in the passage to outline the process of cell signalling. [3]

- Chemicals / signalling molecules released are circulating hormones;;
- Hormones bind to cell surface receptors on target cells/ cells where transcription is triggered;;
- Signal is transduced into the cell / reference to extracellular signals are converted into intracellular signals;;
- Action of kinases and phosphatases (within the cell) lead to (specific) response;;

(c) Explain the role of the following in cell signalling.

(i) Phosphatases [2]

- Enzymes that catalyse the removal of phosphate groups from proteins, (must have);;
- Making them inactive to end the signal transmission;;
- Making the proteins in the cell signalling pathway available for reuse;;

(ii) Kinases [2]

- Enzymes that catalyse the addition of phosphate groups from ATP to a protein, causing conformation change and the activation of the protein;;
- When a kinase is activated, it phosphorylates the next kinase which continues sequentially down the pathway in a phosphorylation cascade;;

[Total: 9]

7 Chickpeas may contain a lipase inhibitor that prevents the digestion of fats. There are two forms of lipase inhibitors – inhibitor **W** and inhibitor **X**.

Homozygous plants are known to produce one type of lipase inhibitor, depending on the allele which they are homozygous for.

A heterozygote plant, on the other hand, will two types of lipase inhibitor, inhibitor **W** and inhibitor **X**. A third recessive allele does not code for a lipase inhibitor.

(a) Identify whether the inheritance of lipase inhibitor shows continuous or discontinuous variation. Give a reason for your choice. [2]

- Discontinuous variation;;
- Discrete phenotypes (inhibitor W and X) / distinct groups / no intermediates;;

(b) A second character, seed texture, is controlled by another gene located on a different chromosome and is controlled by two alleles. Smooth seed-coat, **T**, is dominant over wrinkled seed-coat, **t**.

Two chickpea plants were crossed. Their seeds were collected and counted. One of the parental chickpea plants is found to contain only inhibitor **X** and has smooth seed-coats. The progeny of the dihybrid cross is summarised in Table 7.1.

Table 7.1

Inhibitor(s) present in seed	Number of seeds	Seeds with smooth seed-coat / %
W and **X**	12	50
W	14	50
X	22	50

With reference to Table 7.1,

(i) state and explain the mode of inheritance for the lipase inhibitor in the chickpeas. [2]

- The type of lipase inhibitor is determined by co-dominance, since in the heterozygous condition, both alleles are equally expressed;;

(ii) using suitable symbols, draw a genetic diagram to explain the results of this cross. [5]

Let C^W be the (co)dominant allele that produces inhibitor W
C^X be the (co)dominant allele that produces inhibitor X
C^O be the recessive allele for that produces no inhibitor
T be the dominant allele for smooth seed-coat
t be the recessive allele for wrinkled seed-coat

Parental phenotypes:	Inhibitor X, smooth coat	x	Inhibitors W and X, wrinkled coat
Parental genotypes:	C^XC^OTt	x	C^WC^Xtt
		meiosis	
Gametes:	C^XT C^Xt C^OT C^Ot	x	C^Wt C^Xt

Punnett square to show random fusion of gametes by the F_1 generation:

F1 genotypes:

♂ gametes / ♀ gametes	C^XT	C^Xt	C^OT	C^Ot
C^Wt	C^WC^XTt	C^WC^Xtt	C^WC^OTt	C^WC^Ott
C^Xt	C^XC^XTt	C^XC^Xtt	C^XC^OTt	C^XC^Ott

F1 Genotypic Ratio:	$1C^XC^XTt$	$1C^XC^OTt$	$1C^XC^Xtt$	$1C^XC^Ott$	$1C^WC^OTt$	$1C^WC^Ott$	$1C^WC^XTt$	$1C^WC^Xtt$;;
F1 Phenotypic Ratio:	2 Inhibitor X & smooth seed-coat		2 Inhibitor X & wrinkled seed-coat		1 Inhibitor W & smooth seed-coat	1 Inhibitor W & wrinkled seed-coat	1 Inhibitor W & X & smooth seed-coat	1 Inhibitor W & X & wrinkled seed-coat;;

(c) Observed results of the above genetic cross differ from the expected results.

Suggest two reasons why such a discrepancy occurs, referring only to events that occur after meiosis. [2]

- Sample size is too small;;
- Variation is due to chance/ insignificant;;
- Differential survival of gametes/ non-random mating;;
- Differential survival of fertilised zygotes/ some individuals die before being sampled;;

(d) Structure **Q** in Fig. 7.2 is a cell structure which is involved in nuclear division.

Identify structure Q and describe its behaviour during meiosis. [3]

- Centrioles;;
- During S phase, they are duplicated along with DNA replication;;
- Centrioles act as the microtubule-organising centres (MTOC), involved in spindle fibre formation;;
- In animal cells, the centrioles move to opposite ends of the cell. From each pair of centrioles, short microtubules develop and form a star-shaped structure called an aster;;

[Total: 14]

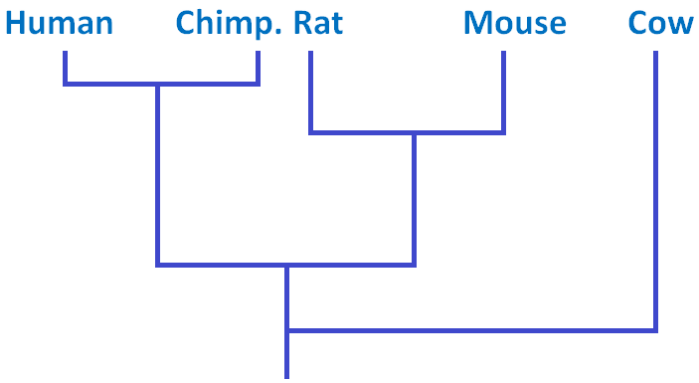
8 **(a)** Define the term "phylogeny". [1]

- The organisation of species to show their evolutionary relationships;;

(b) **(i)** state, with reasons, the species that is most closely related to mouse. [2]

- Rat;;
- Least number of differences in amino acid sequence, 2 differences;;

(ii) construct a phylogenetic tree to show the evolutionary relationships between the species. [2]



- Correct grouping of human and chimpanzee, rat and mouse, cow;;
- Human and chimpanzee diverged the latest, followed by rat and mouse, cow the earliest;;

(c) Explain how the amino acid sequences in Fig. 8.1 supports Darwin's theory of evolution. [3]

- Ref. to molecular homology and descent with modifications;;
- Having the same protein with similar amino acid sequence shows that the species had a common ancestor;;
- Differences in the amino acid sequence are accumulated during the evolution of the different species due to natural selection;;

(d) Describe a modification to the investigation in **(b)** to deduce the evolutionary relationships between the mammalian species and *E. coli*. [2]

- Ref. to the use of the sequence of a homologous gene / protein present in the mammalian species and *E. coli*;;
- E.g. RNA polymerase / ribosomal protein / AVP;;

(e) **(i)** Explain the advantages of molecular methods in reconstructing phylogenetic relationships. [3]

- Objective and unambiguous;;
- Quantitative and can be easily converted to numerical form for mathematical and statistical analysis;;
- Amino acid and DNA sequences can be easily obtained from electronic databanks;;
- More points of comparison as each nucleotide / amino acid can be regarded as a character for comparison;;

(ii) Explain why reptiles do not constitute a monophyletic grouping. [2]

- Does not consist of an ancestral species and all its descendants;;
- Ref. to birds as a descendant but are not reptiles;;

[Total: 15]

9 **(a)** Explain how macrophages function to protect the lungs from becoming infected. [4]

- recognise, non-self/ foreign, antigens on pathogen ;
- receptors (on macrophage) bind antigens (on pathogen) ;
- infolding of macrophage cell surface membrane around/ engulf/ phagocytosis of,
- pathogen ; R engulf antigen
- vacuole/ vesicle/ phagosome, forms ;
- ref. to lysosomes ;
- hydrolytic / digestive/named, enzymes ;
- e.g. lysozyme/ protease/ nuclease
- A pathogen broken down by enzymes
- hydrolysis of named compound(s) ;
- ref. to destroying/ killing, pathogen ;
- ref. to antigen presentation ;

accept idea even though does not occur in alveoli

(b) Very few helper T-lymphocytes respond to the presence of APCs by binding in the way shown in Fig. 9.2. Suggest why this is so. [2]

- idea that only, a few/ some/ small number / AW, with correct specificity;
- different T-lymphocytes are specific to different antigens;
- T cell receptor is, complementary (in shape to antigen);
- AVP; e.g. this may be during a primary immune response so no memory cells or, e.g. disease state (HIV / AIDS and leukaemia) or treatment where few T-lymphocytes in the body

(c) During an immune response, cells divide by mitosis. Describe how mitosis is involved in an immune response. [3]

- occurs in both primary and secondary (immune) responses;
- selected / specific / AW;
- lymphocytes / B -cells / T-cells / divide (by mitosis);
- clonal expansion / described in terms of producing, clone / many cells;
- A idea that different types of immune cell can result;
- reference mitosis in memory cells (for rapid) secondary response;

(d) Complete the table to indicate how the following types of immunity can occur. [4]

	Acquired	**Natural**
Active	Vaccination using live, attenuated pathogens	Infection by a pathogen
Passive	Injection of antibodies against pathogen	Ingestion of maternal antibodies by an infant through its mother's milk;; or Transfer of maternal antibodies across the placenta to the fetus

[Total: 13]