Nov 2015 H2 Bio Paper 2

N15P2Q1

(a) Identify the structures A and B, as shown in Fig.1.1. [6]
For each structure, state **two** features that can be seen in Fig.1.1.

structure **A**: mitochondrion (R: mitochondria)
feature 1: double membrane
feature 2: highly folded inner membrane/cristae
structure **B:** rough endoplasmic reticulum
feature 1: flattened sacs called cisternae studded with ribosomes
feature 2: continuous with outer membrane of nuclear envelope

(b) Describe **two** functions of the Golgi body.[2]

1. To glycosylate proteins and lipids to form glycoproteins and glycolipids respectively;
2. To modify existing glycoproteins and glycolipids by modifying/cleaving the existing sugar chains;
3. To sort and package proteins into different vesicles and target the proteins to different parts of the cell or for secretion;
4. To form lysosomes;
5. To synthesise polysaccharides such as pectin which is transported in vesicles to the cell membrane;

(c) Suggest two advantages to eukaryotic cells of having membrane bound organelles.[2]
Membranes allows for compartmentalisation which allow

1. unique environments to be formed for highly specialised activities (e.g. acidic environment in lysosomes for hydrolytic enzymes to work);

2. spatial separation of biochemical processes & thus their sequential operation within a cell (e.g. protein modification in RER and further protein modification, sorting and packaging in the GA) ;

3. accumulation of ions to high concentrations (e.g.accumulation of a high concentration of H+ in the intermembrane space of the mitochondria enable a proton gradient to be established for chemiosmosis);

4. Membranes act as a surface for chemical reactions to occur in a sequential manner membranes may have functionally-related proteins grouped together so that sequential biochemical processes can occur (e.g. the thylakoid membranes of the chloroplast have electron carriers & ATP synthetase for chemiosmosis to occur);

5. Membranes increase surface area for chemical reactions (e.g. inner mitochondrial membrane is highly folded to hold more electron transport chains and ATP synthetase);

(d) Explain the role of glycogen in animal cells.[2]

1. Glycogen is an large energy store found in the liver and muscles;
2. which can be hydrolysed to many glucose molecules that can be used as a respiratory substrate which oxidized during respiration to produce ATP.

[Total :12]

N15P2Q2

(a) Describe how replication of the lagging strand template occurs. [2]

1. The lagging strand is synthesised discontinuously in fragments known as Okazaki fragments. Each fragment is initiated by an RNA primer before the addition of DNA nucleotides;
2. A different DNA polymerase then excises the RNA primer and replaces it with deoxyribonucleotides and DNA ligase seals the nicks by forming phosphodiester bonds between adjacent nucleotides of the each of the DNA fragments on the new strand;

Comments: *Do note that in Fig. 2.1:* ***DNA polymerase**** *works only in the 5' to 3' direction. So the DNA polymerases extending new strands in opposite directions with respect to the replication fork. i.e. The leading strand is being synthesized towards the replication fork while the lagging strand is being synthesized away from the replication fork due to the anti parallel nature of the 2 template strands.*

(b) State 2 ways in which DNA replication,

(i) differs from transcription,

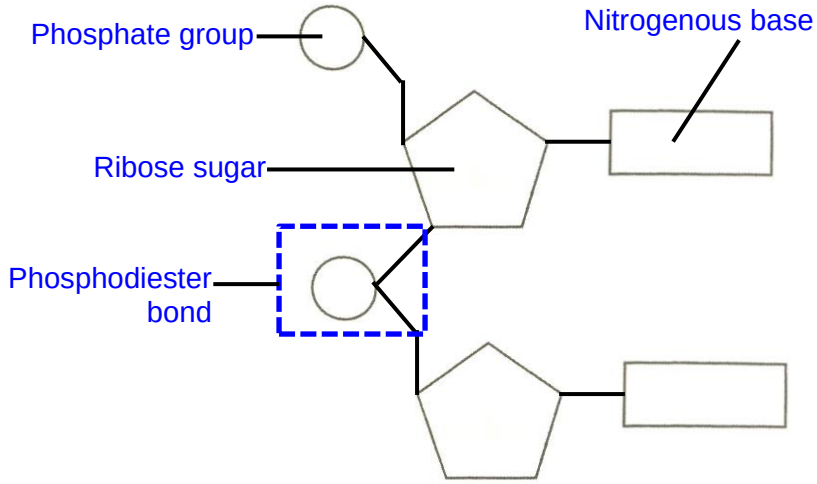
	DNA replication	Transcription
1. Product	Double-stranded DNA	Single-stranded mRNA
2. Enzymes	DNA polymerase links nucleoides	RNA polymerase links nucleotides
3. Primer requirement	RNA primer is required to initiate DNA replication	RNA primer is NOT required to initiate DNA replication

(ii) is similar to transcription.

1. Both use DNA as a template to synthesise the complementary strand;
2. Both processes occur in the nucleus;
3. Nucleotides in the nucleic acid that is synthesized are linked by phosphodiester bonds;

(c) The symbols below represent the main components of RNA.

In the space below, draw a short section of mRNA that is made up of two nucleotides, using these symbols to represent the main components. Add lines to show the positions of any bonds between the components.
Label and name the components and the covalent bond that links the nucleotides.[3]



1. Phosphate group linked to carbon number 5 of ribose sugar and nitrogenous base linked to carbon number 1 of ribose sugar;
2. Correct labels for phosphate group, ribose sugar and nitrogenous base;
3. Phosphodiester bond correctly identified and labelled

[Total : 10]

N15P2Q3

(a) **(i)** Name structures S and T, as shown in Fig. 3.1. [2]

1. S: ***promoter****;
2. T: ***operator****;

(ii) Identify a structural gene in Fig. 3.1 and explain what is meant by the term, structural gene. [1]

1. *lacZ / lacy / lacA* gene +
   Structural gene is any gene that codes for a protein product that has an enzymatic function in a metabolic pathway;

(iii) Identify a regulatory gene in Fig. 3.1 and explain what is meant by the term, regulatory gene. [1]

1. *lacI* gene +
   Regulatory gene codes for a protein (e.g. repressor) involved regulating expression of structural genes;

(b) Using Fig. 3.1, describe how the presence of lactose induces a bacterium to use lactose as a respiratory substrate. [3]

1. Lactose is converted to its isomer allolactose which acts as an inducer to bind to the active repressor protein at its allosteric site;
2. This makes the repressor inactive as it alters the conformation of the DNA-binding site of the repressor and which then can no longer bind to the operator;
3. RNA polymerase is now free to bind to the promoter and can move downstream to ***transcribe**** the structural genes to form β-galactosidase, permease and transacetylase for metabolism of lactose;

[Total: 7]

N15P2Q4

Fig. 4.1 shows the development of a metastatic cancer in the colon over a period of ten or more years. Metastatic is a term used to describe cancer that is spreading from one organ to another. *APC*, *ras* and *p53* are tumour suppressor genes. ***(error: ras is proto-oncogene!!)****

(a) State two environmental causes of cancer. [2]

1. ultraviolet light / radioactivity / ionizing radiations (mention of radiation alone not sufficient as visible light also emits radiation);
2. Carcinogens such as tar in cigarette smoke, asbestos, benzene, formaldehyde, ethidium bromide etc. (give named example);

(b) With reference to Fig. 4.1, explain why cancer development is a multi-step process. [3]

1. The development of cancer requires the accumulation of mutations in the genes in a single cell; [1]
   Idea of accumulation of different mutations using Fig. 4.1 (1mark for any two points 2,3,4)
2. **Loss-of- function mutation** in 2 copies/alleles of APC tumour suppressor gene results in dysregulation of cell cycle to have excessive cell division;
3. **Gain-in-function mutation** in just one copy/allele of ras proto-oncogene to ras oncogene results in hyperactive/excessive ras protein to form tumour/mass of cells;
4. **Loss-of- function mutation** in 2 copies/alleles of p53 tumour suppressor gene results in further dysregulation of cell cycle to have excessive tumour/mass of cells;
5. Chromosomal aberrations and other events (such as activation of telomerase, loss of contact inhibition, angiogenesis) occur to eventually lead to metastasis; [1]

(c) Describe how dysregulation of the checkpoints of cell division may lead to cancer. [2]

1. Ref to dysregulation of any one of the three checkpoints in cell cycle:
   M checkpoint dysregulated thus if any chromosomes are not attached to spindle fibres, the cell continues into metaphase and anaphase to produce genetically altered cell/mutant cell;
   OR
   G_1 / G_2 checkpoint dysregulated thus damaged DNA not repaired and cell continues into the M phase, accumulating the mutations;
2. Uncontrolled cell division / excessive cell division that leads to tumour/a mass of cells;

(d) Outline the role of tumour suppressor genes in the development of cancer. [3]

1. **Loss-of-function mutation** of tumor suppressor genes causes no functional gene products/proteins to form;
   As a result,
2. unable to stop cell cycle to allow repair any damaged DNA;
3. unable to activate DNA repair mechanism to repair damaged DNA thus accumulation of mutations occurs;
4. unable to initiate/promote apoptosis thus cell with potential to cause cancer is not removed;

[Total: 10]

N15P2Q5

In guinea pigs, the black coat allele **B** is dominant to the white coat allele **b**, and the straight hair allele **H** is dominant to the wavy hair allele **h**.
A guinea pig with a black coat and straight hair was crossed with a guinea pig with a white coat and wavy hair. The resultant offspring all had black coats with straight hair.
All these offspring were then crossed with guinea pigs having white coat and wavy hair in a series of test crosses.
The following progeny were produced from the test crosses :

Black coat, straight hair	30
Black coat, wavy hair	10
White coat, straight hair	12
White coat, wavy hair	31
Total	83

(a) Using the symbols for the alleles stated above, draw a genetic diagram t show the expected phenotypic ratios for the offspring of the test crosses if the inheritance is Mendelian.

Parental phenotype: Black coat, straight hair X White coat, wavy hair

Parental genotype: BbHh X bbhh

Gametes: (BH) (Bh) (bH) (bh) X (bh)

	(BH)	(Bh)	(bH)	(bh)
(bh)	BbHh Black coat straight hair	Bbhh Black coat wavy hair	bbHh white coat straight hair	bbhh white coat wavy hair

Offspring genotype	BbHh	Bbhh	bbHh	bbhh
Offspring phenotype	Black coat straight hair	Black coat wavy hair	white coat straight hair	white coat wavy hair
Phenotypic ratio	1	1	1	1

1m for correct parental phenotype and genotype ;
1m for correct gametes which are circled ;
1m for correct offspring genotype and phenotype ;
1m for correct phenotypic ratio ;

(b) Explain why there is a greater number than expected of the parental phenotypes. [3]

1. The genes coding for coat colour and hair texture are linked on the same chromosome;
2. Alleles for black coat and straight hair are linked on the same chromosome;
3. Alleles for white coat and wavy hair are linked on the same chromosome;
4. Greater chance for these alleles to be inherited together, thus resulting in greater number;
5. Number of recombinants are smaller because crossing over/recombination is a chance event and the frequency of recombination is dependent on the distance between the two genes;

(c) Describe how it is possible for progeny with black coats and wavy hair to be produced from these test crosses. [3]

1. During prophase I of meiosis I, ***crossing over**** occurs between ***non-sister chromatids of homologous chromosome****;
2. At the ***chiasma****, portion of chromatid containing allele **B** break and rejoin to portion of chromatid containing allele **h**;
3. Resulting in new linkage group being formed where the allele **B** that codes for black coat and the allele **h** that codes for wavy hair are linked on the same chromosome;
4. Gamete that contained chromosome that contain allele **B** linked to allele **h** fuses with gamete that contain chromosome that contain allele **b** linked to allele **h**;

[Total : 10]

N15P2 Q6

(a) Receptors for some hormones are found within their targets.
Explain why insulin receptors are found on the cell surface membranes of target cells and never within the cells. [2]

1. Insulin is too large, cannot pass through any transient pores form within cell surface membrane;
2. cannot pass through hydrophobic core of cell surface membrane because it is has polar regions and will be repelled;

***Comments:** Do note that insulin receptors actually exist as linked dimers. Since this question shows the 2 subunits dimerising, you need answer the question according to the figure.*

(b) Use Fig. 6.1 to explain how the presence of insulin is able to trigger a response inside the target cell. [3]

1. Insulin has a ***specific 3D conformation**** that is ***complementary**** to the extracellular ligand-binding site of the insulin receptor;
2. This ensures specificity in binding between insulin and the insulin receptors resulting in the ***dimerization**** of two receptor subunits;
3. Conformational change in the intracellular domain of receptor results in activation of intrinsic tyrosine kinase;
4. Intrinsic tyrosine kinase activity of each subunit in the intracellular domain cross-phosphorylates /autophosphorylates the ***tyrosine**** residues on the other subunit;
5. Other relay proteins inside the target cell will be able to bind to the phosphorylated tyrosine residues and become activated themselves;

This will enable the signal to be transduced within the cell until an appropriate cellular response is reached.

(c) Using Fig. 6.2., describe the main effects of insulin on different target cells. [6]

1. Binding of insulin to the insulin receptor will lead to cellular responses such as to trigger the translocation of vesicles with ***glucose transporter-4 (GLUT4)**** to the plasma membrane of the target cells;
2. This will increase the number of glucose transporters (GLUT4) on the plasma membrane;
3. increasing the permeability of the plasma membrane to glucose. There will be an increase in the uptake of glucose from the blood by these cells, causing blood glucose concentration to drop;
4. The glucose taken up by the cells will be used to synthesize ***glycogen**** via a series of condensation reactions (i.e. glycogenesis);
5. Glycogen synthesis is catalyzed by glycogen synthase,
6. which is an enzyme activated as a result as the insulin signalling;
7. The glucose taken up by the cells will increase the rate of glycolysis and can also be broken down by aerobic respiration to form intermediates (e.g. acetyl coA) which is then used for ***fatty acid synthesis****;
8. This process is catalysed by various enzymes which are activated as a result of insulin signalling.

[Total : 11 marks]

N15P2Q7

(a) State what is meant by the term, biological species. [2]

1. a group of organisms of the same species are capable of ***interbreeding**** and; producing ***fertile, viable offspring****;
2. are **reproductively isolated** from other species;

(b) Explain how new species arise. [5]

1. When a population is separated into 2 sub populations as they ***geographically isolated**** due to a physical barrier, interbreeding is prevented and ***gene flow is disrupted****;
2. Different niches will present ***different selection pressures**** and individuals best adapted to the environment will have a selective advantage will be selected for and favourable alleles will be passed on to the next generation and so the frequency of favourable alleles will increase;
3. The 2 sub populations will evolve independently over time, accumulating different mutations which will lead to changes to allele frequencies due to natural selection and genetic drift;
4. Over hundreds and thousands of generations, across long periods of time, accumulation of genetic differences led to each sub population becoming ***reproductively isolated****;
5. Such that they can no longer ***interbreed**** to produce ***viable, fertile**** offspring and hence new species are formed through allopatric speciation;

(c) Describe the advantages of using nucleotide sequences in reconstructing phylogenetic relationships. [3]

1. They are objective. Molecular character states are unambiguous as A, C, G and T are easily recognisable and cannot be confused;
2. Data is quantitative and easily converted to numerical form for statistical analysis. The degree of relatedness can be inferred and quantified by calculating the nucleotide differences between species;
3. Furthermore the mtDNA does not undergo recombination thus any changes to DNA is due solely to the accumulation of mutations over time making it the ideal candidate for a molecular clock. We can thus estimate the time of speciation;

(d) Suggest, with reference to Fig.7.1 and Fig. 7.2, why breeding between *C. lunulatus* and *C. trifasciatus* is possible. [3]

1. Since *C. lunulatus* and *C. trifasciatus* share a common ancestor (as seen in Fig 7.1);
2. and there are areas where they are found overlap (as seen in Fig.7.2);
3. they are able to interbreed and form hybrids;

[Total :13]

N15P2Q8

(a) Describe how DNA is arranged in the two structures. [4]

1. Eukaryotic DNA coils around proteins called histones to form nucleosomes;
2. followed by coiling around itself to form solenoid / 30nm chromatin fiber and solenoid associates with scaffold proteins forming looped domains / 3000 nm fiber;
3. Supercoiling of the loops to condense into the metaphase chromosome;
4. Eukaryotic DNA is linear and prokaryotic DNA is circular;
5. Prokaryotic DNA is associated with relatively fewer proteins (e.g. histone-like proteins) to form loops and there is supercoiling to cause further compaction;

(b) State two ways in which the organisation of genes found in these two structures differ and suggest one advantage of this to the bacterium. [3]

1. In bacteria functionally related genes are organised into an operon which consists of an promoter, operator and structural genes while in eukaryotes usually not organised into operon;
2. One promoter controls expression of more than one gene in bacteria while in eukaryote one promoter controls expression of one gene;
   Advantage of having operons in bacteria: [1 mark max]
3. Operons having related genes expressed under the control of one promoter allows for fast response to environmental changes. This is important as bacteria are unicellular and exposed to fluctuating environment.
4. Functionally related genes in an operon are expressed together as a set when necessary for economical use of energy and resources;

[Total: 7]

N15P2Q9

(a) Describe the structure of a homologous pair of chromosomes at the start of meiosis [6]

1. Homologous pair of chromosome consists of 2 homologues, one of paternal and one of maternal origin;
2. Homologous chromosomes have the same size, shape, ***centromere position**** and ***staining pattern**;*
3. The homologous chromosomes have the ***same genes at corresponding loci**;
4. Homologous chromosomes are non-identical due to the presence of different alleles;
5. Each homologue comprise of two ***sister chromatid**** held together by a ***centromere**;
6. Homologous chromosomes pair up to form bivalents/tetrads.
7. Each chromatid consist of a molecule of ***negatively charged****, DNA coiled around ***8 positively charged**** proteins called ***histones**;
8. they form ***nucleosomes**** that come together to form a ***solenoid;***
9. which coils to form looped domains which further supercoil to form a short and thick structure called chromatid.

(b) Outline the behavior of chromosomes during meiosis [8]

1. *At* ***prophase I****, **chromatin**** coils, shortens and thickens into a condensed chromosome;
2. ***homologous chromosomes**** pair up by a process called ***synapsis**** to form a ***bivalents*;**
3. ***Chiasmata**** formation and ***crossing over**** occurs;
4. such that exchange of equivalent portion of genetic material or alleles occur between ***non-sister chromatids**** **of** ***homologous chromosomes*;**
5. At ***metaphase I****, ***homologous chromosomes**** arranged as pairs at ***metaphase plate/equator*;**
6. At ***anaphase I****, each homologue is pulled by a shortening kinetochore microtubule (that attaches to the centromere) towards opposite poles ;
7. At ***anaphase II****, ***centromeres**** divide and sister chromatids separate to form daughter chromosomes and;
8. are pulled by a shortening kinetochore microtube (that attaches to the centromere) toward opposite poles;
9. At ***telophase II****, chromosomes reach the poles of the spindle where they decondense and become diffuse/indistinct;

(c) Explain the role of nuclear envelope and centrioles during meiosis. [6]

Nuclear Envelope

1. Nuclear envelope is made of double membrane made up of phospholipid bilayers;
2. During prophase I, nuclear envelope ***disintegrate**** so that spindle fibres can attach to the ***centromere**** and the chromosomes can be pulled to opposite poles;
3. During telophase II, nuclear envelope reforms around the chromosomes to form the nucleus;

Centrioles

4. A ***pair**** of cylindrical, rod-like structures;
5. which are ***perpendicular/right angle/ 90º**** to each other;
6. Each consists of ***9 triplets**** of ***microtubules**** arranged in a ring;
7. After the centrioles replicate during interphase, the two pairs of centrioles move to ***opposite poles**** during ***prophase**;*
8. The centrioles become part of the ***microtubule-organising centre**** in which the assembly of spindle fibres and asters occur;
9. Spindle fibres are needed for the separation of chromosomes and chromatids during meiosis I and II;

N15P2Q10

(a) Describe the role of NAD and FAD in cellular respiration. [6]

1. Organic molecules are oxidized during ***glycolysis, link reaction and Krebs cycle**** and the electrons (and protons) from the oxidation process are transferred to the coenzymes ***NAD***** and ***FAD***** to form ***NADH**** (reduced NAD^+) and ***FADH**** (reduced FAD^+) respectively;
2. NAD and FAD serves as mobile electron (and proton) carriers to carry the high energy electrons and protons from these organic molecules to the ***electron transport chain**** on the cristae of mitochondria;
3. High energy electrons in NADH and FADH are used to reduce electron carriers of the ***electron transport chain****, while NADH and FADH itself gets re-oxidised;
4. As electrons pass down the chain, the release of energy in a series of redox reactions is coupled to the phosphorylation of ADP to form ***ATP****;
5. Protons liberated in the oxidation of NADH and FADH is used to establish the ***proton gradient**** necessary for ATP synthesis *(the H^+ can be either*

pumped into intermembrane space or combines with oxygen to form water in the matrix).

6. Re-oxidation of NADH and FADH allows the ***regeneration of NAD^+ and FAD$^+$**, allowing it to pick up more protons and electrons from Krebs cycle, link reaction and glycolysis, so that these reactions can continue;
7. Each reduced NAD in the matrix yields 3 ATP;
8. and each reduced FAD in the matrix yields 2 ATP through ***oxidative phosphorylation***;
9. During anaerobic respiration, re-oxidation of NADH allows the ***regeneration of NAD$^+$**** (during alcohol or lactate fermentation) allowing glycolysis to continue. [6 max]

(b) Outline the main stages of the Krebs cycle. [8]

1. Krebs cycle takes place in matrix of mitochondria and when oxygen is present;
2. Acetyl CoA (2C) formed through link reaction combines with oxaloacetate (4C) to form citrate (6C);
3. Citrate is decarboxylated and dehydrogenated to form α-ketoglutarate (5C) and NADH.
4. Each decarboxylation step results in a loss of carbon in the form of a carbon dioxide;
5. Regeneration of oxaloacetate (4C) involves one decarboxylation step and three dehydrogenation steps to yield 2 ***NADH****, 1 ***$FADH_2$**** and 1 CO_2;
6. Electrons (and protons) originally from glucose molecule have now been transferred to electron carriers ***NAD^+**** and ***FAD****;
7. $NAD^+ + 2H^+ + 2e^- \rightarrow NADH + H^+$ (or reduced NAD)
8. $FAD + 2H^+ + 2e^- \rightarrow FADH_2$ (or reduced FAD)
9. 1 ***ATP**** is also produced through substrate-level phosphorylation during this regeneration process;
10. All the carbon in glucose is lost as carbon dioxide;
11. Altogether 1 molecule of glucose will yield 6 NADH, 2 $FADH_2$ & 2 ATP through the Krebs cycle. The coenzymes with their reducing power will next be transported to the electron transport chain where the bulk of ATP is generated. [8 max]

(c) Explain how ATP is produced in anaerobic respiration. [6]

1. Anaerobic respiration takes place in the absence of oxygen;
2. Oxygen serves as the ***final electron acceptor**** in ***electron transport chain**;*
3. Without oxygen both ***link reaction**** and ***Krebs cycle**** subsequently stop;
4. As ***NAD^+**** cannot be ***regenerated**** from ***NADH**** in mitochondrion;
5. Anaerobic respiration takes place in the cytoplasm of the cell via ***glycolysis****;
6. with a ***net of 2 ATP molecules**** produced via substrate-level phosphorylation for each glucose molecule oxidised;
7. Pyruvate is reduced by pyruvate dehydrogenase to ethanol and carbon dioxide with the regeneration of NAD^+ in yeast;
8. In mammal NAD^+ can be regenerated by converting pyruvate by lactate dehydrogenase to lactate;
9. NAD^+ regenerated in both processes ensures steady supply of NAD is used for glycolysis to continue. [6 max]

[Total: 20]