2018 H2 A level Paper 3

Section A

Answer **all** questions in this section.

1 Gene expression in eukaryotes can be regulated at different levels. Long-term changes in gene expression that are passed on to daughter cells are called epigenetic changes. An epigenetic change does not alter the DNA nucleotide sequence.

(a)

(i) Describe the patterns shown in Table 1.1. [2]

1. As the degree of differentiation / specialization increases from blood stem cell from bone marrow to mature B lymphocyte from lymph gland,
2. the degree of DNA methylation decreases from 1.00 to 0.61 arbitrary units(AU),
3. and the degree of gene expression increases from 1.0 to 5.5AU;

(ii) Explain how DNA methylation changes gene expression. [3]

1. addition of methyl group to selected ***cytosine**** nucleotides in on DNA (e.g. a CG sequence);
2. leading to recruitment of ***histone deacetylase**** and ***chromatin remodeling complexes**** to condense chromatin (decrease accessibility of promoter to general transcription factors and RNA polymerase)
3. Reduces the accessiblity of promoter, hence prevents the binding of ***general transcription factors**** and ***RNA polymerase**** to ***promoter****, preventing formation of ***transcription initiation complex****
4. Preventing transcription of the gene;

(iii) Table 1.2 shows similar data for cancerous B lymphocytes.

Compare the data for the cancerous B lymphocytes in Table 1.2 with the data in Table 1.1 **and** discuss what this suggests about the nature of the cancerous B lymphocytes. [4]

1. *Both the degree of DNA methylation (0.95AU) and gene expression (1.5 AU) for cancerous B Lymphocytes are in between these values* blood stem cell from bone marrow and immature B lymphocyte from bone marrow.
2. High levels of DNA methylation, which results in high levels of condensation of chromatin in the genome.
3. Hence cancerous B lymphocytes is expected to largely undifferentiated, similar to that of the blood stem cell.
4. And that many tissue-specific genes and proteins, e.g antibodies are not likely to expressed.

(b) Epigenetic changes may be important in the development and treatment of cancer.

Fig. 1.2(a) represents the balance between two types of genes controlling cell division in a healthy cell. If genes of type **X** become overexpressed or genes of type **Y** become under expressed, the balance is tipped towards a cell becoming cancerous, as shown in Fig. 1.2(b).

Epigenetic DNA methylation pattern changes as cell lines age. For example, the promoter region of the *p53* tumour suppressor gene has a tendency to become methylated in the cells of older people.

(i) Describe **and** explain the potential consequences of the cell and individual person of methylation of the promoter region of the *p53* tumour suppressor gene. [4]

1. Methylation at promoter region of p53 tumour suppressor gene results in condensation of chromatin in the promoter region.
2. Hence ***general transcription factors(GTF)**** and ***RNA polymerase(pol)**** cannot bind to the ***promoter**** /thus the ***transcription initation complex**** cannot be formed, hence cannot initiate transcription of the p53 gene / p53 gene note expressed.
3. p53 protein cannot function as a specific transcription factor and cannot activate genes that are involved in DNA repair, cell cycle arrest and stimulating damaged cell to undergo apoptosis;
4. Cell cycle continues without repairing DNA/ cell does not undergo apoptosis;
   Results in uncontrolled cell division / tumour formation

(ii) 5-azacytidine is a chemical that inhibits the enzyme DNA methyltransferase. This enzyme adds methyl groups to DNA.

Explain, with reference to Fig. 1.2, why 5 azacytidine may be useful in treating cancers in older people. [3]

1. 5 azacytidine inhibits enzyme DNA methyltransferase and hence preventing methylation at promoter region of p53 tumour suppressor gene, preventing condensation of chromatin in the promoter region.
2. Hence allowing ***general transcription factors**** and ***RNA polymerase**** to bind to p53 ***promoter**** / form the ***transcription initiation complex**** at promoter, hence initiating transcription of the p53 gene / expression of p53 gene.
3. p53 protein produced function as specific transcription factor and can activate genes that are involved in DNA repair, cell cycle arrest and stimulating damaged cell to undergo apoptosis;
4. There higher expression of tumour suppressor genes hence brings back the balance with proto-oncogene expression and preventing uncontrolled cell division treating cancer.

(c) As cell lines get older, another type of change in DNA occurs in the telomeres of chromosomes, leading to a progressive decrease in telomere length.

Fig. 1.3 shows a small part of the DNA sequence at the end of a telomere. Human telomeres may consist of hundreds of repeats of the sequence TTAGGG.

(i) Telomere DNA is tightly condensed due to histone modification. DNA methylation would have a similar effect on the packaging of the DNA, but DNA methylation is not possible at telomeres.

Explain why telomere DNA cannot be methylated. [1]

1. Telomeres do not have the specific nucleotide sequences (CG sequence) recognized by DNA methyltransferase for DNA methylation / Lack of methylation site
   R: lack of cytosine residues!!!

(ii) Outline **two** functions of a telomere containing hundreds of repeat sequences. [2]

(non-coding must be mentioned somewhere in answer)

Role – main

1. Each round of DNA replication will result in the shortening of daughter molecules at the telomeres because DNA polymerase is unable to replace the RNA primers with DNA; (idea of end replication problem)
2. Since telomeres are non-coding, this ensures that vital genetic information/genes are not lost / eroded with each round of replication; wtte

Role – others

3. By forming a loop with 3' overhang, they protect and stabilise terminal ends of chromosome, hence preventing fusion of the ends with those of other chromosomes;
4. Either: prevent triggering pathways that lead to cell arrest or cell death, because exposed 3' overhang will be perceived as DNA damage/DNA double strand break;
   OR:
   prevent DNA repair machinery from recognising the ends of chromosomes as DNA breaks/damage, hence preventing apoptosis;
5. Either: The 3'overhang of the telomeres allow their own extension, by providing an attachment point for the correct positioning of the enzyme telomerase in certain cells, e.g. germ cells
   OR:
   They possess a 3' overhang which base pairs with the RNA template on telomerase, so ensures proper alignment of telomerase and allows extension of telomeric ends in certain cells e.g. germ cells.

(iii) Explain how changes in the DNA in telomeres prevent most human cell lines from dividing beyond the Hayflick limit **and** suggest how cancer cells and stem cells are able to overcome this limit. [4]

1. Each round of DNA replication will result in the shortening of daughter molecules at the telomeres at the 5'end
2. because DNA polymerase is unable to replace the RNA primers with DNA nucleotides
3. In stem cells and cancer cells, expression of **telomerase*** gene / Presence of **telomerase***
4. which extends telomere / hence telomere length to be maintained / prevents telomeres from reaching critical length / Hayflick limit / thus; wtte
5. Allowing them to undergo continuous cell division to allow many replication cycles to occur / prevents apoptosis;

(d) People of the same chronological age may have different biological ages due to environmental factors, such as diet and exposure to pollution.

Since both telomere length and DNA methylation patterns change as individuals get older, both have been suggested as possible measures of a person's biological age.

(i) With reference to Fig. 1.4, evaluate the extent to which telomere length can predict a person's chronological age. [3]

1. In general, there is a negative relationship between chronological age and average telomere length / the as the chronological age increases from 18 to 78, the average telomere length decreases linearly from 7.8kb to 6.2kb.
2. However, there are wide spread / deviation of telomere length for each age group,
3. with length of telomere for some individuals deviating significantly from that of their average age group,
   - e.g. 31 yo individual with 6.3kb telomere length, which is the average length for people of age 78.
   - E.g Individuals of age 60 having a telomere length of 8.5kb, which is significantly higher than averge 20 yo individual.
4. Hence may not be a reliable prediction.

(ii) On Fig. 1.5, the data point for person **P** lies above the line.

Suggest what this implies for the health and life expectancy of person **P**. [4]

1. The DNA methylation age of Person P of ard 87years, is significantly higher than of the average of 58 years for his age of 58 years;
2. This suggests that significantly high amount of his cells being undifferentiated;
3. Hence an indication that higher chance / tendency of the promoter region of the *p53* tumour suppressor gene being methylated, hence p53 not expressed.
4. Suggesting a high chance / tendency of person P suffering from cancer thus may have a lower life expectancy than the average 58 year old;

[Total: 30]

2 Mammals have both a non-specific (innate) and a specific (adaptive) immune system.

(a) Outline the components of the non-specific immune system in mammals. [4]

1. Impermeable anatomical barriers such as intact skin and mucous membrane that prevents pathogens from entering the organism;
2. Chemical barriers that include secretions in that has antimicrobial substances such as lysozyme that cleaves glycosidic bonds of peptidoglycan cell walls of bacteria, or acidic pH that denature proteins in pathogens;
3. Phagocytes such as neutrophils, macrophages and dendritic cells that make up the cellular component of the non-specific immune system that engulf pathogens by phagocytosis;
4. Macrophages are also responsible for the inflammatory response as they secrete chemokines to recruit neutrophils to the site of infection to carry out phagocytosis;
5. Macrophages secrete cytokines that increases permeability of blood vessels allowing neutrophils to migrate into tissue from the blood;

(b) To protect their offspring from specific pathogens in the environment, female mammals pass on antibodies through the placenta and in the milk.

In contrast, honey bees cannot make antibodies since they only have a non-specific immune system. However, queen honey bees can pass on fragments of pathogenic bacteria in their eggs to their offspring. These fragments stimulate an enhanced immune response in the offspring.

Complete Table 2.1 with **ticks** to show whether these two example of enhanced immunity in offspring are active, natural or passive or a combination of these.

Table 2.1

type of immunity	mammal	honey bee
active		✓
natural	✓	✓
passive	✓	

Active in honey bee because the immune response of the recipient is stimulated and enhanced by exposure to pathogen even though no antibodies are produced;

[2]

(c) Honey bees are important for pollinating fruit crops. Without pollination, fruits are not produced.

Suggest why it is economically important to investigate the mechanism of immunity in honey bees. [3]

1. It is important to protect bees from pathogens, so that pollination of fruit crops could continue to produce fruits and generate revenue; *draw link b/w immune system to economy*
2. An understanding of the bee's mechanism of immunity will allow us to find ways to manipulate or enhance the bee's immune system conferring long term protection against pathogens;
3. E.g. Vaccinate the bees against pathogens by exposing the eggs to fragments of the pathogen;
4. E.g. Stimulate the cells of the non-specific immune system to respond strongly to pathogens; *similar to pt 3*
5. E.g. Stimulate proliferation of cells in the non-specific immune system to combat infectious agents;

1 mark for an example that makes sense. Pt 1 and 2 compulsory for 3marks.

[Total: 9]

3 Coal-fired power stations release large quantities of carbon dioxide into the atmosphere. Two approaches to reduce the quantity of carbon dioxide released are:

- carbon capture and storage (CCS)
- carbon capture and utilisation (CCU)

(a) Explain why environmentalists would like all new coal-fired power stations to include CCS or CCU facilities. [4]

1. CO_2 is a greenhouse gas that will trap infra-red radiation from escaping from the atmosphere that results in global warming;
2. Thus environmentalists would like CCS and CCU to be used to limit CO_2 emission so as to mitigate the effect of global warming:;
3. to prevent coral bleaching as a result of high ocean temperatures;
4. to prevent more extreme weather conditions such as drought in some areas and flood in others as a result of heavy rainfall

(b) Evaluate the effectiveness of the processes shown in Fig. 3.1 as a solution to the problem of carbon dioxide emissions from burning fossil fuels. [3]

1. CCU uses CO_2 from coal burning to extract oil from oil field thus there is no CO_2 emission from burning fossil fuels to provide energy for the process;

2. With CCS CO_2 is stored underground rather than release to the atmosphere thus reducing the emission of greenhouse gases into the atmosphere;
3. However the processes of carbon dioxide transport and pumping may incur extra energy use which results in CO_2 emission from fossil fuels;
4. Furthermore the oil extracted will be used for energy requiring processes such as transport which will add CO_2 to the atmosphere;

(c) Outline how carbon dioxide is produced in respiration. [4]

1. Carbon dioxide is produced in the ***link reaction**** and ***Krebs cycle**** of aerobic respiration in the ***mitochondrion****;
2. During link reaction 3C ***pyruvate**** undergoes oxidative decarboxylation and the addition of coenzyme A to produce 2C ***acetyl coA**** and carbon dioxide;
3. In the Krebs cycle and 6C ***citrate**** undergoes oxidative decarboxylation to produce 5C ***α-ketoglutarate**** and is further decarboxylated to form 4C ***oxaloacetate**** with the release of carbon dioxide;
4. Also during alcohol fermentation in yeast, 3C ***pyruvate**** is decarboxylated /carbon dioxide is released to form 2C ***ethanal****;

[Total: 9]

Section B

4(a) Describe the process by which a C3 plant makes sugars in its leaves using sunlight, water and carbon dioxide. [15]

Light dependent reaction

1. ***Light energy**** from the sun is absorbed by accessory pigments molecules in light harvesting complex of ***photosystems (PS) I and II**;
2. The electrons in these pigment molecules become excited and, when returning to their ground states, pass on the released energy to the next pigment molecule and excite the electrons present in them, as a result. This resonance transfer of energy occurs until it reaches one of the two special chlorophyll a molecules (P700 in PS I & P680 in PS II) in the reaction centre;
3. When the special chlorophyll a molecule absorbs the energy, an excited electron is displaced (Chl a➔chl $a^+ + e^-$) leaving an electron hole in PS I and II. This electron is captured by a primary electron acceptor molecule in the reaction centre;
4. The electron hole in PS II is replaced with electrons from the photolysis of water to give H^+ ions, electrons and O_2.
5. As the excited electrons flow down a chain of carriers of ETC with progressively lower energy levels
6. energy lost is coupled to **pumping H^+ ions** across the membrane into the thylakoid space.
7. **H^+** accumulates in the thylakoid space which serves as the H^+ reservoir. In this way, the electron transport chain transforms redox energy to a ***proton-motive force****.
8. As protons / H^+ diffuse down the concentration gradient back into the stroma via the ***ATP synthase complex****.
9. ADP is phosphorylated to ***ATP**** in the process via ***chemiosmosis****.
10. In non-cyclic photophosphorylation, the ***final electron acceptor**** is ***NADP**** which is a coenzyme.
11. Reduced NADP (NADPH) carries the electrons which are used in the Calvin cycle in the stroma of the choloroplast.

Light independent reaction/Calvin cycle

Carbon fixation:

12. During carbon fixation stage, CO_2 is combined with ***ribulose bisphosphate (RuBP)**** to form an unstable 6 carbon molecule which;

13. splits up immediately into 2 molecules of glycerate phosphate (GP)*;
14. The enzyme catalysing this reaction is ***RuBP carboxylase (RUBISCO)*;***

Reduction by NADPH:
15. NADPH (from light-dependent reaction) is the reducing power used to ***reduce**** GP to glyceraldehyde-3-phosphate (G3P);
16. ATP (from light-dependent reaction) is the source of energy required;
17. G3P is the first sugar formed in photosynthesis and the end product of Calvin cycle;

Regeneration of RuBP:
18. 5 molecules of G3P are used to ***regenerate**** 3 RuBP so that the cycle of carbon dioxide fixation can continue. This requires 3 ATP (from light-dependent reaction);
19. The net synthesis of 1 molecule of G3P requires 3 CO_2 to be fixed;
20. 2 molecules of G3P may be used to form 1 molecule of glucose (hexose sugar);

(b) Explain the decrease and gain in mass as the seed germinated and grew into a young plant over this period of ten days. [10]

1. The food store present in most seeds is in the form of carbohydrates, fats and proteins;
2. The stored food is used to support the embryo during seed germination;

First 5 days of seed germination:

3. Imbibition of water activates ***hydrolytic enzymes**** allowing metabolic activity to resume in the rehydrated seed;
4. The hydrolytic enzymes break down the proteins into amino acids, fats into lipids and the starch into glucose;
5. The amino acids and lipids are transported to the embryo where it is used during cell division and growth of the embryo;
6. Seed begins to undergo ***aerobic respiration**** as oxygen enters and the glucose is broken down into energy in the form of ATP, carbon dioxide and water;
7. As the embryo is still developing, photosynthesis does not occur and the mass is lost mainly in the form of carbon dioxide during the link reaction and Krebs cycle of aerobic respiration;

From day 6 to day 10 of seed germination:

8. As the embryo develops into a young plant, leaf development and chlorophyll synthesis takes place;
9. The young plant is able to undergo ***photosynthesis**** during which glucose is synthesised;
10. The glucose produced is converted to starch where it is stored in different parts of the plant;
11. The glucose produced is also used in cellulose synthesis which is the main component of plant cell wall in newly formed cells;
12. The synthesis of glucose, starch and cellulose in the developing plant will cause an increase in the overall mass of the plant;

[Total: 25]

5 (a) Birds are thought to have descended from dinosaurs.

Sel

Explain how a population of a species of dinosaur could change over time into a new species with bird-like features. [15]

1. There exist ***variation**** in a population of dinosaurs for ***natural selection**** to act on;
2. where some have more distinct bird-like features like wings than others;

3. If the environment changes, such that there is a new ***selection pressure****;
4. such as new predator in the area;
5. those with favourable traits such as wings that enable flight which lets them escape from the predator;
6. will have a selective advantage to the local conditions and will be selected for,
7. and will survive, reproduce and pass on their alleles to the next generation;
8. increasing frequency of favourable alleles in the population;
9. and hence **microevolution*** would have occurred;
10. If this population is geographically isolated from other populations of the same species where there are no predators/ different selection pressures/niches;
11. ***disruption of gene flow**** will occur between the two sub-populations;
12. The two sub populations will evolved independently of each other;
13. their allele frequencies will change as they accumulate different genetic mutations, and are subjected to genetic drift and natural selection;
14. Over a hundreds and thousands of generations, each population will become ***reproductively isolated****
15. Such that they can no longer ***interbreed**** to produce ***viable, fertile**** offspring;
16. and hence new species are formed through allopatric speciation and
17. hence macro evolution would have occurred;

(b) Suggest **and** explain why, in a rapidly changing environment, small animals may be at an evolutionary advantage compared to large animals. [10]

1. A) Small animals populations put only a small investment of resources into each offspring;
   B) so that there will be enough resources to produce more offspring;

2. A)Small animals populations have high reproductive output;
   B) so that there is greater chance of survival in a rapidly changing environment;

3. A) Small animals populations are also generally not very invested in protecting or rearing their young for many years;
   B) Often, the eggs are fertilized and then cared for only a short period of time. The benefit of this strategy is that if resources are limited or unpredictable, you can still produce some young;

4. A) Small animal populations grow rapidly, with shorter lifespans;
   B) this short generation time allow the fittest to survive, reproduce and pass on their favourable alleles to the next generation, allowing faster rate of evolution to adapt to the changing environment;
5. A)The young of small animals tend to be more rapidly maturing and develop early independence;
   B) This allows less dependence on parents so even if parents do not survive the changing environment, there is a chance for their offspring to adapt and survive;
6. A) Small animal populations require less food as compared to large animals or maybe able to avoid predation due to their size;
   B) hence allow them a selective advantage over the larger animal populations;

[Total: 25]