Section A

Answer **all** questions.

1 Animals that possess hair are classified within the phylum Chordata and class Mammalia.

(a) Define biological classification **and** explain how classification relates to phylogeny.[3]

1. Biological classification groups organisms based on overall morphological similarities and usually does not consider their evolutionary history;
2. It uses a naming system where each organism is given a ***binomial name**** and grouped into a domain, kingdom, phylum, class, order, family, genus and species in a hierarchical manner;
3. Phylogeny also groups organisms but they are grouped based on their evolutionary history / ancestor-descendent relationships using molecular data and;
4. It does not rank organisms but instead assigns each organism a position on a ***phylogenetic tree**** based on its evolutionary relationship with other organisms on the tree;

(b) **(i)** Epithelial stem cells and melanocyte stem cells are examples of a particular type of stem cell.

State **two** key features of this type of stem cell. [2]

1. They are ***multipotent**** stem cells that can differentiate into a limited range of specialized cell types in the presence of the correct molecular signals;
2. They are able to undergo extensive proliferation and self-renewal by ***mitosis**** in the presence of the correct molecular signals and hence give rise to a constant pool of cells;

(ii) Discuss how the presence of stem cells within the skin and the presence of hairs covering the skin influence the harmful effects of high levels of ultraviolet light on the health of mammals. [4]

1. The presence of hairs covering the skin play a protective role as they reduce exposure of the skin by blocking the harmful ultraviolet radiation;
2. Since stem cells are near the skin surface, the high levels of ultra violet light can damage the DNA is stem cells as;
3. the ionizing radiation can cause the DNA is the stem cells in the skin to mutate and if these mutations are in genes that regulate cell cycle checkpoints/proto oncogenes/ tumour suppressor genes;
4. it could lead to uncontrolled cell division/ tumour formation and increase the chances of an individual getting cancer;
5. especially because stem cells already have telomerase activity;

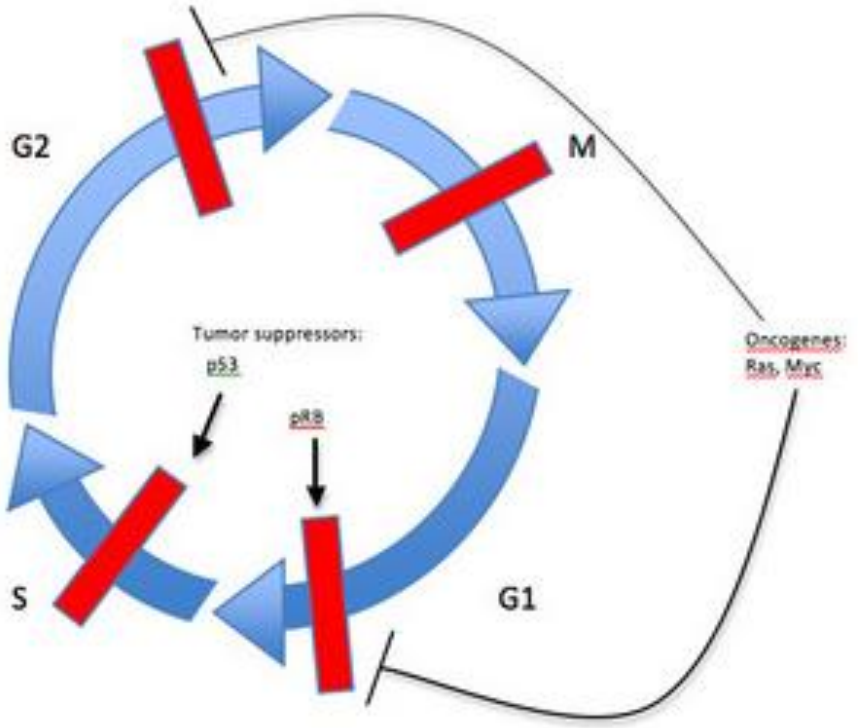

Figure 3: Cell cycle control by tumor suppressors and oncogenes

Checkpoints are depicted as thick red bars. The stages of the cell cycle (G1: Gap 1, S: DNA synthesis, G2: Gap 2, and M: mitosis) are indicated. Tumor suppressors act to maintain checkpoints (arrows) whereas oncogenes allow for checkpoints to be overcome (stop lines) (Adapted from Kopnin 2000).

	(c)	**(i)**	The shape of MC1R is characteristic of a particular group of transmembrane receptor proteins. Name this group of proteins.[1]
			7 pass transmembrane ***G-protein coupled receptor*** *

		(ii)	In cats with agouti hairs, ASIP is secreted at intervals during hair growth. With reference to Table 1.1 and the information provided, explain how this interrupted pattern of ASIP secretion leads to striped agouti hairs in cats.[4]
			1. During intervals when ASIP is not secreted, α-MSH binds to MC1R (a GPCR), causing the MC1R to undergo a conformation change in its intracellular domain allowing G-protein to bind to it; and 2. G-protein is activated when it displaces its attached GDP for GTP; 3. Activated G-protein will translocate along membrane and bind to enzyme adenylyl cyclase and phosphorylate it, thus activating it; 4. Adenylyl cyclase will catalyze conversion of ATP to cAMP, which will trigger a phosphorylation cascade that will cause black eumelanin pigment to be produced, making the hair black; 5. However, during intervals when ASIP is secreted, ASIP will prevent α-MSH from binding to MC1R/ ASIP will preferentially bind to MC1R; 6. Thus MC1R will not undergo a conformational change that allows G-protein to bind to it and so the G protein will not be activated, adenylyl cyclase will not activated, cAMP is not produced and so yellow phaeomelanin pigment is produced making the hair yellow; Hence the interrupted pattern of ASIP secretion, will lead to the striped yellow and black agouti hairs in cats.

Table 1.2

species	fur colour phenotype	number of individuals in sample	number of individuals of each genotype					
			genotype at *ASIP* locus			genotype at *MC1R* locus		
			Δ2/Δ2	Δ2/+	+/+	Δ15/Δ15	Δ15/+	+/+
F. catus	agouti	26	0	15	11	0	0	26
F. catus	black	57	57	0	0	0	0	57
P. onca	agouti	36	0	0	36	0	0	36
P. onca	black	10	0	0	10	1	9	0

key

Δ2 = allele with 2 base pair deletion of nucleotides 123–124 of the *ASIP* gene
\+ = normal allele of the *ASIP* or *MC1R* gene
Δ15 = allele with 15 base pair deletion of nucleotides 301–315 of the *MC1R* gene

(d) (i) Use Table 1.2 to identify:

a recessive allele: △ 2

a dominant allele : △15

an allele containing a frameshift mutation △ 2 [3]

(ii) With reference to Table 1.1, Table 1.2 and the information provided, explain why melanic (black) individuals of *F. catus* have hairs that do not contain any phaeomelanin. [4]

1. Melanic *F.catus* has 2 copies of △2 and hence has 2 copies of the mutated ASIP alleles;
2. A 2 base pair deletion in the gene will result in a frame shift in the DNA resulting in a change the sequence of ***codons**** in the mRNA sequence;
3. which will cause a change in the sequence of amino acids in the polypeptide which in turn will affect the R group interactions between the amino acids in the tertiary structure of the ASIP protein, resulting in a change in its 3D conformation;
   A: truncated non-functional polypeptide
4. As a result, the non-functional ASIP (ligand) cannot bind to the MC1R (receptor) on the melanocyte cell as it is no longer ***complementary**** in shape to it;
5. Thus and cAMP (second messenger) production will continue and black eumelanin is produced in the melanocyte cell;

Thus the melanic individuals have hairs that do not contain any phaeomelanin;

(iii) Scientists have concluded that the black fur colour phenotype found in several cat species has evolved more than once.

Use information in Table 1.2 to justify this conclusion.[1]

Since cats with the same phenotype, that is, having black fur, have 2 different mutations in 2 different gene loci, either in the ASIP locus or the MC1R locus, it shows that black fur colour phenotype in cat species evolved more than once;

(e) **(i)** Explain how temperature variation of the skin contributes to the phenotype of the cat in Fig. 1.1.[2]

1. Since the ears, face, paws and tail are the cooler parts of the body of the cat, the temperature sensitive tyrosinase enzyme does not denature in those areas and hence black pigment can be produced in the hairs in those areas;
2. The other parts of the body are warmer above 30°C and the temperature sensitive tyrosinase enzyme starts to denature, lowering enzyme activity and hence reducing the production of pigment in the hairs there;

(ii) Draw a genetic diagram to show the predicted coat colours of the offspring of this cross.

Insert the symbols **A** and **a** for the alleles of the *ASIP* gene and the symbols **H** and **h** for the alleles of the tyrosinase gene in the key to symbols table, before completing the genetic diagram. [4]

key to symbols

Δ2 allele of the *ASIP* gene	**a**
normal allele of the *ASIP* gene	**A**
Himalayan allele of the tyrosinase gene	**h**
non-Himalayan allele of the tyrosinase gene	**H**

genetic diagram showing predicted coat colours:

Parental phenotype: Himalayan cat with black extremities X Agouti, Non-Himalayan cat

Parental genotype: aahh AaHh

Gametes: (ah) (AH) (Ah) (aH) (ah)

Gametes	(AH)	(Ah)	(aH)	(ah)
(ah)	AaHh Agouti, Non-Himalayan cat	Aahh Himalayan cat with Agouti extremities	aaHh Black, Non-Himalayan cat	aahh Himalayan cat with black extremities

Offspring genotype: AaHh Aahh aaHh aahh

Offspring phenotype: Agouti, Non-Himalayan cat; Himalayan cat with Agouti extremities; Black Non-Himalayan cat; Himalayan cat with black extremities

Offspring 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 ;

(iii) Put a tick (✓) in one box to indicate whether or not this cross is a test cross.

Give a reason for your answer.[1]

test cross	✓	not a test cross	

reason : The heterozygous cat was crossed with a homozygous recessive cat with both the mutant ASIP and heat sensitive tyrosinase gene loci

(iv) Name a statistical test that would allow you to test the assumptions you made in your genetic diagram by comparing the observed results of many crosses of this type with your expected results.[1]

Chi-square test

[Total: 30]

2 **(a)** Describe **and** explain the relationship shown in Fig. 2.1 between the number of cases of measles and the percentage uptake of vaccine.[4]

1. From 1969 to 1996, as the percentage of uptake of vaccine increases from 32% to 94%, the number of measles cases decreases from 320 000 to 0 cases;
2. After 1996, as the percentage of uptake of vaccine remained high above 80%, the number of measles cases were 0;
3. Antigen presenting cells (APCs) macrophages / dendritic cells (A: antigen processing cells) take up the measles vaccine by phagocytosis, process antigen and present it as a peptide:MHC complex;
4. APC activates naïve T cell which will undergo clonal expansion and differentiation to form helper T cells, cytotoxic T cells and memory T cells;
5. ***T helper cells**** bind to secrete cytokines that activate specific naïve ***B cells**** to undergo clonal expansion and differentiation and form antibody-secreting plasma cells and memory B cells;
6. ***Memory B and T cells**** when exposed to virus, will recognize it and mount a faster and stronger and longer lasting secondary immune response;
7. Specific antigen binding site of antibody binds to specific epitope on antigen of incoming virus;
8. Prevent/block viral glycoproteins from binding to host cell receptors, resulting in ***neutralization****;
9. Prevents attachment and subsequent infection of cells, thus reducing the number of cases of infection;

(b) If the percentage of people who are immune to a disease exceeds the herd immunity threshold, the disease can no longer persist in the population. Assuming 100% efficacy of the vaccine, the herd immunity threshold is calculated as:

$$100 \times (1 - 1/R_o)$$

(i) Calculate the herd immunity threshold for measles, if R_o = 11.

herd immunity threshold = ……..% [1]

90.9 or 91%

(ii) Use Fig. 2.1 and your answer to **(b)(i)** to identify the years when the herd immunity threshold was achieved or exceeded in this part of the United Kingdom.[1]

from 1992 to 1999 inclusive

(c) The mutation rate in the measles virus haemagglutinin gene is estimated to be 6.0×10^{-4} substitutions per nucleotide per year. The mutation rate in human nuclear DNA is estimated to be 2.5×10^{-8} substitutions per nucleotide per generation time of 20 years.

(i) Suggest reasons for the difference in mutation rate of the measles virus haemagglutinin gene and the mutation rate of human nuclear DNA.[2]

1. Measle virus has a single-stranded RNA genome unlike human DNA that is double stranded;
2. No backup copy to do correction and hence has a higher mutation rate;

OR

3. (RNA-dependent/ viral) RNA polymerase lacks proof-reading ability unlike human RNA polymerase that has proof reading ability;
4. more errors occur in viral genome replication;

OR

5. RNA genome more reactive (due to the 2'OH group) than DNA genome; R: unstable
6. Higher frequency of mutations of the ***RNA**** genome leading to the changes in the RNA sequence

Note: It is important to make comparative statements. Use of words like more and higher are important

(ii) Explain why knowledge of mutation rates is useful in reconstructing phylogenies.[2]

1. Rate of mutation/time taken for mutation to accumulate in virus types is constant;
2. from the number of nucleotide differences between different virus strains, it is possible to distinguish between different virus strains /infer evolutionary relationships/degree of genetic divergence between different virus strains
   or
   infer common ancestor of virus strains;
3. from the number of nucleotide differences, it is possible to infer the time when a certain strain virus emerged or share common ancestor;
   Reject time of speciation because viruses are not able to form new species.
   A: if not specifically reference to virus

[Total: 10]

3 (a) Name these **two** products and explain how the presence of **each** of these could help coral growth.[4]

1. ***Oxygen**** is produced by the algae during the light dependent reaction of photosynthesis;
2. It is used by the corals for aerobic respiration as the ***final electron acceptor**** of the ***electron transport chain**** during ***oxidative phosphorylation****;
3. ***Glucose**** is produced by algae during the light independent reaction of photosynthesis;
4. It is the main substrate of respiration by the corals;
5. To produce energy in the form of ***ATP**** for metabolism and growth;

(b) (i) Calculate the overall mean percentage changes in coral cover per year in area 1 and area 2 from 1985 to 2012.

State which area shows the greater overall mean percentage change in coral cover per year.

overall mean percentage change in area 1 = (+2.07 – 0.77 – 1.05 – 0.36)% = -0.11%

overall mean percentage change in area 2 = (+2.34 – 1.59 – 1.75 – 0.04)% = -1.04%

overall mean percentage change in coral cover per year in area 1 = …-0.11%……..

overall mean percentage change in coral cover per year in area 2 = ……-1.04%……..

area with greater overall mean percentage change in coral cover per year = …area 2……..[2]

(ii) Use the data in Table 3.1 to evaluate whether or not the changes in coral cover in these two areas of the Great Barrier Reef from 1985 to 2012 can be attributed to global climate change.[4]

Decrease can be attributed to climate change because

1. Coral bleaching is a result of increase in sea water temperatures which cause zooxanthellae to be expelled from corals, eventually leading to death of coral;
2. Mean percentage decrease due to coral bleaching was 0.36% and 0.04% in area 1 and area 2 respectively;
3. Tropical storms are more severe due to increased temperatures from climate change;
4. Mean percentage decrease due to tropical storms 1.05% and 1.75% in area 1 and area 2 respectively;

Decrease should not be attributed to climate change because

1. There were only 2 sites studied, both in the Great Barrier Reef;
2. Changes may be due to localised environmental conditions and not global climate change;
3. Data is represented as a mean value over 27 years, so unable to see changes on a yearly basis to make an informed conclusion;

[Total:10]

Section B

Answer **one** question in this section.

4 (a) Outline the structural features and genomic organisation of bacteria. [15]

(A) Structural features of bacteria

1. Bacteria cells have simple internal structures with ***no membrane-bound organelles****.
2. The bacterial chromosome is a ***double-stranded, circular DNA molecule****;
3. that makes up a dense region within the cell called the ***nucleoid**** region;
4. Some bacteria cells may contain extrachromosomal double-stranded small circular DNA molecules called ***plasmids****;
5. It contains ***70S ribosomes**** needed for protein synthesis;
6. Nutrients and chemical reserves may be stored in the cytoplasm in the form of granules, e.g. glycogen granules, lipid granules, etc;
7. The bacterial cytosol is enclosed by ***cell surface membrane**** made up of a ***phospholipid bilayer**** with proteins embedded in carrying out specific functions such as transport, ATP synthesis, etc;
8. The ***peptidoglycan cell wall**** confers rigidity to the bacterial cell and protects it from osmotic lysis;
9. Gram-positive bacteria have a cell wall with a thick peptidoglycan layer;
10. Gram-negative bacteria have a cell wall with a thin peptidoglycan layer;
11. Some bacteria may have a layer of polysaccharides known as glycocalyx to the exterior of the cell wall;
12. If the glycocalyx layer is a distinct layer, it is known as a capsule;
13. If the glycocalyx layer is a diffused mass, it is known as a slime layer;
14. Some bacteria may have short, bristle-like fibres extending from the cell surface called ***fimbriae****;
15. Fimbriae may be evenly distributed over the entire cell surface or at the poles of the cells;
16. Other bacterial appendages include ***pili****, which are longer, hollow hair-like structures found on the cell surface;
17. They occur in fewer numbers compared to fimbriae and may have specialized functions such as the sex pilus during conjugation;
18. Some bacteria cells may have a long, hollow cylindrical protein thread called the ***flagella****;
19. Flagella are usually used by bacteria cells for motility as it helps propel the bacteria by rotation;

(B) Genomic organization of bacteria

20. The bacterial chromosome is small in size about 10^4 – 10^7 base pairs;
21. It comprises of a single ***double-stranded, circular DNA molecule****;
22. The circular DNA forms looped domains by associating with a small amount of histone-like proteins, followed by further supercoiling to form highly condensed DNA;
23. that makes up a dense region within the cell called the ***nucleoid**** region;
24. The genome is simple with a ***single origin of replication****;
25. where genes with related functions or belonging to the same metabolic pathway are organized together in an ***operon**** under the control of a ***single promoter****;
26. Bacterium being prokaryotic, has no intron sequences in its chromosome;
27. Some bacteria cells may contain extrachromosomal double-stranded small circular DNA molecules called ***plasmids****;
28. There may be more than 1 copy of the same plasmid in the bacterial cell;
29. The plasmid may contain genes which may confer advantages for the bacteria living in stressful environments, e.g. antibiotic resistance genes;

QWC: Address both (A) and (B)

(b) Compare how genetic variation arises in prokaryotes and eukaryotes. [10]

Point of comparison	prokaryote	eukaryote
1. Method of obtaining genetic variation	1A. Mainly by horizontal gene transfer;	1B. Mainly by meiosis and sexual reproduction;
2. Methods of genetic variation	2A1. ***Conjugation*** whereby the F plasmids to transferred from host to the recipient via a mating bridge; 2A2. ***Specialised transduction**** whereby a temperate phage takes up an adjacent bacterial DNA of the provirus when it undergoes the lytic phase and phage infects another bacteria. This is transferred to another bacteria via homologous recombination; 2A3. ***Transformation**** whereby fragments of naked DNA are taken in by a competent bacteria cell and introduced into the bacterial chromosome by crossing over of homologous regions;	2B1. Meiosis: During ***crossing over between non-sister chromatids of homologous chromosomes**** in prophase 1 results in new combinations of alleles on chromatids. (& eventually a variety of offspring) 2B2. Independent assortment of homologous chromosomes at the metaphase plate & their subsequent separation during metaphase I & anaphase I respectively & 2B2. Random orientation of non-identical sister chromatids of each chromosome at the metaphase plate & their subsequent separation during metaphase II and anaphase II respectively 2B3. This results in gametes with different combinations of maternal & paternal chromosomes. (& eventually in a variety of offspring) 3. Random fusion of gamete occurs during sexual reproduction/fertilisation results in offspring with a variety of genotypes & possibly phenotypes (& hence a variety of offspring);
4. Mutations	As there is only 1 chromosome, there will not be mutations that involve more than 1 chromosome, such as non-	As there are more than 1 chromosome, non-disjunction, translocation and polyploidy can occur;

	disjunction, polyploidy and translocation	

Similarities:

5. Mutations are a source of genetic variation for both prokaryotes and eukaryotes;
6. Mutations such as point mutations and gene mutations such as inversion, substitution, deletion and addition can occur in both;
7. Role of mutations in both can be significant as novel phenotypes can be selected for during natural selection hence increasing the frequency of alleles coding for the favourable phenotype in the subsequent generation;

8. QWC: Mention both similarities and differences.

[Total: 25]

5 **(a)** Outline the processes that occur in aerobic respiration in eukaryotic cells. [15]

1. Aerobic respiration occurs when organic food substances such as carbohydrates, fats and proteins are oxidised to provide energy, protons and electrons that will ultimately be used to generate ATP;
2. Oxygen is required for the complete oxidation of these organic food substances and ATP is produced in the process;

(A) Glycolysis

3. ***Glycolysis**** occurs in the cytoplasm of the eukaryotic cell;
4. Phosphorylation of glucose involves the initial investment of 2 ATP molecules which phosphorylate the two ends of glucose molecule forming ***fructose-1,6-bisphosphate**** ;
5. ***Phosphofructokinase**** is the enzyme involved in the second phosphorylation step;
6. The phosphorylated 6C sugar splits into two 3C sugar phosphates;
7. Each fructose molecule ultimately gives rise to two molecules of ***glyceraldehyde-3- phosphate (G3P)**** ;
8. Glyceraldehyde-3-phosphate undergoes ***oxidation by dehydrogenation**** to form 1,3-bisphosphoglycerate;
9. ***NAD^+**** is reduced to ***NADH**** in the process;
10. 2 ATP is produced by ***substrate level phosphorylation**** of 1,3-bisphosphoglycerate forming ***pyruvate**** ;
11. Since each glyceraldehyde-3-phosphate yields 2 ATP and 1 NADH, each glucose molecule yields 2 ATP, 2 pyruvate and 2 NADH taking into account the 2 ATP as an initial investment;

(B) (B) Link reaction

12. ***Link reaction**** occurs in the ***matrix**** of the mitochondria;
13. Pyruvate formed from glycolysis enters the mitochondrial matrix via transport proteins;
14. Pyruvate undergoes ***oxidative decarboxylation**** where it combines with coenzyme A to form ***acetyl CoA(2C)**** ;
15. ***Carbon dioxide**** is released and ***NAD^+**** is reduced to ***NADH**** in the process;
16. Each glucose molecule produces 2 pyruvate which undergoes the link reaction to produce 2 acetyl CoA, 2 CO_2 and 2 NADH;

(C) (C) Krebs cycle

17. ***Krebs cycle**** occurs in the ***matrix**** of the mitochondria and when oxygen is present;
18. Acetyl CoA (2C) combines with ***oxaloacetate (4C)**** to form ***citrate (6C)****;
19. Citrate is decarboxylated and dehydrogenated to form ***α-ketoglutarate (5C)**** and NADH.
20. Each decarboxylation step results in a loss of carbon in the form of a carbon dioxide;
21. Regeneration of oxaloacetate (4C) involves one decarboxylation step and three dehydrogenation steps to yield 2 NADH, 1 $FADH_2$ and 1 CO_2;
22. High energy electrons originally from the glucose molecule have now been transferred to electron carriers NAD^+ and FAD;
23. $NAD^+ + 2H^+ + 2e^- \rightarrow NADH + H^+$ (or reduced NAD)
    $FAD + 2H^+ + 2e^- \rightarrow FADH_2$ (or reduced FAD)
24. ***1 ATP**** is also produced through ***substrate-level phosphorylation**** during this regeneration process;
25. 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.

(D) Oxidative phosphorylation

- Oxidative phosphorylation occurs on the folds of the inner membrane of mitochondria = ***cristae****;
- NADH donates electrons to first electron carrier of the ***electron transport chain**** found on the cristae;
- The electron carriers alternate between reduced and oxidized states as they accept and donate electrons;
- Each successive carrier has a higher electronegativity;
- Each $FADH_2$ donates electrons to the chain at a lower level and hence generates 2 ATP compared to 3 ATP generated by NADH;
- Electron transport through the series of carriers is coupled to the active pumping of H^+ into the intermembrane space. This generates a ***proton gradient***/ ***proton motive force**** across the mitochondria membrane;

26. The proton motive force is used to phosphorylate ADP. As protons diffuse back into the matrix via the ATP synthase complex, ***ADP is phosphorylated to ATP****.
27. This process is known as ***chemiosmosis****;
    - and produces 90% of the ATP during aerobic respiration.
    - With ***oxygen**** as the ***final electron acceptor**** having the highest electronegativity;
    - $2e^- + 2H^+ + 1/2O_2 \rightarrow H_2O$.

QWC: Must have at least two points from (A), (B), (C) and (D).

(b) Compare how ATP is generated in chloroplasts and mitochondria. [10]

Differences:

Feature of comparison	**ATP generation in chloroplasts**	**ATP generation in mitochondria**
1. Process(es) in which ATP is generated	***Photophosphorylation**** in the light-dependent reaction	***Substrate-level phosphorylation**** (Krebs cycle) and ***oxidative phosphorylation**** in aerobic respiration
2. Site of ATP formation	Takes place in/at the ***stroma**/**thylakoid membrane**** of chloroplast	Takes place in/at the ***matrix**/**intermembrane space**** of mitochondria
3. Source of energy	Energy for synthesis of ATP comes ultimately from light;	Energy for the synthesis of ATP comes from the oxidation of glucose which stores chemical energy;
4. Source of electrons which travels down the electron transport chain	Water is the electron donor in the non-cyclic pathway while ***Photosystem I**** is the electron donor in the cyclic pathway;	[oxidative phosphorylation only]: NADH and $FADH_2$ are the electron donors to the first electron carrier of ETC;
5. Location of proton reservoir which supplies protons that diffuse down ATP synthase	Protons are pumped from stroma across the thylakoid membrane, into the ***thylakoid space**** to establish a proton gradient for ATP synthesis;	[oxidative phosphorylation only]: Protons are pumped from mitochondrial matrix across the inner membrane, into the ***intermembrane space**** to establish a proton gradient for ATP synthesis;
6. Direction of proton flow through ATP synthase	Protons diffuse from ***thylakoid space**** to ***stroma****	Protons diffuse from ***intermembrane space**** to ***matrix****
7. Type of phosphate	Inorganic phosphate	[substrate-level phosphorylation only]: phosphate derived from respiratory intermediates/substrate
8. By-product	Splitting of water produces oxygen as by-product during non-cyclic pathway;	[oxidative phosphorylation only]: Water is produced as by-product when oxygen combines electron and proton at the end of ETC;
9. Energy conversion	Light energy is converted to chemical energy in the process;	Chemical energy (from glucose) is converted to chemical energy (in the form of ATP) in the process;

Similarities:

1. Both involve the transfer of electrons down ***electron carriers**** of increasing electronegativity in an ***electron transport chain****;
2. In both cases, energy release from the transfer of electrons down the ***electron transport chain**** is coupled to the ***pumping**** of H^+;
3. Both involve the generation of a ***proton gradient**** across a membrane;
4. Both involve ***facilitated diffusion**** of H^+ through the ***hydrophilic pore**** of ***ATP synthase**** down its proton gradient;
5. In both, ***ATP**** is produced from ***ADP**** and ***inorganic phosphate/Pi*** * via ***chemiosmosis****;

QWC: essays need to include at least one similarity and one difference.

[Total: 25]