

P530/2
BIOLOGY
Paper 2
2½ hours

FACILITATION PAPER 1

BIOLOGY
(THEORY)

Paper 2

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

*This paper consists of sections **A** and **B**.*

*Answer question **one** in section **A** plus **three** questions from section **B**.*

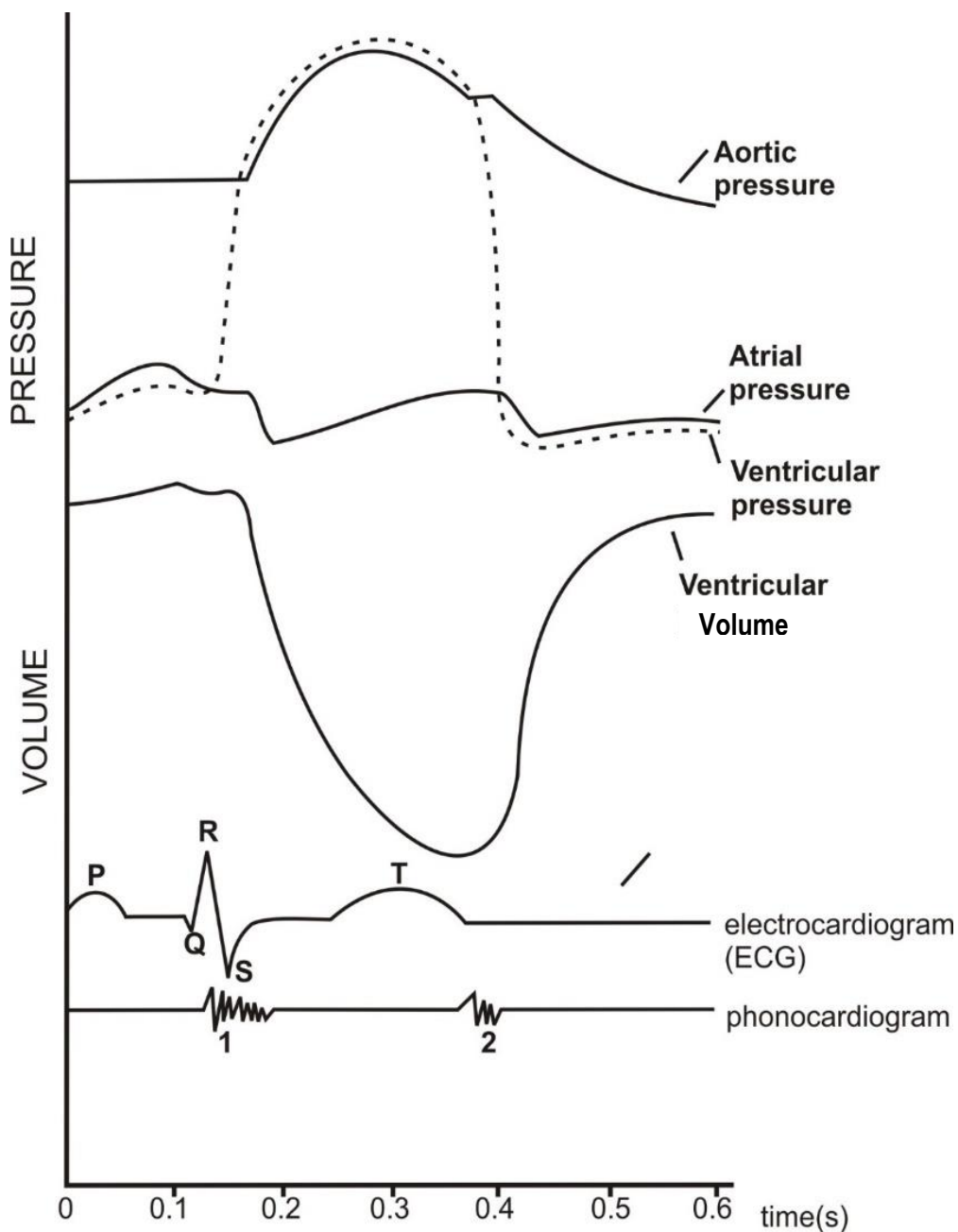
Candidates are advised to read the questions carefully, organize their answers and present them precisely and logically, illustrating with well labelled diagrams where necessary.

SECTION A: (40 MARKS)

Question 1 is compulsory.

1. The figure below shows the pressure and volume changes that occur during the mammalian cardiac cycle (of a dog). The pressure changes were measured in the left atrium and ventricle, and the aorta. Volume changes were measured for both ventricles.

The electrical activity in the heart wall (electrocardiogram) and heart sounds (phonocardiogram) as recorded in a human subject are also shown.



- (a) Describe the changes in:
- (i) Atrial pressure. **(07 marks)**
 - (ii) Ventricular pressure. **(07 marks)**
- (b) What are the differences in the changes in ventricular pressure and ventricular volume between 0.1 seconds and 0.5 seconds? **(03 marks)**
- (c) Explain the effect of the changes in atrial, aortic and ventricular pressures to blood flow during the cardiac cycle. **(15 marks)**
- (d) What is represented by the:
- (i) Waves on the electrocardiogram? **(03 marks)**
 - (ii) Sounds 1 and 2 on the phonocardiogram? **(02 marks)**
- (e) Explain three factors that ensure efficient flow of blood within the mammalian heart. **(03 marks)**

SECTION B: (60 MARKS)

2. (a) (i) Describe P. Mitchell's physiology that occurs in the chloroplast. **(10 marks)**
(ii) Compare the physiology above with that which occurs in the mitochondrion. **(05 marks)**
- (b) How is the chloroplast suited to its functions? **(05 marks)**
3. (a) With examples, discuss the mode of action of hormones. **(12 marks)**
(b) How is the secretion of aldosterone controlled? **(08 marks)**
4. Discuss the adaptations of plants and mammals to reduce water loss in extreme dry conditions. **(20 marks)**
5. (a) In cats the allele for short hair is dominant to the allele for long hair; the gene involved is autosomal. Another gene which is sex-linked produces hair colour; its alleles produce black or white coat colour, and the heterozygote combination produces tortoise-shell colour. If a long-haired black male is mated with a tortoise-shelled female homozygous for short hair, what kind of offspring will be produced in F_1 ? **(08 marks)**

(b) Explain the inheritance of the ABO blood groups in man. **(08 marks)**

(c) What is the role of mutation in evolution? **(04 marks)**

6. (a) Explain how the co-existence of plants and animals in a terrestrial ecosystem is beneficial to them. **(12 marks)**

(b) Explain the significance of predator-prey relationship towards the partners in the relationship. **(08 marks)**

END

MARKING GUIDE
SECTION A: (40 MARKS)

1. (a) (i) Changes in atrial pressure

From 0 seconds to 0.08 seconds atrial pressure increases gradually to a peak.

From 0.08 seconds to 0.14 seconds atrial pressure decreases gradually.

From 0.14 seconds to 0.16 seconds atrial pressure increases very gradually to a peak.

From 0.16 seconds to 0.19 seconds atrial pressure decreases rapidly.

From 0.19 seconds to 0.4 seconds atrial pressure increases gradually to a peak

From 0.4 seconds to 0.44 seconds atrial pressure decreases rapidly.

From 0.44 seconds to 0.58 seconds atrial pressure increases very gradually to a peak

From 0.58 seconds to 0.6 seconds atrial pressure decreases very gradually

(ii) Changes in ventricular pressure

From 0 seconds to 0.08 seconds ventricular pressure increases gradually to a peak.

From 0.08 seconds to 0.14 seconds ventricular pressure decreases very gradually.

From 0.14 seconds to 0.16 seconds ventricular pressure increases very rapidly.

From 0.16 seconds to 0.28 seconds ventricular pressure increases rapidly to a peak.

From 0.28 seconds to 0.38 seconds ventricular pressure decreases gradually.

From 0.38 seconds to 0.42 seconds ventricular pressure decreases very rapidly.

From 0.42 seconds to 0.58 seconds ventricular pressure increases very gradually to a peak.

From 0.58 seconds to 0.6 seconds ventricular pressure decreases very gradually.

1. (b) Differences in changes in ventricular pressure and ventricular volume

From 0.14 seconds to 0.16 seconds ventricular pressure increases very rapidly, while ventricular volume increases very gradually.

From 0.16 seconds to 0.28 seconds ventricular pressure increases, while ventricular volume decreases.

From 0.38 seconds to 0.42 seconds ventricular pressure decreases, while ventricular volume increases.

From 0.42 seconds to 0.5 seconds ventricular pressure increases very gradually, while ventricular volume increases very rapidly.

Ventricular pressure attains a peak later at 0.28 seconds, while ventricular volume attains a peak earlier at 0.16 seconds.

1. (c) Effect of changes in atrial, aortic and ventricular pressures

From 0 seconds to 0.14 seconds the cardiac muscle in the wall of the left atrium contracts during atrial systole, atrial volume decreases, and atrial pressure increases and exceeds ventricular pressure, forcing the bicuspid valve to open, and so oxygenated blood flows from the left atrium into the relaxed left ventricle through the open bicuspid valve.

From 0.14 seconds to 0.38 seconds the cardiac muscle in the wall of left ventricle contracts more powerfully than the atrial wall during ventricular systole, ventricular volume decreases, and ventricular pressure increases, and exceeds atrial pressure at 0.14 seconds, forcing the bicuspid valve to close, preventing backflow of blood into the left atrium; and as ventricular pressure increases further ventricular pressure exceeds aortic pressure at 0.16 seconds, forcing the semilunar/aortic valve of the aorta to open, and oxygenated blood is pumped from the left ventricle into the aorta.

From 0.38 seconds to 0.6 seconds the cardiac muscle in the wall of the left ventricle relaxes during diastole, the ventricular volume increases, and so ventricular pressure decreases, and falls below aortic pressure at 0.38 seconds, forcing the semilunar/aortic valve of the aorta to close, preventing backflow of blood into the left ventricle; and ventricular pressure decreases further and falls below atrial pressure at 0.4 seconds, forcing the bicuspid valve to open, and oxygenated blood flows from the left atrium into the left ventricle.

1. (d) (i) Waves on the electrocardiogram

P wave corresponds to the wave of electrical excitation spreading over the atria during atrial systole/contraction.

QRS wave corresponds to the wave of electrical excitation spreading over the ventricles during ventricular systole/contraction.

T wave corresponds to the wave of electrical excitation spreading over the ventricles during ventricular diastole/relaxation.

(ii) Sounds on the phonocardiogram

1 is the first heart sound produced by the sudden closure of the atrioventricular valves, described as the 'lub'

2 is the second heart sound produced by the sudden closure of the semilunar valves of the aorta and pulmonary artery, described as the 'dub'

(f) Factors ensuring efficient flow of blood within the mammalian heart

Myogenic initiation of the contraction of cardiac muscle by the sinoatrial node/SAN ensures continuous and rhythmic contraction and relaxation without stopping.

Rhythmic contraction and relaxation of heart chambers creates an orderly pressure gradient for blood flow in the heart.

Atrioventricular and semilunar valves ensure unidirectional blood flow, by preventing it back-flowing.

Septum completely separates oxygenated and deoxygenated blood

Tendinous cords attached to atrioventricular valves prevent them being turned inside out.

SECTION B: (60 MARKS)

2. (a) (i) P. Mitchell's physiology that occurs in the chloroplast

The hypothesis by Peter Mitchell called chemiosmotic hypothesis explains synthesis of Adenosine triphosphate/ATP from Adenosine diphosphate/ADP and inorganic phosphate using energy formed due to electro-chemical proton gradient which exists across the thylakoid membrane of the chloroplast span by the respiratory chains of electron carriers.

In the stroma the hydrogen atoms dissociate into protons and electrons.

The electrons are fed into the respiratory chain of carriers at different energy levels leading to formation of energy used to combine ADP with inorganic phosphate to form ATP.

Active transport of protons from the stroma into the thylakoid space across the impermeable thylakoid membrane occurs.

This proton pump is driven by energy released from the excited electrons as they pass down the electron transport system.

This increases the acidity within the thylakoid space and creates the electrochemical proton gradient across the thylakoid membrane.

This results into diffusion of some protons back into the stroma via the special channels called chemiosmotic channels down the electrochemical gradient.

These channels are associated with catalytic knobs on the stroma side and ATPase enzyme.

The diffusion of protons through the chemiosmotic channels result into release of energy used to combine ADP with inorganic phosphate to form ATP.

2. (a) (ii) Comparison of P. Mitchell's physiology that occurs in chloroplasts and mitochondria

Similarities

An electron transport chain assembled in a membrane pumps hydrogen ions across the membrane as the electrons are passed through a series of carriers that are progressively more electronegative.

ATP synthase complex couples the diffusion of hydrogen ions down their gradient to the phosphorylation of ADP.

Both contain cytochromes as electron carriers.

Differences

Mitochondria	Chloroplasts
High energy electrons produced by oxidation of organic molecules.	High energy electrons produced by capture of light energy by photosystems.
Inner membrane of mitochondria	Thylakoid membrane of chloroplast pumps protons

Mitochondria	Chloroplasts
pumps protons from the mitochondrial matrix out to the intermembranal space.	from the stroma into the thylakoid space.
Intermembranal space serves as a hydrogen ion reservoir	Thylakoid space serves as the hydrogen ion reservoir
Inner membrane of mitochondria forms ATP as hydrogen ions diffuse down their concentration gradient from the intermembranal space back to the mitochondrial matrix through ATP synthase complexes, whose catalytic knobs are on the mitochondrial matrix side of the membrane.	Thylakoid membrane forms ATP as hydrogen ions diffuse down their concentration gradient from the thylakoid space back to the stroma through ATP synthase complexes, whose catalytic knobs are on the stroma side of the membrane.
<p>Hydrogen gradient maintained by:</p> <p>As electron carrier complexes I, III, and IV accept and donate electrons from mobile electron carriers, they pump hydrogen ions from the mitochondrial matrix into the intermembranal space.</p>	<p>Hydrogen gradient maintained by:</p> <p>(a) Photolysis of water by photosystem II/PSII on the side of the membrane facing the thylakoid space produces hydrogen ions</p> <p>(b) As Plastoquinone transfers electrons to the cytochrome complex, hydrogen ions are translocated across the membrane from the stroma to the thylakoid space.</p> <p>(c) Oxidized Nicotinamide Adenine Dinucleotide Phosphate/NADP⁺ removes hydrogen ions from the stroma to form Reduced NADP /NADPH + H⁺.</p>

2. (b) Adaptations of the chloroplast to its functions

Chloroplasts within the mesophyll cells can move towards light, arranging themselves in the best position within the cells for maximum absorption of light.

Bound by a double membrane, to isolate the photosynthetic reactions from other cell activities.

Contains numerous closed, flattened, fluid-filled sacs, called thylakoids, to hold chlorophyll and accessory pigments in a structured way, in a suitable position to trap maximum light.

Thylakoids are stacked on top of each other forming grana, interconnected by lamellae to provide a large surface area within the small volume for maximum light absorption.

Lamellae are suspended in a water matrix/stroma containing enzymes for the reduction of carbon dioxide, and other chemicals essential in the photosynthetic pathways and for the storage of the end –products of photosynthesis.

Chloroplast is transparent due to the thin envelope and the colourless stroma, allowing maximum absorption of light by photosynthetic pigments.

Stroma serves as a site for the light-independent reactions of photosynthesis.

Arrangement of chlorophyll in the thylakoids brings it into close proximity to other molecules necessary for its functioning in light harvesting photosystems.

Inner membrane of envelope is highly selective in what it allows in and out of the chloroplasts, regulating the conditions of the internal chloroplast environment for optimum rate of photosynthesis.

3. (a) Mode of action of hormones

Alteration of cell membrane permeability; The hormone binds itself to the cell surface membrane of its target cells, and alters the permeability of the membrane towards a certain metabolite, for example, insulin attaches itself to the receptor site of the surface membrane of the liver cells, increasing their permeability towards influx of glucose molecules, thereby increasing glucose uptake into the liver cells/ Adrenaline works on smooth muscle cells by opening or closing ion channels for sodium or potassium ions or both, changing membrane potentials and either stimulating or inhibiting contraction as a result.

Second messenger system; Some hormones, such as Adrenaline, and Thyroid stimulating hormone/TSH, bind themselves to the receptor site on the surface membrane of their target cells, and activate the receptor protein into an enzyme Adenyl cyclase, which enters the cytoplasm, and catalyses the hydrolysis of Adenosine triphosphate/ATP into cyclic Adenosine monophosphate/AMP, which serves as a second messenger, which can trigger a wide variety of responses, depending on the type of stimulated cell.

In case of Adrenaline, Cyclic Adenosine monophosphate activates the inactive enzyme protein kinase into active kinase enzyme, which activates the inactive phosphorylase enzyme into active phosphorylase enzyme, which catalyses the hydrolysis of glycogen to glucose. The amplification at each stage due to the high efficiency of the enzymes involved in the process is termed the cascade effect.

Influence of genes; The hormone diffuses into the cytoplasm of their target cells, for example Ecdysone, and bind to the receptor site of a receptor protein, to form a hormone-receptor site complex, such as an Ecdysone-receptor site complex. This complex passes via the nuclear pore into the nucleus and has a direct influence on the chromosomes by activating the genes which code for synthesis of proteins used for formation of an adult cuticle. Activation of the gene leads to transcription and the formed messenger Ribose nucleic acid/mRNA moves to the cytoplasm and attach on the ribosome for protein synthesis including enzymes to catalyse different reactions.

3. (b) Control of secretion of aldosterone

The control of the secretion of aldosterone involves negative feedback mechanisms involving the adrenal cortex and the juxtaglomerular complex.

If the aldosterone levels in the blood are high above the norm, the blood sodium ion levels are high above the norm, so the juxtaglomerular complex is not stimulated to secrete the enzyme renin, absence of renin implies there is no catalysis of the conversion of angiotensinogen to the hormone angiotensin, so the adrenal cortex is not stimulated to secrete aldosterone.

In the absence of aldosterone, sodium ion levels in the blood decrease back to the norm.

If the aldosterone levels in the blood are far below the norm, the blood sodium ion levels are low below the norm, so the juxtaglomerular complex is stimulated to secrete the enzyme renin, which catalyses the conversion of angiotensinogen to angiotensin, which stimulates the adrenal cortex to secrete aldosterone, which stimulates increased reabsorption of sodium ions in the distal convoluted tubule, increased absorption of sodium ions in the gut, decreased loss of sodium ions in sweat, raising sodium ion concentration in blood back to the norm.

4. Adaptations of plants to reduce water loss in extreme dry conditions.

Possession of a thick waxy cuticle, which serves as a waxy water-proof barrier that reduces cuticular transpiration, as in *Opuntia*.

Reduction of the number of stomata, which reduces stomatal transpiration, as in *Opuntia*.

Stomata are depressed, and sunk into pits, lengthening the diffusion path by trapping still moist air above the stomata, so reducing transpiration, as in *Amnophila*, pine, holly.

Leaf surface covered with a protective layer of numerous fine hairs/ pubescence, which trap moist air, and lengthen the diffusion path, so reducing transpiration, as in ling, *Amnophila*.

Rolling leaves in to cylinders, to trap moist air within the leaf, and preventing water vapour diffusing out through the stomata, which are then confined to the inner surface, as in *Amnophila*.

Reduction of leaves into spines or needles, reducing the surface area over which transpiration occurs, as in cacti, barberry, spurges.

Leaves may be succulent, or small and circular, to reduce the surface area to volume ratio for gaining heat and losing water vapour, and so reduce transpiration, as in pine.

Total absence of leaves, which limits water loss to stems that have fewer stomata, hence reducing transpiration, as in most cacti.

An upper epidermis with very few or no stomata, with the lower epidermis having more stomata - hidden away from the warming effect of the Sun, to reduce transpiration, as in oak, apple.

Adaptations of mammals to reduce water loss in extreme dry conditions.

Bergman's rule; Small size to reduce surface area for gaining heat and losing water by evaporation, as in *Dipodomys*.

Bipedal gait/ walking on two feet, to reduce heat gain through contact with hot sand during day, as in *Dipodomys*/Kangaroo rat.

Extra-long loop of Henle in the kidneys, coupled with anomalously high levels of Antidiuretic hormone/ADH in the blood, to increase water reabsorption from the glomerular filtrate, and reduce excretory water losses, as in the camel.

Tissues highly tolerant to high temperatures, allowing the mammal to let its temperature rise to even 41°C. This partial ectothermy reduces water loss through sweating by reducing the temperature gradient between the animal and its surroundings, as in the camel.

Possession of fur which insulates the body against heat gain, thereby reducing evaporatory water loss, as in camels.

Small mammals pass the hot desert days in their burrows to avoid heat gain, and reduce water loss, as in *Dipodomys*.

Cornified epithelium serves as a waterproof integument, reducing evaporatory water loss, as in camels.

Oily skin secretions serve as a waterproof, reducing evaporatory water loss, as in the camel.

Viviparity ensures that the embryo is protected from desiccation, and nourished within the uterus, as in camels.

Countercurrent heat exchange; As air is inhaled it gains heat from the nasal passages which are cooled as a result. During exhalation water vapour condenses on the cool nasal passages, reducing respiratory water loss from the lungs, as in camels.

Reduced number of kidney nephrons, to reduce excretory water loss, as in camels.

High urea concentration in the blood, aiding absorption of water from kidney tubules, as in camels.

Reduced sweating, to reduce evaporatory water loss, as in the camel

High rectal water reabsorption, producing hard dry faeces, reducing defaecatory water loss, as in camels.

Slit-like, closable nostrils, guarded by dense hairs, to prevent evaporatory water loss during breathing, as in camels.

Light skin/fur colour reduces heat absorption, to reduce evaporatory water loss, as in camels.

5. (a) Working out the offspring obtained when a long-haired black male and a tortoise-shelled female homozygous for short hair are crossed.

Let **H** represent the allele for short hair (dominant)

h represent the allele for long hair (recessive)

X^B represent the allele for black coat colour

X^w represent the allele for white coat colour

Crossing a long-haired, black male with a tortoise-shelled female, homozygous for short hair:

Parental phenotypes: **long-haired, black male (♂) x tortoise-shelled,
Short-haired female (♀)**

Parental genotypes (2n): **hhX^BY x HHX^BX^w**

Meiosis: ↓ ↓

Gametes (n): **hX^B hY HX^B HX^w**

Random fertilization:

F1 genotypes (2n): **HHX^BX^B HhX^BX^w HhX^BY HhX^wY**

F1 phenotypes: 1 short-haired, black female: 1 short-haired, tortoise-shelled female: 1 short-haired, black male: 1 short-haired, white male

Fi phenotypic ratio: 1: 1: 1: 1

5. (b) Inheritance of ABO blood groups in man

ABO blood groups are determined by the multiple alleles **A**, **B**, and **o**, of an autosomal gene, whose locus is represented by the symbol **I** for **Isohaemagglutinogen**, whereby **alleles A** and **B** are equally dominant, while **o** is recessive to both **A** and **B**.

Inheritance of any of the following allelic combinations via fertilization, results in possession of any of the four blood groups; **A, B, AB** and **O**.

Blood group A is determined by inheritance of genotype $I^A I^A$ or $I^A I^O$ through fertilization, determining production of **antigen/agglutinogen A** on the red blood cell/erythrocyte cell membrane, and possession of **agglutinin anti-B/antibody b** in plasma.

Blood group B is determined by inheritance of genotype $I^B I^B$ or $I^B I^O$ through fertilization, determining formation of **antigen/agglutinogen B** on the erythrocyte cell membranes, and possession of **agglutinin anti-A/antibody a** in plasma.

Blood group AB is determined by inheritance of genotype $I^A I^B$ through fertilisation, determining formation of **antigens/agglutinogens A and B** on the erythrocyte cell membranes, and absence of agglutinins in plasma.

Blood group O is determined by inheritance of genotype $I^O I^O$ through fertilization, determining absence of agglutinogens on the erythrocyte cell membrane, and possession of both **agglutinins a and b** in plasma.

(c) Role of mutation in evolution

Mutation is the sudden, spontaneous and unpredictable change in the amount, arrangement, or structure of the DNA of an organism.

Mutation leads to increased genetic variation in the gene pool of a population.

Somatic mutations occur in somatic cells that do not produce gametes and are only inherited by daughter cells produced by mitosis and so are lost when the organism dies, and do not contribute to evolution.

Mutations occurring in gamete cells and gamete-producing germ cells are inherited by subsequent generations, and contribute to evolution.

Inheritable mutations increase genetic variation, and those mutations which confer a competitive advantage to mutants/bearers are selected for by natural selection, persist and reproduce more offspring; while mutations which confer a competitive disadvantage to mutants/bearers are eliminated as they fail to survive or reproduce.

The resultant change in allele frequency in the population gene pool from generation to generation leads to evolution.

6. (a) Benefits from animals to plants.

Obtaining mineral nutrients from decomposition of dead organic matter of animals.

Obtaining carbon dioxide for their photosynthetic activities from the respiratory activities of animals.

Being dispersed by animals which minimizes their overcrowding, competition and spread of disease; and enables them colonize new habitats.

Being pollinated, leading to sexual reproduction

Their population size being regulated by animals, by feeding upon them

Co-evolution of both plants and animals; Co-evolution involves development of flowers with attractive shape, colour, and smell, for the insects to visit the flower, and pollinate it; and at the same time the insects evolve sense organs, and mouth parts, specialized for quickly locating and extracting nectar from particular species of insect-pollinated flowers

Benefits from plants to animals.

Obtaining food manufactured by the plants

Obtaining oxygen for their respiratory activities produced as a by-product of photosynthesis by the plants

Obtaining shelter from the plants

Co-evolution of both plants and animals

Camouflaging against the plant background /hiding against their potential enemies for their survival.

6. (b) Benefits of the prey from the predator-prey relationship

Regulates the prey population thereby minimizing overcrowding, and its effects such as increased competition, overgrazing, increased spread of diseases, enhanced soil erosion, reduced soil fertility, decreased vegetation, which would lead to abrupt collapse of prey population.

Puts up a selection pressure which favours the well-adapted prey to evolve with mechanisms to survive and multiply in large numbers; while the less adapted are eliminated from the population. This leads into new species formation.

Benefits of the prey from the predator-prey relationship

Obtain food by feeding on the prey for their growth and reproduction

Increase in the prey population increases the population size of predators, due to increased availability of food in form of the prey, reduced competition among predators, and promotion of predator immigration, while discouraging emigration.

Regulates the population of the predator at that which can be fully supported by the environment.

Puts up a selection pressure whereby the poorly adapted predators are naturally selected against, and fail to obtain prey to feed upon, hence their elimination from the population; while the well adapted evolve certain mechanism which enable them efficiently in detect and capture the prey. This can result into formation of new species.