MARKING GUIDE FOR APRIL 4TH TEST

SECTION A

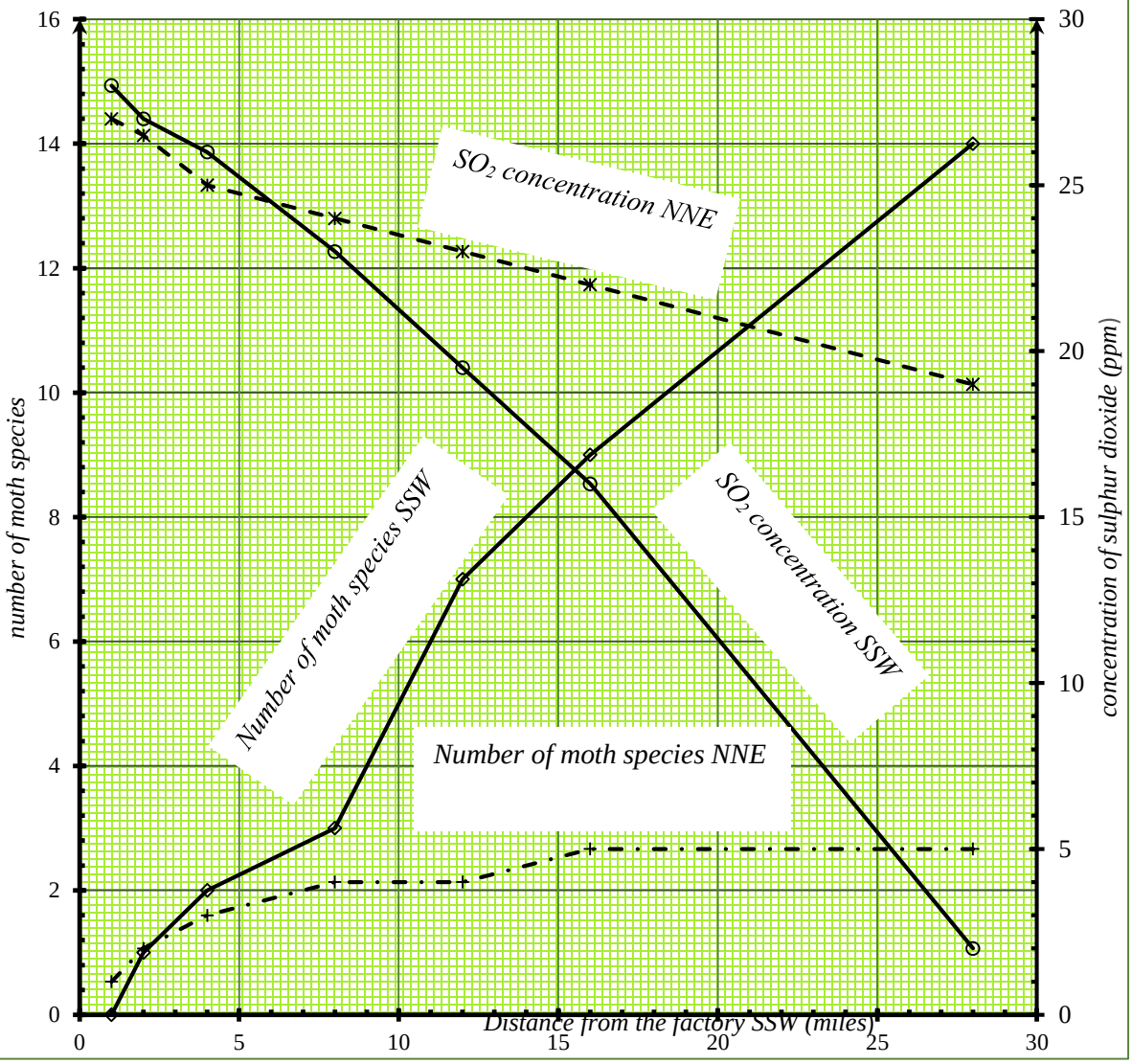
COMPULSORY QUESTION (40 marks)

1. A factory emitting smog containing sulphur dioxide and carbon dioxide was cited in a rural district. The tables below give distances and directions of:
    i. Number of moth species and
    ii. Concentration of sulphur dioxide in smog in different directions from the factory chimney.

Distance from the factory (miles)	*Sulphur dioxide concentration (parts per million)*		*Number of moth species*	
	South-South -West direction	North-North-East direction	South-South - West direction	North-North-East direction
1	28	27	0	1
2	27	26.5	1	2
4	26	25	2	3
8	23	24	3	4
12	19.5	23	7	4
16	16	22	9	5
28	2	19	14	5

a. Plot the information to show the relationship between the moth species, Sulphur dioxide concentration, and distance from the factory using the same x-axis and two y-axes. (11marks)

Graphs showing the relationship between the number of moth species, concentration of sulphur dioxide and distance from a factory in a direction NNE and SSW



b. Explain the difference in results between those obtained for the SSW direction and those obtained for the NNE direction. (16 marks)

Interval of distance	Observed trend in sulphur dioxide concentration	Observed trend in moth species; NNE	Observed trend in moth species; SSW	Explanation
1 to 4miles	Decreased gradually	Increased slowly	Increased slowly	High concentration of toxic Sulphur dioxide destroyed many lichens which would favor camouflage of moths against their predators. Mutation rates caused emergence of new species in presence of certain isolating mechanisms. A higher mutation rate was favored by low SO_2 concentration in NNE than in SSW.
4 to 16 miles	Decreased gradually	Increased slightly, then remained constant	Increased slightly;	Levels of toxin still high in NNE direction. Lichen death is still rapid causing greater reduction in moth species due to selective predation few could even mutate. But increase in moth spp is greater in SSW because of lower concentration of toxic SO_2 allowing rapid mutation rates and immigration of moths to increase species diversity.
16 to 28 miles	Decreased rapidly	Remained constant;	Increased rapidly	• Decreased levels of Sulphur dioxide allowed growth of lichens that increased camouflage patterns of moth species. • An equilibrium is established between environmental selection pressure in the NNE direction but more moth species mutated from the original stock in the SSW direction. • Mutation to increase moth species still occurred in the SSW direction

c. Explain why the number of moth species increases with increasing distance from the factory.

(04 marks)

There is progressively a decreasing concentration of Sulphur dioxide as distance increases away from the factory. This reduces the rate of death of lichens which allow camouflage of moths. Many species of moths arise by random mutation due to changing concentrations of Sulphur dioxide but are better adapted for life in the less polluted areas. But many moth species survive better in a less polluted environment.

d. The results obtained give evidence of present-day evolution. Explain this evidence fully and its significance in evolution. (05 marks)

Changing concentration of Sulphur dioxide is a change in intensity of a selection pressure.✓ Lichens allow successful camouflage by the moths✓ so that they are less readily predated upon✓. With increasing distance away from the factory in any direction, the selection pressure decreases ✓and the number of moth species keeps increasing.✓

e. What are the environmental effects of sulphur dioxide and carbon dioxide pollutions?

(04 marks)

- ✓ *Causes acid rain which;*
- ✓ *Corrodes buildings and rocks*
- ✓ *It kills lichens and many plant like organisms*
- ✓ *It is an air pollutant which irritates the skin*
- ✓ *Causes respiratory disorders*
- ✓ *Contributes to the greenhouse effect*
- ✓ *Causes changes in soil pH which lowers crop yields*

SECTION B (60 marks)

2.

a. How do hormones in the brain and kidney interact to regulate the amount of water and salt in tissue fluid? (12 marks)

Control of water

- A rise in blood concentration (more negative ψ); is detected by the osmoreceptors in the hypothalamus which send impulses to the posterior lobe of the pituitary.
- As a result, it releases more **Anti diuretic hormone** into the blood stream which; increases the permeability of the DCT and collecting ducts to water.
- ADH binds to specific sites on the cell surface membrane and acts via cyclic AMP to stimulate the fusion of Golgi vesicles to the membrane. This increases the number of water channels. Water channels are proteins synthesized in the cell and stored in the membranes of Golgi vesicles which accumulate in cytoplasm. Increase in the number of water channels therefore causes more water to move from the glomerular filtrate, the cortex and medulla and then into blood and more hypertonic urine is produced thus retaining water in blood.
- ADH also increases the permeability of the collecting duct to urea hence it passes from the ultra-filtrate in the collecting duct to the medulla making its ψ more negative therefore causing a greater loss of water from the descending limb of the loop of Henle.
- ADH also stimulates the brain to increase the sensation of thirst. It also increases blood pressure by vasoconstriction of the arterioles
- A fall in blood concentration (less negative ψ) inhibits release of ADH. This occurs when endocytosis happens and the Golgi vesicles are taken back into cytoplasm ready for recycling during the next release. Thus walls of the collecting ducts are made impermeable to water, less water is re – absorbed and a hypotonic urine is produced.

Control of salt;

A reduction in the concentration of Na^+ in blood causes its ψ to become less negative hence water passes by osmosis to the tissues of the body and the volume of the blood decreases. Special cells lining the efferent arterioles and juxtaglomerular complex are stimulated by this decrease in blood volume to release an enzyme renin which catalyzes the conversion of a blood protein **angiotensinogen** released by the liver to **angiotensin;** a hormone in blood stimulates the adrenal cortex to secrete aldosterone into the blood stream. Another hormone adrenal corticotrophin hormone (ACTH) released by the hypothalamus after stimulation by Adreno corticotrophin releasing hormone from the hypothalamus (ACTRH) stimulates production of aldosterone by stimulating the formation of deoxycortisosterone which is a precursor for aldosterone.

On reaching the kidney, aldosterone

- stimulates the active uptake of Na^+ from the glomerular filtrate accompanied by uptake of water and loss of K^+ due to the Na^+-K^+ pump mechanism.
- Increases permeability of epithelial cells in the colon and collecting ducts to sodium ions thus upregulating absorption.
- Increases the rate of absorption of chloride ions in conjunction with sodium ions.
- Stimulates absorption of potassium ions into the tubular system.

- *Stimulates Na^+ and water reabsorption form the gut, salivary and sweat glands in exchange for potassium ions.*
- *Stimulates H^+ ion secretion via ATPase in cells of the cortical collecting ducts.*

b. Explain the operation of a hairpin counter current multiplier in the loop of Henle. (5 marks)

- *The descending limb is more permeable to water than salts whilst the ascending limb is less permeable to salts than water.*
- *Renal fluid flows in opposite directions in both limbs setting a counter flow system*
- *Sodium potassium pumps are activated to remove Na^+ ions from the fluid in the ascending limb into the medulla. This is followed by co-transport of chloride ions.*
- *A more negative water potential in the medulla makes water leave the descending limb by osmosis into the vasa-recta where it is carried away into blood capillaries.*

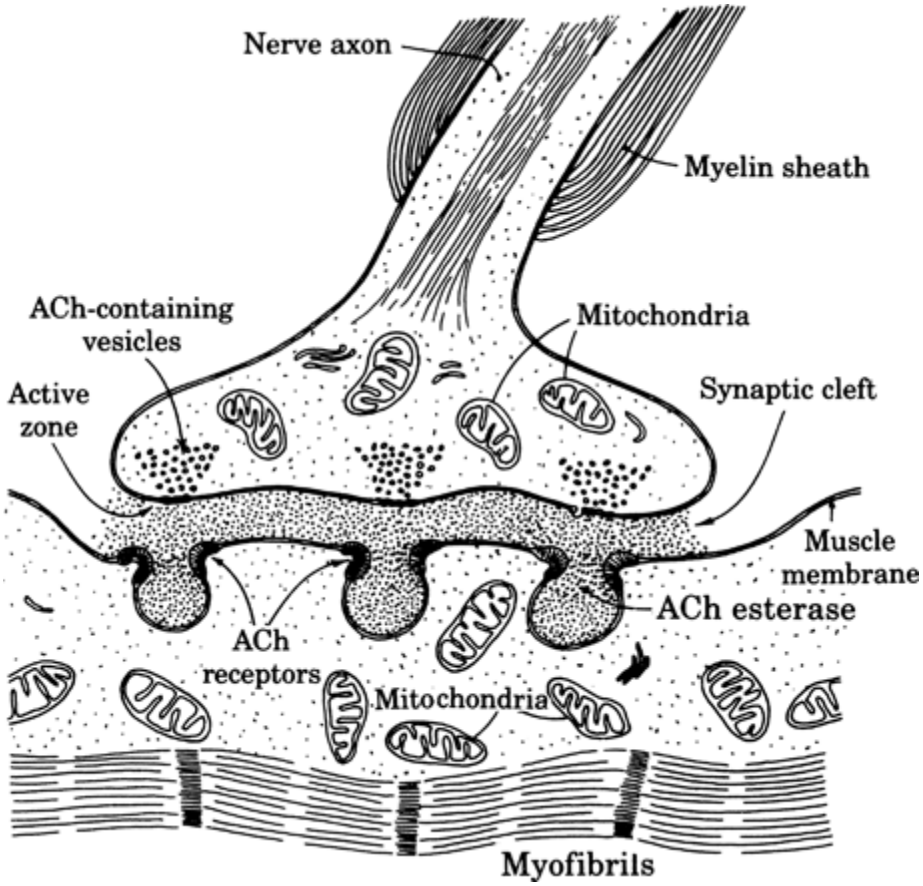
c. State the significance of counter flow systems in homeostasis. (3 marks)

- *Exchange of gases in teleost fish gills*
- *Temperature regulation in vertebrate limbs*
- *Regulation of water in kidneys*

3.

a. Describe the structure of a nerve muscle junction. (8 marks)

- ✓ *A nerve muscle junction is a precise point where a motor neuron terminates at a skeletal muscle fiber.*
- ✓ *At the motor end plate, the motor neuron divides to form fine branches ending in synaptic knobs. These branches lack myelin sheath.*
- ✓ *The fine branches run in shallow troughs on the sarcolemma.*
- ✓ *Each post synaptic membrane encloses a number of synaptic vesicles containing a neurotransmitter but the membrane is permeable to calcium ions*
- ✓ *The synaptic cleft contains a high concentration of calcium ions.*
- ✓ *The post synaptic membrane consists of various receptors for acetylcholine and sodium ions.*



b. Outline the events that occur leading to excitation of a muscle end plate (9 marks)

- ✓ *Arrival of an impulse at the neuromuscular junction depolarizes the pre synaptic membrane causing the calcium channels to open. This increases permeability to Ca^{2+} ions.*
- ✓ *Ca^{2+} ions enter into the synaptic knob causing the synaptic vesicles to fuse with the presynaptic membrane releasing acetylcholine into the synaptic cleft.*
- ✓ *Acetylcholine diffuses across the end plate and attaches to receptor sites causing a conformational change.*
- ✓ *Conformational changes in receptor sites result in opening of ion channels in the motor end plate increasing permeability of the sarcolemma to Na^+ and K^+ ions. Na^+ ions enter the cytoplasm causing a depolarization.*
- ✓ *Changes in membrane permeability cause a local depolarization known as end plate potential.*
- ✓ *The end plate potential builds up to reach an action potential which passes through the sarcolemma.*

c. Clearly distinguish between temporal and spatial summation.

Feature	Temporal summation	Spatial summation
Form of raising action potential	Several neurons are excited one after the other; there is a time lapse after excitement of each.	Many neurons are excited simultaneously
Transmitter substance	Accumulates after several doses	Accumulates after single minute doses from several neurons.
Significance	Enables weak background stimuli be filtered	Integration of stimuli from a variety of sources
Result	Facilitation	Integration

4.

a. Explain the effect of variation of pH on the saturation of hemoglobin with oxygen. (5 marks)
   - ✓ As acidity increases, there is a great tendency of hemoglobin to release oxygen. Thus;
   - ✓ The oxygen dissociation curve (ODC) shifts to the right in regions of increased carbon dioxide concentration.
   - ✓ Carbon dioxide dissolves in plasma forming a weak carbonic acid which dissociates to release hydrogen and hydrogen carbonate ions.
   - ✓ Hydrogen ions tend to displace oxygen from oxyhaemoglobin.
   - ✓ In conditions of increased alkalinity, the percentage saturation of hemoglobin with oxygen is high and the ODC shifts to the left.

b. Describe the differences in structure and function of normal and sickled hemoglobin. (4 marks)

Feature	Normal hemoglobin	Sickled hemoglobin
Functional amino acid at position 6 of β- polypeptide chain	Glutamic acid	Valine
Solubility in water	Soluble; hydrophilic	Insoluble; hydrophobic
Fate after dissociation	Dissolves in plasma	Crystallizes into rod like fibers
Effect on erythrocyte shape	Maintains the disc shape	Causes a crescent shape

c. Explain the factors that affect the rate of heart beat in mammals.
   - ✓ pH levels; high levels of acidity (low pH) increase heart beat by causing dilation of arterioles to increase blood pressure. Heart beat rate decreases under alkaline conditions.
   - ✓ Temperature: An increase in temperature results in an increase in heart rate because tissues metabolize rapidly and accumulate carbon dioxide. At low temperature, the rate of accumulation of carbon dioxide is low hence low heart rate.

- ✓ Mineral ions; certain mineral ions such as Na^+ and Ca^{2+} increase which increase excitability of the heart muscle. This increases heart rate. Presence of certain ins like cyanides reduces heart rate by inhibiting respiratory enzymes.
- ✓ Age; As age increases, the excitability of the heart muscle decreases hence heart rate decreases. Young mammals have a faster rate of heart beat coz of great excitability of the heart muscle.
- ✓ Anxiety levels; Anxiety and stress increase levels of adrenalin in the blood stream which stimulates the sympathetic nervous system to increase heartbeat. Under low levels of such hormones, heart beat rate decreases due to prolonged action of the parasympathetic nervous system.
- ✓ Medication; certain drugs may act as stimulants for heart muscle contraction thus increasing heart rate. Sedative/ depressant drugs reduce heart rate.
- ✓ Exercise increases the amount of carbon dioxide levels reducing pH and increasing heart rate.
- ✓ State of health; sickness may stimulate heart rate due to presence of pyrogens which increase temperature by resetting the thermostat in the hypothalamus.
- ✓ Hormones; adrenaline and noradrenaline stimulate the sympathetic nervous system to increase heart rate.

d. Outline three effects of sickle cell anemia on heart function
- ✓ Dilation of the heart due to sickled red cells destroyed by oxygen deficit.
- ✓ Sickled cells get jammed in capillaries and small arteries causing interference with circulation which results in heart failure.

5.

a. Distinguish between

i. allopatric and sympatric speciation. (4 marks)

Allopatric speciation	Sympatric speciation
✓ genetic isolation occurs for a longer time	✓ genetic isolation occurs for a shorter period of time
✓ no hybrid formation; niche specialization determines new phenotypes hence genetic isolation.	✓ hybrids form and overlap forming new species
✓ Characterized by occurrence at some stage of spatial separation	✓ No spatial separation of subpopulations.
✓ Genetic isolation occurs during geographical isolation	✓ Genetic isolation occurs via an isolating mechanism.

ii. Clines and demes (3 marks)

Cline	Demes
A species exhibiting gradual change in phenotypic characteristics throughout its geographical range.	Small interbreeding subpopulations within a species

b. How do each of the following contribute to speciation?

i. mutations (4 marks)

Mutations introduce new alleles and allele combinations which confer new phenotypes to the organisms. This increases genetic variability within a population. If these mutations occur in geographically isolated subpopulations such that gene flow is interrupted, genetic differences confer differential breeding potentials among members of the same natural population. This may make them become separate species.

ii. Geographical barriers (5 marks)

Geographically isolated populations encounter different climatic and ecological conditions. These seasonal and ecological variations produce isolating mechanisms which prevent formation of hybrids. As a result, these differences make subpopulation co-exist as separate species in the same geographical location.

iii. Seasonal variations. (4 marks)

Changes in seasons cause variation in temperature, light and rainfall distribution which confer differential maturation in gonads and other reproductive structures. When sexually reproducing organisms of different sexes have their reproductive structures mature at different times, they are much more likely to form new species allopatrically because timing of mature gametes must synchronize between opposite sex.

6.

a. Describe the role of transport proteins in absorption of digested food in the mammalian intestine. (5 marks)

- ✓ *Uptake of these end products occurs by diffusion and then supplemented by active transport.*
- ✓ *Active transport is favored by a sodium- potassium pump in the cell surface membrane of the intestinal epithelium.*
- ✓ *As sodium is pumped out, it tends to diffuse back in.*
- ✓ *A carrier protein which requires both sodium and glucose, amino acids to function is situated in the membrane. These are transported together by facilitated diffusion into the cell.*
- ✓ *Active transport only works to remove sodium ions from the cytoplasm.*

b. What is the role of the mammalian liver in assimilation and metabolism of proteins? (6 marks)

- ✓ *The liver produces a number of plasma proteins. The hepatocytes can also convert one amino acid to another (transamination). In this way dietary deficiency of non-essential amino acids can be remedied.*
- ✓ *A major role of the liver is the de-amination of surplus amino acid which cannot be stored in the body. De-amination refers to removal of the amine group from an amino acid. It must be removed before the carbohydrate residue can be stored*
- ✓ *The amino group is removed with a hydrogen atom so that the nitrogenous waste products ammonia (NH_3) is formed.*

- ✓ *The bulk of ammonia formed is converted by the hepatocytes into urea (carbamide) which is then excreted in urine. The production of urea occurs in cyclical series of reactions also known as the* ***ornithine cycle.***

c. How do gastric and intestinal hormones interact to control digestion of food in the gut? (9 marks)

Hormone	**Source**	**Target**	**Stimulus for secretion**	**Effect**
Gastrin	Stomach mucosa	Gastric glands	Nerve impulses in the Meissner's plexus	✓ Stimulation of the secretion of gastric juice ✓
Secretin	Duodenum	Liver Pancreas	Acid chyme in duodenum	✓ Stimulates the **liver** to secrete **bile** into the **gall bladder.** ✓ Stimulates pancreatic secretion of **non-enzymatic** substances (**hydrogen carbonate ions**) from **acinar cells.** HCO_3^- neutralise the acid from the stomach to provide an alkaline pH optimum for pancreatic enzymes. ✓ Inhibits secretion of **HCl** by **oxyntic cells** as chyme leaves the stomach.
Enterogastrone		Stomach wall	Acid and fat in the duodenum	✓ Inhibits oxyntic cells from secreting hydrochloric acid in order to provide an optimum pH for pancreatic enzymes. ✓ Signals the stomach to empty slowly when fat is present, allowing much time for digestion of fat already emptied.
Cholecystokinin-pancreozymin complex	Duodenum		Partially digested **fat** and **protein** in the duodenum	✓ Stimulates contraction of **gall bladder** to release **bile** into **duodenum.** ✓ Bile salts (sodium glycocholate) emulsify fats i.e. fats physically break into droplets due to reduced surface tension, which increases their surface area

				✓ Stimulates the pancreas to secrete **pancreatic enzymes**: ▪ **Pancreatic amylase** which catalyses the hydrolysis of **starch** into **maltose** ▪ **Enterokinase**, a non-digestive enzyme which activates **Trypsinogen** to **Trypsin.** ▪ **Trypsinogen**, which is activated by **enterokinase** to **Trypsin.** ▪ **Trypsin:** ▪ Catalyses hydrolysis of **polypeptides** to **peptides.** ▪ Activates **chymotrypsinogen** to **chymotrypsin**. ▪ **Chymotrypsinogen**, which is activated to **chymotrypsin** by **Trypsin. Chymotrypsin** catalyses hydrolysis of **casein / polypeptides** into **peptides.**