ST. JOSEPH'S SENIOR SECONDARY SCHOOL NAGGALAMA
POSSIBLE SOLUTIONS TO THE A LEVEL BIOLOGY SEMINAR QUESTIONS 2025

1. (a) Similarities
From 1 to 5 arbitrary units (a.u), the ratio in both plants decreases; From 5 to 6 a.u, the ratio in both plants remains constant; At 3.1 a.u, the ratio in both plants is the same; Both attain a ratio of 1.
Differences
From 1 to 3.1 a.u, the ratio in sun plants is higher than in shade grown plants;
From 3.1 to 6 a.u, the ratio in sun plants is lower than in shade grown plants;
Shade grown plants attain a higher maximum
Both attained a ratio of 1 at different light intensities.
(ii) Initially at 1 a.u, the ratio of carbon dioxide evolved to carbon dioxide absorbed is high; due to **very little light available** hence little carbon dioxide absorbed since **photosynthesis is low**; with a high rate of respiration; From 1 to 2.3 a.u, the ratio decreases rapidly; and is above 1; this is due to an increase in light intensity which stimulates increase in the stomatal aperture; hence carbon dioxide taken into the leaf increases; increasing the amount of photosynthesis at a rate higher than that of respiration; but respiration is still higher than photosynthesis; light is the limiting factor ;
At 2.3 a.u, the ratio is 1; photosynthesis is equal to respiration; Compensation point attained
From 2.3 to 4 a.u, the ratio decreases rapidly; and is below 1; this is due to an increase in the amount of photosynthesis at a rate higher than that of respiration; respiration is lower than photosynthesis; light is a limiting factor.
From 4 to 5 a.u, the ratio decreases gradually; light and other factors such as temperature are limiting factors for the process of photosynthesis; 5 a.u is light saturation point
From 5 to 6 a.u, the ratio remains constant; light is no longer a limiting factor/ low carbon dioxide concentration or temperature limit
(b) (i) Shade plants have a lower compensation point because they possess adaptations for low-light photosynthesis**;** due to a lower respiration rate**;** thinner leaves that permit more light penetration**;** and the leaves are more spread out to trap light over a wider area**;** with fewer deep cells**;** hence they can absorb light more efficiently**;**
(ii) Ratio is <u>lower in sun plants</u>**;** the sun plants have a higher rate of photosynthesis than respiration as compared to shade plants, at high very high intensities**;** because sun grown plants have abundant chlorophyll a (high chlorophyll a to chlorophyll b ratio) to increase light absorption;
Shade plants, on the other hand more quickly reach photosynthetic saturation, where all available light-harvesting complexes are fully active occurs then undergo photoinhibition by too much light, leading to a higher ratio or fall in CO_2 absorption compared to the sun plants.
(c) From 1 to 5 arbitrary units increase in light intensity causes and increase in the net accumulation of sugars; to a maximum; Light provide energy to excite electrons in the magnesium atoms of chlorophyll molecules to higher energy levels; leading to production of ATP and $NADPH_2$; used in the light independent stage in the production of sugars; via the Calvin cycle;
From 5 to 6 a.u increase in light intensity leads to a constant net accumulation of sugars; because the light saturation point has been reached; and the leaves are producing ATP and NADPH2 at the highest possible rate;
(d) Shade leaves have a thinner waxy cuticle therefore they have more water available for photolysis; have larger stomatal sizes to allow loss of excess water;
Shade plants have chloroplasts that are evenly distributed between the palisade and spongy mesophyll to avoid shading chloroplasts below them while is sun plants most of the chloroplasts are found in the

palisade; some chloroplasts take turns in bright light and then shelter in the shade of others as they make use of the light that they have absorbed;
Shade leaves have a greater number of chloroplasts per unit area; and the chloroplasts are larger; to maximize light absorption;
Shade plants have the leaves at a horizontal orientation to maximise light trapping; while sun plants have an erect orientation to minimise light trapping;
Shade plants have a lower stomatal density; to avoid over cooling;
Sun grown plants have a higher mesophyll cell surface / leaf area ratio; to minimise excessive light and transpiration;
(e) To ensure uniformity in the experiment**;** and obtain more accurate results**;** by avoiding other factors such as genetic/ structural factors that could affect the rate of photosynthesis**;** ensuring that differences in CO_2 exchange and sugar are due to variation in light intensity only.

2. (a) (i) The brain secretes **prothoracicotrophic hormone (PTTH) that stimulates prothoracic gland to secrete moulting hormone.** Cutting off the head **too soon** (after only 2 days) means the PTTH had not yet circulated to prothorax and thus moulting hormones had **not yet been secreted** to induce **moulting.**
(ii) By 7 days, the brain had already secreted PTTH, which stimulated the **prothoracic glands** to release **ecdysone (moulting hormone)** in sufficient amounts to initiate the moulting process
b) The brain **releases PTTH** and **juvenile hormone (JH)**. PTTH promotes moulting via stimulation of ecdysone. However **JH** levels in the larva determine whether the moulting leads to another larval stage or adult stage by maintaining new instars. Since the recipient still had **high JH levels**, it moulted into another **larval stage**, not an adult.
(c) (i) Surgical removal of carpus allatum gland to **lower or eliminate juvenile hormone** levels in the larva before the next moult.
Injections of ecdysone hormone that induces growth thru moulting
(ii) Motile larvae like caterpillar are a means of dispersal of species; act as transition stage of the species as adapts to environment; increases chances of survival as larvae can inhabit different niches from adult; Reduces competition for resources; some larvae can reproduce asexually hence enabling quick multiplication of species and utilization of favorable reasons in particular seasons; some are feeding stages for rapid growth into adult
(d) Food ingestion leads into expansion of guts, which stimulate the stretch receptors within the gut walls to fire impulses to the brain. The brain is stimulated to secrete the brain hormones or PTTH into the blood stream to the thorax. Brain hormone stimulates the prothoracic gland to secrete ecdysone hormone into blood stream.
Ecdysone stimulates certain genes to code for synthesis of a new cuticle; developing from one larval stage to another; if the concentration of the juvenile hormone is completely lacking in blood; the larva moults into adult grasshopper.
e) Neurosecretion is a chemical substances (neurohormone) released by specialized neurosecretory cells or neurons found in specific regions of the brain, particularly in the hypothalamus; directly into the bloodstream to regulate various physiological processes; e.g. Oxytocin & Vasopressin
Oxytocin hormone: Stimulates contraction of myometrium of the uterus during birth; stimulates the ejection/ release of milk from the milk glands during breast feeding; stimulates bonding behaviour among married couple
Anti-diuretic hormone: Increases the rate of osmotic water re-absorption from the collecting duct into blood capillaries; by increasing the permeability of the walls of collecting duct and distal convoluted tubule towards water; Important for osmoregulation; It increases blood pressure by causing local vasoconstriction of arteriole.

3.(a) (i) **Sound detection** occurs when vibration of the oval window creates pressure in perilymph within cochlea; making it vibrate, which in turn makes basilar membrane to vibrate; causing endolymph into vibration. The vibrations create a shear force on sensory hair cells as they slide past the tectorial membrane of Organ of corti. Once the straining of the sensory hair cells is sufficient; generator potential reaches threshold; and an action potential is fired to the brain for interpretation.
Pitch is determined by the **relative vibration along the length of basilar membrane;** whose thickness increases from its base to the apex. High frequency sound causes vibration of the thinner and stiff base of the basilar membrane near the oval window; stimulates the sensory hair cells therein while low frequency sound causes vibration of the portion of membrane which is wider and more flexible at the apex of the cochlea.
Volume (intensity) of sound is as a result of possession of a range of sensory cells with different thresholds of vibration in a given portion of the basilar membrane; and the amplitude of its displacement. Loud sound induces membrane to vibrate by a larger amplitude and sensory cells of higher threshold of vibration are stimulated; where as soft sound is perceived when a few sensory cells of lower threshold are stimulated in a given portion of the basilar membrane.

(ii) **Cone Cells are of** three types, blue cone, green cone and red cone; each containing a different **photopigment that is stimulated by differing wave length of light to determine the nature of colour perceived. Discrimination of Colour** is based on the **relative stimulation** of different types of cone cells. Stimulation of one cone type results into primary colour perceived; Equal stimulation of **two different cone types** gives **secondary colour** while equal stimulation of all three types results in **white** perception.
(b) (i) Rod cells have a high degree of retinal convergence, where several rods synapse with a single bipolar cell which reduces the ability to resolve detail; where several stimuli on rod cells synapsing to single neuron are fused; such that a single impulse is fired to the brain which it interprets as one; resulting in low visual acuity and blurred image.
(ii) The much retinal convergence of rod cells allows for summation whereby if subliminal stimuli (dim light) land of rods synapsing to single bipolar neuron; there is an additive effect at synapse to threshold stimulation of the neuron to cause a response. In addition, rods contain the photopigment rhodopsin, which is highly sensitive to low light intensity

(iii) Fovea is densely packed with cone cells; which are structurally arranged to ensure high visual acuity; as cone cells have now or low retinal convergence; each cone cell to synapse to single own neuron and subsequently respond to single stimulus and transmit own separate impulse to brain to interpret images of high precision; without fusion of stimuli;

(iv) From bright sunlight ,much photo-decomposition of rhodopsin has occurred hence much of the retinene is in trans form, thus rod cell sensitivity to light is too low hence objects in the room at first cannot be seen , the objects gradually become visible due to resynthesis of cis-retinene (which is the physiologically photosensitive form) in adequate amounts, the resynthesize process is a slow enzyme -catalysed reaction, the adequate cis-retinene amounts causes the rod cells to regain sensitivity hence when they are struck by dim light, they are bleached causing their hyperpolarisation, producing generator potentials hence producing action potentials in bipolar and neurons transmitted to the brain.
More still while bright light, the pupil is narrowed to reduce on over-stimulation of the retinal cells by entry of light into the eye. So then when one gets in dim light, some time is spent as the radial muscles contract to dilate the pupil slowly to allow entry of light; whose threshold at first is low to stimulate the rods for objects to be seen; but later improves to enable vision as the pupil dilates fully

(v) Initially, the volatile smell-giving molecules bind to specific receptors on olfactory sensory neurons in the nostrils creating generator potentials and firing impulses to brain at high frequency and thus the intensity of the smell seems great.
Without continuous stimulation; the frequency of generator potentials reduces and thus the intensity of smell reduces too.
Eventually the generator potentials along the olfactory neurons fall below firing threshold (as sodium channels get closed) and one fails to detect the foul-smell; of which by then the olfactory cells are said to be adapted; a phenomenon that allows the brain to ignore constant, non-threatening unchanging stimuli and remain alert to new and potentially important smells.

4 (a) From 1 to 3 days, increase in sugar content rapidly increases respiration rate of fruit to the peak. From 3 to 7 days, further increase in sugar content reduces respiration rate of the fruit.
(b) From 1 to 3 days, increase in sugar content increases respiration rate rapidly in order to generate sufficient energy required for the increased metabolic activity during ripening.
From 3 to 7 days, further increase in sugar content reduces respiration rate because the process of ripening is almost complete; cellular activity drops so the energy demand of the fruit reduces.
(**b**) The chlorophyll content of the fruit reduces while the carotene content increases. chlorophyll is being broken down by enzymes; carotenes are being synthesized so that the fruit attains an attractive colour (e.g., green to yellow/orange) of animals for seed dispersal.
(c) The rate of respiration increases to generate more metabolic energy to facilitate fruit ripening. Sugar content increases to make the fruit sweet and more palatable to animals which leads to its dispersal. Chlorophyll content decreases to allow fruits to ripen. Content of carotenes increases to give the fruit an attractive colour important in luring animals for dispersal.

(d) **Breakdown of cell wall components**, such as pectins, hemicelluloses, and cellulose by enzymes like pectinases and cellulases are responsible for degrading these components to softening it allowing fruits to become more palatable and facilitates seed dispersal through animals that consume the fruit;
Increased synthesis of volatile compounds including esters, alcohols, and aldehydes responsible for the characteristic flavors and aromas associated with ripe fruit contributing to the pleasant scent and taste of ripe fruit enhancing the attractiveness of ripe fruits to animals
Sugar accumulation occurs due to hydrolysis of starch reserves and the activation of enzymes involved in sugar metabolism contributing to the sweet taste of ripe fruit but also serves as a source of energy for seed development and germination
Increased breakdown of organic acids, such as citric acid, malic acid decreasing acidity of fruit contributes to the overall flavor balance of the ripe fruit;

5. (b) A fully plasmolysed cell has a very low (very negative) water potential due to loss of water and high solute concentration inside; and the cell membrane is pulled away from cell wall. When placed in a hypotonic solution (higher water potential outside), water enters by osmosis. As water enters, the solute concentration inside becomes diluted, and water potential increases (becomes less negative) due to increased kinetic energy of water molecules. Eventually, the vacuole expands, the cell membrane presses against the cell wall, and the cell becomes fully turgid, with water potential approaching zero.
(c) (i) Glucose uptake increases rapidly and then gradually to the maximum beyond which the rate remains constant.
(ii) The rate of water uptake increases rapidly; throught.

(d) As extracellular glucose increases, more molecules are available to bind to carriers, so the rate increases. When all carriers are occupied (saturated), further increases in glucose concentration do not increase the rate; hence rate remains constant; as by then rate is limited by the number of transport proteins.
Water passes directly through the phospholipid bilayer or via aquaporins. Diffusion rate increases as the concentration gradient increases. No saturation occurs under normal conditions, so the rate continues to rise with the gradient.

6. (a) Similarities: Antibodies initially low; antibody concentration increases after exposure in both; Both attain maximum/peak; Both decrease after maximum; Both increase gradually shortly after exposure.

Differences: First exposure	**Second exposure**
No antibodies initially present	Antibodies initially present
Attain a lower peak	Attain a higher peak
Increases less rapidly to peak	Increases more rapidly to peak
Rises gradually just after exposure	Rises rapidly just after exposure
Falls rapidly after peak	Falls very gradually after peak

(b) During the first exposure, **naive B cells are activated** for the first time; there is **no memory B cells specific against the virus present** at exposure; thus, the whole process takes time.
In contrast, during the second exposure, **already present memory B cells specific to the measles virus** are quickly reactivated; to release antibodies against the virus; leading to a faster, robust, and more sustained immune response to give long-term immunity.
c) (i) This is because the primary immune response, although slower, eventually leads to the production of sufficient antibodies to neutralize the virus. The immune system eliminates the virus over time, resulting in recovery.
(ii) Following the primary infection, **specific memory cells are formed and persist in the body**; and these enable a **rapid and robust secondary immune response if re-exposed**, preventing reinfection.
(iii) This corresponds to the incubation period during which the virus replicates and spreads within the host before **the immune system is sensitized to mount a significant antibody response**.
(iv) At birth, maternal antibodies acquired through the placenta can interfere with the vaccine by neutralizing the attenuated virus before the infant's immune system can respond. Vaccination is delayed until maternal antibodies decline, usually after 6 months.
d) Innate immunity is called the 'first line of defense' because it provides **immediate**, **non-specific** protection against all pathogens before the **adaptive immune response is activated**. It does not require prior exposure to the pathogen to develop.
In children, innate immunity includes: Skin and mucous membranes acting as physical barriers; Mucus and cilia in the respiratory tract trapping and expelling pathogens; Stomach acid destroying ingested microbes; - Phagocytic cells (e.g., macrophages and neutrophils) engulfing and digesting pathogens; Natural killer cells targeting infected cells; Inflammatory response that limits the spread of infections; Protective reflexes like coughing, sneezing; Lysozymes in saliva have antiseptic property; Vaginal acids in females

7. (a) (i) A quadrat is a square usually wooded frame of known area (say $1m^2$) used to sample organisms in a defined area. The abundance of millipedes in leaf litter are determined by;

- Randomly place the quadrat on the leaf litter at different points in the study area to avoid bias.
- Carefully collect or count all millipedes within each quadrat.

- Repeat this process at multiple locations to obtain a representative sample.
- Calculate the mean number of millipedes per quadrat.
- Multiply this mean by the total area to estimate abundance over a larger area if needed.

(ii) Random distribution; of millipedes in the habitat, so samples represent the whole area.
Representative sampling: Assumes the sample quadrats adequately represent the entire habitat's conditions.
Organisms counted once: Assumes no double counting of individuals in overlapping samples.
Organisms are visible and identifiable within the quadrat during sampling.
Population is relatively stable during the sampling period, with no immigration or emigration.
(iv) Non-random distribution: If millipedes cluster, random quadrats may not accurately reflect population density.
Small sample size: Too few quadrats may give inaccurate estimates.
Detectability issues: Organisms may hide or burrow, making them difficult to count.
Disturbance: Repeated sampling can disturb the habitat and affect organism's behaviour.
Time-consuming: Requires careful searching and counting, especially for small, mobile organisms.
Only samples a small area at a time, thus may be ineffective for a wide area
(b) Millipedes are important detritivores; they feed on decaying organic matter such as leaf litter and dead plant material; breaking down organic matter, speeding up decomposition and nutrient recycling.
By fragmenting leaf litter, they increase the surface area available for microbial decomposition.
This process enriches the soil with nutrients, improving soil fertility and supporting plant growth.
Millipedes also play a role in soil aeration as they burrow through soil and litter.
They form a key part of the food web, serving as prey for birds, reptiles, and small mammals

8. (a) A gene mutation is a change in the nucleotide sequence of the cistron of DNA; which leads to changes in the mRNA transcript and subsequently changes in the amino acid sequence of the encoded protein.
Gene mutations may lead to the expression of abnormal traits, loss of function, gain of function, or sometimes no change at all, depending on the nature and context of the mutation.
In case of a missense mutation; it results in the substitution of only one amino acid for another in the whole polypeptide chain; which depending on the location and nature of the substitution, the protein's tertiary structure and function may be mildly affected.
For a nonsense mutation, premature stop codon is introduced, leading to the production of a shortened and typically non-functional protein.
For a silent mutation; it alters the DNA sequence without changing the amino acid sequence due to the degeneracy of the genetic code; thus has no phenotypic effect.
For a frameshift mutation (due to insertion or deletion); it disrupts the triplet reading frame, leading to widespread changes in amino acid sequence and then a non-functional protein; changing phenotype.
(b) Deletion mutations, especially those involving the loss of one or two nucleotides, cause a frameshift in the reading frame of the gene. This alters every codon downstream of the mutation into a completely new re-arrangement, resulting in a completely different and non-functional polypeptide. Such proteins often contain abnormal amino acid sequences and premature stop codons, leading to shortened proteins that may be rapidly degraded or dysfunctional.
In contrast, a substitution mutation usually affects only a single codon, leading to:

- A silent mutation (no amino acid change),
- A missense mutation (change in one amino acid, possibly tolerable), or
- A nonsense mutation (a premature stop codon, which can be severe but localized).

(c) Homozygous recessive individuals (HbSHbS) **suffer from sickle cell anemia condition**, characterized by RBCs that assume a rigid, sickle shape under low oxygen conditions. These cells are

prone to rupture (hemolysis), block capillaries, and reduce oxygen delivery, leading to severe pleiotropic health complications which can be even fatal.
In malarial regions, heterozygous individuals (HbAHbS) have **a heterozygote advantage**; as they are **resistant to severe malaria infection,** as the parasite has difficulty surviving in their abnormal red blood cells; but also they have sufficient haemoglobin for sufficient oxygen delivery.
Homozygote dominants (HbAHbA) on the other hand suffer severe and fatal malaria due to the sufficiency and optimal conditions (RBCs) for malaria parasites reproduction.

9. (a) In **low salinity (dilute seawater)**; The **external environment is hypotonic** compared to the cytoplasm; o**smotic influx of water** occurs through the semipermeable plasma membrane. This increases the rate of **contractile vacuole contractions**, as the amoeba actively pumps out excess water to maintain internal osmotic pressure and prevent osmotic bursting.
With **increasing salinity**; the **osmotic gradient decreases**, so water enters the cell at a **slower rate**, thus, the **frequency of vacuolar contractions decreases**; to expel the decreasing excess water.
At very high salinity (100% seawater), the environment becomes very **hypertonic**, and water exits the cell osmotically instead. In such cases, vacuolar activity **ceases altogether**, as there's no excess water to expel.
(b) Species A vacuolar contractions cease (become zero) at a lower OPe which is hypothetically isotonic to its OPi thus species A osmoregulates to maintain a lower optimum OPi; while........
(c) **Species A is adapted to freshwater (water of lower salinity**) as its vacoular contractions cease at a lower OPe, where osmotic influx of water is significant, and vacuolar action is essential.
Species B is adapted to waters of higher salinity since it has greater tolerance to saline environments; by continiung to expel excess water at a higher OPe than species A.
(d) **Cyanide** is a potent **inhibitor of cytochrome oxidase**, a key enzyme in the **electron transport chain** of **aerobic respiration**.
In amoebae, **ATP is required** for the **active transport mechanisms** that drive contractile vacuole functioning, particularly **vacuole filling and expulsion**. In **freshwater**, where **constant expulsion of water** is required to prevent cell lysis, ATP-dependent vacuole contraction is **vital for survival**.
If cyanide is introduced: **ATP synthesis halts**, leading to **vacuole inactivity**; The amoeba **cannot expel excess water**, resulting in **osmotic swelling**; and eventually, the cell may **rupture** due to inability to regulate internal pressure.

10. (a) The **genetic code** is a unique sequence of nucleotides by which information encoded in DNA is translated into proteins. A **cistron** (gene) is a code with the following features.
A triplet code where each amino acid is coded by a sequence of three nucleotides called a **codon**
Non-overlapping as each nucleotide is part of only one codon;
Degenerate: More than one codon may code for the same amino acid
Universal: The same codon codes for the same amino acid in almost all organisms.
Punctuated: It has a start and a stop.
Non-ambiguous: A given triplet /codon can not code for more than one amino acid
(b)

Transcription	**Replication**
Synthesis of RNA from DNA template	Synthesis of new DNA molecule
RNA polymerase adds nucleotides	DNA polymerase adds nucleotides
Single-stranded RNA made	Double-stranded DNA made
Only one strand of DNA involved	Both strands are copied separately
Produces mRNA	Produces two identical DNA molecules

Transcription	Replication
Occurs during protein synthesis	Occurs during Cell division
DNA helix unwound by RNA polymerase	DNA helix unwound by DNA helicase
Product leaves nucleus	Product remains in nucleus
Uracil base used	Thymine used

(c) The ribosome assembles around the mRNA at the start codon (AUG) and the initiator tRNA carrying methionine binds to the start codon. Second tRNA molecule with anticodon complementary to the mRNA second codon bring specific amino acid to the ribosome, and fixes at the codon position thru codon-anticodon complementary base pairing; until the ribosome catalyzes **peptide bond formation** between the amino acids.The ribosome then moves along the mRNA, reading codons sequentially; one at a time elongating the polypeptide chain; as the same pattern is repeated; with release of tRNAs whose amino acids are already bound to the chain from the ribosomes. When the ribosome reaches a stop codon (UAA, UAG, UGA), translation ends and the completed polypeptide is released.

(c) tRNA folds into a cloverleaf shape due to complementary base pairing creating loops
Contains a sequence of three nucleotides (anticodon) complementary to the mRNA codon, allowing specific binding; Variable anticodon sequences enable it bind different amino acids
Has 3' end of tRNA has the sequence CCA where the specific amino acid is covalently attached.
Loops/ Arms provide sites for binding of enzyme molecules

11. (a) **Photoautotrophs** (e.g., *Cyanobacteria*): Use **light energy** to convert CO_2 and H_2O into organic compounds via **photosynthesis** contributing to **oxygen production** and **carbon fixation** in aquatic ecosystems.
Chemoautotrophs (e.g., *Nitrosomonas*, *Nitrobacter*); Obtain energy from **oxidation of inorganic compounds** (e.g., ammonia, nitrites) playing a central role in **biogeochemical cycles**, particularly the **nitrogen cycle** thru nitrification; reducing concentration of toxic ammonia
Saprophytic bacteria decompose dead organic matter esential for **nutrient recycling**, **humus formation**, and improving **soil fertility**.
Parasitic bacteria live in or on hosts, often causing disease (e.g., *Mycobacterium tuberculosis*); important in **host-pathogen coevolution**, and influence **population dynamics**.
Symbiotic bacteria form mutualistic relationships, e.g., *Rhizobium* in legume root nodules fix atmospheric nitrogen needed for efficient plant growth and **agricultural productivity**

(b) **Development of Limbs and Support Structures:** Evolution from aquatic fins to tetrapod limbs allowed effective movement on land Vertebral column and girdles evolved to support body weight against gravity. **Efficient Respiratory Systems**: Transition from gills to lungs in early amphibians and further adaptations in reptiles, birds, and mammals; Alveoli in mammals and air sacs in birds enable high-efficiency gas exchange.
Amniotic Egg: Evolution of the amniotic egg (in reptiles, birds, and mammals) allowed reproduction independent of water; provided protective membranes (amnion, chorion) and nutrient-rich yolk, supporting embryonic development.
Thermoregulation and Skin Adaptations; Keratinized skin reduced water loss: Evolution of homeothermy (constant body temperature) in birds and mammals increased metabolic efficiency.
Advanced Nervous System and Sensory Organs: Larger, more complex brains enabled better coordination, learning, and environmental interaction; Development of eyes, ears, and olfactory systems tailored to land life.

Efficient Excretory and Circulatory Systems: Evolution of kidneys adapted to conserve water: Double circulatory system improved oxygen delivery in terrestrial environments.
(c) Wide Range of Nutritional Modes to thrive in diverse environments. Saprophytic fungi decompose dead organic matter (e.g., *Mucor*, *Rhizopus*), contributing to nutrient recycling. Parasitic fungi live on living hosts and cause diseases (e.g. candida in women). Mutualistic fungi form symbiotic relationships (e.g., mycorrhizae with plant roots, lichens with algae).
Adaptation to Diverse Habitats; Soil (decomposers, mycorrhizae), Water (aquatic fungi), Plants and animals (symbiotic or parasitic),
Structural and Morphological Variations: Unicellular forms like yeasts adapt to rapid reproduction and sugar-rich environments; Septate vs. coenocytic hyphae allow for different growth and transport mechanisms within the fungal body.
Reproductive Diversity and Life Cycles: Genetic variation through sexual reproduction, Survival of unfavorable conditions via resistant spores.
Symbiotic Relationships: Mycorrhizal associations enhance nutrient and water uptake in plants and allow fungi access to carbohydrates. Lichens are capable of colonizing barren substrates and initiating ecological succession

12. (a) **Similarities In both**; Are equal from 1 to 3 trials; Increase gradually from 1 to 4 trials; Decrease gradually from 9 to 10 trials; Increase gradually from 10 to 14 trials; Increase gradually from 16 to 18 trials;
Differences in mean speed between group C and group B:
Group B gradually decrease while group C gradually increase from 4 to 6 trials;
Group B gradually decrease while group C gradually increase from 15 to 16 trials;
Group B gradually increase while group C gradually decrease from 17 to 18 trials;
Group B gradually decrease while group C gradually increase from 18 to 20 trials;
(b) Learning took place; because the mean speed for the rats to get through the maze increases; as the number of trials increases;
(c) The mean speed of group C is higher than group A; because rats of group C were given more pellets for food; thus a higher reward of food stimulus; the behaviour was reinforced more; while group A rats were given one pellet of food at the end of the maze; and behaviour was punished more; thus less likely to develop.
(d) (i) Operant learning behaviour; increases with experience; the mean speed of rats out of the maze increases with increase in number of trials; it is reinforced with food reward of food pellet.
ii) Genes; Species of the organism; Environmental stimuli; Experience (number of trials); Degree of complexity of learning situation
(e) Allows predators master appropriate hunting skills to easily capture prey; Allows prey to avoid predators;
Allows animals to quickly acclimatise to new environments; Habituation conserves energy of animals against irrelevant stimuli; Imprinting increases survival of offspring by bonding strongly to parents;
It improves courtships behaviour, and chances of mating and reproduction;
(f) **Living in groups increases success of organisms by:**
Better protection against predators, such as improved detection or escape system;
Better use of and defence of limited resources; Increased feeding efficiency;
Increased reproductive efficiency;
Increases survival of offspring through communal feeding and protection;
Saves energy by endothermic animals as a result of being close together;
Saves energy by moving fish and birds which take advantages of vortices created by others in a group;
Group living decreases survival by:

Increased competition of resources; e.g. water, food etc.; Increased susceptibility to diseases and parasites;
High risk of being harvested by humans; High risk of cannibalism on the young individuals.

13 (a) (i) Allen's Rule states that **animals in hot climates** tend to have **longer extremities** (ears, tails, limbs) than those in colder climates. This increases **surface area** across which heat is lost for cooling. **Desert mammals have long ears, legs, and tails** to help radiate excess heat. These appendages are **thin to increase rate of radiation of heat and richly vascularized** allowing efficient transfer of heat from blood to the environment.
(ii) Bergman's Rule states that within a species, **individuals in hotter climates tend to have smaller body sizes** than those in colder regions. This is because a smaller body has a **higher surface area-to-volume ratio**, promoting **faster heat loss**. Desert mammals are often **smaller and leaner** compared to their relatives in colder regions facilitating heat loss and reduce heat storage.
(b) Water produced from fat = 40,000 g × 1.07 g = 42,800 g (or 42.8 kg)
Water Loss via Respiration per dm^3 of air = 44 - 5 = 39 mg
Camels breathe continuously and lose significant water vapour with each breath due to the high difference in humidity between inhaled and exhaled air. At 40°C, camels lose much water through sweating and evaporation for thermoregulation. particularly respiratory water loss and evaporative cooling under high desert temperatures which can not be accounted for by only metabolic water from the hump.
(ii) The camel fat is 10% of its body weight while human fat is 20% of body weight. However, the camel's fat is localized in the hump, while in humans it is more evenly distributed under the skin and around body organs.
- Camel's localized fat storage minimizes insulation over the body surface, increasing heat loss.
- Human widespread distribution of fat offers a better thermal insulation and energy reserves suitable for a variety of climates.
(iii) Camels likely have juxtamedullary nephrons with longer loops of Henle, increasing the medullary osmotic gradient enhances high water reabsorption; and a thicker medulla which allows for more effective counter-current multiplication; resulting in minimal water loss via urine crucial for desert survival.
(c) (i) Walking naked results in higher sweating compared to clothed due to direct sun exposure. Clothes reduce solar radiation reaching the skin. Evaporation is more effective on bare skin; hence more sweating is needed to maintain body temperature.
(ii) Carrying 15kg mass increases sweating because physical effort raises metabolic rate and heat production, requiring more sweating for thermoregulation.
(iii) Sweating is higher when lying on the ground than sitting due to heat conduction from the hot ground surface over a larger surface area. The ground at 38°C transfers much heat to the body, increasing core temperature and triggering more sweating.

1**4. (a) Changes in amylase activity:**
Amylase activity is constant from 0 to day 1; It increases gradually from day 1 to day 3; It increases rapidly from day 3 to day 6; It increases more rapidly from day 6 to day 7; It increases gradually from day 7 to day 8;
It decreases gradually from day 8 to day 10; It decreases rapidly from day 10 to day 12;
(b) Rate of increase in amylase activity = $\frac{change\ of\ amylase\ activity}{change\ in\ time}$

$$= \frac{(4-0.5) arbitrary\ units}{(6-4) days}$$

=1.75 arbitrary units/ day

(c) Amylase catalyses hydrolysis/ digestion/ breakdown; of complex starch in the endosperm of barley; to simple sugars; translocated to the embryo for respiration; to produce ATP energy; for cell division and biosynthesis;
(d) From 0 to day 1, activity of amylase is constant; because no amylase is available; the testa is hard and very little water in the seed;
Amylase activity increases from day 1 to day 8; testa softens due to imbibition of water into the seed; water activates the synthesis of Gibberellic acid by the embryo cells; they are translocated to the aleurone layer; stimulate synthesis of alpha amylase enzyme; which catalyses the hydrolysis of starch in the endosperm;
(e) Beyond day 8, amylase activity decreases; because amylase synthesis reduces; as germination progresses endosperm starch reduces; and the substrate concentration for amylase activity decreases; The leaves of the embryo emerge; and the seedling utilises simple sugars made form photosynthesis; Reduction in amylase activity allows the plant tissues too store excess starch for future use; and increases the dry mass of the plant;
(f) Softens the seed coat; Allows easy diffusion of oxygen to the embryo for respiration;
Allows easy emergence of the embryo during growth;
Allows entry of water for cell elongation in the embryo for faster growth;
Allows hydrolysis of complex food reserves;
For translocation of metabolites during germination process;
(g) Exposure of the soaked seeds to air; provides oxygen to the embryo to carryout aerobic respiration to produce much energy for faster germination; Incubate at optimum temperature; to activate enzymes to catalyse metabolic reactions in the cells of the embryo; Apply growth promoters; for example GA to overcome the effect of growth inhibitors; Use of buffer medium to maintain PH; favourable for enzyme activity;

15. (a) The concentration of dissolved oxygen decreases rapidly; due to aerobic respiration; where the oxygen is used in the mitochondria as a substrate; to accept electrons at the end of the electron transport chain; to form ATP energy;
The electrons are obtained from succinate; by the Kreb's reaction in the mitochondrial matrix; succinate diffuses into the mitochondria from the medium;
(b) Sodium azide is an inhibitor; of aerobic respiration in the mitochondria; because dissolved oxygen becomes constant from 5 to 10 minutes; after sodium azide is applied; implying it stops the process consuming oxygen;
(c) Buffer solution prevents a fall in P^H; which lowers the affinity of enzymes in the mitochondria; as the enzymes become denatured; this is because oxidative decarboxylation produces carbon dioxide;
(d) Mitochondrion has enzymes in the matrix; to catalyse Kreb's reactions;
It is elongated and cylindrical; increases spaces for the Kreb's reaction;
It has circular DNA; to direct the synthesis some respiratory enzymes;
The mitochondrial matrix has coenzymes like NAD; these facilitate oxidation of respiratory intermediates;
Mitochondrial membrane is permeable; allows entry of metabolites of the Kreb's cycle;
Mitochondrial envelop has double membrane; which isolates Kreb's reactions for optimum conditions;
(e) **During exercise:** Aerobic respiration produces ATP energy; using oxygen delivered to tissues by haemoglobin; due to increased pumping of the heart; and increased breathing rate;
Oxygen is also obtained from myoglobin reserves when the oxygen demand is high;
Anaerobic respiration also provide energy; by glycolysis; and produces lactate.
The glucose required is supplied by blood; derived from glycogen reserves; and other substrates like lipids are also used; Creatinine phosphate also provides energy used to make ATP;

After exercise, energy demand decreases and the body relies mainly on aerobic respiration to produce ATP; used to transport lactate out of cells to the liver; restore oxygen reserves in myoglobin; and creatinine phosphate reserves;

17. (a) A phospholipid consists of glycerol backbone; two non-polar fatty acid tails each attached to the first and second carbon of glycerol via ester bonds; A phosphate group is attached to the third carbon of glycerol, which is often further bonded to an additional polar group making the head hydrophilic/polar
(b) The primary structure of a protein is the linear sequence of amino acids in a polypeptide chain, joined by peptide bonds. This sequence is directly determined by the nucleotide sequence of a cistron, which is the coding region of a gene.
Each group of three nucleotides in the cistron forms a codon, which specifies a particular amino acid according to the genetic code. During transcription, the cistron is copied into mRNA, which is then translated by ribosomes. tRNA molecules carrying specific amino acids, recognize codons via anticodons and ensure the correct amino acid sequence is assembled, thus linking the cistron sequence to the primary structure of the protein.

(c) **Folding**: the polypeptide folds into a specific tertiary or quaternary structure, stabilized by hydrogen bonds, ionic bonds, disulphide bridges, and hydrophobic interactions, forming the active site.
Cleavage: In some cases, the polypeptide is cleaved to activate the enzyme (e.g. trypsinogen to trypsin).
Addition of functional groups: Includes phosphorylation, glycosylation, methylation, acetylation, and lipidation, which can affect enzyme activity
Assembly into quaternary structure: Some enzymes consist of multiple subunits that must assemble correctly.
(d) At low temperatures, phospholipids pack closely, and the membrane becomes less fluid and more rigid which can impair membrane protein function and reduce permeability. At high temperatures, increased kinetic energy causes phospholipids to move more freely, making the membrane too fluid and potentially leaky.
To adapt, animals in cold environments may:

- Incorporate more unsaturated fatty acids into phospholipids, which have kinks in their tails that prevent tight packing, maintaining membrane fluidity.
- Increase cholesterol content, which acts as a fluidity buffer: it restricts movement at high temperatures and prevents tight packing at low temperatures; and vice versa.

18. (a) (i) Fertilisation is most likely to occur around day 20; when ovarian follicle diameter was largest meaning it was at full rupture; ovulation occured
(ii). Degeneration (shrinking) of the corpus luteum from day 28 onwards
Restart of follicle development; from day 36 new follicles begin to develop, indicating start of a new menstrual cycle.

(b) High LH levels stimulates ovulation at day 20; and development of corpus luteum is active which in turn is stimulated to secrete progesterone; which maintains the thickened endometrium in preparation for implantation. Beyond day 28, corpus luteum begins to degenerate since fertilisation did not occur; and LH level dropped significantly. Meanwhile progesterone levels fall, leading to breakdown of the endometrial lining (menstruation (around day 28–34). A new follicular phase starts, as FSH levels rise, stimulating the development of new follicles (day 30–38).

(c) (i) Negative feedback ensures optimal hormonal balance and regulation at different levels during different times ensuring correction of hormonal imbalances such that the right sequence and timing of different events occurs along the cycle
(ii) Prepares the body for reproduction; Maturation of ova and development of the endometrium for possible implantation; Regulates hormone levels; Healing and repair of uterine wall; Resumption of development of new follicle; Shedding of endometrium at end of cycle
(d) (i) In spring and summer, **conditions are favorable** (warm, abundant food), so **asexual reproduction (parthenogenesis) occurs** producing only females to **allow rapid population growth thru utilising the favorable conditions**.
In autumn, **conditions worsen** (cold, scarce food), triggering **sexual reproduction to produce males and resting eggs**, which **survive remain dormant and survive harsh conditions** of incoming winter.
(ii) Rapid population growth during good conditions ensures dominance and quick colonization.
Genetic variation from sexual reproduction increases adaptability to changing environments.
Resting eggs produced during sexual reproduction are resistant to cold and desiccation, ensuring survival through winter.

19. (a) The highest pressure is in the aorta due to the direct pumping action of the heart; involving contractions of heart muscles that cause the rises in pressure and relaxation of heart muscles that cause drops in pressure as blood flows thru arteries. As blood flows, resistance caused by friction against vessel walls and branching of few large into many smaller vessels reduces pressure. Capillaries have the highest drop in pressure due to their very narrow diameter and so large total cross-sectional area. By the time blood reaches the vena cava, the pressure is very low despite their wide lumen.
(b) Blood velocity is highest in the aorta due to its large diameter and high pressure by the pumping of heart. As blood moves into arterioles and especially into capillaries, velocity decreases sharply. This is due to the increased total cross-sectional area of the capillary network, which slows down the flow to allow for exchange of materials. Velocity increases slightly as blood enters venules and veins due to decreasing total cross-sectional area,
c) Presence of one-way valves that prevent backflow of blood and ensure unidirectional flow toward the heart.
- Skeletal muscle contractions: Muscles surrounding veins contract during movement, compressing the veins and pushing blood forward.
- Respiratory movements: During inhalation, pressure in the thoracic cavity decreases, drawing blood into thoracic veins.
-Pumping action of the heart provides the initial force to propel blood thru all vessels
d) An overall increase in blood pressure ensures that adequate blood flow is maintained to vital organs during injury. Local vasodilation around the wound causes increased blood flow to the area to supply more oxygen and nutrients needed in energy generation reactions of the metabolically very active phagocytic cells at the site; swelling in the area enhanced delivery of immune cells (like phagocytes) to the wound to combat infection.

20 (a) (i) Water stress refers to the physiological condition in **plants** that arises when the **availability of water in the soil is insufficient** to meet the **metabolic demands** of the plant; e.g. when transpiration rate exceeds water absorption rate on very hot dry days
(ii) Physiological drought refers to a situation where plants are unable to obtain (sufficient) water from its environment despite its abundance; due to external factors such as high salinity in halophytes, and extremely low temperatures when water freezes in winter

(b) - Reduced cell turgor, leading to wilting and drooping of leaves.
- Closure of stomata to reduce water loss, which limits CO_2 intake and reduces photosynthesis.
- Decreased growth rate due to reduced cell division and elongation.
- Leaf abscission and reduced leaf area to minimize transpiration.
- Accumulation of abscisic acid (ABA), which regulates stress responses.

(c) (i) Xerophytes like cacti and succulents store water in thick, fleshy stems or leaves; Reduced leaf surface area (e.g., spines in cacti) to minimize transpiration; Thick waxy cuticles and sunken stomata reduce water loss; Reversed stomatal rhythm to conserve water during day; Deep or extensive root systems to access deeper soil moisture; Stomatal distribution where upper epidermis has few or no stomata to reduce direct light effect which would increase evapotranspiration
(ii) Halophytes survive in saline environments by excreting excess salts via hydathodes; actively pump salts into their roots to raise the OPi of root cell sap above OPe to increase osmotic influx of water; Succulence to store water when its available for use when its inaccessible e.g. in winter; Freeze-tolerant tissues by forming antifreeze proteins to prevent ice crystal damage; Mycorrhizal associations enhance water and nutrient absorption in nutrient-poor or saline soils.

21.(a) (i) Biomagnification is the progressive increase in the concentration of non-biodegradable substances (such as pesticides like DDT or heavy metals like mercury) up a food chain; reaching toxic levels in top predators.
(ii) Pest resurgence occurs when a pest population, after being initially reduced by pesticides or biological control, rapidly increases to levels higher than before.
(b) **Specificity:** Targets only the pest species without harming beneficial organisms
Biodegradability: Breaks down into harmless products quickly, avoiding long-term environmental contamination.
Non-persistence: Does not bioaccumulate or persist in ecosystems, reducing the risk of biomagnification.
Effectiveness: Kills or suppresses the pest efficiently at low concentrations.
Low toxicity to humans and animals: Safe to handle and does not cause health hazards.
Cost-effective: Affordable and economical for farmers to use.
(c) (i) Pest resurgence may occur if the introduced control agent only at first suppresses, but does not completely eliminate the pest; Later the predator (control agent) population declines (e.g., due to environmental changes or lack of alternative prey), allowing pests to multiply again or if the natural enemy affects non-target species, disrupting the ecological balance and indirectly promoting pest outbreaks. Ecological imbalances in biological control can unintentionally lead to secondary pest outbreaks or resurgence of the target pest.

(ii) High productivity/ turnover rate of the producers e.g. phytoplankton in aquatic systems have a small standing biomass but a high rate of reproduction and photosynthesis. This rapid turnover provides a continuous supply of energy and nutrients to herbivores (e.g., zooplankton), allowing the consumer biomass to exceed that of producers at any one time.

(iii) Pesticide resistance arises through natural selection acting on genetic variation within a pest population:
Random mutations occur into alleles that confer resistance (e.g., through enzyme production, altered receptors). When a pesticide is applied, susceptible individuals die, while resistant individuals survive and reproduce.The resistant allele becomes more frequent in the gene pool over generations. Eventually, the majority of the population may become resistant, rendering the pesticide ineffective.

(d) This is an example of sympatric speciation; occurring within the same geographical area due to reproductive isolation.
The two strains of *Spartina* are ecologically differentiated: one is adapted to copper-rich soils (resistant strain), while the other is not. The difference in flowering seasons creates temporal isolation, preventing cross-pollination. Over time, genetic divergence accumulates due to mutations, genetic drift, and selection pressures specific to their respective environments. Eventually, reproductive isolation becomes complete, and the two strains may become distinct species, unable to interbreed even if their flowering times overlap **later**.

22. (a) An antibody is a Y-shaped glycoprotein; made of 4 polypeptide chains: quaternary structure; 2 identical heavy chains and 2 identical light chains, held together by disulphide bonds. Each chain has a variable region and a constant region: The variable region is at the tips of the Y arm while constant region is at the stem and lower parts of the arms Also has hinge region at the bend of Y- arm
(b) Neutralization: Bind to toxins or viruses and block their interaction with host cells.
Agglutination: Cause pathogens to clump together, making them easier for phagocytes to engulf.
Opsonization: Coating of pathogens to enhance recognition and phagocytosis by macrophages and neutrophils.
Complement activation: Binding of antibodies triggers the complement cascade, resulting in lysis of pathogens.
Precipitation: Antibodies bind soluble antigens, forming insoluble complexes that are removed by phagocytosis.
(c) Arteriolar vasoconstriction or vasodilation: changes in arteriole diameter control the **volume and pressure of blood** entering the capillary network.
Nervous and hormonal control: sympathetic nervous system and hormones (e.g., adrenaline) can alter arteriole flow to **redirect blood flow** as needed.
(d) Increased cardiac output: Heart rate and stroke volume rise, boosting **blood flow to muscles**.
Vasodilation of skeletal muscle arterioles: triggered by local metabolites (e.g., CO_2, lactic acid), increasing capillary flow
Shunting effect of blood flow: Blood is diverted from non-essential organs (e.g., digestive system) to **working muscles**.
Increased ventilation rate and depth: Enhances **oxygen uptake** in the lungs.
Bohr shift: Lower pH and higher temperature in muscles reduce hemoglobin's affinity for oxygen, facilitating **oxygen unloading** at tissues.
More capillaries; increasing **surface area for exchange**.
Increased oxygen extraction: Muscles extract a higher proportion of oxygen from the blood.
(e) Short-term changes
Increased ventilation rate: To increase oxygen intake due to lower atmospheric pressure.
Increased heart rate and cardiac output: To circulate available oxygen more rapidly.
Bohr shift enhancement: Promotes oxygen unloading at tissues.
Long-term changes
Increased red blood cell production: stimulated by erythropoietin hormone, raising hemoglobin levels.
Increased capillary density: improves oxygen diffusion to tissues.
Increased myoglobin content in muscles: enhances oxygen storage and transport within muscle cells.
Increased mitochondrial density and efficiency: Improves aerobic metabolism.
Altered hemoglobin structure: Higher oxygen affinity.

increased persistence and performance.

23. (a)

Organic Evolution	Adaptive Radiation
Gradual change in the genetic composition of a population over generations, leading to the formation of new species.	Rapid evolution of diverse species from common ancestor to exploit different ecological niches.
Driven by mutation, natural selection, recombination	Driven by divergent evolution due to environmental pressures and isolation.

(b) **Transient /Unstable polymorphism;** temporary polymorphism undergoing directional selection. One form may be replaced by another over time e.g. the peppered moth (*Biston betularia*) during the Industrial Revolution
Balanced polymorphism: Maintained over long periods due to natural selection maintaining multiple alleles.
e.g. Sickle-cell trait in malaria-endemic areas where heterozygotes are resistant to malaria.
(c) **Ecological significance**

- Enhances the population’s ability to adapt to environmental variation.
- Different forms may exploit different niches, reducing competition.
- Stabilizes population dynamics under changing conditions (e.g., seasonal variation).

Evolutionary significance

- Maintains genetic diversity, which is essential for long-term survival and adaptability.
- Acts as a reservoir of alleles for future evolutionary change.
- Can lead to speciation if polymorphic forms become reproductively isolated.

(d) From the chronological sequence; fossils in older low-lying layers of rock are more primitive and fewer in diversity than those in newer upper layer- rocks which are more complex and diverse showing gradual change over time
(e)

Change	**Significance for Survival**
Increase in size	Enhanced visibility and predator detection on open grasslands.
Reduction in toes (from 4 to 1)	Development of a single, strong hoof improved speed and efficiency of movement on hard ground.
Elongation of limbs	Enabled faster running, aiding escape from predators.
Development of high-crowned teeth	Allowed for efficient grazing of abrasive grasses, adapting to dietary shifts.
Enlargement of brain	Improved balance, coordination, and awareness, important in open environments.

24 (a) a) i) Releasers are simple stimuli / sequence of the stimuli produced by a member of a species which evokes an innate behavioral response in another member of the same species e.g. posture adopted by courting birds;
(b) **Hormones** serve as a motivational stimulus towards a given behavioral response;
They may affect the growth of nervous connections in the brain.
They may alter the sensitivity of peripheral receptors;
They may directly influence the performance of effectors; by either enhancing or suppressing them.
They may directly affect nerve cells, and synapses within the CNS and by so doing block inhibitory pathways or open exciting pathways;

Hormones can modulate the intensity, frequency, and expression of behaviors e.g. during the breeding season, increased levels of testosterone in male animals can lead to heightened aggression and territorial behaviour

(c) Thin placental barrier facilitates fast diffusion of nutrients; High vascularisation rapidly transports nutrients to maintain a steep diffusion gradient; Countercurrent flow across umbilical vessels maintains steep diffusion gradient; Foetal haemoglobin has a higher affinity for oxygen than adult haemoglobin ensuring efficient oxygen uptake from maternal blood

c) Advantages: Better protection of the developing embryo; Stable environment for optimal growth; Efficient nutrient supply enhances foetal development; Results in better chances of survival due to parental care and few young; Reduces competition as few young are born

Challenges: The mother requires more energy and nutrients to support the growing foetus; Fewer young can be carried at a time; Limits feeding and locomotion of the mother; Mother susceptible to danger while carrying foetus; Long gestation period in some species

(e) Young animals leave their birthplace before reaching sexual maturity; Animals can recognize relatives (via scent, sound, or visual cues) and avoid mating with them; Many species prefer mates that are genetically different based on visual cues and pheromones emitted; In social groups, **dominant individuals** do most of the breeding and the rest are less likely to mate

25. (a) (i)) Action potential is a rapid, all-or-nothing electrical impulse that travels along the axon of a neuron on liminal (threshold) stimulation while generator potential is a graded electrical signal produced by neuron in response to a stimulus varying with stimulus intensity; GPs can summate temporally (over time) or spatially (over different areas) to produce a larger potential; If large enough to reach the threshold, it can initiate an action potential in the sensory neuron.

(ii) Simple reflex is an inborn automatic response to a specific stimulus while conditionned reflex is a learned response to an originally meaningless neutral stimulus

(b) **Blocking neurotransmitter release** at synapse; **Neurotransmitter degradation** e.g acetylcholinesterase before they bind to receptors; **Blocking receptor sites o**n the post-synaptic membrane e.g., curare blocks acetylcholine receptors) Blocking sodium channels, preventing depolarization and neurotransmitter release; Opening of potassium or chloride channels causing hyperpolarisation of post-synaptic neuron; Insufficiency of neurotransmitter at synapse

(d) Having few synapses allows faster response due to few delays in impulse transmission; allowing a shorter pathway and quick coordination; minimises chance of transmission failure; less neurotransmitter is required; conserving energy in the nervous system.

26. (a) (i) From 100-300m, Oxygen concentration drops sharply due to the high amount of organic matter in sewage, which stimulates microbial activity. Microbes use up oxygen to decompose the organic waste; suspended solids reduce air mixing in water reducing rate of dissolving of oxygen in water; Reduced photosynthesis which yields oxygen

Further downstream from 300–500 m, Oxygen levels gradually increase as the organic load decreases and re-aeration from the atmosphere and photosynthesis by aquatic plants or algae replenishes the oxygen; reduced microbial activity

(ii) At and near the sewage discharge (100–200 m**);** BOD is very **high** due to a large load of decomposable organic material; where there is a lot of aerobism by microbes.

Further downstream; BOD decreases as organic matter is broken down and fewer decomposers are active due to decreasing food supply.

(b) **Ammonium ions** immediately increase **after sewage discharge** due to **the breakdown of proteins and urea in the sewage by microbes** into NH4+; in addition to their already high amounts in the sewage.

Further downstream: Ammonium levels **decrease** while **nitrate levels increase** because of **nitrifying bacteria** (e.g., *Nitrosomonas* and *Nitrobacter*) converting ammonium into **nitrites** and then **nitrates** through **nitrification**. Dilution of ammonium ions downstream also accurs

(c) (i) Sewage contains **nutrients (nitrates and phosphates)**, which can cause **algal blooms**. Between 200–450 m, these blooms flourish initially due to high nutrient levels.

Over time, **dense algal growth** may: **Block sunlight** from reaching submerged plants; which later **die off in large amounts**, leading to increased **BOD** as decomposers break them down; **Further deplete oxygen**, causing **anoxic conditions**, killing fish and other aerobic aquatic life; Long-term blooms can lead to **eutrophication**, destabilizing the aquatic ecosystem.

(ii) During a dry season, **river flow decreases**, and there is **less dilution** of pollutants. Oxygen levels fall faster due to **stagnant water** limiting re-aeration; i**ncreased temperatures** accelerates microbial activity and oxygen depletion; pollutants becomes **more concentrated** in the river with reduced dilution and **more harmful** to aquatic life; greatly reducing biodiversity

(iii) **Turbidity** – Indicates presence of suspended solids; high turbidity may suggest pollution.
Colour and odour – Foul smells can signal chemical or organic contamination.
Temperature – Elevated temperatures can affect dissolved oxygen and indicate thermal pollution.
Flow rate – Low flow correlates with higher pollutant concentrations.
Presence of floating debris or foam – Can indicate industrial or domestic waste inputs

27. (a)

LIPIDS	**CARBOHYDRATES**
Smaller proportion of oxygen	Larger proportion of oxygen
Esters	Aldehydes or ketones
Low solubility (insoluble) in water	High solubility in water
Yield twice more energy on oxidation	Yield less energy on oxidation
Do not form long chain polymers	Form long chain polymers

Similarities: Both are energy Storages; composed of C, H, and O; both are organic compounds;

(b) Lipids have a higher calorie value; thus are a **more efficient energy storage form**, allowing animal to store **more energy in less body mass**, which is crucial for surviving long periods without food; and still when metabolized, they produce **metabolic water** that helps the animal **stay hydrated** during hibernation without drinking.

(c) Phospholipids are components of cell membrane where they determine selective passage of materials across; Waxes are used in construction of honey combs; Storage e.g. in linseed, castor, peanut; water proofing using an oily secretion produced by glands near cloaca of birds, Insulation; Source of metabolic water on oxidation; a store of fat soluble vitamins; They provide **long-term energy reserves** especially in animals, Lipids cushion and **protect vital organs** from mechanical damage; Steroid hormones regulate many body functions e.g. testosterone;

28. (a) (i) Stimulation causes slight depolarization of the neuron membrane; Voltage-gated **sodium (Na^+) channels open**, **allowing Na^+ to rush into the cell**. This increases depolarization, making the membrane potential even less negative; **opening more Na^+ channels**, causing **further Na^+ influx**; thru a positive feedback loop; **until a threshold** is reached and the action potential is fully generated.

(ii) In non-myelinated axons, the action potential propagates by **local currents**: When an area of the axon membrane depolarizes, Na^+ enters to threshold firing an action potential. The local influx of Na^+

creates **electrical currents that depolarize the adjacent section of the axon**. This **opens voltage-gated Na^+ channels in the next segment**; Meanwhile the previous segment gets repolarised due to opening of K+ channels causing K+ efflux. Depolarization at one segment causes adjacent segments to depolarize, propagating the impulse along the axon.
(iii) The foetus pushes against the cervix, **stimulating stretch receptors**. This sends nerve signals to the hypothalamus, prompting the posterior pituitary to release oxytocin; which causes **stronger uterine contractions**, pushing the foetus further against the cervix; **More stretching leads to more oxytocin release**; and this positive feedback loop continues (more stretching → more oxytocin → stronger contractions) until the baby is born.
(b) **Low thyroxine levels** in blood are detected by the **hypothalamus**; the hypothalamus secretes **thyrotropin-releasing hormone (TRH);** stimulates the **anterior pituitary** to release **thyroid-stimulating hormone (TSH)**; which further stimulates the **thyroid gland** to produce and release more **thyroxine to rise to the norm**
When thyroxine exceeds norm; it **inhibits** the secretion of TRH and TSH by negative feedback **prevents excess thyroxine** production; already excess thyroxine is transported to the kidney for excretion in urine or degraded by liver cells.

29. (a) Re-arrangement of genetic material between different molecules of DNA; leading to the production of offspring with new combinations of traits that differ from those found in either parent; increases genetic diversity within a population. Gene recombination arises due to Crossing Over & Independent Assortment during meiosis, random ffertilization.
(b) Asexual reproduction allows for little or no recombination.
Inbreeding: Mating between closely related individuals reduces genetic variation and the opportunities for new combinations of alleles.
Small population size: Smaller gene pools mean fewer alleles are available for recombination.
Low mutation rates: Fewer new alleles are introduced into the gene pool
Genetic linkage: Genes that are located close together on the same chromosome are often inherited together, reducing recombination between them.
Nonrandom mating: individuals consistently choose similar partners; the variety of allele combinations remains limited.
(c) **Increasing genetic variation**: Recombination during meiosis shuffles alleles into new combinations, creating genetic diversity in offspring; resulting variation in traits **provides raw material for natural selection**; favoring those that confer a survival or reproductive advantage; Populations with greater genetic diversity ar**e better able to adapt to changing** environments, promoting evolutionary change.

30. (a) Chemical Digestion	**Physical Digestion**
Involves enzymes breaking down large, complex molecules into soluble, absorbable units	Involves mechanical breakdown of food into smaller pieces to increase surface area for enzyme action.
Specific to particular substrates (e.g., amylase acts on starch).	Non-specific, affects all food types physically.
Occurs mainly in mouth, stomach, and small intestine	Occurs in mouth (mastication) and stomach (churning).

(b) Both have muscular walls, mucosal linings, blood vessels, nerve supply.

Stomach	Ileum
Mainly for storage, mechanical churning, and initial protein digestion.	Mainly for absorption of digested nutrients and completion of digestion.
Lined with gastric glands secretory surface.	Lined with villi and microvilli Absorptive surface.
Thick muscular wall; for churning.	Thinner muscular layer for peristalsis, not churning.
Pepsinogen	peptidases, nucleotidases
Acidic due to HCl.	Slightly alkaline due to bile

(c) Intestinal phase is triggered when chyme enters the duodenum from the stomach; Hormonal
Secretin: Stimulates the pancreas to release bicarbonate ions to neutralize acidic chyme.
Cholecystokinin (CCK): Stimulates bile release from the gallbladder and enzyme secretion from the pancreas.
Enterogastrone: Inhibit gastric motility and secretion, slowing stomach emptying to allow efficient digestion and absorption.
(d) **Saprotrophic nutrition:** Fungi secrete digestive enzymes (extracellular digestion) onto dead organic matter; Enzymes break down complex compounds (e.g., cellulose, lignin); then absorb the formed soluble products through their hyphal walls e.g. *Mucor*, *Rhizopus*.
Parasitic nutrition: Some fungi obtain nutrients from living hosts, often causing disease; they form haustoria (feeding structures) that penetrate host tissues and secrete enzymes to digest host tissue e.g. *phytophthora infestans* that causes potato blight
Mutualistic nutrition: In mycorrhizae, fungi form mutualistic associations with plant roots where the fungus provide minerals, while the plant provides sugars. In lichens, fungi live with algae in a symbiotic relationship.

31.(a) As relative humidity decreases from about 7 to about 13 hours, the xylem tension increases; because saturation of vapour around the leaf surface decreases, creates more room for vapour to escape out of the leaf, which creates a vacuum with a lower pressure in the leaf substomatal region. Water is drawn from the leaf xylem and same tension is transmitted through the entire xylem of the stem.
As the relative humidity increases the xylem tension decreases, because less water is lost by transpiration, and water accumulates in the plant tissues including the xylem, which builds up turgor pressure.
b) At top of the tree xylem tension is higher than at the bottom, because the top of the tree has many leaves with many stomata, these lose a lot of water vapour to the atmosphere leaving a space with a much lower pressure, which is transmitted through the xylem in the leaves and top branches, while the bottom of the tree receives much water as result of root pressure, the accumulation of water in this region increases turgor pressure and decreases xylem tension.
c) Water is absorbed from the soil surrounding by root hairs; it crosses the cortex of the root via symplast, vacuolar and apoplast pathways; at the endodermis of the root all water is diverted to the symplast pathway by the casparian strip; the cells of the endodermis actively pump ions into the root xylem using ATP energy; and this lowers the solute potential of the xylem of the root; water rapidly fluxes into the root xylem by osmosis;
The root pressure is generated and moves the water at the base of the plant to about 1metre;
By cohesion, water molecules stick each other; and by adhesion they stick to the lignified wall of the narrow xylem; and rises a single column by capillarity;

The water column is further pulled towards the leaves by transpiration suction force; due to evaporation of water, that greatly lowers the leaf water potential;
d) Trunk diameter greatly decreases at 13 hours; because that is when the xylem tension is highest; at such time the sun is overhead and temperature and light intensity are at maximum; more transpiration occurs and most plant cells lose water; and turgidity; and size decreases;
(e) (i) Loading of sugars into the sieve tubes; occurs at the source, such as near photosynthetic cells or storage centers. In photosynthetic cells/ mesophyll cells of leaves, photosynthesis produces glucose, which is converted to sucrose in the cytoplasm which must be fed into sieve tubes using companion cells and in some flowering plants, they also use specialized parenchyma cells called transfer cells.
In storage tissues such as roots, tubers, or seeds, stored starch can be broken down into glucose and converted to sucrose for transport. Sucrose moves through plasmodesmata directly from mesophyll cells/ storage cells to the companion cells following a symplastic Pathway mainly. Sucrose can also be moved into the cell wall space following apoplastic Pathway and then actively transported into companion cells. H^+ are actively moved by specific carrier proteins called Proton pumps (or H^+-ATPases) in the plasma membrane of companion cells using ATP. These protons (H^+ ions) are moved from inside companion cells to the outside into their cell walls (the apoplast), creating a high concentration of protons outside the companion cells. Other carrier proteins (sucrose transporters) use this proton gradient to co-transport sucrose molecules along with protons back into the companion cells. Since companion cells are connected to sieve tube elements through numerous plasmodesmata., sucrose and other organic molecules move from companion cells into sieve tube elements via these plasmodesmata.

32. (a) i) **Bony Fish: Water is suitable because**; It has high density and high viscosity preventing collapse of gill filaments to maintain large surface area for gaseous exchange. It also prevents drying up of gills allowing easy dissolution and diffusion of oxygen into the gills.
Air is not suitable because; it causes drying of gill filaments reducing the dissolution of oxygen and diffusion into gills. It has low density and low viscosity hence causes collapse of gill lamellae reducing surface area for gaseous exchange
(ii) **Land mammals: Air is suitable because;** it has a high percentage of oxygen by volume allowing the animals to obtain enough oxygen and achieve high metabolic rates.
It has low density and low viscosity allowing less energy is spend on ventilation movements to deliver it to the respiratory surface.
Water is unsuitable. Oxygen content is too low to meet metabolic needs, High density makes ventilation difficult. High viscosity gives high resistance to passage through air tubes.
b) i) For most of the cycle, buccal cavity pressure is higher than opercular cavity pressure, so water is rushed from buccal cavity to opercular cavity.
Water flows from buccal cavity to opercular cavity in one direction.
Opercular cavity generates a suction force that draws water from buccal cavity.
ii) 0.45s have 1 cycle
60s have (1/0.45)x60 cycles
133 cycles/minute
iii) **buccal cavity:** From 0 to 0.15s, buccal cavity pressure increases due to raising of the floor of the mouth cavity caused by contraction of muscles in the floor. This reduces volume and increases pressure in buccal cavity.
From 0.15 to 0.23s, pressure decreases due to lowering of the floor of the buccal cavity. This increases volume and reduces pressure to let in water into the buccal cavity.
From 0.23 to 0.45s, buccal cavity pressure increases gradually due to influx of water through the open mouth.
Opercular Cavity:

From 0 to 0.12s, opercular cavity pressure increases rapidly due to influx of water from the buccal cavity.
From 0.12 to 0.23s, pressure increases gradually to a peak due to contraction of operculum reducing internal volume and water flows out.
From 0.23 to 0.3s, pressure decreases rapidly due to bulging of operculum outwards, increasing volume and reducing pressure.
iv) Fish with small lamellae that are closely packed have smaller opercular cavities because thin lamellae allow close packing allowing a large surface area for diffusion in a small space and vice versa

33. (a) From 0600h-1400hrs; rapid increase in sucrose content of leaves is as a result of increasing light intensity that increases leaf photosynthesis; increasing rate of building up of organic solutes like sucrose in leaves; that has to be translocated via phloem to the sink;
Peak of sucrose content of leaves at 1400hrs is as a result of high optimum light intensities favoring high rate of photosynthesis such that there is high rate of synthesis of sugars; for its translocation to the sink.
A rapid decrease in sucrose content of leaves from 2pm onwards is as a result photosynthesis rates decreasing due to reduced sunlight, while much is being translocated away via phloem; or used as substrate in the increasing respiration of plant leaves
(b) **similarities:** Both attain peak, Both lowest at 6am; Both increase from 6am to 2pm
Differences: Sucrose content of leaves attains higher peak; is higher throught; attains peak earlier; increases more rapidly to peak from 6am to 2pm.

(c) Sucrose content of leaves is greater than that of phloem since leaves **are the source / site of sucrose synthesis thru photosynthetic activity**. During the day, glucose is synthesized in chloroplasts via photosynthesis and quickly converted into sucrose leading to accumulation of sucrose in the leaf cells, especially when production exceeds the rate translocation from leaves.
While phloem acts as a transport route, not even a storage site for the sugar; thru which sucrose is actively loaded and immediately transported to sinks (e.g., roots, fruits, growing tissues).

(d) The rise in sucrose levels in leaves during daylight shows that sugars are synthesized via photosynthesis; and the subsequent **increase in sucrose concentration in phloem shortly after** the peak in leaves suggests that the sugars are **translocated** from the leaves to other parts of the plant.
Sucrose content of leaves is greater than that of phloem showing that leaves are the source where there should be higher solute concentration in comparison to sink; **enabling mass flow of these organic solutes into phloem**; and shows that the hydrostatic pressure as a result of osmotic influx of water from xylem is greater at leaves that the phloem /sieve tubes.
(e)

Phloem	**Xylem**
Translocates organic molecules	Transports inorganic solutes; ions
Bidirectional flow	Unidirectional flow
A positive pressure propels phloem sap	A negative pressure propels xylem sap
Movement hindered by metabolic poison	Metabolic poison has no effect
Active/ energy dependent	Passive
Due to mass flow; cytoplasmic streaming	Due to transpiration pull

35. (a) **Marine Teleosts**: Live in hypertonic environments thus tend to lose water excessively by osmosis and gain a lot salts; therefore have small and few glomeruli to reduce glomerular filtration excrete small volumes of highly concentrated urine; conserving water
Freshwater Teleosts: Live in hypotonic environments thus tend to gain a lot of water by osmosis and lose useful salts; therefore have large and numerous glomeruli to filter large volumes of blood, producing copious dilute urine to eliminate excess water.
(b) **Uric acid** is a **non-toxic**; **insoluble in water** nitrogenous waste excreted as a **paste or semi-solid** in **birds, reptiles, and insects**
It has an ecological significance of water conservation for organisms in arid or terrestrial habitats where water is scarce; since very little water is required in its excretion;
And has provided an evolutionary significance for animals to colonise hot dry land by minimizing water loss; and amniotes which are egg-laying species (e.g., birds, reptiles) as uric acid can be stored in the cleiodoic egg without harming the embryo, unlike ammonia or urea.
(c) **Estivation**: Dormancy during prolonged dry seasons (e.g., lungfish form mucous cocoons).
Burrowing into moist soil to avoid desiccation e.g. earthworms
Behavioral adaptations e.g. Nocturnal activity to reduce water loss during hot days e.g. desert shrews
Highly efficient kidneys with juxtamedullary nephrons that concentrate urine e.g., kangaroo rats).
Water reabsorption in the cloaca or rectum e.g. rectal glands of insects
Highly specialised water absorption surfaces e.g. antennal glands, malpighian tubules
Water storage in body tissues e.g. humps in camels which provide metabolic water
(d) **Seed dormancy:** Desiccation of seeds allows long-term survival in unfavorable conditions; enables **germination when water is available**.
Hibernation/Estivation: Dehydration helps **reduce water loss and metabolic rate**, supporting dormancy.:
Organisms being tolerant to low body water levels enables them survive in severe desert environments without needing constant hydration.

36. (a) Air has low density, low viscosity thus very diffusible with ease, contains much oxygen and has a high diffusion rate for gases
(b) Air rapidly travels through spiracles to tracheoles, delivering oxygen directly to muscle cells used in flight; Tracheoles penetrate deep into tissues minimizing the distance oxygen must diffuse; The branching network of tracheae provides a large surface area for gas exchange; A ventilation mechanism of the abdominal pumping movements force air in and out of the tracheal system, increasing gas exchange during flight.
(c) The exoskeleton is covered in a waxy cuticle which limits diffusion of gases across the body surface. Some cells lie deep within the body and cannot rely solely on diffusion from the surface. Insects require more oxygen to maintain their high metabolism than what simple diffusion could avail
(d) Numerous alveoli provide a **huge surface area** to maximize gas exchange; **Thin a**lveolar walls which are **one cell thick** minimizing diffusion distance for fast diffusion; **Moist lining** allowing gases to **dissolve before diffusion** enhancing efficiency; dense capillary networks surround alveoli **maintaining steep concentration gradients** for rapid oxygen and carbon dioxide transport. Breathing movements via diaphragm and intercostal muscles **refresh air in the alveoli**, keeping oxygen levels high and carbon dioxide low

37. (a) **Similarities**: %germination increases each day in the first 4 days; For both %germination attain maximum; From 10 days to 12 days, %germination for both remains constant; %germination increases gradually for the first 2 days.

Differences

%germination for long day illuminated seeds	**%germination for long day illuminated seeds**
higher	Lower
From 2 to 4 days, increases rapidly to maximum	Increases gradually
Attains maximum earlier	Attain maximum later
Attains higher maximum	attains lower maximum
Remains constant for a longer time	Remains constant for a shorter time
From 5 to 9 days; is constant	Increases during this time

(b) When seed were exposed to light, **phytochrome red absorbed red light** and rapidly converted to phytochrome far red which **accumulated to larger amounts** stimulating synthesis and **release of Gibberellins** that stimulate germination of seeds.

In the first 2 days small amounts of gibberellins are secreted by embryo causing gradually increase %germination for both long and short day illuminated seeds.

From 4 days to 6 days, increase secretion of gibberellins occurs from embryo, however due to the varying concentrations of Pfr available more gibberellins are produced rapidly in long day than in short day illuminated seeds thus causing a rapid increase in % germination for the long day illuminated seeds and a gradual increase for the short day illuminated seeds.

From 10 days to 12 days, %germination for both long and short day illuminated seeds remains constant because the embryo grows in to seedling which is not in position to produce gibberellins

(c) **Lack of water (moisture)**: water is essential for activating enzymes that initiate seed metabolism. Without adequate moisture, the seed remains dormant.

Oxygen deficiency: Seeds require oxygen for cellular respiration to produce energy for growth. Waterlogged or compacted soils can limit oxygen availability.

Extremes of temperature since each seed has an optimal temperature range for germination. Too cold or too hot temperatures can prevent or slow down the process

Presence of germination inhibitors: Some seeds contain natural chemicals (like abscisic acid) that prevent germination until conditions are favorable. These must be broken down or leached away.

Hard or Impermeable seed coat: Some seeds have tough seed coats that prevent water and gases from entering.

(d) **Auxins:** Promote cell elongation, apical dominance, and root initiation in cuttings. Involved in phototropism and geotropism.

Gibberellins: Stimulate stem elongation, seed germination, and flowering.

Cytokinins: Promote cell division and delay leaf senescence. Work with auxins to control growth.

Abscisic Acid (ABA): Inhibits growth, promotes seed dormancy, and helps the plant respond to stress (e.g., drought by closing stomata).

Ethylene: A gaseous hormone that promotes fruit ripening and leaf abscission.

(e) Light influences phototropism via auxin redistribution and triggers flowering in short- and long-day plants;

Gravity: Is detected by **statoliths** in root and shoot cells directing gravitropism

Touch: induces thigmotropism in climbing plants or trigger defensive movements e.g., in *Mimosa pudica*.

Water: availability triggers hydrotropism, guiding roots toward moisture.

38 (a) (i) Oxygen shortage: Increased breathing rate (hyperventilation) to take in more oxygen since more inhaled air will be reaching the alveoli more frequently; Increased heart rate to circulate oxygen-rich blood more quickly to tissues, especially the brain and muscles; Vasoconstriction in non-essential body organs such as skin constrict to redirect blood to vital organs like the heart and brain, ensuring they receive adequate oxygen.

Cells may switch to anaerobic respiration, producing energy without oxygen but generating lactic acid, which can lead to muscle fatigue; Release of erythropoietin from kidneys over time to stimulate red blood cell production, increasing the blood's oxygen-carrying capacity.

(ii) **Oxygen deprivation:** Oxygen deprivation (anoxia) causes rapid heart rate and rapid breathing: Initially, the body increases heart and breathing rates to maximize any available oxygen, but this cannot be sustained if deprivation persists.

Without oxygen, brain cells begin to die, leading to confusion, loss of consciousness, and irreversible damage to vital organs.

Cells switch entirely to anaerobic respiration, producing lactic acid and causing a drop in blood pH (increased acidity), which disrupts cellular functions. If oxygen deprivation continues, the body cannot maintain vital functions, leading to organ failure and death.

(b) (i) Mammals maintain a core body temperature of around 37°C through homeostatic mechanisms. The air temperature of 15°C is cooler than body temperature, but the body can effectively counteract heat loss due to; increased metabolism/respiration where the body generates enough heat to compensate for the lost heat to maintain constant temperature, Vasoconstriction reducing blood flow to the skin and minimizing heat loss to the cooler air, Shivering ie a rapid muscle contraction that generates heat to maintain constant body temperature, the men's skin subcutaneous fat provide insulation, slowing heat loss to the air

(ii) Heat Loss in Water: Water conducts heat away from the body much faster than air. When the men entered the water at 15°C, their bodies began losing heat rapidly through conduction to the cold water. The rate of heat loss exceeded rate of heat generation leading to temperature decrease in both men.

Person A, who swam, experienced a greater drop in body temperature due to increased convection since increased water movements around the body, enhancing heat loss by convection. As Person A moved through the water, the layer of warmer water near the skin was constantly replaced by colder water maintaining steep temperature gradient and accelerating heat loss.

Swimming involves active movement of arms and legs, exposing more of the body's surface area to the cold water, which increases the rate of heat loss.

Swimming increases blood flow to the muscles to supply oxygen and nutrients to muscles to yield energy for movement. This brings warmer blood to the skin, where it loses heat to the cold water more quickly, cooling the body faster. Swimming generates some heat through muscle activity, this heat is quickly lost to the water, and the net effect is a faster drop in body temperature.

Person B, who lay still, experienced a smaller drop in body temperature (1°C) because of minimized water movement around the body, allowing a layer of warmer water to form near the skin. This boundary layer acts as a partial insulator, slowing heat loss compared to the moving water experienced by Person A.

Staying still reduces the exposure of different body parts to the cold water, decreasing the overall rate of heat loss. Constriction of blood vessels in the skin, reducing blood flow to the surface and minimizing heat loss.

Lying still requires less energy than swimming, so Person B's metabolic rate was lower, reducing the need for increased blood flow to muscles and preserving core heat more effectively

40 (a) **Net Photosynthesis (N):**

From 20-30^{o}C, N increases with increasing temperature for both C3 and C4

From 30-40^oC, N in C4 continues to increase with while it decreases in C3
Below 23 ^oC, N is higher in C3 than in C4.
Above 23^oC, N is higher in C4 than in C3 plants,

Photorespiration (P):

P increases gradually with increasing temperature in C3 plants while it remains very low (almost zero) and constant in C4 plants.

(b) C3 plants are less efficient at higher temperatures because photorespiration increases, reducing net photosynthesis. Therefore they are better suited to cooler environments such as high altitudes and temperate regions.

C4 plants are more efficient at higher temperatures, with minimal photorespiration, making them better adapted to hot, dry climates such as low altitudes and semi-arid areas and in tropical regions (near equator). They maintain higher photosynthesis rates i.e. N due to no photorespiration.

(c) Suggest explanations for the differences in the physiology of the plants.

(c) (i) Photosynthesis

net photosynthesis (N = Photosynthesis - R). For C3 plants, the decline in N after 25°C, combined with rising photorespiration (P) and respiration (R), suggests that photosynthesis becomes less effective at higher temperatures. C3 plants use the Calvin cycle in mesophyll cells, where RuBisCO fixes CO_2 to form phosphoglycerate. However, as temperature increases, RuBisCO's affinity for CO_2 decreases relative to O_2, leading to increased photorespiration. This reduces the efficiency of photosynthesis, as some of the fixed carbon is lost through photorespiration.

C4 plants maintain a higher N across the temperature range because they have Kranz anatomy where a ring of mesophyll cells blocks atmospheric oxygen from reaching RUBISCO enzyme inside the bundle sheath cells. This prevents photorespiration. In mesophyll cells, CO_2 is fixed into a 4-carbon compound by PEP carboxylase, which has a high affinity for CO_2 and does not bind O_2 hence there preventing photorespiration.

The low photorespiration (P) allows C4 plants to sustain higher photosynthesis rates than in C3.

(ii) Photorespiration

The graph directly shows photorespiration (P) increasing sharply in C3 plants while remaining low in C4 plants. Photorespiration occurs when RuBisCO binds O_2 instead of CO_2, producing a 2-carbon compound (phosphoglycolate) that the plant must metabolize, releasing CO_2 and consuming energy. In C3 plants, photorespiration increases with temperature because RuBisCO's specificity for CO_2 decreases and instead combines with Oxygen as temperatures rise. The high photorespiration rate in C3 plants contributes to the sharp decline in net photosynthesis (N) due to increased loss of carbon by the plants in form of carbon dioxide.

C4 plants minimize photorespiration through their C4 pathway. By concentrating CO_2 in bundle sheath cells, they create a high CO_2 concentration from decarboxylation of malate in bundle sheath cells ensuring that RuBisCO primarily fixes CO_2 rather than O_2. the absence grana in bundle sheath cells prevents light reactions from occurring. This prevents internal generation of oxygen from photolysis of water thus preventing photorespiration. The mesophyll cell ring of cells also protects bundle sheath cells from atmospheric oxygen shielding enzyme RUBISCO in bundle sheath cells from photorespiration.

(iii) Respiration

Respiration (R) increases gradually in both C3 and C4 plants. Respiration is the process of breaking down sugars to produce energy, releasing CO_2 as a byproduct. As temperature rises, there is enzyme activation due to increased kinetic energy of enzyme molecules seeding up respiration in both plant types.