IJSO MCQ mock test

Biology Mock Test no. 1

This is an IJSO Biology mock test, designed to mimic the style, breadth, depth, and difficulty of IJSO biology questions. Its aim is to provide students with an array of problems to help them prepare for the IJSO and IJSO-like biology competitions.

The questions in this paper were made by the following past IJSO participants (in alphabetical order):

- Alex Jicu (Romania)
- Bianca Buzas (Romania)
- Ha Chi Vuong (Vietnam)
- Josephine Ankomah (Canada)
- Jathurshan Myuran (Sri Lanka)
- Mila Porjazoska (North Macedonia)
- Parthipan Kasiban (Sri Lanka) – Biology Mock no. 1 coordinator
- Ruslanbekov Ulukbek (Kyrgyzstan)
- Tamara Bračko (Croatia)

In solving the questions, you might need to use the following constants:

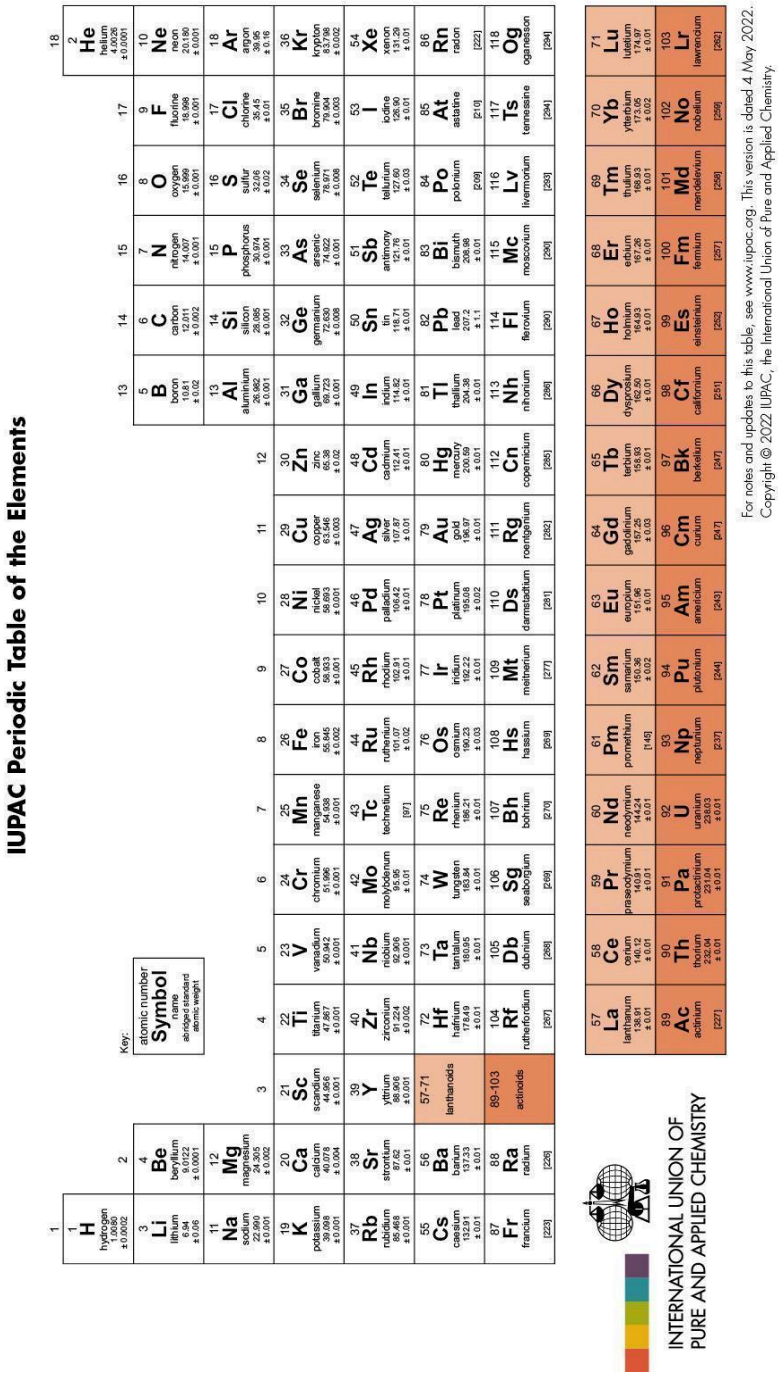
Constant	Notation	Value
Acceleration due to gravity	g	$9.8\ ms^{-2}$
Gravitational constant	G	$6.67{\cdot}10^{-11}\ m^3/\ kg{\cdot}s^2$
Planck's constant	h	$6.62{\cdot}10^{-34}\ J{\cdot}s$
Elementary charge	e	$1.6{\cdot}10^{-19}$ C
Speed of light in vacuum	c	$3{\cdot}10^{8}\ ms^{-1}$
Density of water	ρ	$1000\ kg\ m^{-3}$
Stefan-Boltzmann constant	σ	$5.67{\cdot}10^{-8}\ \frac{W}{m^2K^4}$
Universal gas constant	R	$8.314\ J\ mol^{-1}\ K^{-1}$ $0.0821\ atm\ L\ mol^{-1}\ K^{-1}$
Avogadro's number	N_A	$6.022{\cdot}10^{23}\ mol^{-1}$
Faraday's constant	F	$96\ 500\ C/mol$
Pi	π	3.14
Electrical permittivity of free space	ε_0	$8.85{\cdot}10^{-12}\ F{\cdot}m^{-1}$
Magnetic permeability of free space	μ_0	$4\pi{\cdot}10^{-7}\ H/m$
Mass of Earth		$5.97{\cdot}10^{24}$ kg
Mass of Moon		$7.35{\cdot}10^{22}$ kg
Mass of Sun		$1.99{\cdot}10^{30}$ kg
Radius of Earth		$6.4{\cdot}10^{6}$ km
Radius of Moon		$1.7{\cdot}10^{6}$ km
Radius of Sun		$6.96{\cdot}10^{8}$ km
Specific heat capacity of water	c_w	$4200\ J/kg{\cdot}°C$
Average molar mass of air	M	$28.9\ g/mol$

If any other value is provided in the problem, use the value provided, not the one in the table.
You can also use the following conversion formulas:

$T\ (K) = t\ (°C) + 273$	$t\ (°F) = \frac{9}{5}t\ (°C) + 32$
$1bar = 1atm = 101\ 000Pa = 760mmHg$	$1u = 1Da = 1.66{\cdot}10^{-27}kg$
$1L = 10^{-3}\ m^3$	1 day $= 24h$

If needed, you can use the periodic table given below:

(Use atomic masses rounded to two decimal places.)



(Use atomic masses rounded to two decimal places.)

Question 1 – Abiotic influence in the Arctic Tundra

An ecological research station was established in the high Arctic tundra to investigate factors affecting the distribution and survival of autotrophic organisms. Although this biome receives continuous daylight during peak summer, researchers observed very low biomass, minimal plant diversity, and large areas of exposed soil. While daily light conditions appear favorable, the team hypothesized that the limiting factors are not immediately obvious.

Which of the following abiotic conditions most plausibly explains the severe constraint on primary productivity among stationary autotrophs in this biome?

A. Consistently high humidity and extended photoperiods accelerate transpiration, leading to desiccation stress in exposed leaf tissues.

B. Intense ultraviolet radiation damages the photosynthetic apparatus, while volcanic soil chemistry prevents nutrient uptake.

C. The presence of permafrost, minimal nutrient cycling due to slow decomposition, and a severely compressed growing season limit biomass accumulation.

D. Low herbivore density and abundant soil moisture reduce selection pressures for hardier plant adaptations, limiting survival in extreme cold.

Problem proposed by Parthipan Kasiban

Question 2 – Evolutionary Relationships in the Artics

The group of researchers found a few animal species living close to their exploration site. To understand their evolutionary relationship, they gathered data on several characteristics found in those animals.

Species	Vertebral column	Amniotic egg	Hair/Fur	Hollow bones	Wings
Greenland shark	+	-	-	-	-
Arctic tern	+	+	-	+	+
Polar bear	+	+	+	-	-
Ringed seal	+	+	+	-	-

An absent character is absent its shown as -
A present character is shown as +

Based on this table select the correct statement out of the following:

A. The Arctic Tern shares a more recent common ancestor with the Ringed Seal than it does with the Greenland Shark.

B. The presence of "Hair/Fur" is a homologous trait that defines a monophyletic group including the Polar Bear and the Arctic Tern.

C. The Polar Bear and the Ringed Seal belong to different major evolutionary lineages, as indicated by their unique combinations of traits.

D. The common ancestor of all animals in this table that possess "Hair/Fur" also possessed "Hollow bones."

Problem proposed by Parthipan Kasiban

Question 3 – Study of Plant Leaves

A biologist studying photosynthesis and respiration in plants conducts a study in which he uses samples from the following plants: Nerium oleander (oleander – xerophytic plant cultivated in Sout-Western regions of Asia), Nymphaea alba (commonly known as the white waterlily), Eucalyptus spp. (native to Australia - adapted to having high photosynthetic rates in short periods of time) and Zea Mays (commonly known as corn).

He takes a sample from each side of each species leaves and labels them with different letters corresponding to different species, and numbers indicating the side from which the sample was taken. For example, A1 and C2 are from different species, while B1 and B2 are samples from the different sides of species B's leaves.

After some microscopic investigations, he obtains the following data regarding stomatal density (no. of stomata/mm2):

Sample	A1	A2	B1	B2
Stomatal density	156	147	0	358
Sample	C1	C2	D1	D2
Stomatal density	7	10	673	681

After finishing, he accidentally discarded the samples, without noting which sample corresponds to which species.

The following day, he wanted to continue his research but didn't know what species each sample came from. However, he was able to determine this from the data in the table.

After that, he continued his research and determined the area of a stomata in Zea Mays to be approximately 80 μm^2. What is the total area of the stomata on a Zea Mays leaf with each side having an area of 200 cm^2?

A. 249.6 mm^2

B. 484.8 mm^2

C. 572.8 mm^2

D. 2166.4 mm^2

Problem proposed by Alex Jicu

Question 4 – Osmoregulation in the digestive system

Sodium ions play a crucial role in regulating blood pressure and volume, enabling proper nerve and muscle function and managing the body's fluid balance. Being so important in our bodies, a change in its concentration can completely unbalance the organism.

Because of this, diarrhea has been considered a life-threatening condition as the speed with which waste is expelled from the body does not allow time for the reabsorption of the sodium ions in the colon and so its concentration decreases rapidly. Doctors have come up with a way to help patients who encounter this issue by having them drink a solution with high concentrations of NaCl and glucose. What was the doctors' reasoning for this choice of treatment?

A. By having a high sodium ion concentration, drinking the solution ensures that at least some part of the ions will remain inside the body (if diarrhea persists) to ensure the organism's systems can work normally.

B. For the absorption of enough sodium ions, a cotransport is necessary through the membrane of the intestinal cells. The glucose and the sodium will move in opposite directions through the Na^+/glucose cotransporter so that the movement of the glucose will give the energy necessary for the Na^+ to cross the membrane.

C. The cotransporter mentioned at B. is existent in the intestinal cells, however both the Na^+ and the glucose move in the same direction, as the Na^+ needs to be in the company of glucose to be able to cross the membrane.

D. The high NaCl content of the solution will get the concentration inside the body back to normal and the glucose will ensure that the body has a reliable source of energy after having it lost through the toll diarrhea takes on the body.

Problem proposed by Bianca Buzas

Question 5 – Plant Water Transport Under Stress

A botanist is studying a plant species endemic to a semi-arid region characterized by infrequent but intense rainfall, followed by long dry spells. The plant exhibits deep root systems and small, succulent leaves with a thick cuticle. During prolonged drought, the stomata remain closed for extended periods, and the plant's metabolic activity significantly slows down, but it avoids desiccation.

Which of the following physiological adaptations or processes is crucial for this plant's survival during severe drought conditions, beyond simply having closed stomata, and how does it relate to water potential?

A. Increased rate of transpiration to cool leaf surfaces, creating a strong negative water potential gradient that draws water from the soil.

B. Accumulation of compatible solutes (osmolytes) within cells, lowering their water potential and maintaining turgor pressure even at low external water potentials.

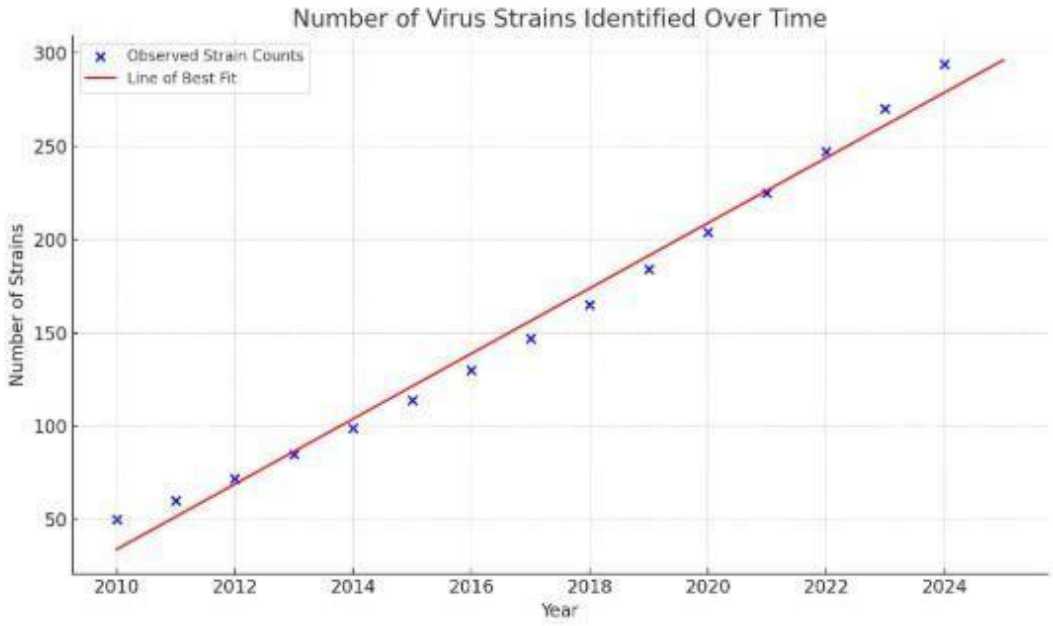
C. Enhanced activity of xylem sap in the roots, actively pumping water against the water potential gradient from dry soil into the plant.

D. Rapid shedding of all leaves to reduce photosynthetic demand, forcing the plant into a state of dormancy until water becomes available.

Problem proposed by Parthipan Kasiban

Question 6 – Virus strains in the Arctic

A Virus outbreak (caused by a virus named Virox-10) was first identified in 2010 in the Siberian region of Russia. The number of strains of this virus has been documented since then and is presented as a graph below.



Select the correct option and reason regarding the year in which the virus first evolved:

A. 2010, since that is the year the virus was first recorded and all prior data is speculative.

B. 2008, assuming an average 2-year delay from initial mutation to detection of multiple distinct strains.

C. 2009, based on graphical extrapolation where the trendline of strain accumulation intersects the x-axis.

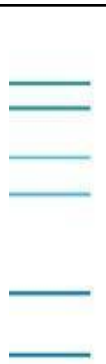
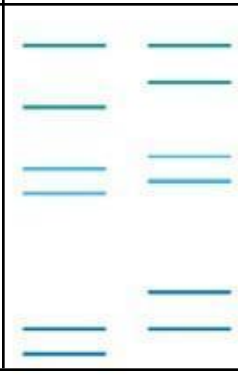
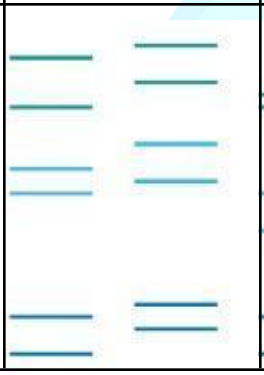
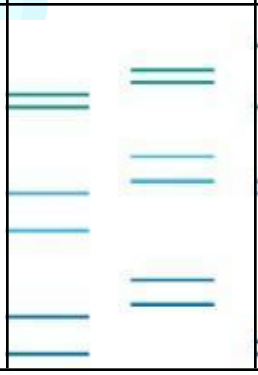
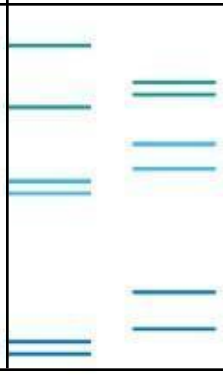
D. 2006, under the assumption that early strain emergence was slow and accelerated only after population exposure.

Problem proposed by Parthipan Kasiban

Question 7 – Multilocus Electrophoresis in Arctic Wolf

To find the biological parents of an abandoned Arctic wolf cub (C), researchers used multilocus electrophoresis. This molecular technique separates DNA fragments based on size, revealing unique genetic band patterns (genotypes) at multiple specific locations (loci) in the genome. An offspring inherits one allele (represented by a band) from each biological parent at every locus.

The table below shows the electrophoretic banding patterns for the cub and four potential parent pairs. Each band represents a distinct allele.

C	Pair 1	Pair 2	Pair 3	Pair 4
				

Which pair is most likely the parents of the cub

A. Pair 1

B. Pair 2

C. Pair 3

D. Pair 4

Problem proposed by Parthipan Kasiban

Question 8 – Allele frequency in Arctic Wolves

The parents of the cub were found successfully, and in an attempt to return it to them, the researchers encountered another pack of Arctic wolves not far from the research site. To understand the genetic diversity of this new pack, the research team recorded the genotypes of its members for a specific gene that regulates fur pigmentation. This gene has two alleles: **A** (dominant, leading to darker fur) and **a** (recessive, leading to lighter fur).

Among 50 wolves which were identified in the pack, 40 had dark fur and 10 had light fur.

Assuming a Hardy-Weinberg model, which of the following best describes the observed allele distribution and its deviation from equilibrium?

A. The population is in equilibrium; genotype frequencies (AA: 0.306, Aa: 0.494, aa: 0.20) match allele predictions based on $p^2 + 2pq + q^2$.

B. The population shows an excess of heterozygotes (Aa), likely due to heterozygote advantage or overdominance.

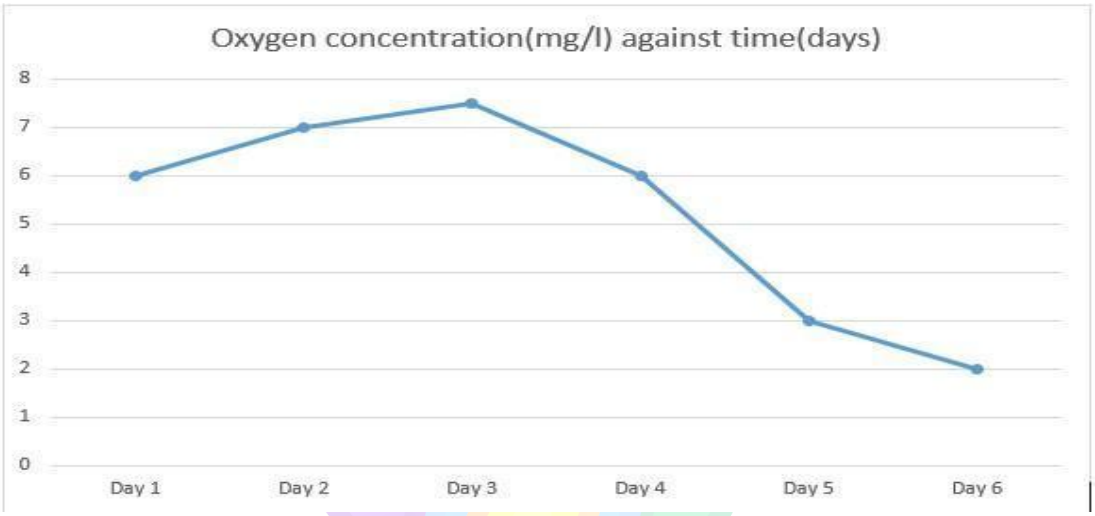
C. There is a deficiency of heterozygotes and excess homozygotes, suggesting inbreeding or non-random mating.

D. The ‘aa’ genotype is underrepresented, possibly due to strong negative selection against the lighter fur phenotype in snow-covered habitats.

Problem proposed by Parthipan Kasiban

Question 9 – Effects of chemical compounds in oxygen concentrations in a water body

Waste water from a newly formed industrial complex was found to be improperly discharged into a water body. Even though the immediate effects aren't obvious, an environmental conservation society was interested in its adverse effects on the environment. They documented the oxygen concentration of water samples taken from a depth of around a few metres throughout 6 days. Their results are shown below.



What could be the compound responsible for the change in oxygen concentration assuming that the industry began releasing wastes from the 1st day onwards?

A. Glucose and other related organic compounds

B. Bicarbonates or carbonate ions

C. Nitrates or phosphate ions

D. Heavy metal such as Mercury

Problem proposed by Parthipan Kasiban

Question 10 – Effects of pollutants in ecosystems

Further investigation reveals that the industrial discharge contained not just one type, but two primary persistent organic pollutants (POPs):

- Pollutant X: Highly lipophilic, very stable, and primarily accumulates in fatty tissues.
- Pollutant Y: Less lipophilic than X, slightly less stable (can undergo slow metabolic transformation in some organisms), and has an affinity for binding to certain proteins in muscle tissue.

Consider a long-lived, predatory bird species that feeds exclusively on the apex predators from the water body. This bird has a well-developed liver capable of metabolizing Pollutant Y into a less toxic but persistent metabolite, we'll call it Pollutant Z. This metabolite Z is also lipophilic and tends to accumulate in fat.

In which tissue of this predatory bird would you expect to find the *highest concentration of the combined total* of Pollutant X, Pollutant Y (including any remaining unmetabolized amount), and its metabolite Pollutant Z?

A. Brain tissue

B. Feather samples

C. Liver tissue

D. Adipose (fat) tissue

Problem proposed by Parthipan Kasiban

Question 11 – Thermoregulatory systems of Arctic Fox

The Arctic fox is supremely adapted to survive the harsh winters of its habitat, where ground temperatures can plummet to -50°C. Despite this, the fox's paws, which are in direct and prolonged contact with the icy ground, remain functional without significant heat loss or tissue damage. One key adaptation involves a specialized arrangement of blood vessels in their limbs. Arterial blood flowing from the fox's core towards its paws passes in close proximity to venous blood returning from the paws towards the core.

Which of the following detailed explanations best describes the primary benefit of this vascular arrangement for the Arctic fox's survival in freezing conditions?

A. By facilitating rapid vasodilation in the paw's arterioles when they come into contact with the ice, this arrangement ensures a surge of warm, oxygenated blood to prevent localized freezing of tissues and maintain nerve sensitivity in the paws for capturing prey.

B. This countercurrent heat exchange system pre-cools the arterial blood reaching the paws, thus minimizing the amount of heat that is lost to the extremely cold environment at the paw surface. Simultaneously, the returning venous blood is warmed by the arterial blood, reducing the energy expenditure required to maintain core body temperature.

C. The close proximity of arteries and veins in the paws allows for efficient diffusion of metabolic waste products from the cold paw tissues into the warmer arterial blood, preventing the buildup of toxins that could impair paw function at low temperatures.

D. This intricate network of blood vessels in the paws contains specialized valves that regulate blood flow based on the external temperature, diverting warm blood to the paws only when absolutely necessary to conserve energy during periods of inactivity.

Problem proposed by Parthipan Kasiban

Question 12 – Properties of histones

Eukaryotic genomic DNA, characterized by its extensive negative charge due to a phosphodiester backbone, is intricately condensed into nucleosomal units via interactions with octameric histone protein complexes. These histones, particularly rich in lysine and arginine residues, are not merely passive scaffolding proteins but serve as active regulators of gene expression through a complex code of post-translational modifications. One such modification—acetylation of ε-amino groups on lysine residues—is catalyzed by histone acetyltransferases (HATs), reducing net positive charge and modulating chromatin accessibility.

Which of the following most accurately describes the epigenetic and structural consequences of such a biochemical modification?

A. Promotes heterochromatin formation by stabilizing nucleosome–nucleosome interactions, thereby repressing gene expression.

B. Facilitates euchromatin expansion by disrupting histone–DNA ionic bonds, enhancing transcriptional accessibility of the chromatin fiber.

C. Leads to histone tail ubiquitination, triggering chromatin looping and long-range enhancer silencing.

D. Induces methylation of CpG islands within promoter regions, permanently inactivating associated transcriptional loci.

Problem proposed by Parthipan Kasiban

Question 13 – Population genetics in hare population

In a population of Arctic hares, coat color is determined by two codominant alleles: (CW) for white fur and (CG) for gray fur. Hares with genotype (CWCW) have white fur, those with (CGCG) have gray fur, and heterozygotes (CWCG) have a speckled white and gray coat. Tail length in this population is determined by a separate, independently assorting gene with two alleles: Long (L) is dominant to short (l). Researchers observe that 9% of the hares have a gray coat and 16% have a short tail.

Assuming Hardy-Weinberg equilibrium for both traits, what percentage of the Arctic hare population would you expect to have a speckled coat and a long tail?

A. 8.4%

B. 16.8%

C. 28%

D. 35.3%

Problem proposed by Parthipan Kasiban

Question 14 – Dysregulation of Cyclin D and G1/S Checkpoint Integrity

In the regulation of the eukaryotic cell cycle, progression from the G1 to S phase is mediated by the accumulation of Cyclin D proteins. Cyclin D forms a complex with CDK4/6 to phosphorylate the retinoblastoma (Rb) protein. This phosphorylation cascade releases E2F transcription factors, initiating S-phase gene expression. Suppose a somatic gain-of-function mutation in the CCND1 gene results in constitutive overexpression of Cyclin D in mitotically active epithelial tissues.

What is the most probable outcome of this perturbation within the framework of cell cycle dynamics?

A. Persistent hypo-phosphorylation of Rb, resulting in G1 arrest and reduced DNA replication fidelity.

B. Unchecked Rb inactivation, hyperactivation of E2F, and aberrant S-phase entry contributing to neoplastic transformation.

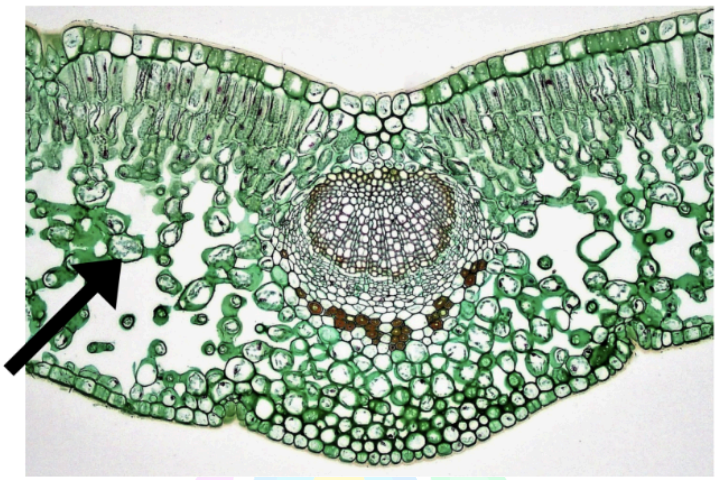
C. Enhanced p21-mediated feedback inhibition of CDK2, initiating programmed cell death to protect genomic integrity.

D. Activation of ATM/ATR checkpoint kinases due to cyclin misregulation, causing mitotic slippage and polyploidy.

Problem proposed by Josephine Ankomah

Question 15 — Analysis of leaf cross section

A sample of a leaf was collected and observed under a microscope. The transverse cross section of that leaf is given below:



Based on these features, which of the following best describes the species' photosynthetic strategy and environmental niche adaptation?

A. C3 dicot employing RuBisCO-mediated carbon fixation across mesophyll, optimized for temperate regions with diffuse light.

B. CAM plant utilizing temporal carbon fixation and malate storage in vacuoles for nocturnal stomatal opening in xeric habitats.

C. C4 monocot with Kranz anatomy enabling phosphoenolpyruvate (PEP) carboxylase-mediated carbon capture and translocation to bundle sheath cells, enhancing photosynthetic efficiency under high irradiance and low humidity.

D. Aquatic monocot with aerenchyma-dominated gas exchange zones, favoring bicarbonate assimilation and reduced stomatal reliance.

Problem proposed by Josephine Ankomah

Question 16 – Comparison of hepatic portal veins and systemic veins

In the human circulatory system, veins typically function to return blood from various parts of the body directly to the heart. This process is fundamental to the continuous supply of oxygen and nutrients to peripheral tissues and the efficient removal of metabolic waste products. Veins generally have deoxygenated blood which is low in nutrient contents and have valves to prevent backflow.

Unlike systemic veins which primarily function as passive conduits of deoxygenated blood toward the heart, the hepatic portal vein represents a specialized vascular network that transports nutrient-rich but oxygen-depleted blood from the gastrointestinal tract to the liver. This system enables first-pass metabolic processing, allowing hepatocytes to detoxify xenobiotics, synthesize plasma proteins, and regulate glucose levels prior to systemic circulation.

Which of the following most accurately characterizes this hepatic circulatory specialization?

A. Directly channels oxygenated blood from the pancreas and stomach to the heart, ensuring rapid nutrient assimilation.

B. Facilitates primary hepatic metabolism of absorbed compounds including amino acids, monosaccharides, and lipid fragments, thus acting as a metabolic filter before systemic dissemination.

C. Operates independently of capillary beds, allowing blood to bypass hepatic tissues en route to renal clearance.

D. Functions identically to systemic veins, with unidirectional valves and oxygen gradients determining nutrient flow.

Problem proposed by Josephine Ankomah

Question 17 – Structural Neurobiology of Reflex Arcs

Within the somatic nervous system, the rapid transmission of stimuli from peripheral receptors to effectors is mediated by reflex arcs. Sensory (afferent) neurons are pseudounipolar, allowing direct relay from dendritic terminals to the central nervous system with minimal synaptic delay. Motor (efferent) neurons are multipolar, enabling integration of complex upstream inputs and coordinated muscular responses. This structural asymmetry reflects an evolutionary optimization for speed and specificity in reflex physiology.

Which of the following best explains the contribution of this neural architecture to reflex efficiency?

A. The bipolar morphology of sensory neurons enhances spatial summation, improving localization of stimuli for precise motor feedback.

B. Pseudounipolar sensory neurons facilitate direct signal transduction to spinal interneurons, minimizing synaptic latency and maximizing reflex speed.

C. Multipolar motor neurons reduce conduction velocity, thereby ensuring graded responses to variable sensory input.

D. Dendritic redundancy in motor neurons provides fault tolerance in action potential propagation, increasing reflex reliability under stress.

Problem proposed by Josephine Ankomah

Question 18 – Plant dependency on Bees

At the end of 2006, beekeepers in Kyrgyzstan began noticing a troubling phenomenon—the sudden disappearance of honeybees from commercial hives. This mysterious condition was termed "colony collapse disorder," which led to a sharp decline in the population of commercial honey bees across the country. It is estimated that one-third of our food supply depends on bees and is now at risk. Crops that rely most heavily on honeybees include apples, almonds, blueberries, and pumpkins. If colony collapse disorder cannot be effectively treated or managed, farmers may have to turn to other insects, possibly other species of bees or even moths.

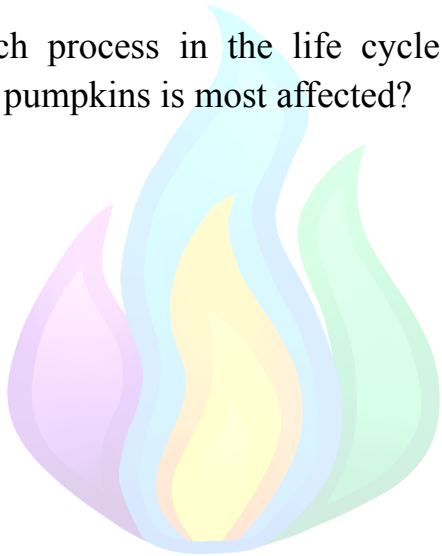
Without honeybees, which process in the life cycle of plants such as apples, almonds, blueberries, and pumpkins is most affected?

A. Seed dispersal

B. Pollination

C. Seed germination

D. Secondary growth

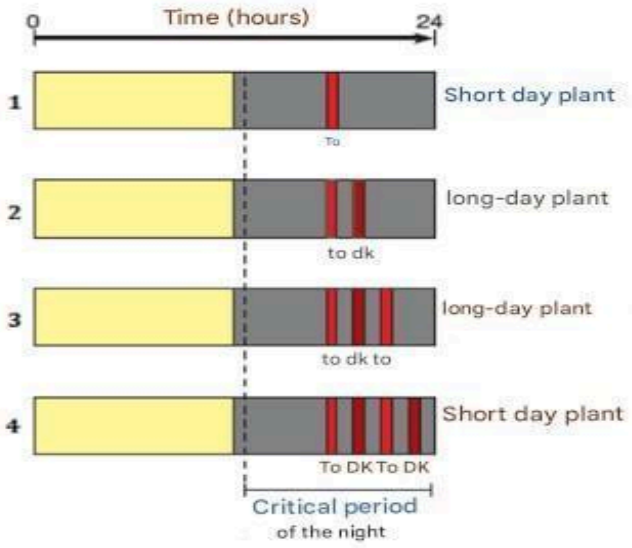


Problem proposed by Ruslanbekov Ulukbek

Question 19 – Effects of artificial lighting on flowering plants

Plants have complex chemical coordination systems to regulate flowering and fruiting. Plants are generally classified as short day flowering plants and long day flowering plants based on their flowering behavior when exposed to daylight of varying length.

An experiment was conducted by exposing 4 plants (1-4) with red light (625-730 nm) and far red light (730-740 nm), and the overview of the experiment is shown below.



If the period when the plant was exposed to red and far red light was denoted by to and Dk respectively, find which plant will bloom.

A. Plant 1

B. Plant 2

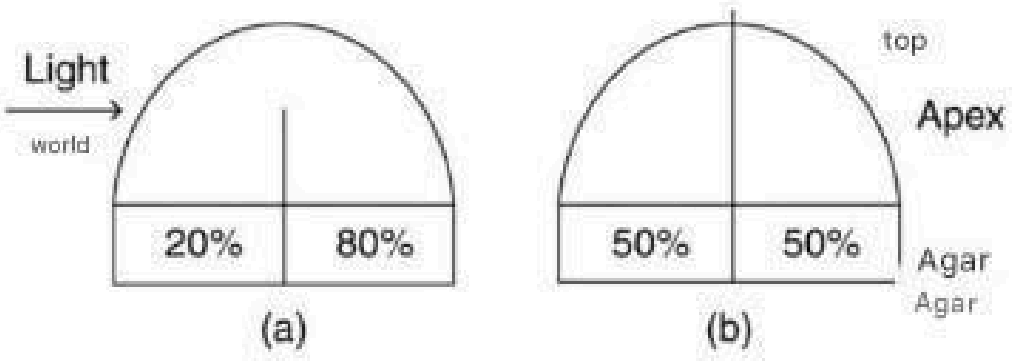
C. Plant 3

D. Plant 4

Problem proposed by Ruslanbekov Ulukbek

Question 20 – Effect of phototropins on plants

An experiment was conducted on plants which investigated the effects of auxin and its concentration on plant tips. In the experiment sections of apical shoots were placed in a small block of agar with light shining from only one side. The tips were either partially or completely divided into 2 parts by a barrier that also separated the blocks. The figure below shows the results of the experiment. The numbers indicate the percentage of Auxin transported from the shoot segment to the agar below it.



Which of the following is best supported by the data?

A. Auxin is distributed throughout the plant apoplast

B. Auxin is synthesized by the shaded side of apex

C. Light destroys auxins

D. Auxins can move away from light

Problem proposed by Ruslanbekov Ulukbek

Question 21 – Cold resistant adaptations in plants

In the Arctic tundra, plants like *Dryas octopetala* and *Salix arctica* survive extreme cold, light, and drought. *S. arctica* maintains root aquaporin expression for water uptake from thawed permafrost. Both species upregulate CBF transcription factors, leading to cold-responsive (COR) gene expression for osmoprotection and protein cryo stabilization. Membrane fluidity is enhanced by increased desaturase activity, leading to more *cis*-unsaturated fatty acids. *D. octopetala* avoids photoinhibition through non-photochemical quenching (NPQ). Antifreeze proteins (AFPs) in both species inhibit ice crystal growth.

Which combination BEST explains the multi-layered cold adaptation strategy of these Arctic vascular plants?

A. Overexpression of aquaporins for active water transport, RuBisCO suppression to limit photorespiration, and chloroplast membrane saturation to stabilize photosynthetic membranes.

B. Non-photochemical quenching to prevent photoinhibition, CBF-induced COR gene expression for protein cryo stabilisation, and increased membrane unsaturation via desaturase enzymes.

C. Reduced aquaporin expression to minimise ice formation, overproduction of ATP to maintain active transport, and downregulation of light-absorbing pigments to avoid ROS.

D. Constant high-stomatal conductance to maintain transpiration, use of saturated lipids for structural rigidity, and inhibition of cold-responsive gene expression to prevent overreaction.

Problem proposed by Jathurshan Myuran

Question 22 – Thermoregulation in humans

In very cold places, humans need to keep their body temperature stable. When it's cold, skin sensors tell the hypothalamus, a region of the brain. The hypothalamus then causes blood vessels near the skin to get narrower (vasoconstriction) to save heat, via a chemical called norepinephrine.

Also, muscles shiver to make heat. For long-term cold, a special fat called brown adipose tissue (BAT) helps. BAT has a protein called UCP1, which makes heat directly instead of making energy for the body.

The brain works to keep the body temperature just right, but too much narrowing of blood vessels can cause problems like frostbite.

Which of the following best describes the coordinated physiological mechanisms involved in human cold adaptation?

A. The posterior hypothalamus inhibits norepinephrine to induce vasodilation, while UCP1 promotes ATP synthesis to maintain metabolic rate in brown adipose tissue.

B. Cold signals activate the anterior hypothalamus, triggering parasympathetic stimulation of BAT and skeletal muscle for heat production.

C. Norepinephrine-driven vasoconstriction reduces heat loss, while UCP1 uncouples oxidative phosphorylation in BAT, generating heat without ATP.

D. Vasoconstriction is mediated by β2-adrenergic receptors, while core temperature is regulated solely by spinal thermoreceptors independent of the hypothalamus

Problem proposed by Jathurshan Myuran

Question 23 – Endosymbiosis in the Nitroplast

Evidence suggests a newly discovered organelle, the "nitroplast," evolved from an endosymbiotic prokaryote, similar to _____ and _____. For an endosymbiont to be classified as a true organelle, it must meet several integration criteria with its host.

Genomic Sequencing	Nitroplast genome is 160 kbp (free-living relatives: 3 Mbp). Several nitroplast genes are nearly identical to host nuclear genes.
mRNA localization	mRNAs for key nitroplast enzymes are detected in both the host nucleus and the nitroplast.
Protein import assay	Radiolabeled proteins synthesized in the host cytoplasm accumulate in the nitroplast after several hours.
Protein inhibition	Inhibiting nuclear transcription halts synthesis of essential nitroplast proteins. Inhibiting nitroplast transcription has a milder effect.
Ribosome analysis	Nitroplast ribosomes resemble prokaryotic ribosomes and are sensitive to antibiotics that do not affect host ribosomes.

Based on the provided data, which is an essential requirement for classifying nitroplasts as organelles?

A. Chloroplast and mitochondria; the nitroplast is surrounded by a double membrane with specialized transport proteins.

B. Chloroplast and mitochondria; the nitroplast relies on host nuclear-encoded proteins for essential functions, as shown by nuclear transcription inhibition and protein import experiments.

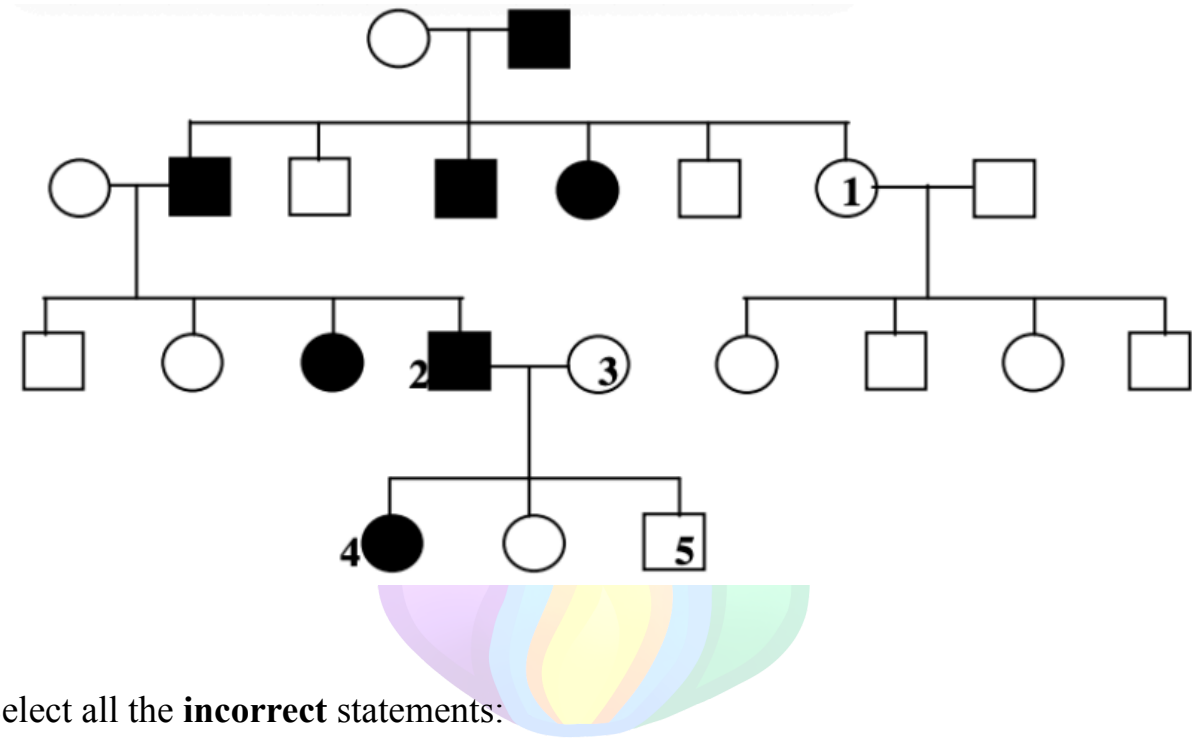
C. Chloroplast and golgi apparatus; the nitroplast's ribosomes resemble prokaryotic ribosomes and are sensitive to different antibiotics than the host’s.

D. Mitochondria and golgi apparatus; the nitroplast genome is much smaller than free-living relatives, and some genes are also present in the host nucleus.

Problem proposed by Josephine Ankomah

Question 24 – Pedigree Analysis

A family has sought genetic counseling due to the presence of a rare neurological disorder in several members across multiple generations. The disorder typically presents in childhood, leading to progressive loss of muscle control and speech difficulties. The family history is summarized in the pedigree below:



Select all the **incorrect** statements:

i) The mode of inheritance is autosomal dominant

ii) The mode of inheritance is X-linked recessive

iii) Individual 1 cannot be heterozygous

iv) Individual 2 is homozygous

v) Individual 4 cannot be homozygous

vi) If individual 5 marries a homozygous person, their offspring may be homozygous

A) i, ii, iii

B) i, ii, v

C) iv, iii, v, vi

D) ii, iii, iv, v

Problem proposed by Josephine Ankomah

Question 25 – Thermoregulation in Humans

A team of researchers is studying physiological adaptations in animals living in extreme cold environments. They observe that despite a significant thermal gradient existing between the internal body core and the external environment, these animals consistently maintain a stable core body temperature. The hypothalamus plays a crucial role in this thermoregulation.

Considering the primary mechanisms of heat exchange and the body's responses to cold, which of the following best explains how the hypothalamus facilitates the maintenance of core temperature in cold climates, given the thermal gradient between the body core and the periphery?

A. The hypothalamus initiates a significant decrease in metabolic heat production within the brain itself, thereby preserving energy reserves for vital organ function.

B. The hypothalamus stimulates an enhanced sympathetic vasodilation of peripheral arterioles, aiming to increase blood flow to the skin and facilitate heat dissipation.

C. The hypothalamus triggers an active vasoconstriction of superficial capillaries and arterioles in the skin, which significantly reduces the rate of heat loss from the body's surface to the colder environment.

D. The hypothalamus promotes a substantial increase in blood flow to the extremities, ensuring adequate oxygen delivery to muscles and preventing frostbite in digits.

Problem proposed by Ha Chi Vuong

Question 26 – Impact of Afferent Arteriole Constriction

A medical student is analyzing a physiological diagram illustrating the components of a single nephron within the kidney. They are particularly interested in understanding how changes in the renal vasculature impact filtration. The student considers a hypothetical situation where the afferent arteriole leading to a specific glomerulus undergoes significant constriction.

Assuming all other physiological parameters remain constant, which of the following changes would you most directly expect as a result of this afferent arteriole constriction?

A. An increase in the Glomerular Filtration Rate (GFR) due to a higher pressure gradient across the filtration membrane.

B. A decrease in blood flow to the glomerulus, leading to a reduction in the hydrostatic pressure within the glomerular capillaries.

C. An increase in the hydrostatic pressure within the Bowman's capsule, consequently hindering the filtration process.

D. A decrease in the reabsorption of glucose in the proximal tubule, attributed to an altered tubular fluid composition.

Problem proposed by Ha Chi Vuong

Question 27 – Chronic radiation exposure and plant growth

The pine trees near Chernobyl have been exposed to radiation for almost 30 years. That leaves us to wonder, does radiation affect plant life as much as it does animal life? There have been several studies proving that ABA and auxin concentrations have decreased in trees from plots contaminated with radionuclides such as 137Cs, 90Sr, 241Am, 238Pu, and 239+240Pu. Choose the correct statements regarding the effects these new levels of hormones will have on the plants:

i) Pine trees that are exposed to radiation are more likely to have one main stem over having other lateral stems

ii) Pine trees that are exposed to radiation may have a lower desiccation tolerance than ones that aren't exposed to radiation

iii) Pine trees that aren't exposed to radiation should be less likely to germinate early as opposed to pine trees that are exposed to radiation

iv) Pine trees that aren't exposed to radiation may be less sensitive to light and gravity when compared to trees that are exposed to radiation

A. i. and ii.
B. ii. and iii.
C. iii. and iv.
D. i and iv.

Problem proposed by Mila Porjazoska

Question 28 – Role of Cryoprotectants in the Cold

In the frozen landscapes of the Arctic tundra, life has evolved extraordinary ways to survive intense cold, limited sunlight, and scarce food. Organisms such as the Arctic fox, polar lichens, and certain cold-tolerant bacteria rely on biochemical and physiological adaptations to endure these extreme conditions. One of the most fascinating adaptations involves cryoprotectants—natural antifreeze molecules like glycerol or trehalose that prevent the formation of damaging ice crystals inside cells. When temperatures drop below freezing, water in cells usually forms sharp ice crystals that can rupture membranes. But in some tundra species, the presence of cryoprotectants slows or alters ice formation, allowing the organism to remain frozen for months without cell damage.

This strategy is also studied in cryobiology, a field of science that investigates how biological materials behave at low temperatures. For example, scientists are exploring how to use cryoprotectants in human organ preservation for transplants, extending the time organs remain viable outside the body. However, one challenge is recrystallization—when small ice crystals merge into larger, more damaging ones during thawing.

Why are cryoprotectants like glycerol crucial for organisms in extremely cold environments such as the tundra?

A. They increase the freezing point of water so organisms can remain active in the cold.

B. They prevent all freezing, allowing organisms to stay warm in icy environments.

C. They help regulate body temperature by converting ice into metabolic energy.

D. They protect cells by preventing the formation of sharp ice crystals that cause damage.

Problem proposed by Jathurshan Myuran

Question 29 – Membrane structure adapted for the cold

Biological membranes are not just structural barriers—they are dynamic environments where critical processes like signaling, ion exchange, and energy transfer occur. These membranes are composed primarily of a phospholipid bilayer, and their fluidity is essential for proper protein mobility and function. In organisms living in tundra and polar regions, environmental temperatures often fall well below 0°C, threatening membrane integrity by causing the lipids to pack too tightly, reducing fluidity and impairing cellular function.

To overcome this, many cold-adapted organisms increase the proportion of polyunsaturated fatty acids in their membrane lipids. These fatty acids contain multiple double bonds that create kinks in the hydrocarbon tails, disrupting tight packing and thus lowering the membrane's phase transition temperature (the point where it shifts from a fluid state to a gel-like state). This adaptation is part of a broader physiological strategy known as homeoviscous adaptation. Additionally, steroids like cholesterol may be present in variable amounts to buffer fluidity, though their role in extreme cold differs between taxa.

However, in the context of rapid climate warming, the balance becomes delicate: a mismatch between ambient temperature and membrane composition can lead to membrane phase separation or lipid domain instability, potentially destabilizing membrane-bound proteins such as ion channels or ATP synthase.

Which of the following most accurately explains how polyunsaturated fatty acids (PUFAs) contribute to membrane function in cold-adapted organisms?

A. PUFAs increase hydrogen bonding between lipid molecules, stabilizing the bilayer under freezing conditions.

B. PUFAs increase membrane rigidity by enhancing sterol interaction at low temperatures.

C. PUFAs decrease the membrane phase transition temperature, maintaining fluidity essential for protein function.

D. PUFAs directly generate metabolic heat by oxidizing within the lipid bilayer to prevent freezing.

Problem proposed by Jathurshan Myuran

Question 30 – Varying Enzyme Activity

Trypsin and elastase are substantially well researched enzymes that are part of the serine protease group, meaning that they use a serine residue in their active site to facilitate the hydrolysis (breakdown) of peptide bonds in proteins. Interestingly, trypsin primarily cuts peptide chains after basic amino acids like arginine and lysine. On the other hand, elastase tends to cleave after small, neutral amino acids such as alanine. Although the overall architecture of their active sites contains many similar key chemical characteristics, the two enzymes exhibit varying cutting behaviors.

Which option below most effectively explains the fundamental reason that trypsin and elastase have such varying behaviours?

A. Charge differences near the reaction site influence the reactivity of serine residues, subsequently impacting the enzyme's alignment with and interaction with the protein substrate.

B. Trypsin features a deep pocket with a negatively charged residue, enabling it to fit and stabilize the side chains of basic amino acids, whereas elastase has a considerably smaller pocket that is partly obstructed by large, neutral side chains, limiting it to small amino acid residues.

C. Elastase depends on a metal ion as a cofactor to aid in the cleavage process, while trypsin utilizes solely the amino acids that constitute its active site, without needing extra cofactors.

D. The temporary unstable intermediate called the "transition state," which occurs during the cleavage process, structurally varies among different enzymes, resulting in distinct targeting of specific amino acid residues.

Problem proposed by Josephine Ankomah