THEORETICAL EXAM INSTRUCTIONS

1. The examination will last **4 hours**.
2. The examination consists of **two parts (Theory A and Theory B)**. There will be **no break** between the two parts.
3. **Theory A** consists of **31 questions**.
4. **Theory B** consists of **14 questions**.
5. You may allocate your time between the two parts at your own discretion.
6. All answers must be written **only on the Answer Sheet**. Answers written on the Question Paper will **not** be evaluated.
7. Mark your answers as asked in the questions.
    - To cancel an answer, draw **two horizontal lines** through it.
8. The following items are provided during the examination:
    - Pen
    - Pencil
    - Scratch paper
    - Calculator
9. If you need assistance, wish to drink water, or need to use the restroom, **raise your hand** to attract the attention of an invigilator.
10. You may leave the examination room to use the restroom **only when accompanied by an invigilator**.
11. You may begin the examination **only after the invigilator gives the official start signal**. Do **not** open the question booklet before this signal.
12. At the end of the examination, you must **immediately stop writing**, put down your pen or pencil, and **raise both hands** to indicate that you have finished.
13. Place all your materials inside the provided folder on your desk and **leave the room only when instructed by the invigilator**.
14. Any form of **cheating or attempting to copy** will result in **immediate disqualification**

Part A

Cell Biology

Q1

Immune Checkpoint Inhibitors (ICIs) are breakthrough drugs that help the immune system attack cancer cells. However, they can cause a dangerous side effect: myocarditis (severe inflammation of the heart). Scientists are studying the role of a signaling protein called TNF (Tumor necrosis factor) to understand how to stop heart damage without making the cancer treatment less effective.

Researchers used a mouse model where the immune system is triggered to attack the heart following ICI treatment. They tested a "Dual ICI" therapy (combining two drugs: αCTLA-4 and αPD-1). They also looked at the effects of blocking TNF receptors and using TNF-deficient immune cells.

Figure 1 - Changes in tumor volume over 15 days under three conditions: no treatment, dual ICI therapy, and dual ICI combined with a TNF-receptor blocker (αTNFR2)

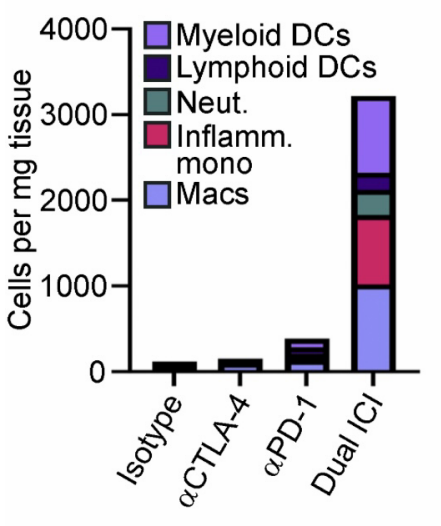


Figure 2 - The number of immune cells (leukocytes) that entered the heart tissue.

This was compared between normal T cells (the 2-4 columns of the fig. 2) and T cells that cannot produce TNF (Isotype, the 1st column of the fig. 2).

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	According to Figure 1, the Dual ICI therapy is significantly more effective at reducing tumor size compared to no treatment at all.		
B	Data in Figure 2 suggest that the signaling molecule TNF is a primary driver for the migration of various inflammatory cells into the heart tissue		
C	Based on Figure 1, adding a TNF-receptor blocker (αTNFR2) to the treatment successfully reduces heart inflammation but completely cancels out the anti-tumor effects of the ICI drugs.		
D	The results in Figure 2 indicate that the heart damage is likely caused by a complex inflammatory response involving multiple cell types (such as macrophages and monocytes), rather than a single type of immune cell.		

Q2

A research group designs a fluorescently labeled secreted protein to study the early steps of the secretory pathway. The protein carries a classical N-terminal ER signal peptide and, in normal cells, enters the ER lumen, passes through the Golgi, is transported to the plasma membrane, and is secreted. The team uses CRISPR to generate a loss-of-function mutation in an essential subunit of the COPII coat complex, then (2 hours later) measures intracellular localization and the amount of secreted protein.

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	After COPII loss-of-function, the secreted protein is expected to accumulate in the ER, and the amount of protein detected in the extracellular medium should decrease.		
B	After COPII loss-of-function, the secreted protein is expected to accumulate in the Golgi, because COPII primarily mediates retrograde transport from the Golgi back to the ER.		
C	After COPII loss-of-function, the secreted protein is expected to accumulate in the cytosol, because an ER signal peptide causes proteins to be retained on cytosolic		

	ribosomes.		
D	COPII loss-of-function directly reroutes newly synthesized secretory cargo to lysosomes, so lysosomal accumulation is the most consistent outcome.		

Biochemistry

Q3

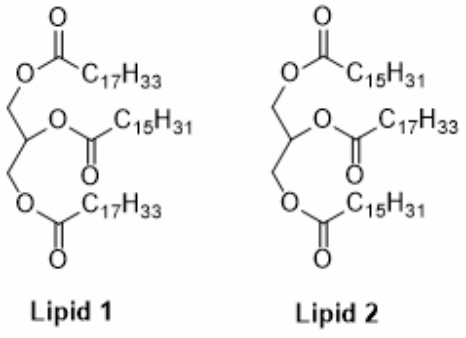
It is well known that humans cannot digest dietary chitin. However, the human genome contains several chitinase genes that are expressed in various tissues. This specific circumstance allows for the use of chitin in the production of resorbable surgical sutures and scaffolds. What, then, is the biological function of chitinases in the human body?

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

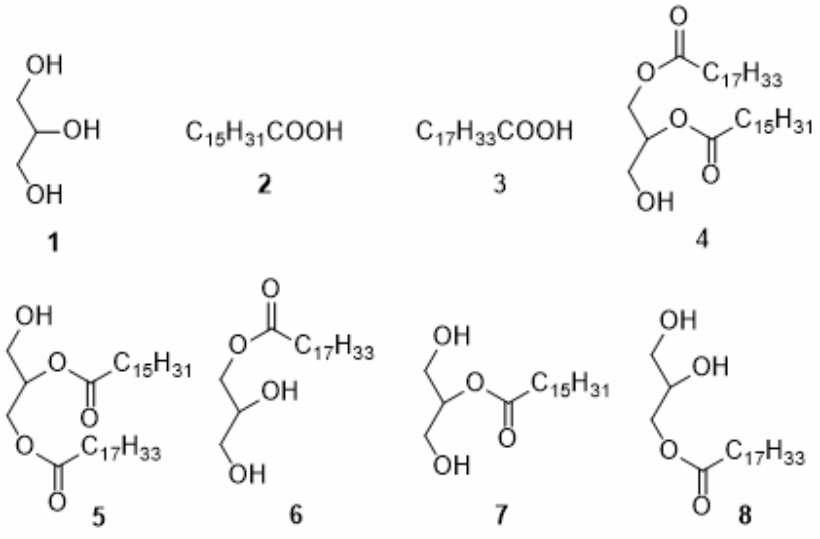
	Statement	True	False
A	Chitinases are involved in defense against pathogenic bacteria.		
B	Chitinases are involved in defense against pathogenic fungi.		
C	Chitinases participate in the breakdown of chitin present in blood vessel walls.		
D	Human chitinases are involved in chitin biosynthesis rather than its degradation.		

Q4

Human milk, as opposed to cow's and goat's milk, contains more lipids with palmitic acid residue in the β-position of glycerol (**Lipid 1**). This structural feature makes human milk more easily digestible for infants.



Human *pancreatic lipase* hydrolyses two of the three ester bonds in lipids during digestion. When Lipid 2 is hydrolysed in the infant intestine, free palmitic acid can react with calcium ions to form an insoluble precipitate, calcium palmitate ((C H COO) Ca). This may lead to constipation and loss of calcium in the feces. In contrast, **Lipid 1**, under the same conditions, does not form this byproduct.



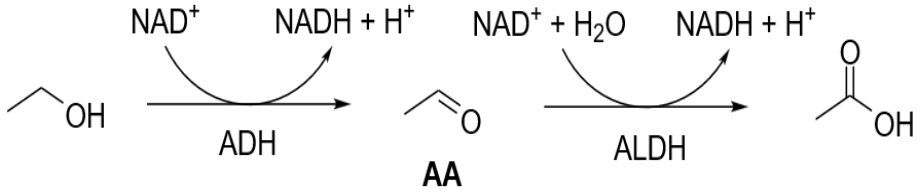
Choose from the following list of products of the hydrolysis of **Lipid 1** by *pancreatic lipase* and put "X" below the correct number of a product.

Every correct answer is 0.5 points; every incorrect answer will remove 0.17 points.

1	2	3	4	5	6	7	8

Q5

Acetaldehyde (**AA**) is a reactive aldehyde primarily produced in cells as a metabolic intermediate during ethanol oxidation:



ADH – alcohol dehydrogenase, ALDH – aldehyde dehydrogenase.

Excess AA, often resulting from impaired AA detoxification, leads to aberrant DNA, protein, and lipid damage and increases the risk of diseases such as cancer, hepatitis, and cirrhosis. Which cell culture demonstrates the highest intracellular steady-state acetaldehyde concentration?

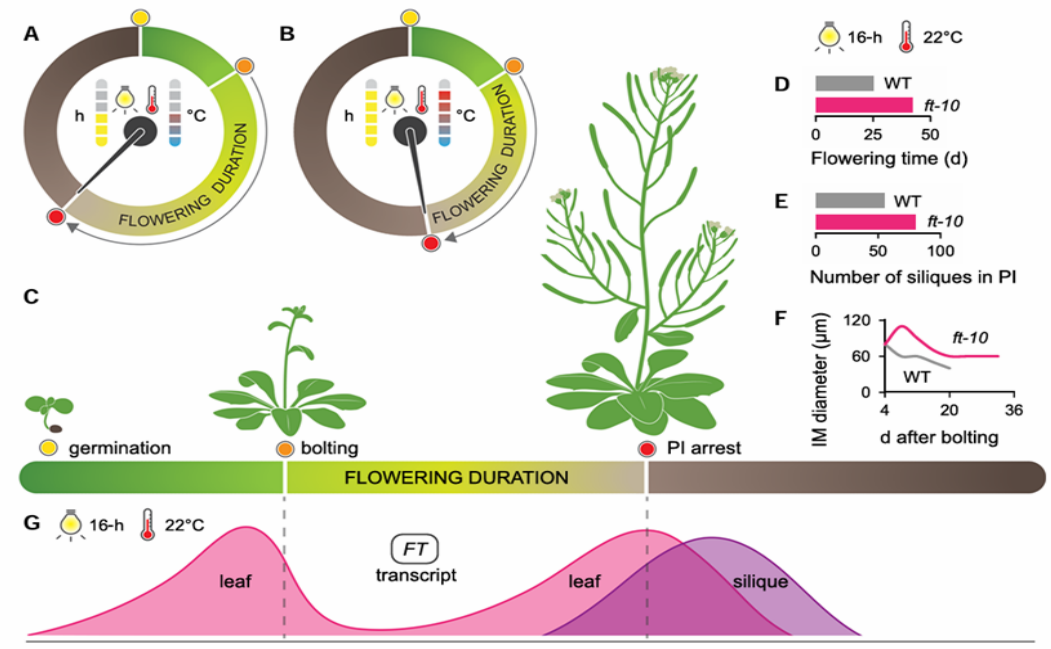
Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	Cell culture + C_2H_5OH		
B	Cell culture + CH_3COOH		
C	Cell culture + C_2H_5OH + Fomepizole (ADH inhibitor)		
D	Cell culture + C_2H_5OH + CVT-10216 (ALDH inhibitor)		

Plant Biology

Q6

The genetic and physiological regulation of flowering duration is a relatively less-studied topic. In this context, the effects of high temperature and long photoperiod on flowering duration are investigated in the inflorescence meristem (IM) of *Arabidopsis*. For this purpose, different *Arabidopsis* mutants were used, in which genes sensitive to changes in day length and temperature were individually mutated. The genes ft-1, ft-10, tsf-1, co-2, and gi-4 are sensitive to day length. The results of the study are presented in the diagram below.



Notes: Images A–F show the results of the corresponding experiments. PI – primary inflorescence, PI arrest – arrest of primary inflorescence, IM – inflorescence meristem, WT – wild type

Figure - Photothermal signals regulate flowering duration in *Arabidopsis*.

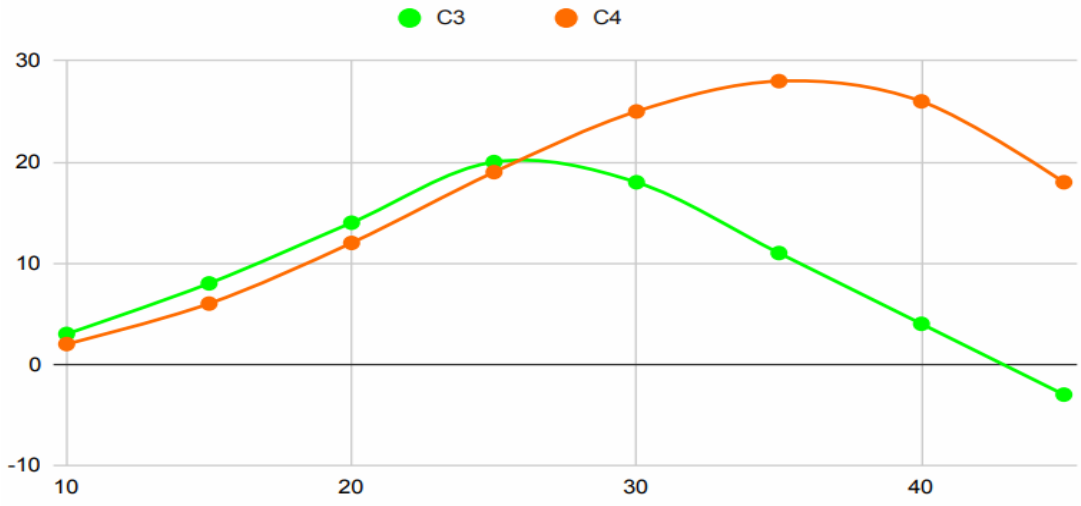
Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	These results indicate that flowering duration can be shortened in response to both increased temperature and extended photoperiod; however, day-length-sensitive genes play the major role in this process.		
B	Experiments A and B are designed to analyze the effects of high temperature and long photoperiod on the plant, and these results were used to select appropriate conditions for conducting experiments D, E, and F.		
C	Similar results would be expected for light wavelengths to which the ft-10 gene product (or the gene itself) is not sensitive.		
D	In plants that overexpress the FT gene, the reproductive period will be significantly prolonged.		

Q7

In C_3 plants, RuBisCO fixes CO directly; however, at high temperatures, it also reacts with O , which intensifies photorespiration and reduces net photosynthesis. In contrast, C plants utilize Kranz anatomy and the high affinity of PEP carboxylase to increase the CO concentration within the bundle sheath cells, effectively suppressing photorespiration almost entirely.

The CO compensation point is the CO concentration at which the amount of CO assimilated through photosynthesis equals the amount released by respiration and photorespiration. This value is approximately 50–100 ppm for C_3 plants and 5–10 ppm for C plants.



X-axis: Temperature, Y-axis: Net Photosynthesis (*μmol CO /m²/s)*

Figure - Net photosynthetic rate in C (green) and C_4 (orange) plants as a function of temperature (µmol CO /m²/s). Light intensity is at saturating levels

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

	Statement	True	False
A	The enzyme PEP carboxylase has a very high affinity for CO_2 and does not accept O_2 as a substrate. This enables C_4 plants to function efficiently even at low CO_2 concentrations.		
B	The lower CO_2 compensation point in C_4 plants compared to C_3 plants is due to their RuBisCO enzyme functioning with higher efficiency than PEP carboxylase even at low CO_2 concentrations.		
C	The higher net photosynthetic rate of C_3 plants to the left of the 25°C intersection point is explained by the fact that, at these temperatures, the energetic cost of photorespiration is lower than the cost of the CO_2 pump (ATP consumption) in C_4 plants.		
D	Because the decarboxylation process in the C_4 pathway occurs within the chloroplasts of mesophyll cells, photorespiration does not take place even if the partial pressure of oxygen increases in the bundle sheath cells.		
E	The fact that the net photosynthetic rate of C_4 plants at 40°C is lower than its maximum potential is primarily caused by a sharp increase in photorespiration.		

Q8

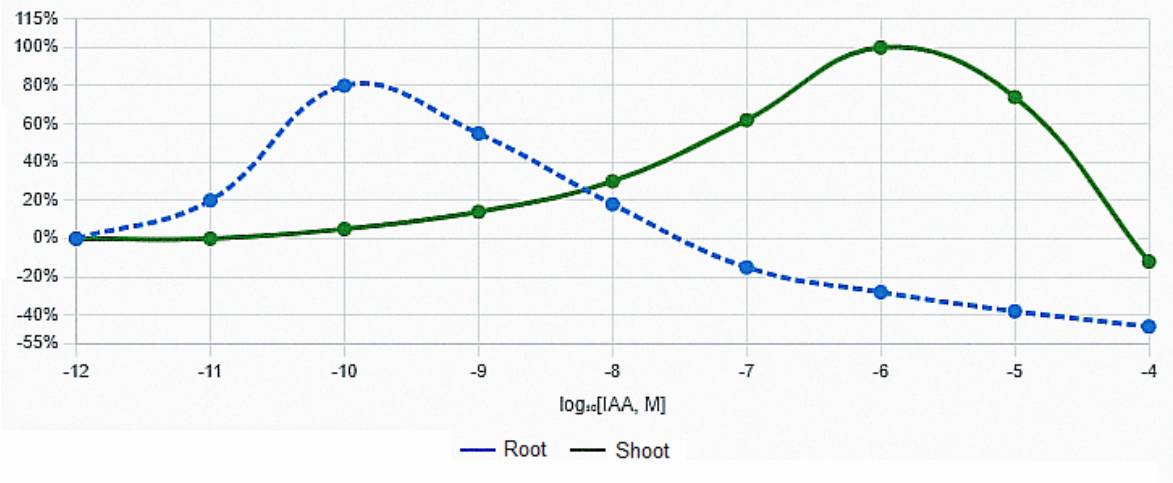
Auxin (indole-3-acetic acid, IAA) primarily functions through the TIR1/AFB intracellular receptor, which is an F-box component of the SCF ubiquitin E3 ligase complex.

Auxin acts as a "molecular glue" between TIR1 and Aux/IAA repressor proteins—forming a ternary complex (TIR1–auxin–Aux/IAA). This leads to the K48-ubiquitination of Aux/IAA and its subsequent degradation in the 26S proteasome, which releases ARF (Auxin Response Factor) transcription factors.

The polar transport of auxin involves PIN (PIN-FORMED) efflux carriers and AUX1/LAX influx carriers. The asymmetric localization of PIN proteins within the membrane depends on the relative activity of the PINOID kinase and PP2A phosphatase. The PIN carrier must be phosphorylated to move to the apical membrane. The PIN carrier must be dephosphorylated to move to the basal membrane.

Furthermore, strigolactones (SL) inhibit the growth of lateral buds through the D14–SCF^{MAX2}–SMXL7 pathway, acting independently of the auxin pathway.

Ethylene biosynthesis chain: SAM ACC (ACS enzyme) Ethylene(ACO enzyme). Auxin induces ACS genes at high concentrations. The following graph shows the response of root and shoot elongation to IAA concentration.



X-axis: $\log_{10}$[IAA, M]

Y-axis: change relative to basal elongation (%).

Figure - Root (blue) and shoot (green) elongation responses to IAA concentration

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	In the process of gravitropism, the auxin concentration increases sharply in the lower part of the root. Although auxin releases ARF factors in root cells under this condition, it does not stimulate cell elongation but rather stops it; this is because ethylene induced by auxin in the root blocks elongation.		
B	The ethylene hormone enhances the auxin gradient at the root tip by increasing the gene expression of PIN2 transporter proteins. Thus, auxin stimulates ethylene synthesis through its high concentration, forming a "positive feedback" loop that indirectly accelerates its own transport.		
C	Based on the figure, at an IAA concentration of 10^{-8} M, while shoot elongation is positive (stimulated), root elongation is negative (inhibited). This confirms at the graphical level that root tissues are approximately 10000 times more sensitive to the effects of auxin than shoot tissues.		
D	Strigolactones (SL) support the apical dominance of the plant by inhibiting the growth of lateral buds. Logically, when a plant encounters unfavorable conditions (nutrient deficiency), strigolactone synthesis should decrease, allowing the plant to		

	branch more and increase its chances of survival.		

Q9

Pollen grain is the male gametophyte of seed plants and is the main structure that delivers genetic material to the reproductive organs during sexual reproduction. The pollen grain has a complex morphological structure, and its outer layer — the exine — is highly resistant and performs a protective function. This is especially important in desert plants, for which the production of small and large amounts of pollen is an adaptive feature.

Pollen morphology varies significantly in different plant groups: it can be smooth, spiny or netted. These features are mainly associated with the method of pollination.

The biological significance of pollen lies in its provision of genetic diversity and increased plant adaptability. In the process of evolution, the structure and mechanisms of pollen dispersal have been formed in accordance with environmental conditions, which plays an important role in the successful reproduction of plants.

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. Each correct row awards **0.17 points.** Only one answer for each row is possible**.**

	Pollen morphology	**Pollen dispersal**		
		wind	**insects**	**water**
A				
B				
C				

D				
E				
F				

Animal Physiology

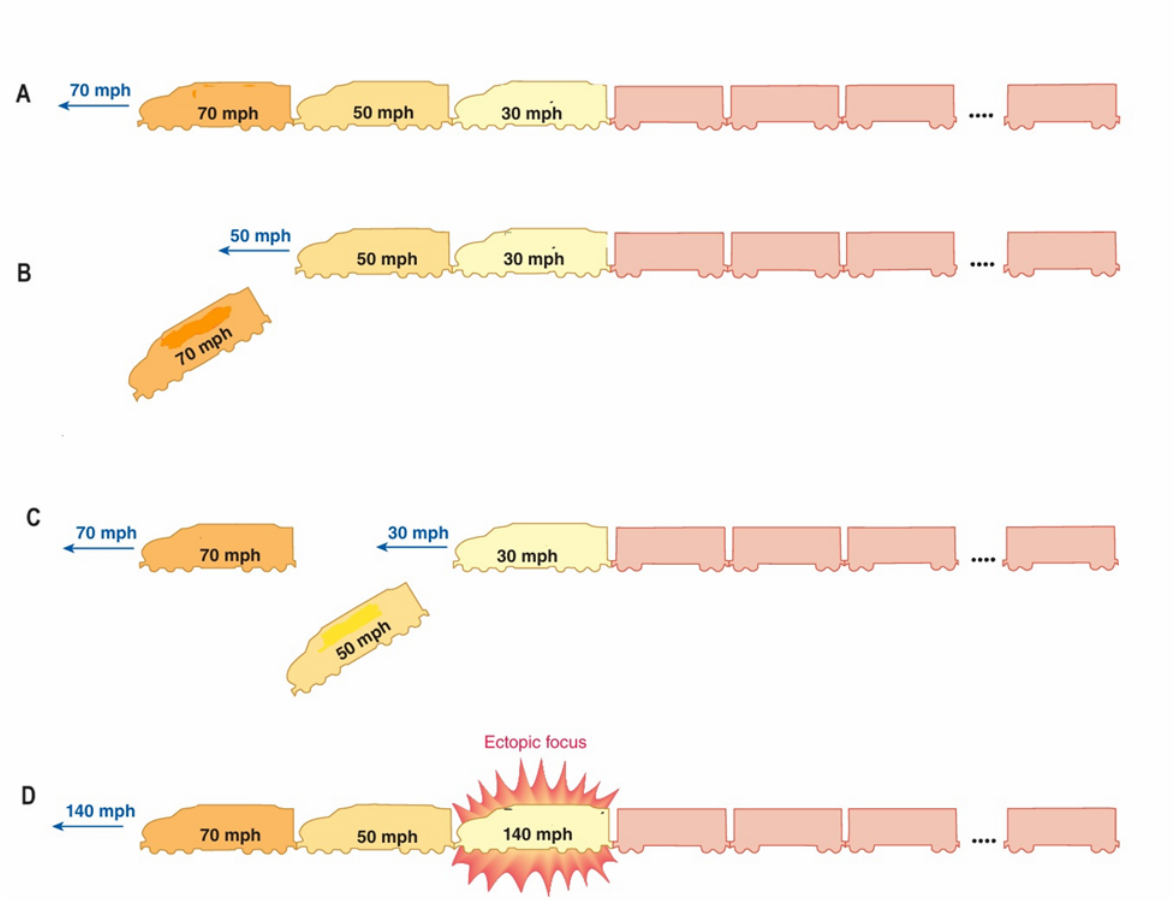
Q10

To describe the automatic activity of the heart, a locomotive train analogy is often used. In this model, the leading carriage generates its own driving force and pulls the other carriages along. Its speed is 70 miles per hour (mph) (mile is a unit of length; 1 mile = 1.6 km). The second carriage has an intrinsic speed of 50 mph,

and the third carriage has an intrinsic speed of 30 mph. The subsequent carriages are unable to move independently and represent cells that undergo contraction and relaxation.

The entire train moves at the speed of the first carriage, i.e., 70 mph. To better understand this analogy, refer to the figure below (Source: *Human Physiology: From Cells to Systems, Ninth Edition. L. Sherwood. 2016, 2013 Cengage Learning*).

Note: mph = miles per hour.



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

	Statement	True	False
A	The first carriage represents the signal coming from the brain, the second carriage represents the sinoatrial node, and the third carriage represents the atrioventricular node.		
B	Condition C can only maintain a very immovable state; this type of heartbeat is associated only with a comatose state.		

C	To treat conditions B and C, an artificial pacemaker is implanted in the heart, and the impulses generated by this device restore the heartbeat to normal.		
D	Condition D occurs more frequently as a result of recurrent anxiety, insomnia, or excessive intake of caffeine, nicotine, or alcohol.		
E	In condition C, although the signal passes from the atrioventricular node to the Purkinje fibers, the connection between the sinoatrial node and the atrioventricular node is interrupted.		

Q11

The honey badger (*Mellivora capensis*) is considered one of the most resilient mammals in Africa and Asia. When bitten by venomous snakes such as cobras and mambas, the honey badger exhibits clinical signs of envenomation; however, within a few hours, the animal recovers and overcomes the toxic state. This phenomenon is mediated by the following mechanisms:

Mechanism 1: Receptor Mutation.

An amino acid substitution in the ligand-binding domain of the nicotinic acetylcholine receptors (nAChR) in muscle cells—specifically the Asn→Lys change—blocks the binding of α-neurotoxins (cobratoxin) to the receptor. Consequently, the action potential is maintained, preventing paralysis.

Mechanism 2: Adaptive Immunity.

Specific IgG antibodies against the venom neutralize toxic proteins (such as phospholipase A_2 and cytotoxins), thereby reducing histamine release and tissue damage. A rapid immune response is generated through immunological memory.

Mechanism 3: Detoxification.

Hepatic CYP450 enzymes and metalloproteinase inhibitors degrade phospholipase A_2 and hemorrhagic toxins at high rates. The animal's high metabolic rate results in a shortened half-life for the toxins.

Mechanism 4: Integumentary Barrier (Skin Barrier).

The exceptionally thick skin (up to 6 mm around the neck) traps most snake fangs within the connective tissue, preventing the venom from reaching the vascular system. This serves as a passive mechanical defense.

Notes:

α-neurotoxin: Blocks postsynaptic nicotinic acetylcholine receptors, leading to paralysis.

Phospholipase A_2: Catalyzes the hydrolysis of cell membrane phospholipids, leading to cellular degradation.

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	Generally, in all animals, due to α-neurotoxin binding with the nAChR, the receptor fails to detect acetylcholine in the synaptic cleft. As a result, contracted muscles cannot relax, leading to spastic paralysis.		
B	The presence of IgG antibodies in the honey badger's blood is a product of directional selection resulting from a constant struggle for survival with snakes; it is common to all individuals of the species and is hereditary.		
C	Both honey badgers and mongooses have evolved nAChR mutations that confer resistance to cobratoxin through changes at different amino acid positions, what represents a remarkable example of convergent evolution		
D	It is highly likely that the nAChR mutation will facilitate the survival of the organism during tetrodotoxin poisoning.		

Q12

Hypothyroidism is a condition that develops when the thyroid gland is unable to produce an adequate amount of thyroxine hormone, and its causes can vary. Below are the results of hormonal tests for individuals A and B who are diagnosed with hypothyroidism.

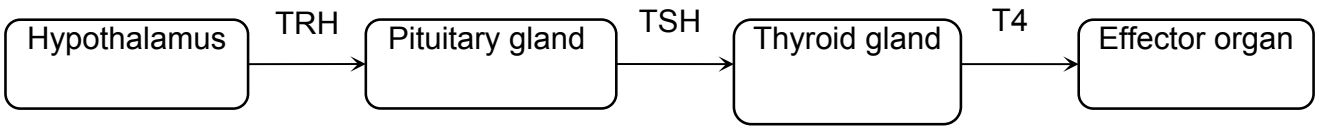
Indicator	Normal range	Patient A	Patient B
T4	10.3–24.5 pmol/L	6.2 pmol/L	6.8 pmol/L
TSH	0.4–4.0 mIU/L	28.0 mIU/L	1.1 mIU/L
TRH	0–40 pg/mL	72 pg/mL	68 pg/mL

TRH – Thyrotropin releasing hormone

TSH – Thyroid stimulating hormone (thyrotropin)

T4 – Thyroxine

Explanation: The production of thyroxine (T4) occurs in the following sequence and is regulated through negative feedback.



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	In patient B, hypothyroidism symptoms may have developed due to dysfunction of the pituitary gland and thyroid gland.		
B	In patient A, hypothyroidism may have occurred due to autoimmune damage to the thyroid gland.		
C	Patient A may have developed endemic goiter.		
D	In a person with T4 levels of 12.8 pmol/L, TSH levels of 25 mIU/L, and TRH levels of 63 pg/mL, subclinical hypothyroidism may have developed.		

Q13

A radiogram is a visual representation of a body part captured on specialized film or a digital sensor using X-ray radiation. As X-rays penetrate the body, different tissues attenuate (absorb) the radiation at varying rates based on their density:

Bones: Due to their high mineral density, bones absorb a significant portion of X-ray beams, appearing white or light gray on the image (radiopaque).

Soft Tissues: Tissues such as muscles and fat provide less resistance to the beams, resulting in a dark gray appearance.

Air (Lungs): Air provides almost no resistance to X-rays, causing the lungs to appear black on the radiogram (radiolucent).

Below are the radiographic images of two individuals.





Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	Individual A exhibits a developmental anomaly of the carpal bones, which is often associated with genetic mutations or congenital anomalies occurring during intrauterine development.		
B	In Individual B, it is highly probable that the cell cycle checkpoints in the osteoblasts (bone cells) are malfunctioning.		
C	Radiogram A belongs to a young child and shows a closed fracture of the radius and ulna of the right forearm.		
D	Radiogram A demonstrates a fracture of the cortical layer while		

	the periosteum remains intact. This type of fracture is caused by Vitamin D deficiency.		

Q14

Below are skulls belonging to several animals from the class Mammalia.









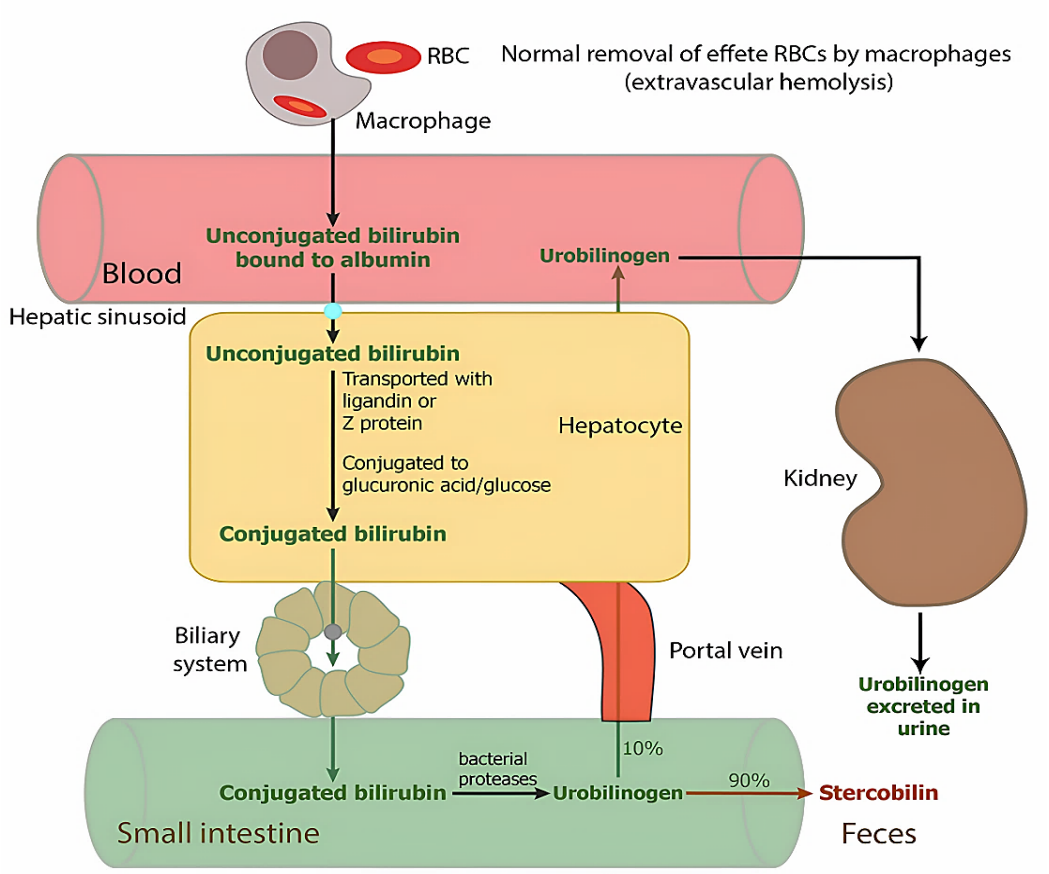
Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	The organism with the skull shown in image A has a well-developed cecum, within which numerous bacteria live in symbiosis.		
B	The organism shown in image B uses ultrasound to locate and capture its prey.		
C	If organisms B and C inhabit the same environment, species C could be the predator while species B could be the prey.		

D	The reduced development of teeth in species D is a result of feeding on very small food particles.		

Q15

Jaundice syndrome is a medical condition characterized by a yellow discoloration of the skin and mucous membranes due to an increased level of bilirubin in the blood. The schematic representation of bilirubin metabolism is provided below. Depending on which part of the metabolic pathway is impaired, the types of jaundice and their treatment differ.



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

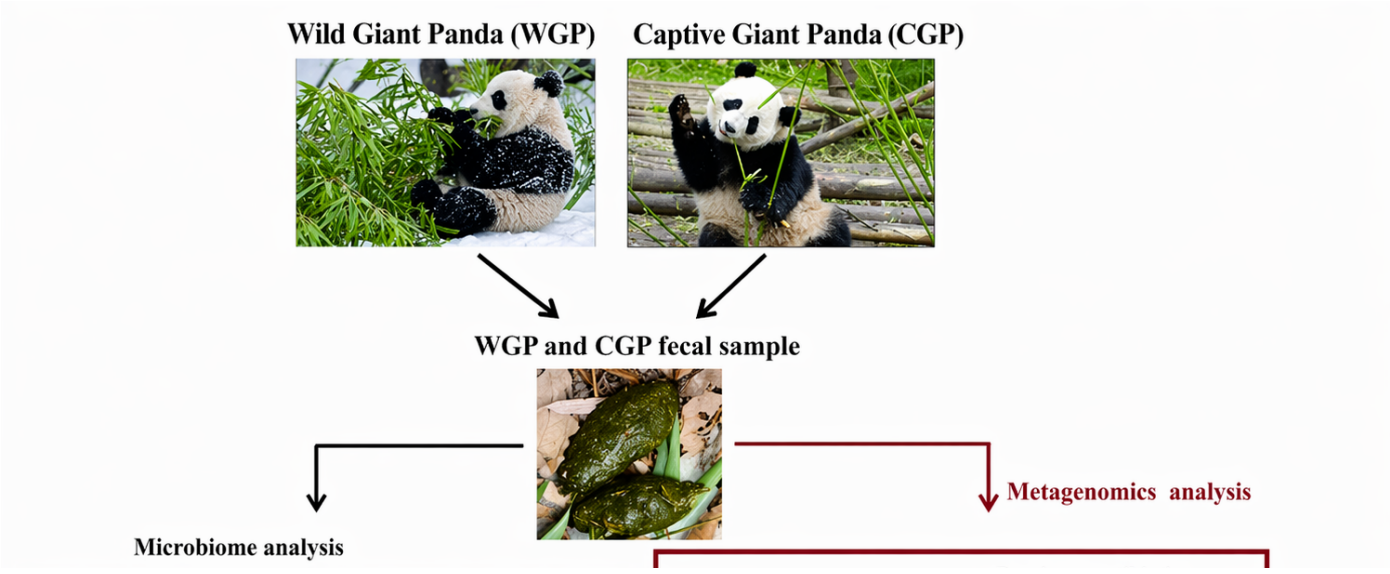
	Statement	True	False
A	During the acute phase of hemolytic jaundice, the increase in serum bilirubin occurs solely due to the unconjugated fraction, while the level of urobilinogen in		

	the urine is significantly elevated.		
B	Physiological jaundice in newborns (neonatal jaundice) occurs due to insufficient activity of the enzyme glucuronyl transferase. In this condition, phototherapy converts bilirubin-IXα into a form that can be excreted without the involvement of glucuronyl transferase.		
C	In viral hepatitis A, the number of functionally active hepatocytes decreases, leading to an increase in unconjugated bilirubin in the blood. Additionally, the accumulation of cellular debris from damaged hepatocytes obstructs the bile canaliculi, causing cholestasis and an increase in conjugated bilirubin.		
D	In a patient with jaundice syndrome, an increase in conjugated bilirubin in the blood plasma may be caused by obstruction of the bile ducts due to helminths.		

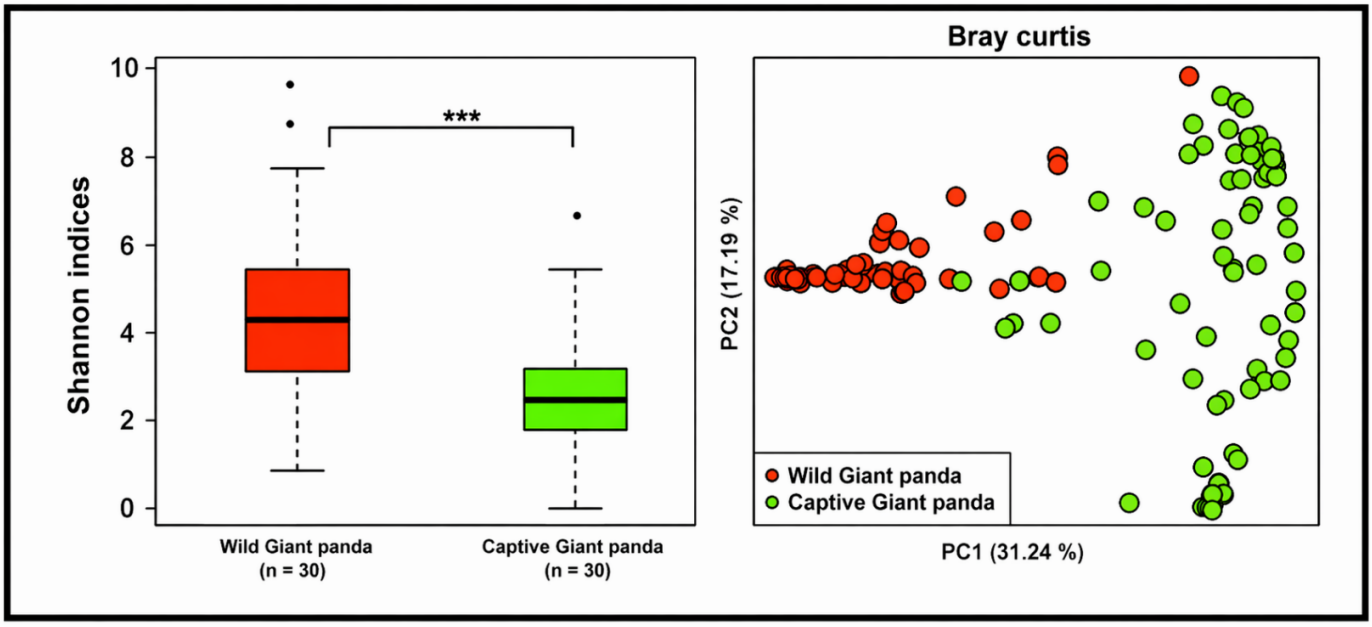
Q16

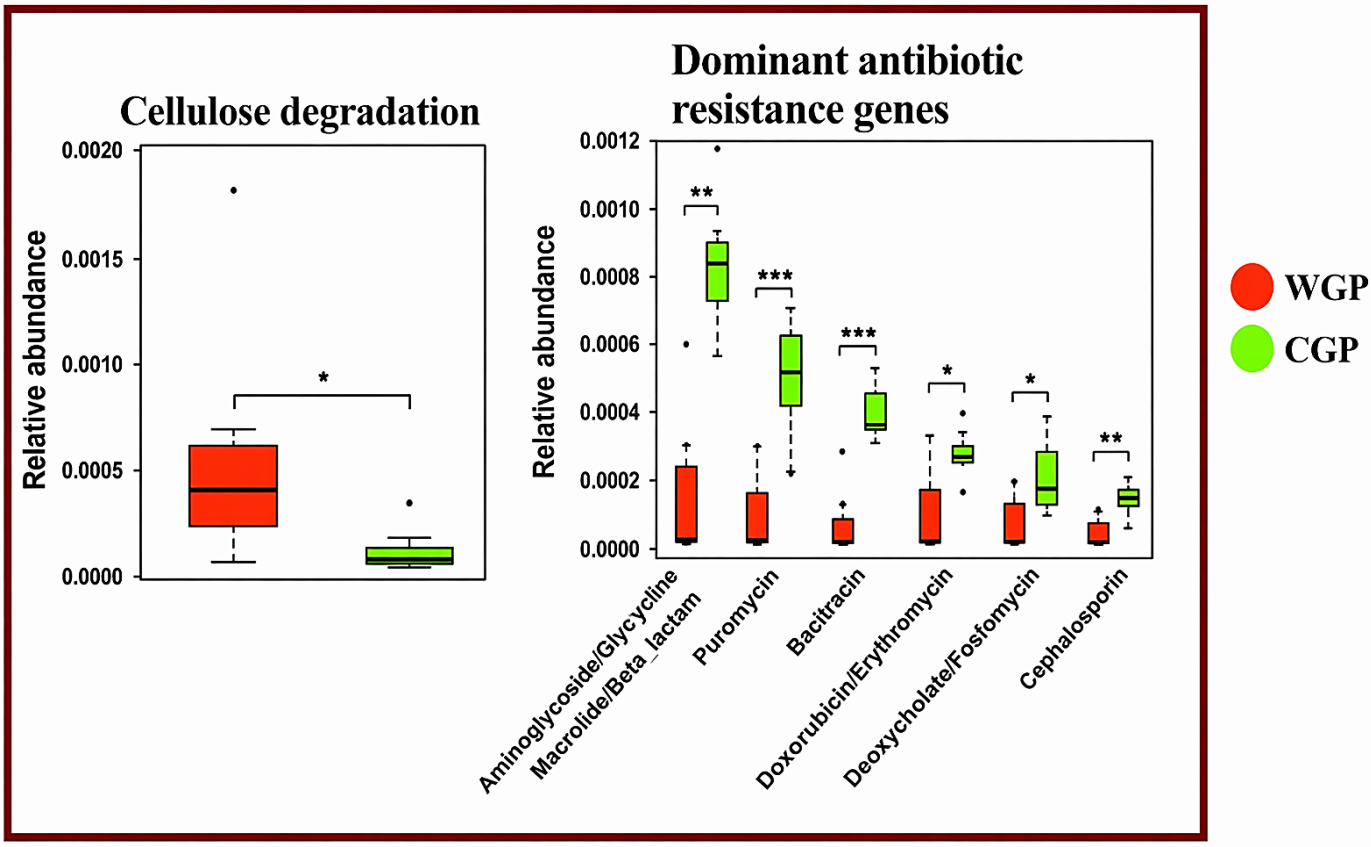
Captive breeding has been used as an effective method to protect endangered animals, but its impact on the gut microbiome and the conservation status of these species is of great concern, as it could spread to other wild animals and ecosystems when released into the wild. One such endangered species is the Giant Panda.

The graphic abstract below compares the gut microbiome of captive (CGP) and wild (WGP) Giant Pandas.



Microbiome analysis





Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

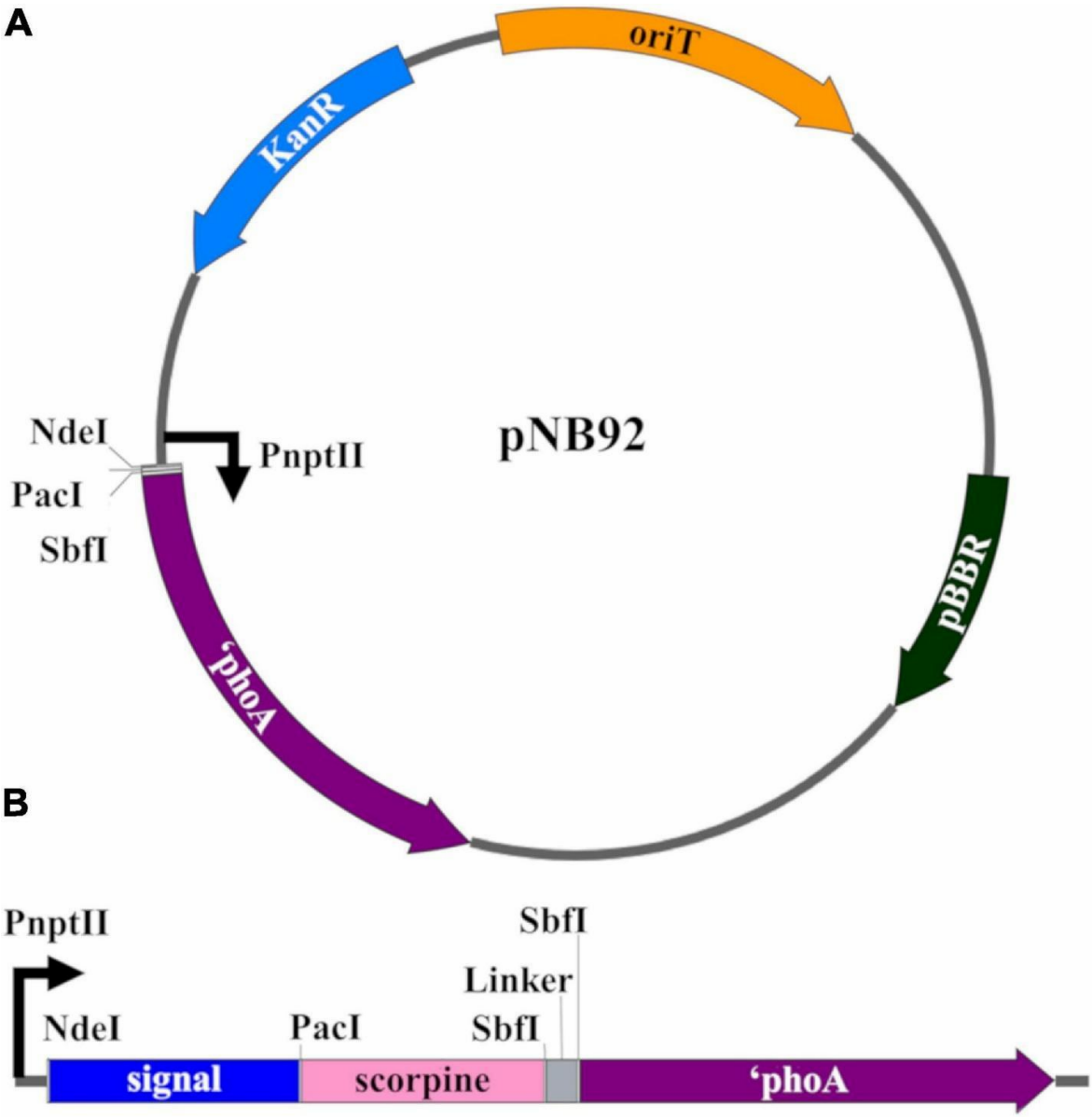
	Statement	True	False
A	Captivity has altered the giant panda microbiome, which may have unintended negative consequences for the adaptation and ecosystem of giant pandas when they are reintroduced into the wild.		
B	Antibiotic resistance genes and virulence factors, as well as heavy metal resistance genes, have been identified in the panda microbiomes, which is only due to human intervention		
C	Wild pandas have been found to have low cellulase activity and high amylase activity		
D	The reduction in cellulose degradation pathways and enrichment of starch metabolism in captive giant pandas is due to their being fed a variety of products other than bamboo		

Q17

Paratransgenesis is a malaria control technique that involves modifying symbiotic microbes within mosquitoes, rather than the mosquitoes themselves. In this process, the bacterium *Asaia bogorensis* is used as a vehicle to deliver antiplasmodial agents to the mosquito's gut.

Using the pNB92 plasmid, the researchers insert effector genes, such as scorpine, which kills the malaria parasite, into the bacterial genome. This genetic construct uses a special signal sequence to ensure that the drug proteins are released outside the cell.

As a result, the malaria parasites that enter the mosquito when it sucks blood are destroyed by these substances, and the transmission of the disease is stopped.



The diagram shows a map of the pNB92 plasmid and its components. This construct is to synthesize an antimalarial effector protein (scorpine). What is the function of the PnptII part of the construct and what happens if it is removed?

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	This is a restriction site; without it, the gene will not be integrated into the plasmid		

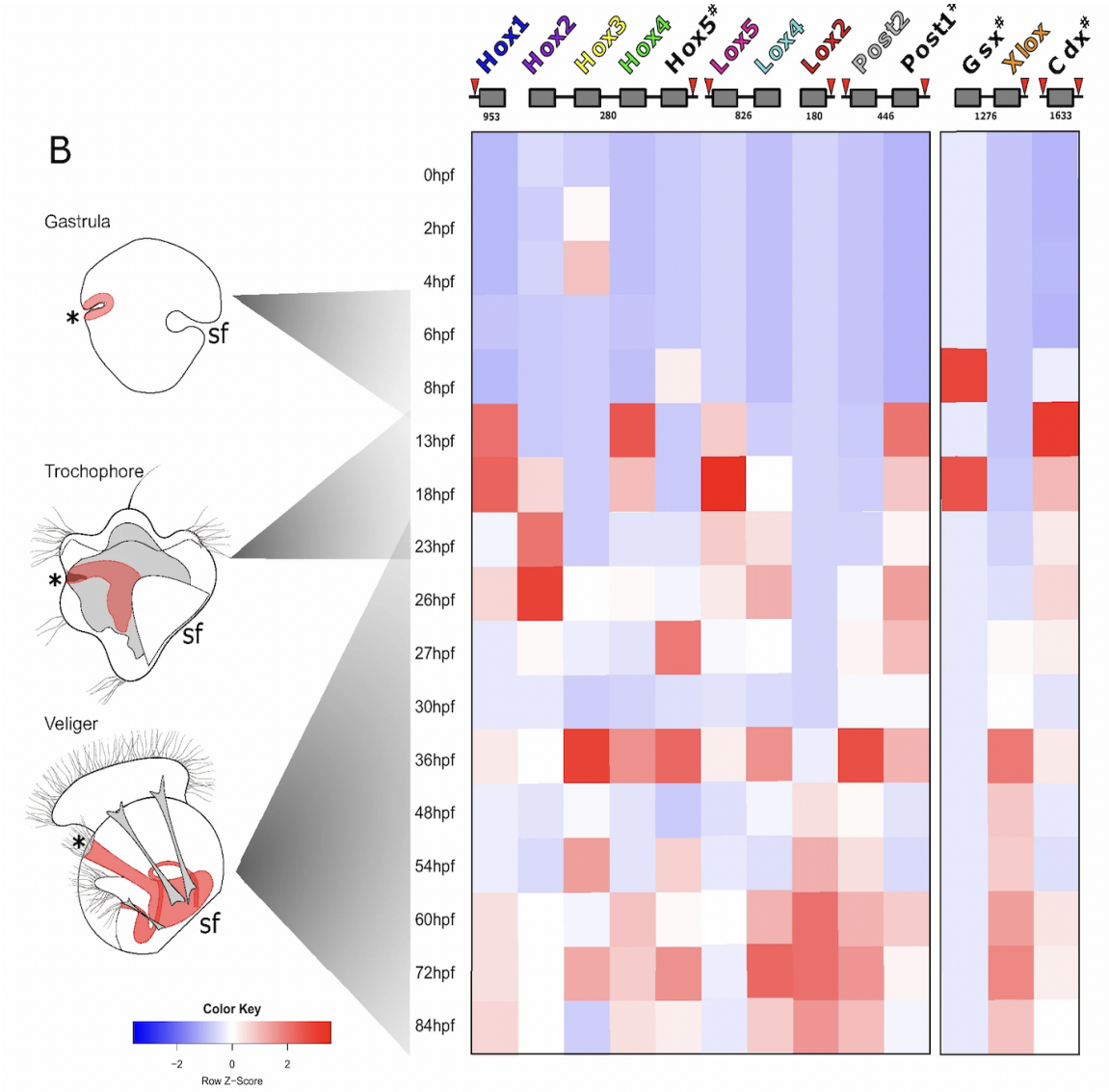
B	This is a promoter; without it, the scorpine and phoA genes will not be transcribed		
C	This is a selective marker; without it, the bacterium will become antibiotic-resistant		
D	This is a replication point; without it, the plasmid will not replicate inside the cell		

Genetics

Q18

For the Hox genes of the model invertebrate *Drosophila melanogaster*, a unique pattern of collinearity in gene expression has been demonstrated. It was shown that the order of genes along the chromosome corresponds both to the sequence of their activation during development and to the spatial distribution of their expression domains along the anterior–posterior axis of the embryo.

In a recent study, the expression of the Hox cluster was analyzed in the bivalve mollusk *Dreissena rostriformis*. The results are presented as a heatmap (on the x-axis, genes are arranged in the same order as in the genomic Hox cluster; on the y-axis, developmental time points at which expression was measured; color indicates expression intensity). Which of the following statements are correct?



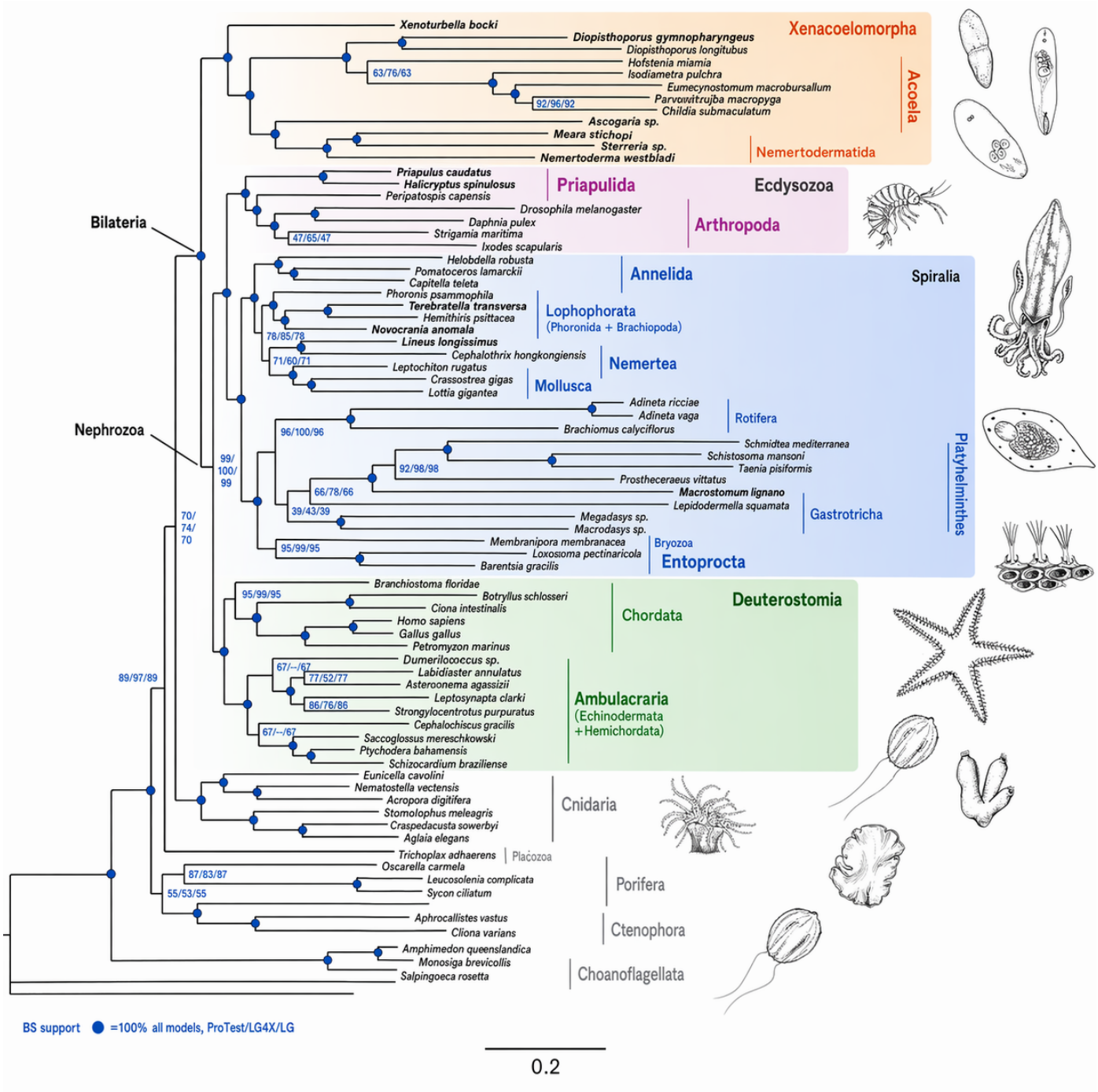
Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

	Statement	True	False
A	*Hox* genes begin to be strongly expressed at the gastrula stage		
B	Once the expression of a *Hox* gene has been induced, it is not switched off until molluscan metamorphosis		
C	The expression of *Hox* genes is probably induced by other transcription factors that begin to function 8–12 hours after fertilization (hpf);		

D	Based on the available data, the hypothesis of collinearity of gene expression can be rejected		
E	*Hox* genes are transcription factors that regulate animal morphogenesis		

Q19

Consider the phylogenetic tree published in 2016 in *Nature* in the article *"Xenacoelomorpha is the sister group to Nephrozoa."* Based on the analysis of this phylogenetic tree, it can be stated with confidence that.



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

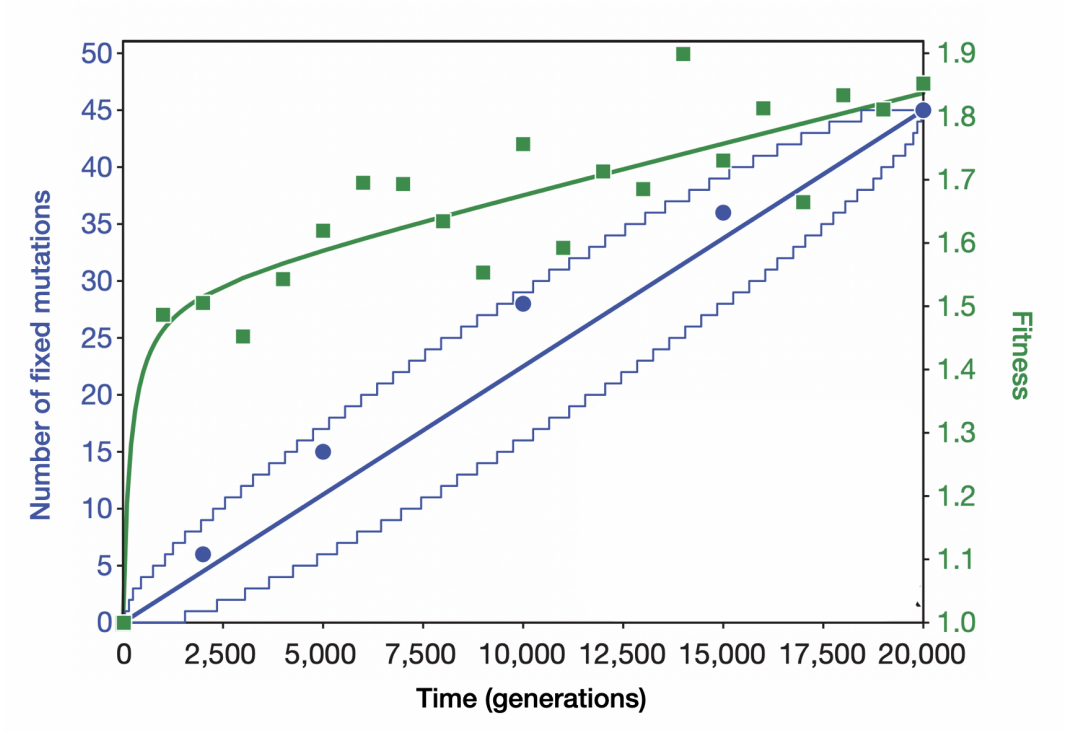
	Statement	True	False
A	Nematodes, mollusks, and flatworms form a monophyletic clade that is		

	sister to the group including arthropods and annelids		
B	The moulting animals (Ecdysozoa) form a monophyletic group		
C	The group of animals possessing a distinct excretory system (Nephrozoa) is not monophyletic		
D	The group of "true animals" (*Eumetazoa*) includes all animal phyla except sponges (*Porifera*) is monophyletic		
E	Flatworms and annelids form a monophyletic clade that is sister to the group including arthropods and nematodes		

Q20

To investigate the rate of mutation accumulation at the genomic level, the authors cultivated populations of *Escherichia coli* on a minimal medium for 20,000 generations. Each day, part of the population was transferred from the culture to a new, identical medium. Samples were collected and sequenced at generations 2,000, 5,000, 10,000, and 20,000. Fitness was assessed as the growth rate relative to the ancestral strain. It turned out that all fixed mutations were nonsynonymous, that is, they resulted in amino acid substitutions. Carefully analyze the graph and the reference data, then select the correct statements.

Reference data:
Genome size of *E. coli*: 4.6×10 base pairs
Mutation rate per generation: 1.6×10^{-1} per nucleotide
Population size in the experiment: ~100,000 individuals



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

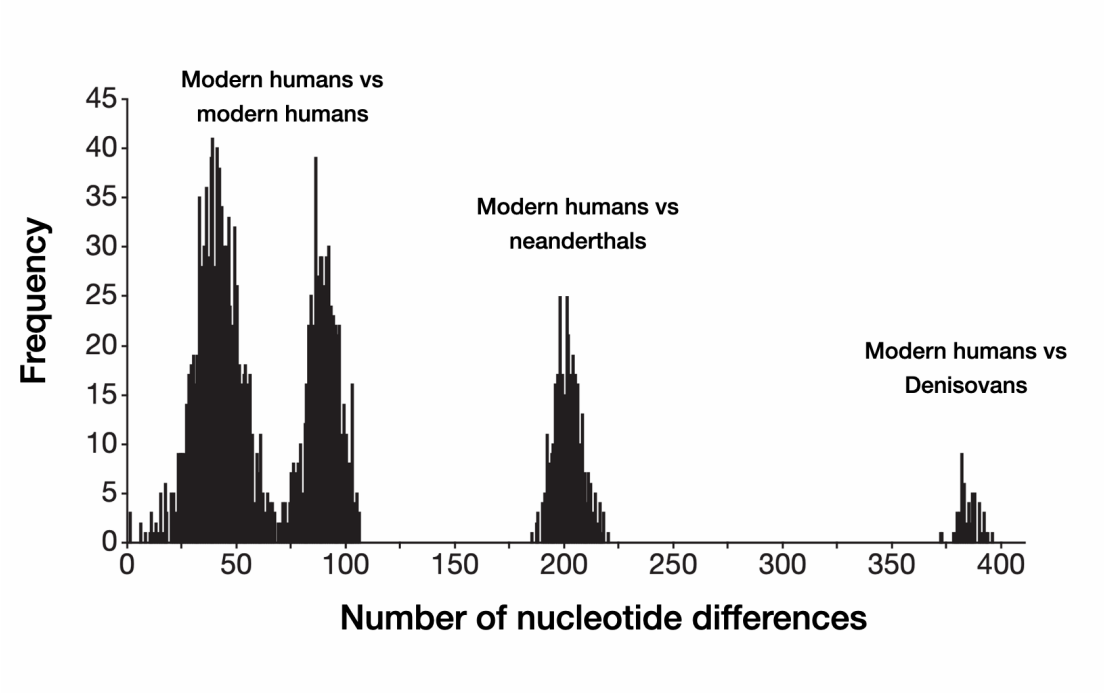
	Statement	True	False
A	The pattern of increase in the number of mutations and in fitness indicates that the overwhelming majority of accumulated mutations are neutral		
B	The mutations that became fixed early in the populations initially confer a substantially greater selective advantage because they outcompete alternative variants through clonal interference		
C	If mutagenesis in *E. coli* were assumed to be completely neutral, the number of accumulated mutations after 20,000 generations would be approximately 15		
D	Based on genome size, recurrent bottlenecks caused by serial transfer, and the mutation rate, it can be assumed that most mutations became fixed due to genetic drift		
E	The increase in fitness most likely follows a hyperbolic model, whereas the increase in the number of mutations over 20,000 generations is linear		

Q21

In 2010, a paper was published in *Nature* describing the first sequenced and analyzed mitochondrial DNA from Denisova Cave. Later, after studying nuclear genome data, it became clear that this mitochondrial DNA belonged to a new species—the Denisovan—distinct from both Neanderthals and modern humans.

Consider the histogram of polymorphism* in mitochondrial DNA among modern humans, Denisovans, and Neanderthals, and choose the one correct statement.

**For constructing the histogram, 54 mitochondrial genomes of modern humans from all major populations, 6 Neanderthal genomes, and 1 Denisovan genome were compared pairwise.*



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

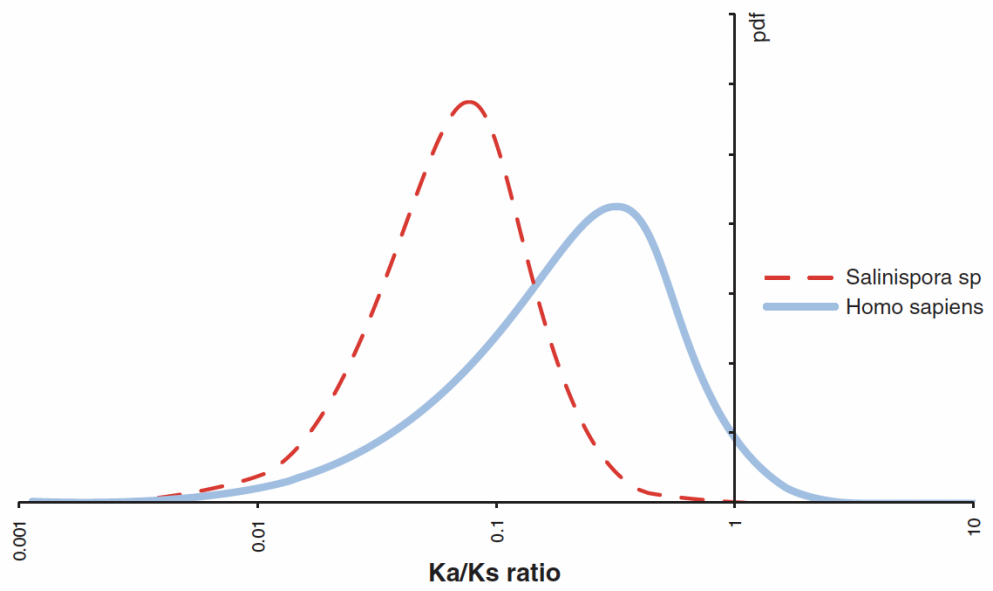
	Statement	True	False
A	According to mitochondrial data, the age of the most recent common ancestor of Neanderthals and modern humans (in millions of years ago) is younger than that of Denisovans and modern humans		
B	On average, there are approximately 80 differences between the mitochondrial DNA of any two modern humans		

C	All modern humans differ from one another in mitochondrial DNA to approximately the same extent;		
D	In humans, the age of the most recent common ancestor (in millions of years ago), as estimated from mitochondrial and nuclear genomes, would be the same		
E	The bimodal distribution of differences among modern humans is due to high mitochondrial genome diversity in indigenous African populations and lower mitochondrial genome diversity in non-African human populations		

Q22

Ka/Ks is the ratio of the number of nonsynonymous substitutions (Ka) to the number of synonymous substitutions (Ks). This metric is used to assess the action of natural selection on protein-coding genes. When Ka/Ks is less than 1, it is assumed that purifying (stabilizing) selection is acting on the gene, removing functional changes. A Ka/Ks value close to 1 is interpreted as neutral evolution. Values greater than 1 indicate positive (directional) selection, where amino acid substitutions are being fixed.

The graph shows the distribution of this ratio for protein-coding genes in a bacterium (*Salinispora* sp.) and in humans (*Homo sapiens*).



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

	Statement	True	False
A	Purifying (stabilizing) selection acts more strongly on bacterial genes		
B	Most human genes evolve neutrally		
C	Although the medians of the distributions differ, the mean Ka/Ks value is the same for bacteria and eukaryotes		
D	Most human genes are under positive (directional) selection		
E	The proportion of genes under positive selection is higher in humans than in bacteria		

Q23

In a population, linkage disequilibrium (LD) was measured for 8 consecutive SNPs (SNP1–SNP8) in the same chromosomal region. LD is the degree of deviation from random (independent) association of alleles at two loci in a population; it reflects haplotypes (specific allele combinations) appearing more or less frequently than expected.

In this question, LD is summarized using r^2: values near 1 indicate strong correlation, whereas values near 0 indicate independence.

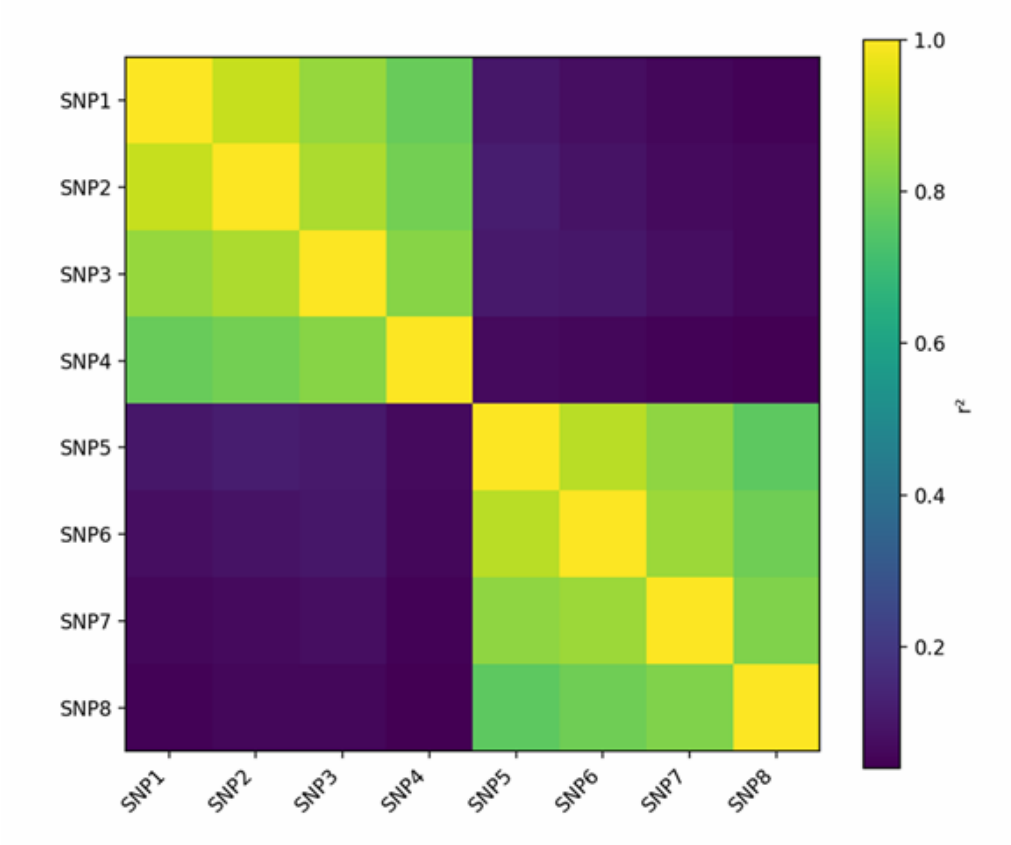


Figure - LD heatmap (r^2) for an 8-SNP regions

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	The heatmap suggests a clear haplotype-block boundary between SNP1–SNP4 and SNP5–SNP8, consistent with a recombination hotspot between SNP4 and SNP5		
B	Because SNP4 shows low r^2 with all other SNPs, SNP4 may be a rare variant and that is why LD is low.		
C	The very low r^2 between SNP1 and SNP8 shows that these two SNPs are located on different chromosomes		
D	High r^2 among SNP5–SNP8 is evidence that these SNPs are under natural selection		

Q24

In a genome-wide association study (GWAS), a p-value is computed for each SNP testing its association with a phenotype. In a Manhattan plot, the x-axis shows genomic position (chromosomes arranged sequentially along the genome), and the y-axis shows -log10(p).

Because GWAS tests many variants simultaneously, a commonly used threshold to control false positives is p = 5×10 (dashed line in the figure).

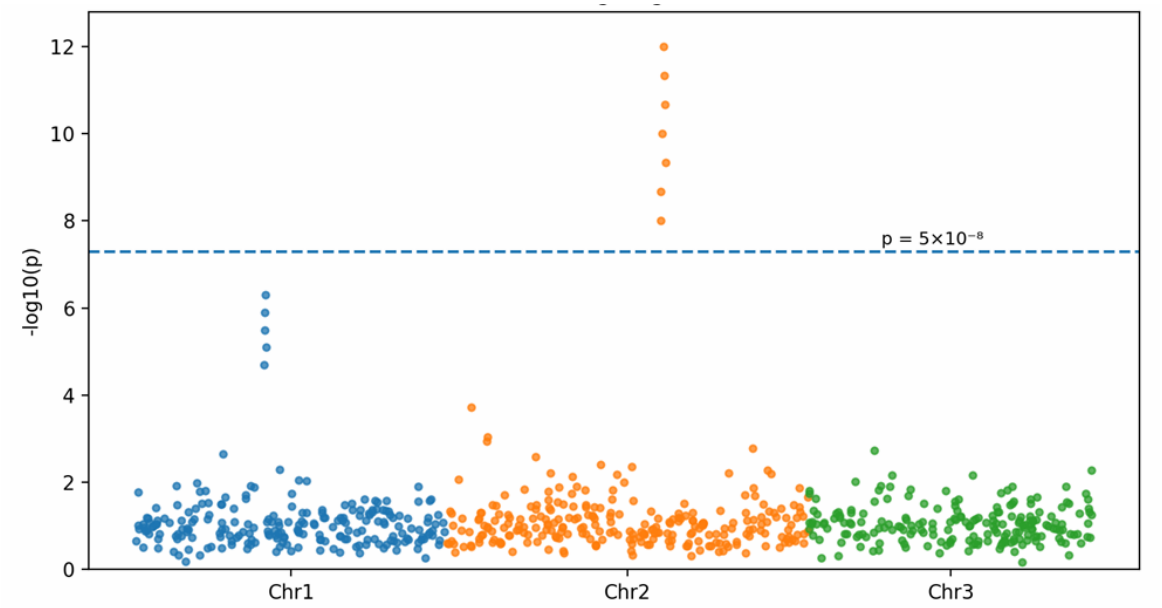


Figure - GWAS Manhattan plot. Dashed line: p = 5×10

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	Only the peak on chromosome 2 exceeds the genome-wide significance threshold; the signal on chromosome 1 does not pass the multiple-testing threshold (it may be suggestive).		
B	The peak on chromosome 1 is genome-wide significant, while the peak on chromosome 2 is only suggestive		
C	The presence of two peaks in the Manhattan plot proves that the phenotype is controlled by exactly two genes		

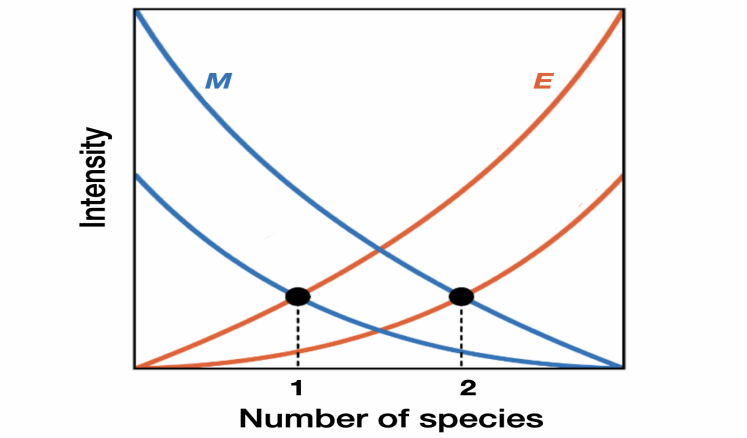
D	A higher -log10(p) for a SNP demonstrates that this SNP is causal for the phenotype		

Ecology

Q25

The number of species inhabiting a particular oceanic island can be described using the "island biogeography model." Within this model, the number of species on an island is determined by the balance between species extinction (E) and immigration (M) from the mainland. Both parameters are functions that depend on the number of species present on the island. For example, the more species already exist on the island, the higher the extinction rate; conversely, the fewer species are present, the more successful immigration from the mainland will be.

The intersection of the two curves represents the island equilibrium—that is, the stable number of species on the island. It is known that both extinction intensity and immigration success depend on island size. The figure shows curves for a large and a small island. Points 1 and 2 indicate equilibrium states.



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

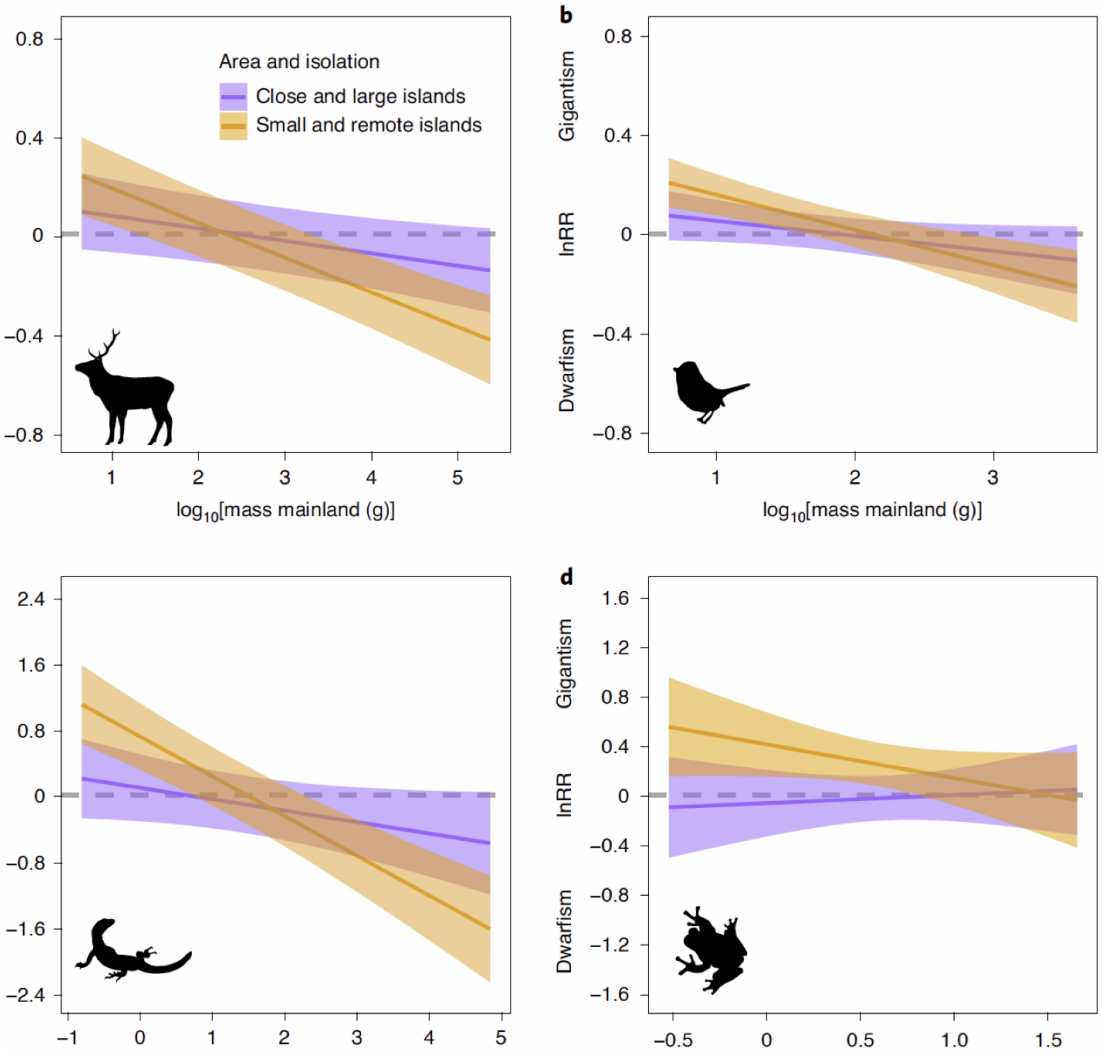
	Statement	True	False
A	On large islands, the extinction rate is significantly higher because interspecific competition is stronger there		
B	The rate of successful immigration increases as the number of species on the island decreases, because the number of available ecological niches decreases		

C	Point 2 represents the equilibrium for the larger island		
D	On small islands, the rate of successful immigration is higher because large species that strongly outcompete others cannot establish there		
E	The main factor determining the differences in the shape of the curves for large and small islands is the number of available ecological niches		

Q26

It is generally believed that changes in the body size of island species relative to their mainland ancestors follow the Bristol Foster rule. According to this rule, large species that colonize islands tend to decrease in size over evolutionary time (for example, dwarf elephants and hippopotamuses). Small animals, by contrast, tend to increase in size after colonizing islands (for example, giant rats).

In a study by European ecologists, more than 2,000 island vertebrate species (and their mainland ancestors) from islands in the Pacific, Indian, and Atlantic Oceans were analyzed. To test the island rule, the authors calculated a linear regression between the decimal logarithm of species body mass and the natural logarithm of the evolutionary response (RR), defined as follows:



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

	Statement	True	False
A	Based on the presented data, Foster's rule does not hold for amphibians inhabiting islands close to the mainland		
B	Foster's rule is less clearly expressed on small remote islands than on large islands close to the mainland		
C	The island rule is most strongly expressed in amphibians		
D	Based on the presented data, Foster's rule does not apply at all to		

	species capable of prolonged active migration		
E	Based on the presented data, Foster's rule does not hold for birds inhabiting islands close to the mainland		

Q27

The construction of river dams and the intensification of agricultural fertilizer use fundamentally alter the delivery of dissolved nutrients to coastal ecosystems. The ecological stoichiometry of marine phytoplankton is tightly constrained; marine diatoms typically require Carbon (C), Silicate (Si), Nitrogen (N), and Phosphorus (P) in a specific molar ratio known as the Redfield-Brzezinski ratio (C:Si:N:P = 106:15:16:1).

Deviations from this ratio can cause abrupt shifts in phytoplankton community structure, triggering harmful algal blooms and altering the biological carbon pump.

A long-term ecological monitoring program recorded the decadal summer averages of dissolved macronutrients in a coastal bay from 1980 to 2010. During this period, several hydroelectric dams were constructed upstream, and regional agriculture intensified.

Table - Dissolved nutrient concentrations (μmol/L) and Diatom relative abundance

Year	Silicate (Si)	Nitrogen (N)	Phosphorus (P)	Diatom Abundance (% of total phytoplankton)
1980	30.0	10.0	1.0	85%
1990	20.0	24.0	1.2	50%
2000	10.0	40.0	2.0	20%
2010	5.0	60.0	2.5	5%

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	The shift in nutrient stoichiometry from 1980 to 2010 creates a competitive advantage for nitrogen-fixing cyanobacteria over non-fixing phytoplankton		
B	The construction of upstream dams contributed to the decline of diatoms by		

	acting as a sink for particulate and dissolved biogenic silica		
C	The observed shift in the phytoplankton community will likely increase the efficiency of carbon sequestration to the deep ocean benthic zone		
D	In 2010, an artificial addition of orthophosphate to the bay would trigger a massive bloom of diatoms		

Biotechnology

Q28

Cheese is a highly nutritious dairy product that has been produced since ancient times. There are many types of cheese, including hard, semi-hard, soft, and spreadable varieties. The texture and overall structure of cheese depend on the fat content of milk, moisture, salt concentration, pH, temperature, ripening conditions, and the microorganisms used.

The "eyes" or holes observed in Emmental cheeses are not typical of all cheese varieties. Lactic acid bacteria play an important role in their formation. Lactic acid bacteria ferment lactose to produce lactic acid (lactate), which leads to a decrease in pH, coagulation, and the formation of the initial texture.



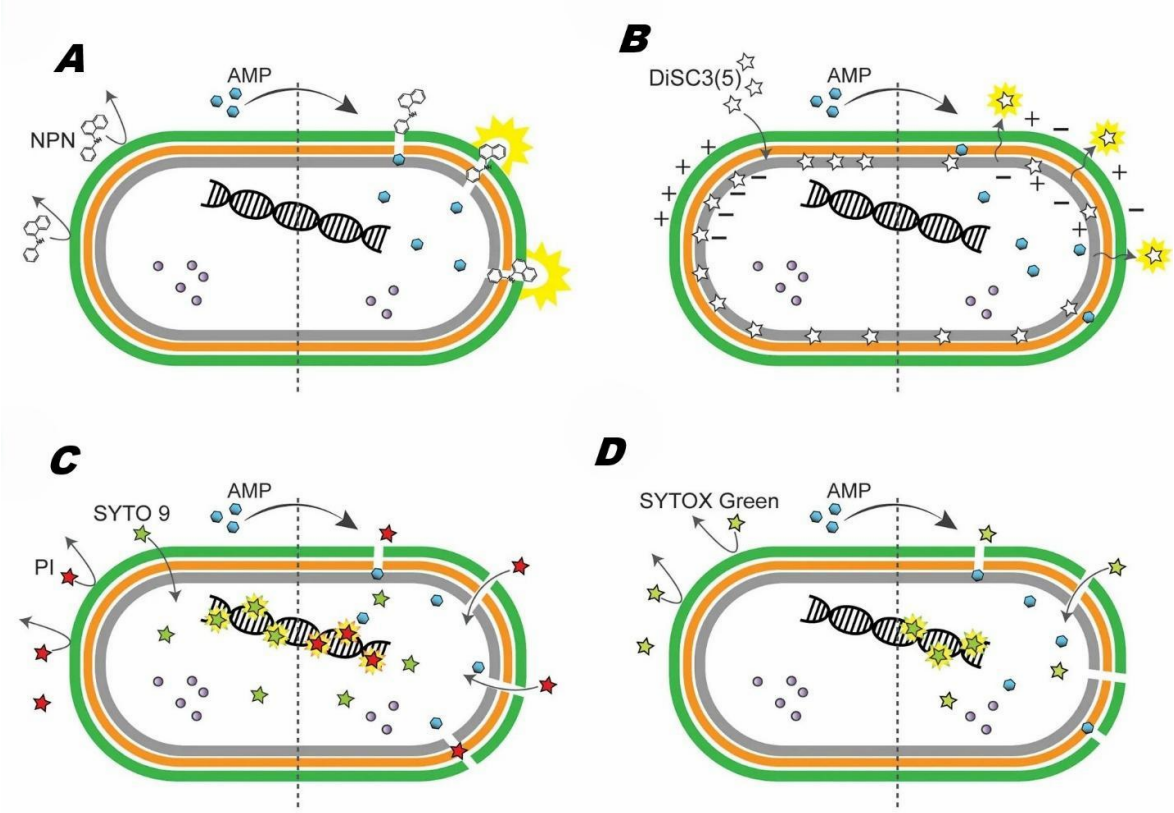
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	Statement	True	False
A	*Lactobacillus paracasei, Lactobacillus acidophilus, Lactobacillus casei,* and *Bifidobacterium* cultures lower the pH, and in a salty environment, the CO produced by *L. delbrueckii* subsp. bulgaricus dissolves in the fat and aqueous		

	phases at 10°C, resulting in a sweet and porous cheese.		
B	*Streptococcus thermophilus and Lactobacillus helveticus* convert lactose into lactic acid; *Propionibacterium,* in turn, utilizes this lactate ($C_3H_6O_3$) to produce CO and propionate($C_3H_5O_2^-$), and therefore holes develop in the cheese.		
C	The lactate produced by *Lactobacillus rhamnosus, Lactobacillus buchneri,* and *Lactobacillus curvatus* promotes the growth of *Penicillium roqueforti*, resulting in CO production and the formation of holes in the cheese.		
D	*Lactobacillus helveticus* and *L. delbrueckii* break down lactose into lactic acid, while the holes are formed due to the polysaccharides produced by *Streptococcus thermophilus.*		
E	Due to the fermentation of lactate produced by *Lactobacillus acidophilus* and *Lactobacillus casei*, *Clostridium tyrobutyricum* produces gases, including CO and H , which results in the formation of holes in the cheese.		

Q29

Researchers used different fluorescent indicators to study the effects of cationic antimicrobial peptides (AMPs) on bacterial cells.

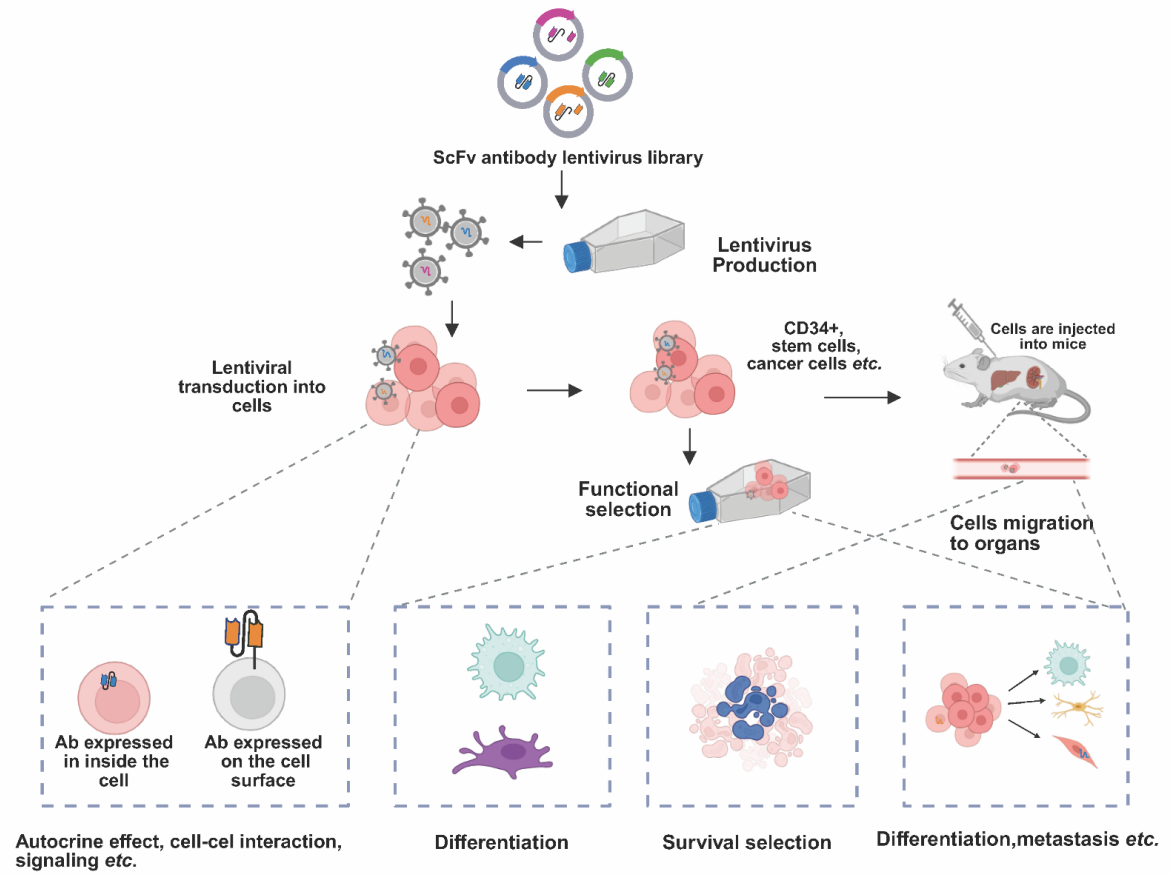


Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	Cationic AMPs bind to the bacterial surface and disrupt the outer membrane's integrity. This allows the hydrophobic NPN dye to penetrate the membrane's lipid layer, which leads to a significant increase in fluorescence.		
B	An increase in the DiSC3(5) signal is a classic indicator of membrane hyperpolarization. When AMPs create pores in the membrane, the ion gradient is strengthened, causing the dye to be absorbed more deeply into the membrane, which leads to a significant decrease in the fluorescence signal.		
C	Propidium Iodide (PI) is a large, membrane-impermeable molecule that can only enter cells with a compromised membrane. Once inside, it binds to DNA with higher affinity than SYTO 9, effectively quenching (suppressing) the green SYTO 9 signal and staining the cell red.		
D	SYTOX Green is a membrane-permeable dye that easily enters healthy bacterial cells via active transport. Once inside, it binds to the lipid droplets in the cytoplasm, and its fluorescence increases only when the membrane remains perfectly intact and undisturbed by AMPs.		

Q30

The figure shows a lentiviral system for screening antibodies. Why were lentiviruses (e.g., the HIV core) chosen for this technology?



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	They can signal from the outside without disrupting the cell membrane		
B	They have the ability to stably integrate genetic information (scFv antibody gene) into the host cell genome		
C	They recognize and reanimate only dead cells		

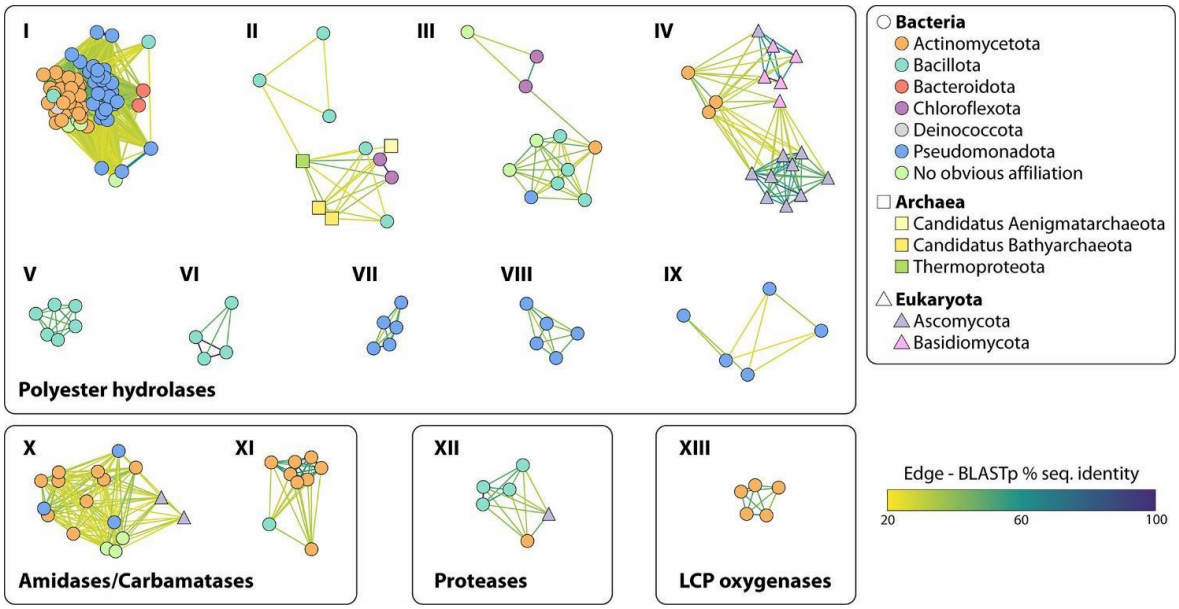
D	They deliver antibodies only to the nucleus, not to the cell surface		

Q31

In modern biotechnology, the utilization of plastic waste through microbial degradation is a relevant strategy. The basis of this process is the ability of special exoenzymes synthesized by microorganisms to break down polymer chains. Bioinformatic analyses, in particular sequence similarity networks (SSN), help to understand the functional diversification of enzymes.

Studies show that polyester hydrolases (clusters I–IX) specialize in breaking down ether bonds of polymers such as Polyethylene Terephthalate (PET) and Polylactic Acid (PLA), while amidases and carbamate hydrolases (clusters X–XI) act on chemical bonds of polyurethanes and polyamides. It is noteworthy that cluster XII proteases have been found to selectively act only on PLA plastics. This enzymatic activity is characteristic mainly of bacterial phyla such as *Pseudomonadota*, *Actinomycetota* and *Bacillota.* Studying the evolution of enzymes and their structural similarities will allow for the creation of effective industrial technologies for biological processing of plastic waste.

The figure shows a similarity network (SSN) of enzymes that degrade plastic materials. It shows that clusters I-IX degrade polyesters (PET, PLA, etc.), and clusters X-XI degrade polyurethane (PUR) and polyamides.



Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statement	True	False
A	Cluster XII enzymes have sequence similarity to proteases (protein-degrading		

	enzymes).		
B	Proteases can degrade PLA plastic because its chemical bonds (ether bonds) are similar to peptide bonds in proteins.		
C	According to the figure, the ability to degrade polyesters is specific to only one type of microorganism (for example, only Bacillota).		
D	The change in distance and color of lines in the SSN network indicates the differences in amino acid sequences between enzymes.		

Theory
Part B

Cell Biology (7)

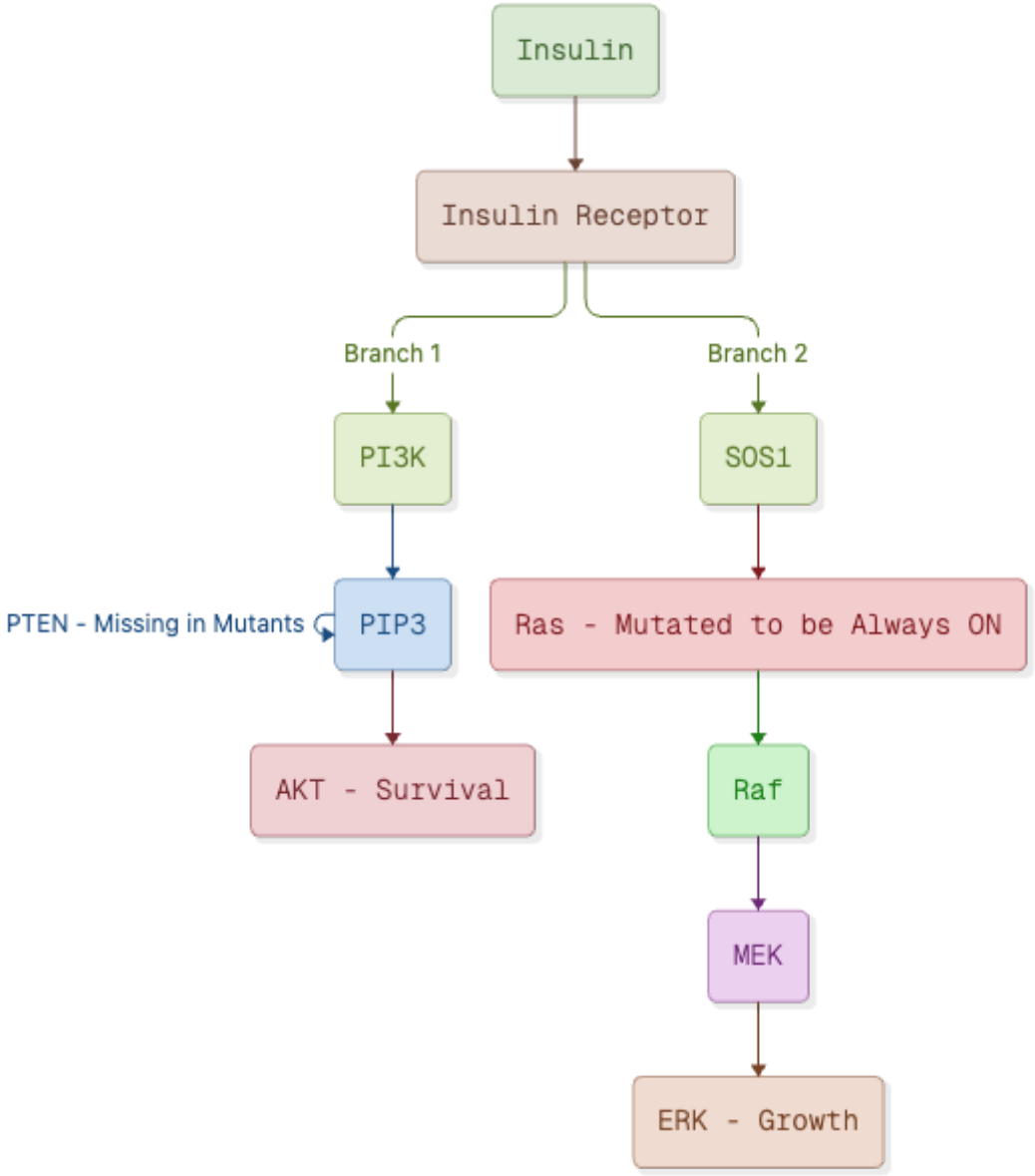
Q1.

HLC-7 is a cancer cell line that relies on insulin signaling to grow and survive. The insulin receptor triggers two main branches of intracellular signaling:

1. The survival branch: Leads to the activation of AKT. It is negatively regulated by PTEN, which stops the signal.

2. The growth branch: Leads to the activation of ERK. It is negatively regulated by MKP3.

The diagram below shows the pathway.



"Always On" Mutations In HLC-7 cancer cells, two specific mutations keep these pathways active even when no insulin is present:

- Mutation 1 (KRAS G12V): The Ras protein is permanently locked in its active "GTP-bound" state. It no longer needs the upstream signal from the insulin receptor or the SOS1 protein to turn on.

- Mutation 2 (PTEN Deletion): The "brake" for the survival branch (PTEN) is completely missing. This causes the signaling molecule PIP3 to accumulate, keeping AKT active at all times.

Doctors want to stop both the survival (AKT) and growth (ERK) signals simultaneously using a combination of drugs. The team wishes to suppress both branches simultaneously. They evaluate three pharmacological strategies:

Strategy W: An anti-insulin receptor blocking antibody that prevents insulin binding and receptor activation, combined with a high-affinity SOS1 catalytic site inhibitor that blocks nucleotide exchange on Ras.

Strategy X: A selective MEK1/2 inhibitor combined with the selective AKT inhibitor.

Strategy Y: Adenoviral re-expression of wild-type PTEN to restore PIP3 phosphatase activity, combined with overexpression of NF1 (a high-affinity Ras-specific GAP that accelerates Ras GTP hydrolysis using a catalytic arginine finger mechanism).

Based on the signaling map and the nature of the mutations, determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statements	True	False
A	A drug that blocks the insulin receptor (Strategy W) would be effective at stopping growth in these mutant cells because it cuts off the signal at the very beginning of the chain.		
B	Because the Ras mutation makes it independent of upstream input, a drug that inhibits SOS1 (the protein that normally activates Ras) will fail to stop the growth signal in these cells.		
C	To successfully stop both signals in this specific mutant line, the most effective strategy (Strategy X) is to use a combination of drugs that inhibit AKT and MEK directly.		
D	Restoring the PTEN protein to the cells (Strategy Y) would help stop the Survival branch, but it would have no direct effect on the Growth (Ras-ERK) branch.		

Q2.

During mitochondrial uncoupling, the energy generated from the oxidation of nutrients is not used for ATP synthesis; instead, it is released as heat. However, energy dissipation does not occur only through mitochondrial uncoupling—it can also occur via other mechanisms. One such mechanism involves metabolic reactions known as *futile cycles*. In these reactions, ATP is consumed to convert a substrate into a product, but this product is subsequently converted back into the original substrate, resulting in the release of energy as heat. Depending on the ATP demand of the cell, energy dissipation can be regulated through the rate and number of such futile cycles. In mammals, heat production occurs via two mechanisms:

1. Shivering thermogenesis
2. Non-shivering thermogenesis

In non-shivering thermogenesis, the uncoupling protein (UCP1) plays a key role. This protein allows protons to return directly to the mitochondrial matrix without passing through ATP synthase, thereby dissipating the proton gradient as heat.

2.1. Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

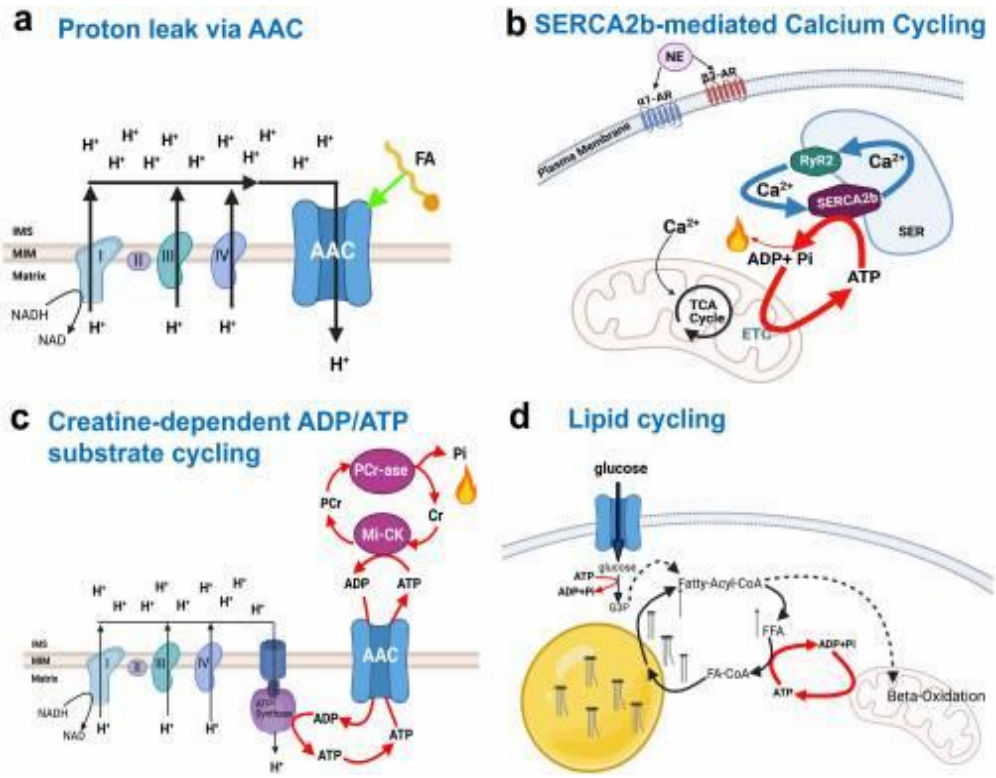
	Statements	True	False
A	During heat production via mitochondrial uncoupling, the proton gradient is maintained and ATP synthesis continues.		
B	During shivering, heat production occurs mainly through ATP consumption used to activate uncoupling proteins in mitochondria of skeletal muscles.		
C	Non-shivering thermogenesis is initiated by activation of the sympathetic nervous system, and norepinephrine induces the expression and activation of uncoupling proteins.		
D	Thyroxine does not participate in non-shivering thermogenesis because its main function is to regulate basal metabolic rate rather than heat production.		

2.2. In mice with a UCP1 gene knockout, resting energy expenditure remains normal. Even in mildly cold conditions, they can still generate heat and adapt to cold environments. This is associated with the presence of futile cycles.

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statements	True	False
A	UCP1 knockout mice suffer less from diet-induced obesity compared to mice expressing the UCP1 gene		
B	Futile cycles occur more frequently in cells with higher expression of the UCP1 gene.		
C	In UCP1 knockout mice, thermoregulation via futile cycles requires less ATP.		
D	The ratio between UCP1 protein and ATP synthase channels can indicate whether thermoregulation occurs via mitochondrial uncoupling or futile cycles.		

2.3. Some mechanisms of futile cycles are shown below.



https://pubmed.ncbi.nlm.nih.gov/34741717/"ATP-consuming futile cycles as energy dissipating mechanisms to counteract obesity" Alexandra J Brownstein, Michaela Veliova, Rebeca Acin-Perez, Marc Liesa, Orian S Shirihai

Figure 1.1. Legend: AAC – ADP/ATP carrier, FA – fatty acid, TCA – tricarboxylic acid cycle, ~~1 and 2 – enzymes~~, b – process occurring in beige adipose tissue, NE – norepinephrine, SER – smooth endoplasmic reticulum, Cr – creatine, FFA – free fatty acid, FA – fatty acid.

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 7 are correct, award **1.5 point**; if 6 are correct, award **1 .1points**; if 5 are correct, award **0.8 points**; if only 4 is correct, award **0.5 points, if 3 is correct award 0.2 points, 2 and 1 correct answers award 0 points.**

	Statement	True	False
A	During heat production via futile cycling, the amount of ATP consumed equals the amount of ATP utilized, i.e., the net ATP usage is zero.		
B	Proton leak via AAC requires the presence of free fatty acids and is negatively regulated by ADP/ATP exchange.		
C	None of the given processes resemble thermogenesis mediated by the UCP1 protein.		
D	Both the release of Ca^{2} from the endoplasmic reticulum and its uptake into the ER occur via facilitated diffusion.		
E	If the activity of SERCA2b decreases, more ATP will be synthesized in the mitochondria.		
F	Acceleration of mechanisms b, c, and d generally increases blood glucose levels.		
G	Among these processes, the highest ATP consumption occurs in the lipid cycle.		

2.4. To prevent uncontrolled energy dissipation, some futile cycles have their key steps occurring in different tissues or cellular compartments. An example of this is the hexokinase/glucose-6-phosphatase system. In this case, hepatic hexokinase is replaced by **glucokinase (GK)**, which is regulated by the **glucokinase regulatory protein (GKRP)**, thereby enabling the occurrence of futile cycling.

Another example is the **Cori cycle**, which connects the liver and skeletal muscle. Schematics of these two mechanisms are shown below.

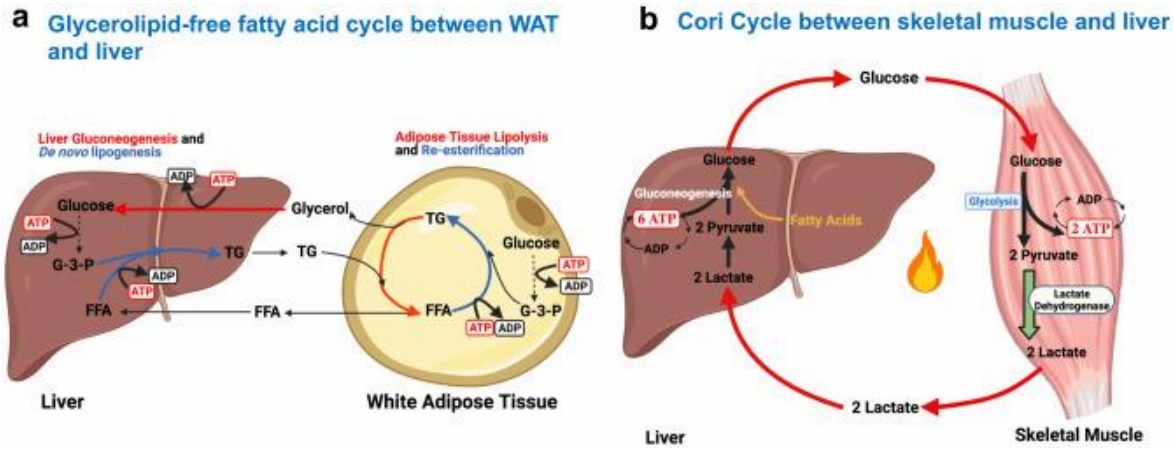


Figure 1.2. Legend: FFA – free fatty acids, TG – triglyceride,

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statements	True	False
A	During fasting, the GKRP protein inactivates glucokinase (GK), thereby further accelerating the futile cycle.		
B	One of the reasons the Cori cycle is considered a futile cycle is that its net ATP yield is –4 ATP.		
C	Deletion of the gene encoding the pyruvate transporter in the mitochondria of skeletal muscle cells leads to a decrease in blood lactate levels.		
D	In both mechanisms, fatty acids are used as an energy source.		

Q3.

Calcium (Ca^{2}) is a ubiquitous second messenger in cells. The resting concentration of Ca^{2} in the cytosol is extremely low (~10 M), whereas outside the cell and inside the endoplasmic reticulum (ER) it is thousands of times higher. Various stimuli trigger Ca^{2} channels opening in the plasma membrane or release of Ca^{2} from internal stores.

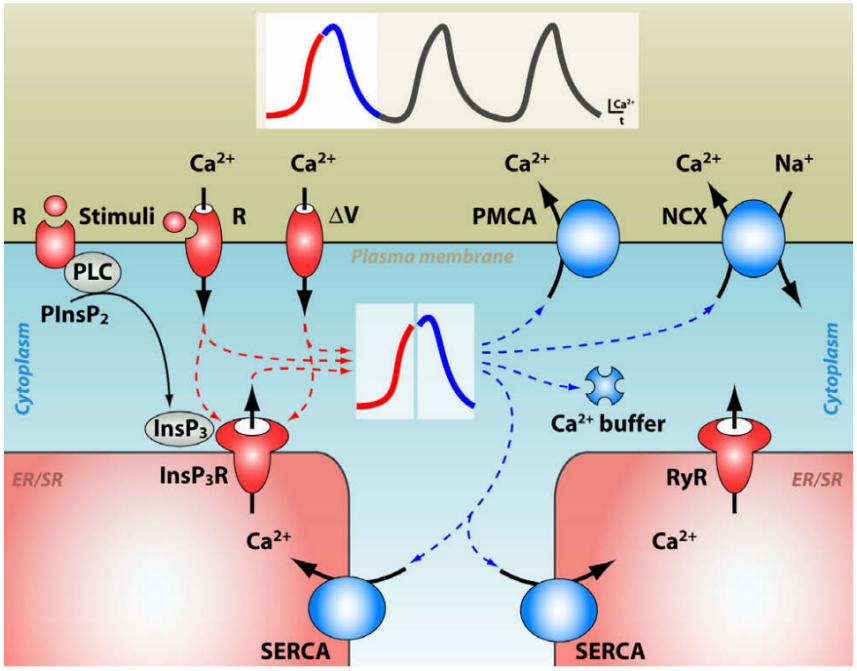


Fig. 1. Mechanisms generating cytosolic Ca² oscillations. Ca² entry occurs through receptor-operated (ROC) or voltage-gated (VGCC) channels, while release from ER/SR is mediated by IP receptors. Ca² itself activates IP receptors and ryanodine receptors (RyRs), causing Ca² -induced Ca² release (CICR). Recovery involves Ca² buffers, PMCA, NCX (extrusion), and SERCA (uptake into ER/SR).

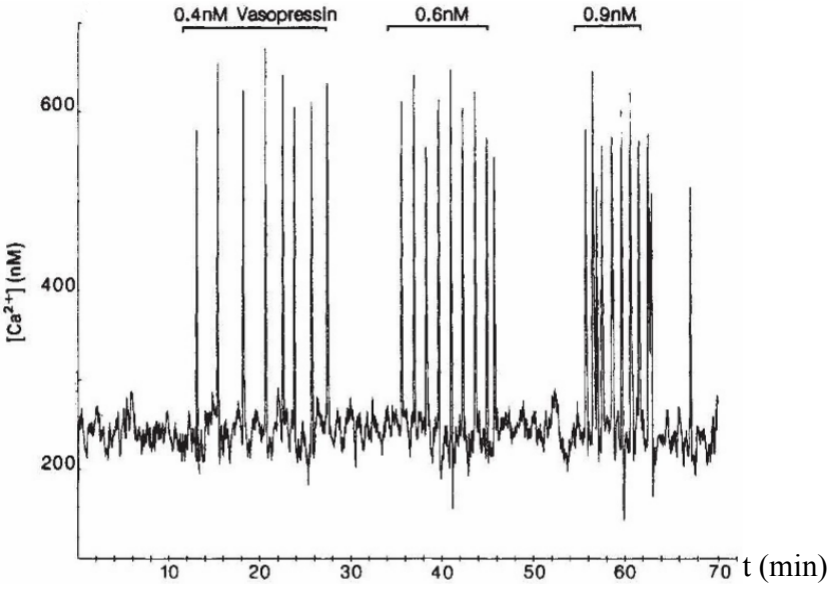


Fig. 2. Ca² oscillations in a hepatocyte at increasing [Arg]vasopressin concentrations (0.4, 0.6, 0.9 nM). Traces show Ca² concentration (nM) in cytosole over time. Peak heights are comparable across concentrations.

3.1. Based on Figure 2, match each statement with the correct answer. There must be one letter for each statement. Each correct answer award 0.25 points.

Options:
A — consisted by the results
B — can not be justified
C — contradicted by the figure

	Statement	Answer
1	Increasing vasopressin concentration increases the amplitude of Ca^{2} spikes.	
2	The frequency of Ca^{2} oscillations increases with vasopressin concentration	
3	At 0.9 nM vasopressin, Ca^{2} remains elevated without returning to baseline.	
4	The cell encodes hormone concentration through oscillation frequency rather than spike amplitude.	

3.2. Match each cell type with the correct function and the main Ca^{2} source in given table below. Each correct row award 0.3 points. One number or letter for each box in the table.

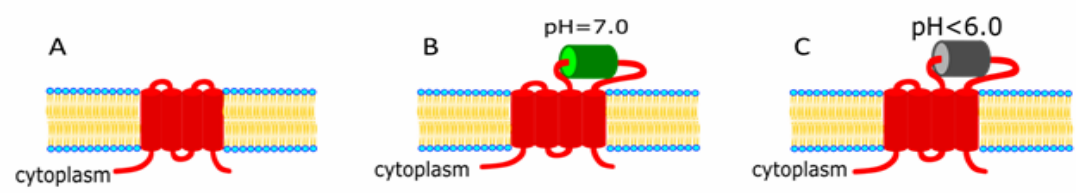
Functions:
1. Insulin secretion
2. Synaptic transmission / long-term potentiation
3. Contraction

Ca^{2} sources:
A. IP receptors on ER
B. Ryanodine receptors (RyR) + voltage-gated Ca^{2} channels
C. NMDA receptors + voltage-gated Ca^{2} channels

Cell type	Functions(write just number)	Ca^{2} sources(write just letter)
Skeletal muscle cell		
Pancreatic β-cell		
Neuron		

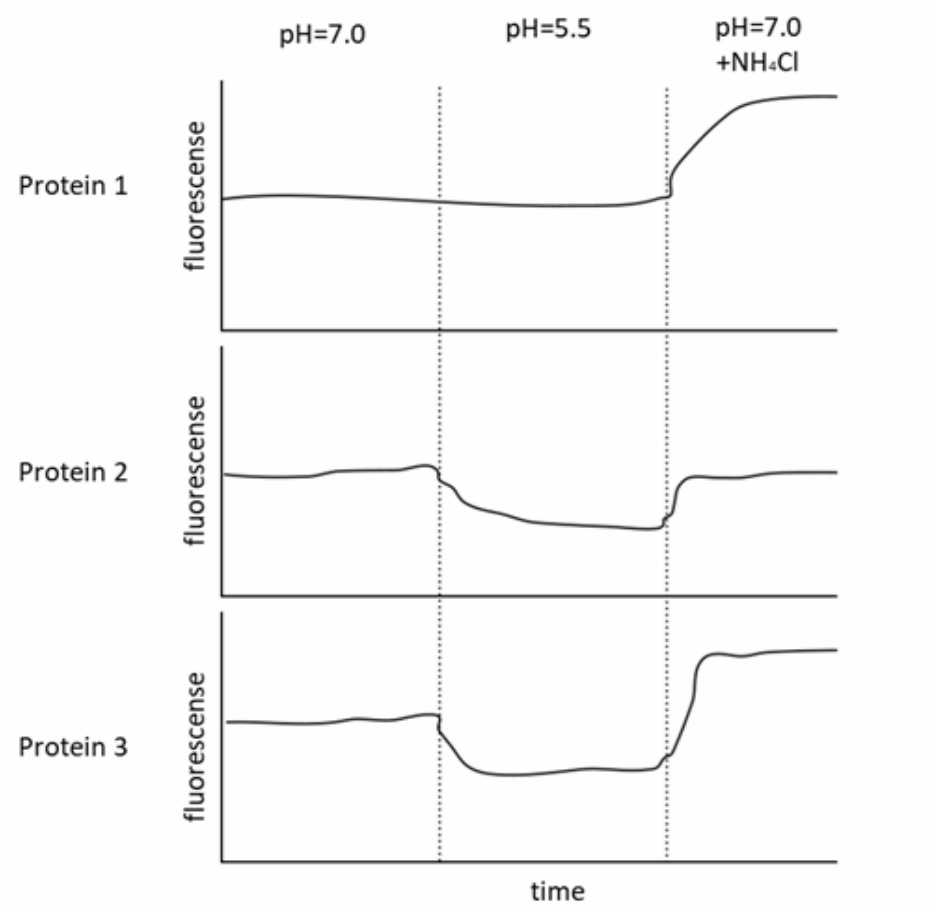
Q4.

A scientist is investigating the intracellular localization of membrane proteins. To do this, using genetic engineering techniques, he attached a pH-sensitive fluorescent sensor to the proteins under study. The fluorescent sensor is positioned so that it faces the side opposite to the cytoplasm. The sensor fluoresces only when the surrounding pH is neutral and quenches (dims) at acidic pH values. The figure below schematically illustrates a transmembrane protein (A), and a transmembrane protein with the embedded fluorescent sensor at neutral and acidic pH levels (B, C). Note: the pH sensor is oriented towards the side opposite the cytoplasm.



The scientist is investigating three transmembrane proteins from the same family, each of which has undergone a similar modification. The resulting genetic constructs were delivered into HEK 293 cells (a human cell line). Subsequently, the following experiment was conducted for each construct using a fluorescence microscope:

1. **Initial Imaging:** Cells are first imaged under physiological conditions, with the surrounding solution at **pH 7.0**.
2. **Buffer Change:** The solution is then replaced with a buffer at **pH 5.5**.
3. **Ammonium Chloride Treatment:** Finally, the solution is changed to a buffer at **pH 7.0** containing ammonium chloride (NH_4Cl), which is capable of crossing membranes and equilibrating proton gradients.



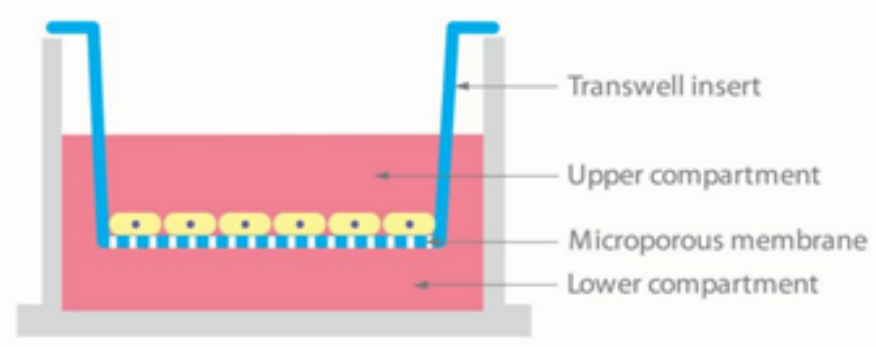
What conclusions can the researcher draw about each of the proteins under study? Match each protein with its characteristics by putting "X" to appropriate box, if you think that there is/are conclusion that doesn't match with any protein leave it empty. Each correct raw award 0.25 points.

	Conclusions	Protein 1	Protein 2	Protein 3
A	The protein is predominantly located in the plasma membrane; its fraction in intracellular vesicles is negligible.			
B	The protein is predominantly located in intracellular compartments with acidic contents; its fraction in the plasma membrane is small.			
C	The protein is predominantly located in intracellular compartments with neutral contents; its fraction in the plasma membrane is small.			
D	The protein is located both in intracellular compartments with			

	acidic contents and in the plasma membrane.			

Q5.

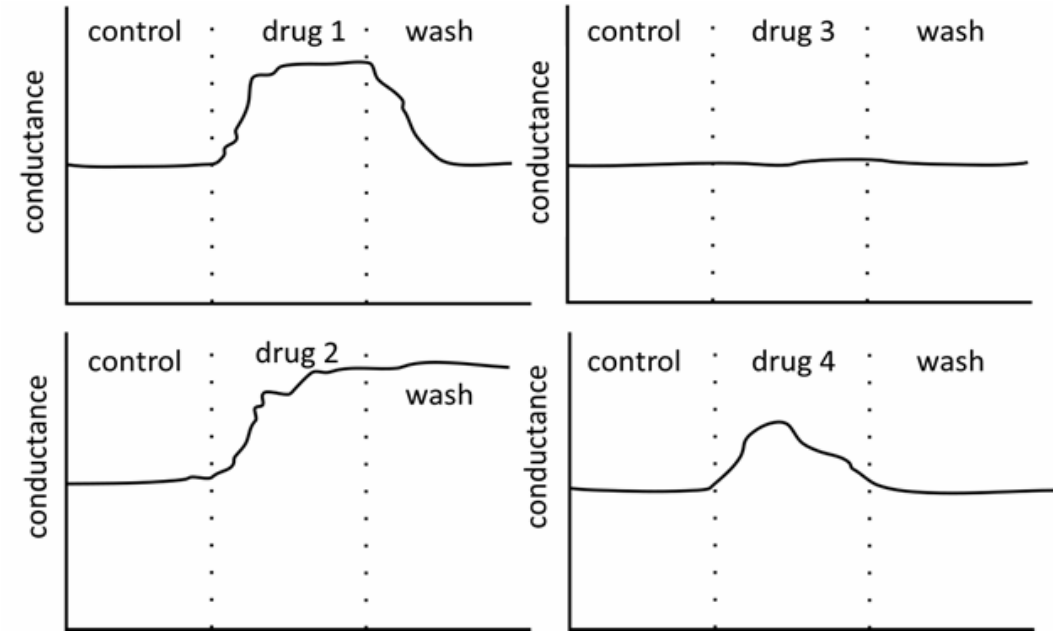
A scientist is investigating the effect of various drugs on the permeability of the endothelial layer. To do this, he uses the widely used **Transwell** system. The essence of this system is that cells are grown on porous membranes, forming a **monolayer**. In this experimental setup, the insulating properties of the monolayer can be studied by measuring **electrical conductance**. To achieve this, electrodes are placed on both sides of the monolayer, and the resistance is measured. Which statements about this experiment are correct?



5.1. Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statements	True	False
A	If cells are seeded on a porous membrane and left to cultivate, the resistance will initially be low and then begin to increase.		
B	If the monolayer is treated with a substance that destroys cells (e.g., soap or ethanol), the resistance of the monolayer will increase.		
C	Tight junction proteins, such as occludins and claudins, play a crucial role in maintaining high monolayer resistance.		
D	The resistance of a fibroblast monolayer will be higher than the resistance of an endothelial cell monolayer.		

5.2.



Match the drug number with the description of its effect on endothelial cells, by putting "X" to appropriate box. Each row has only one answer and correct row awards **0.25 points.**

	Description	Drug number			
		1	2	3	4
A	Causes a temporary increase in permeability, but the cells quickly adapt to the drug's effect.				
B	Causes reversible disruption of tight junctions.				
C	Causes irreversible disruption of tight junctions and cell death.				
D	Has no significant effect on the integrity of tight junctions.				

5.3. Which drug(s) can be used to increase endothelial permeability for delivering medicinal substances into tissues across the endothelial barrier? Put the X below the correct answer/s, leave the box below the incorrect answer. Each correct answer is awarded 0.5 points; incorrectly marked X penalizes 0.5 points.

Drug 1	Drug 2	Drug 3	Drug 4

Q6.

Mitochondria are the powerplants of the cell, but their function and density are highly specialized according to the metabolic needs of the tissue. The efficiency of oxidative phosphorylation is controlled by the activity of the Electron Transport Chain (ETC), the availability of specific substrates like succinate, and the impact of pharmacological inhibitors such as rotenone and oligomycin.

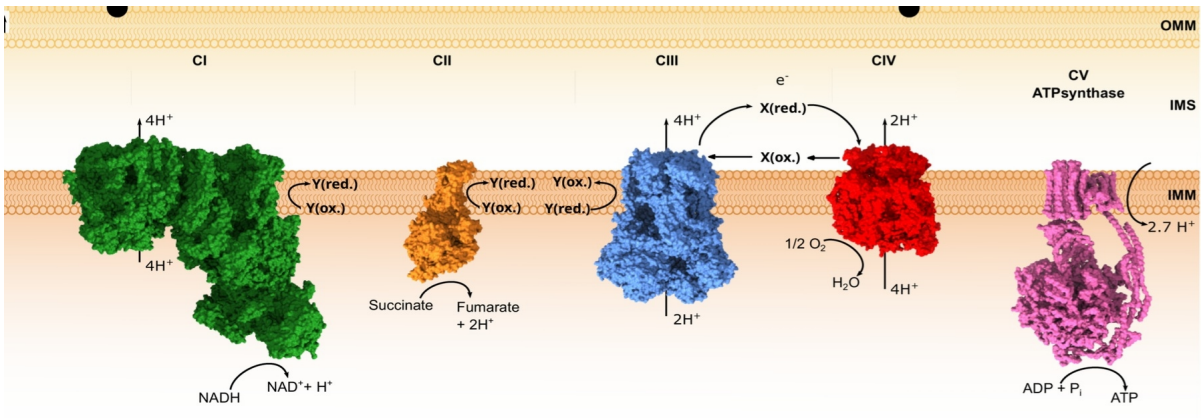


Figure - Architecture of the Electron Transport Chain

6.1. Molecular Carriers and ETC Architecture

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; if 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points,** if only 1 is correct, award **0 points**

	Statements	True	False
A	The compound labeled **X** represents **Cytochrome C**, a small peripheral protein that shuttles electrons through the intermembrane space from Complex III to Complex IV.		
B	The compound labeled **Y** is **Ubiquinone (Coenzyme Q)**, which acts as a lipophilic electron collector from both Complex I and Complex II.		
C	Because carrier **X** is a protein in the aqueous intermembrane space, its diffusion rate is generally less affected by changes in membrane fluid viscosity than the lipid-soluble carrier **Y**.		
D	If a mutation prevents **Y** from binding to Complex III, the oxidation of both NADH and Succinate would be completely inhibited.		
E	In the ETC shown in Figure 1, mobile carrier **X** is the only component that interacts with molecular oxygen to produce water.		

6.2. Physiological Distribution and Mitochondrial Density

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; if 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points,** if only 1 is correct, award **0 points**

	Statements	True	False
A	**Slow-twitch muscle fibers** have the highest mitochondrial density because they are specialized for sustained aerobic activity and possess high myoglobin levels.		
B	**Erythrocytes** are placed at the bottom of the mitochondrial density ranking because they completely lack these organelles to maximize space for		

	hemoglobin.		
C	**Neutrophils** possess fewer mitochondria than astrocytes because they operate primarily via glycolysis, allowing them to function in hypoxic infected tissues.		
D	In a comparative study, **fast-twitch fibers** would show a higher rate of oxygen consumption per gram of tissue than slow-twitch fibers due to their rapid contraction speed.		
E	The mitochondrial density order **Slow-twitch > Astrocytes > Neutrophils > Erythrocytes** accurately reflects the decreasing reliance on oxidative phosphorylation for energy.		

6.3. Redox Logic and Inhibitor Dynamics

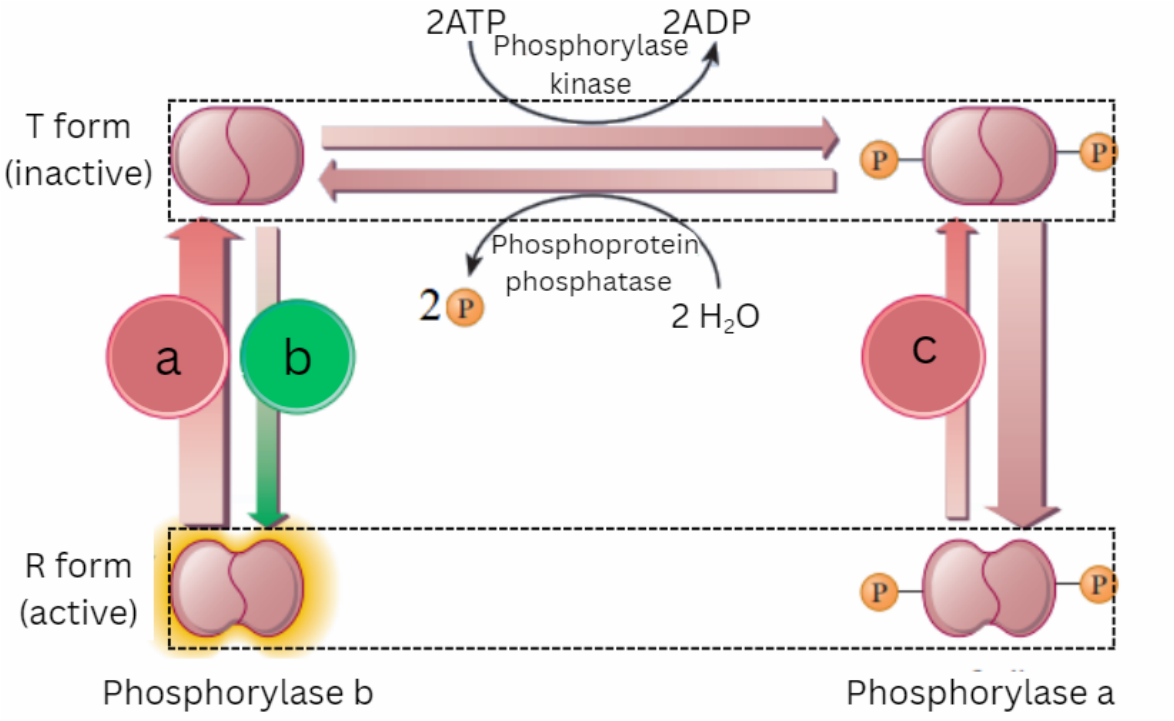
Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; if 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points,** if only 1 is correct, award **0 points**

	Statements	True	False
A	The addition of **Rotenone** causes the NADH/NAD ratio to become **High** because it blocks the only path for NADH-derived electrons to enter the ETC.		
B	If **Succinate** is added after Rotenone, the NADH/NAD ratio will return to a **Low** (normal) state because respiration is restored.		
C	Respiration and oxygen consumption can continue in the presence of Rotenone if a substrate that enters at **Complex II** is provided.		
D	The addition of **Oligomycin** (an ATP synthase inhibitor) increases the **proton motive force**, which subsequently increases the production of **Reactive Oxygen Species (ROS)**.		
E	High levels of NADH in the matrix (induced by Rotenone) act as a mitochondrial antioxidant, effectively reducing the net production of superoxide.		

Biochemistry.

Q7.

Glycogen synthesis and breakdown doesn't occur simultaneously, because this would lead to unnecessary hydrolysis of UTP and waste of energy. A key enzyme in controlling this process is glycogen phosphorylase. This enzyme is regulated by two mechanisms: covalent modification and allosteric regulation. Through allosteric regulation, glycogen phosphorylase can exist in T (tense, less active) and R (relaxed, more active) forms, whereas through covalent modification it can interconvert between phosphorylase a and phosphorylase b. Phosphorylase kinase catalyzes phosphorylation, while phosphoprotein phosphatase catalyzes dephosphorylation. These regulatory changes can occur within seconds to minutes. In the liver, glucose inhibits phosphorylase a, shifts it toward the T form, and promotes dephosphorylation of phosphorylated Ser14. Together, covalent and allosteric regulation coordinate glycogen synthesis and breakdown so that glycogen is synthesized or degraded appropriately according to metabolic needs. The figure below shows the allosteric regulation and covalent modification of glycogen phosphorylase.



7.1. Match the allosteric regulators shown in the figure (a–c) with the given molecules. *(Indicate your answer by placing an "X" in the appropriate box. Each correct row award 0.25 points. Only one "X" for each row.*

	a	b	c
Glucose			
Glucose 6 Phosphate (G6P)			
ATP			
AMP			

7.2. Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; if 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points,** if only 1 is correct, award **0 points**

		True	False
A.	In the pancreas, increased secretory activity of the α-cells in the Islets of Langerhans leads to the activation of the enzyme phosphorylase kinase.		
B.	As a result of the allosteric regulation of the glycogen phosphorylase enzyme by epinephrine, the blood glucose level increases.		
C	An increase in Ca^{2} in the cell enhances glycogenolysis through activation of phosphorylase kinase.		
D.	An increase in the amount of cAMP in the cell inhibits the process of glycogenolysis.		
E.	In hypercalcemia, glycogen reserves in the liver always decrease.		

Plant Biology (3)

Q8.

Cell differentiation is one of the key aspects of development in multicellular organisms. In plants, cell movement is limited, so differentiation occurs in a unique way. To overcome this limitation, asymmetric cell division plays an important role. To investigate this process, researchers studied and compared normal maize plants with their mlks2 mutant form. The authors examined the development of guard cells (GC), which form stomata, and the neighboring subsidiary cells (SC) in the epidermis. In mlks2 mutants, abnormal stomatal patterns were observed, indicating defects in asymmetric division during the formation of GC and SC.

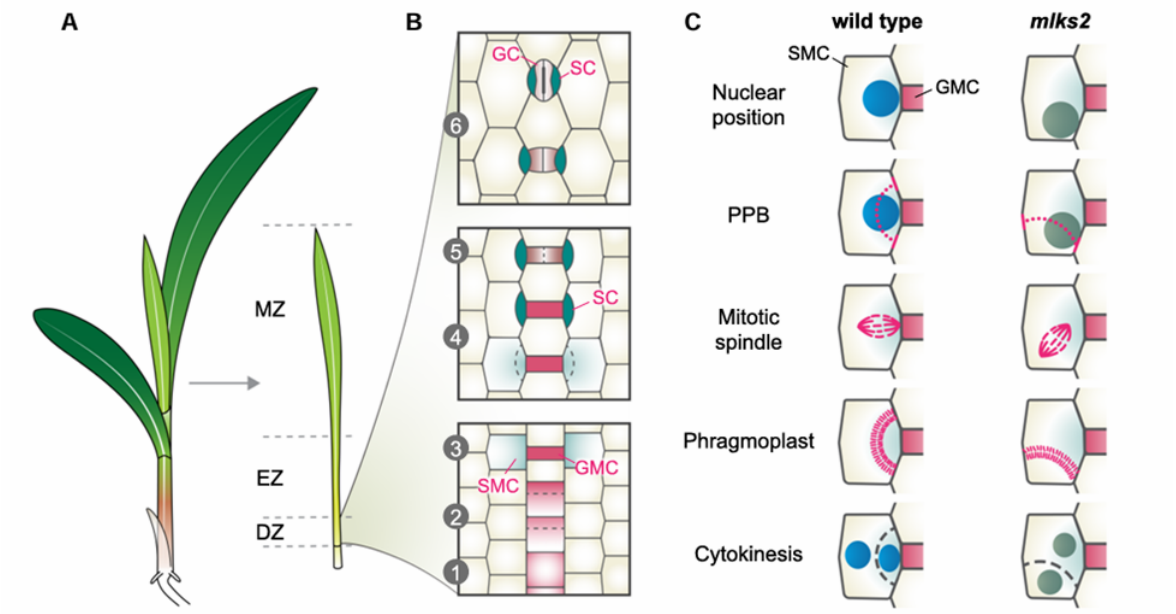


Figure. Developmental trajectory of maize stomata. A. Development of a newly formed leaf, DZ – division zone, EZ – elongation zone, MZ – maturation zone. B. Schematic representation of stomatal development at the base of the leaf: (1) The position of the stomatal file is determined from undifferentiated epidermal cells. (2) Cells in the stomatal file undergo transverse asymmetric division (dashed lines), forming GMCs (guard mother cells) and interstomatal cells. (3) SMCs (subsidiary mother cells) are formed from neighboring lateral cells. (4) These cells undergo longitudinal asymmetric division (dashed lines) to produce SCs (subsidiary cells). (5) The GMC undergoes longitudinal symmetric division to form GCs (guard cells). (6) As a result, GC and SC differentiate to form functional stomata. C. Cell division in SMCs of wild type and mlks2 mutants: PPB (preprophase band)

8.1. During plant development, unlike in animals, cell movement (migration) is not observed. Select the main reasons for this. Put "X" to appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points**

	Statements	Reason	Not Reason
A	Plant cells have a rigid and strong cell wall.		

B	Plasmodesmata in plant cells restrict cell migration.		
C	The cytoskeleton in plant cells mainly regulates vacuole shape and has a weak role in movement.		
D	Cell differentiation in plants is genetically predetermined in advance.		

8.2. Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

	Statements	True	False
A	In *mlks2* mutant cells, the protein (or its function) responsible for proper nuclear migration toward the GMC is disrupted.		
B	In *mlks2* mutant cells, abnormal nuclear positioning does not affect the orientation of the division plane or the mitotic spindle.		
C	These results indicate that the *MLKS2* gene is required for both nuclear migration and stable positioning, which is necessary for correct PPB placement and division plane determination during asymmetric division of SMCs.		
D	This study shows that since the nucleus itself divides, it does not play a critical role in determining the division site of the cell.		

Q9.

The movement of water and mineral ions from soil to the xylem in stele occurs via two primary pathways: the apoplastic pathway (through cell walls and intercellular spaces) and the symplastic pathway (through the cytoplasm via plasmodesmata). The Casparian strip is a structure formed by the deposition of suberin and lignin in the radial and transverse walls of endodermal cells, which blocks apoplastic transport.

Water potential (Ψ) is the key indicator that explains why and where water moves within plants. The water potential equation is:

$$\Psi = \Psi s + \Psi p$$ (Where Ψs = solute/osmotic potential; Ψp = pressure potential).

9.1. Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 5 are correct, award **1 point**; if 4 are correct, award **0.7 points**; if 3 are correct, award **0.4 points**; if 2 are correct, award **0.2 points,** if only 1 is correct, award **0 points**

	Statements	T	F
A	The Casparian strip in the endodermal layer not only blocks the apoplastic pathway, but also functions as a hydrophobic barrier that prevents water from flowing back from the vascular cylinder (xylem) into the root cortex.		
B	Guttation occurs when root pressure is high, typically at night or early in the morning, when transpiration is high and water is pushed upward through the xylem under pressure.		

C	The upward movement of water in the xylem and the mass flow of sugars in the phloem are both purely passive processes and do not require direct ATP energy from the plant.		
D	The osmotic potential (Ψs) of a cell is always negative; however, as the solution concentration increases, this value becomes mathematically larger (i.e., it approaches zero).		
E	The liquid released during the guttation process differs from pure water in its composition because it contains the components of xylem sap, and this process mainly occurs through hydathodes		

Case Study:

A plant cell is being studied under laboratory conditions. The initial state of the cell is as follows:
Osmotic potential (Ψs): -1.2 MPa
Pressure potential (Ψp): +0.4 MPa

This cell is placed into an open beaker containing a solution with a water potential of Ψ= -0.5 MPa.

9. 2. What is the total water potential (Ψ) of the cell at equilibrium in the solution? Write you answer in 1 decimals to the appropriate box in answer sheet. (0.5 mark)

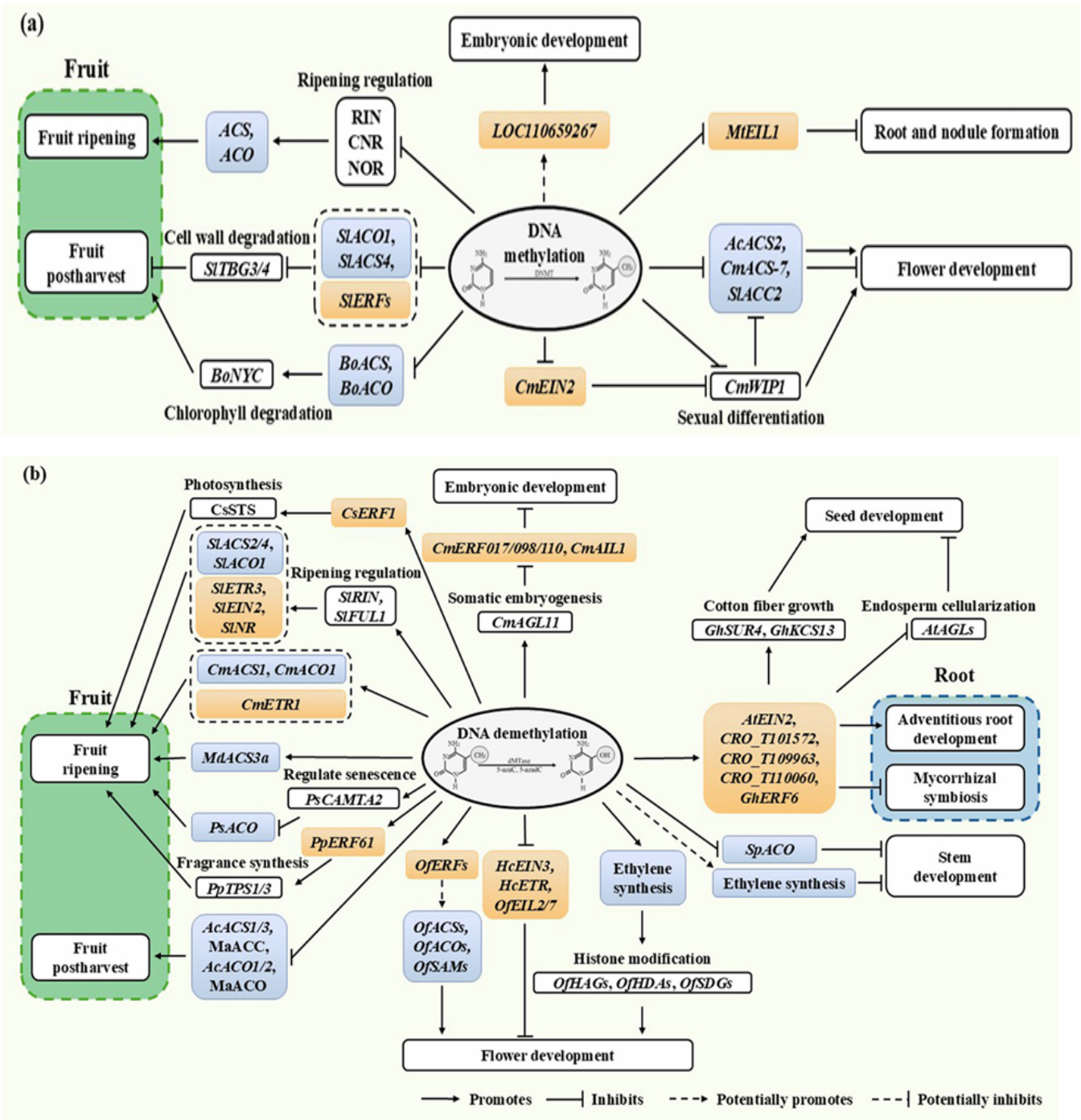
9. 3. At equilibrium, if the cell volume is assumed to remain unchanged, what is the new turgor pressure (Ψ)? Write you answer in 1 decimals to the appropriate box in answer sheet. (0.5 mark)

9. 4. If the external solution is replaced with pure water (Ψ = 0), and the cell wall is stretched to its maximum extent, what value will the turgor pressure (Ψ) approach? Write you answer in 1 decimals to the appropriate box in answer sheet. (0.5 mark)

Q10.

Ethylene is a simple gaseous signaling molecule that can be synthesized in various tissues within plants. Upon induction by external stimuli or exogenous application, ethylene binds to its receptors and activates downstream signaling cascades, initiating a series of physiological and biochemical responses. Ethylene plays extensive roles in regulating plant growth and development, including seed germination, seedling development, root growth, leaf senescence, flower senescence, and fruit ripening.

Ethylene biosynthesis and its physiological activity occur in close correlation with DNA methylation and demethylation mechanisms. The diagram below illustrates how DNA methylation and demethylation influence ethylene-regulated processes.



Regulation of ethylene by DNA methylation (a) and DNA demethylation (b) during plant growth and development. ACC, 1-aminocyclopropane-1-carboxylic acid; ACO, ACC oxidase; ACS, ACC synthase; AGL, agamous-like; AIL, aintegumenta-like; CAMTA: calmodulin-binding transcription activator; CNR, colourless non-ripening; EIN, ethylene insensitive; EIL, EIN3-like; ERF, ethylene response factor; ETR, ethylene receptor; FUL, fruitful; HAG, histone acetyltransferase of the GNAT/ MYST superfamily; HDA, histone deacetylase; KCS, 3-ketoacyl-coa synthase; NOR, non-ripening; NR, never-ripe; NYC, chlorophyll b reductase; RIN, ripening inhibitor; SAM, S-adenosyl-L-methionine; SDG, set domain group; STS: stachyose synthase; SUR, suppression of rvs 161 delta; TBG, β-galactosidase precursor mRNA; TPS: terpene synthase; WIP, WIP domain protein. The blue squares represent ethylene synthesis-related genes, the orange squares represent ethylene signaling- related genes, and the white squares represent different physiological processes or related genes. The black dashed lines indicate regulation of multiple different types of genes, the green dashed boxes denote regulated fruit growth and development stages, and the blue dashed boxes denote regulated root growth and development stages.

Plant Science: Relationship between DNA methylation and ethylene in plants: A review Xinmeng Geng, Zesheng Liu, Caiting An, Min Cao, Qi Wang, Mengkun Liu, Qianbing Li, Chunlei Wang , Linli Hu College of Horticulture, Gansu Agricultural University, NO.1 Yingmen Village, Lanzhou, Gansu 730070, China

Determine whether the following statements are **True or False** by placing an "X" in the appropriate box. If all 4 are correct, award **1 point**; if 3 are correct, award **0.6 points**; if 2 are correct, award **0.2 points**; if only 1 is correct, award **0 points.**

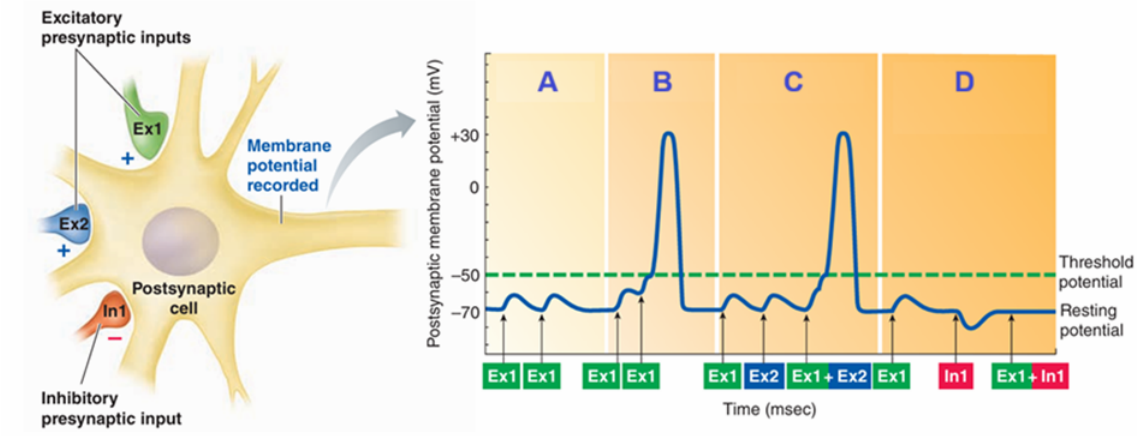
	Statement	True	False
A	The down-regulation of the expression of ethylene-responsive transcription factor genes CmERF017/098/110 and AINTEGUMENTA-LIKE1 (CmAIL1), attenuated the downstream ethylene signal, and ultimately promoted somatic embryogenesis		
B	Generally, DNA demethylation promotes ethylene pathways and accelerates developmental processes, whereas increased DNA methylation tends to suppress ethylene-related pathways and then delay plant development.		
C	In the early stages of a plant's life, DNA methylation downregulates all ethylene signaling–related genes.		
D	Based on knowledge of the seasonal sequence of processes in plants, it can be stated that day length serves as the main signal for DNA demethylation of ethylene-related genes.		

Animal Physiology

Q11.

In the thousands of presynaptic inputs that a typical neuronal cell body receives from many other neurons. Some of these presynaptic inputs may be carrying sensory information from the environment; some may be signaling internal changes in homeostatic balance; others may be transmitting signals from control centers in the brain; and still others may arrive carrying other bits of information. At any given time, any number of these presynaptic neurons (probably hundreds) may be firing and thus influencing the postsynaptic neuron's level of activity.

The diagram below illustrates the combined effect of multiple signals arriving at a postsynaptic cell.



Human Physiology: From Cells to Systems, Ninth Edition. L. Sherwood. 2016, 2013 Cengage Learning

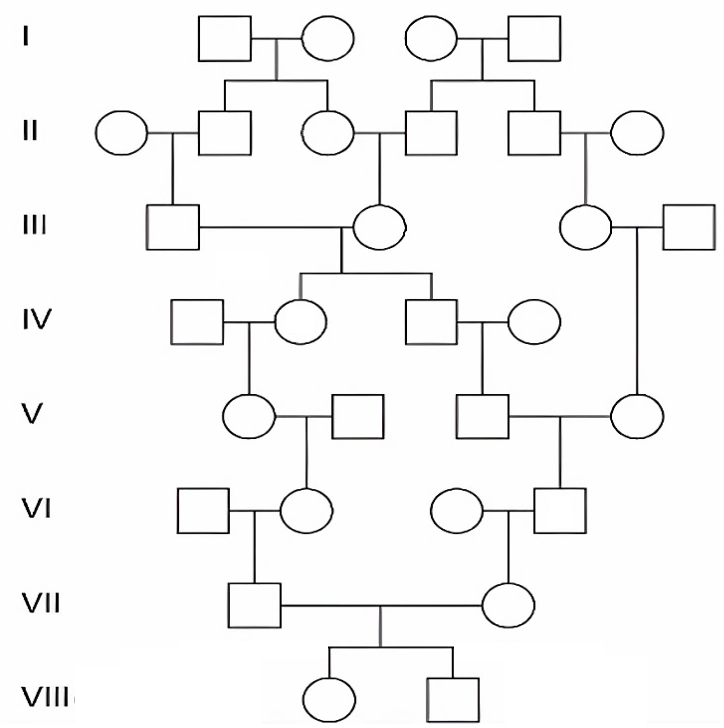
Four different scenarios are described below. Match these scenarios to the positions labeled A–D on the graph. If you think that there is no appropriate match, leave that row blank. Indicate your answers by placing an **X** in the corresponding cell of the table provided. Each correct raw award 0.25 points.

	Scenario	A	B	C	D
1	Several excitatory postsynaptic potentials originating from the same presynaptic neuron at closer times to each other lead to the generation of an action potential.				
2	Several excitatory postsynaptic potentials originating from different presynaptic neurons at closer times are not enough to pass the threshold potential.				
3	If excitatory and inhibitory signals are activated simultaneously, the resulting excitatory and inhibitory postsynaptic potentials neutralize each other.				
4	Several excitatory postsynaptic potentials originating from different presynaptic neurons at closer times to each other lead to the generation of an action potential.				

Genetics & Evolution

Q12.

The genealogical pedigree of two related individuals (VII-1 and VII-2) is presented below. Based on this pedigree, answer the following questions.



Note: *Individuals in the pedigree are numbered sequentially from left to right as 1, 2, 3, …*

12.1 . Which individuals in the pedigree are inbred? (1 point)
Points for the question will be awarded only for a fully correct answer with no incorrect selections.

12.2. Who are the common ancestor(s) of individual VIII-1? (1point)
Points for the question will be awarded only for a fully correct answer with no incorrect selections.

12.3. Determine the inbreeding coefficient of individual VIII-2. Write your answer in 2 decimals to the appropriate box in the answer sheet. (0.5 mark)

Ecology

Q13.

Metabolic rate (B) scales with body mass (m) according to Kleiber's Law:

$$B=B_0*m^{3/4}.$$

This means larger animals are more efficient per gram but consume more in total. This principle shapes entire ecosystems. Consider two hypothetical oceanic islands of equal area (100 km²) but different dominant

fauna. You must calculate the total energy demand (in Watts) of each community to determine which exerts greater pressure on primary production.

Constants:

Metabolic coefficient B_0=0.05 $W \cdot kg^{-3/4}$

1 Joule (J) = 1 Watt·second (W·s)

Island Area = 100 km^2 = 10^8 m^2

Table 1. Fauna Census Data

Island	Species	Avg Body Mass (kg)	Population Density (indiv·km^{-2})
X (Megafauna)	Giant Tortoise	150	400
Y (Microfauna)	Leaf-cutter Ant	0.005 ($5*10^{-3}$)	40,000,000 ($4*10^7$)

Note: Assume these are the only heterotrophs.

Questions

13.1: Determine whether the following statement is **True or False** by placing an "X" in the appropriate box. **1 point** for correct answer.

The metabolic rate of a single Giant Tortoise is approximately 2,270 times lower than that of a single Leaf-cutter Ant.

True	False

13.2: Determine whether the following statement is **True or False** by placing an "X" in the appropriate box. **1 point** for a correct answer.

Although individual ants consume very little energy, the total community metabolic power (P_{total} = Density*Area*B_0*$m^{3/4}$) of Island Y is significantly higher than that of Island X, indicating Island X exerts much higher pressure on primary producers.

True	False

13.3: Island Y suffers an invasion by a bird species (0.5 kg) with a population of 10,000. Each bird requires 40 kJ of energy per day.

Determine whether the following statement is **True or False** by placing an "X" in the appropriate box. **1 point** for correct answer.

Assuming the ants' metabolic energy dissipation is a proxy for the energy available for the next trophic level, the ant population can easily support the bird invasion even if trophic efficiency is as low as 1%.

True	False

Q14.

The Peatland Paradox

Peatlands cover only 3% of Earth's land surface but store more carbon than all the world's forests combined. The stability of this carbon depends on the source of organic matter. Plants use different photosynthetic pathways (C_3 vs. C_4) that fractionate carbon isotopes (^{13}C vs. ^{12}C) differently.

C_3 plants (e.g., mosses, trees) strongly discriminate against ^{13}C, resulting in very negative $\delta^{13}C$ values (approx. -27‰).

C_4 plants (e.g., tropical grasses, some sedges) discriminate less, resulting in less negative values (approx. -13‰).

A 1-meter core was extracted from a bog. It was sliced into 4 depth sections. The "Age" represents years before present (BP).

Table 1. Data Presentation

Depth (cm)	**Age (years BP)**	**$\delta^{13}C$ (‰)**
0-25	0-100	-26.5
25-50	100-1000	-27.0
50-75	1000-3000	-14.2
75-100	3000-8000	-28.1

Questions

14.1: Identify the type of carbon fixation of the layer at 50–75 cm has a value of -14.2‰. Put "X" to appropriate box. Only one correct answer is there. 0.25 points

C_3	C_4	CAM

14. 2: C_4 plants love hot, dry, sunny weather. Identify the age (years BP) where the climate is likely the driest and hottest. Put "X" to appropriate box. Only one correct answer is there. 0.25 points

0-1000	100-1000	1000-3000	3000-8000

14.3: "Soil respiration" is the CO_2 released by the ground. If the bog changes from Moss (C_3) to Grass (C_4), will the CO_2 become "heavier" or "lighter"? Put "X" to appropriate box. Only one correct answer is there. 0.25 points

heavier	lighter

Q4: Imagine a layer is a 50/50 mix of C_3 plants and C_4 plants. Estimate the δ13C of the mixture. Write your answer in the box. 0.25 points for the correct number.
