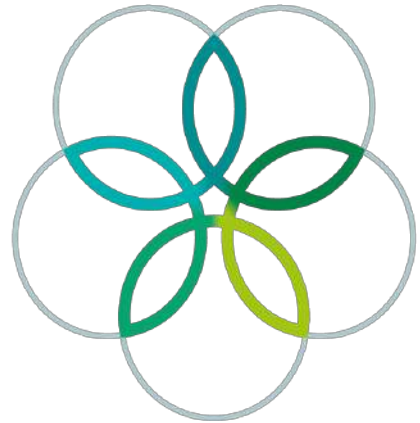
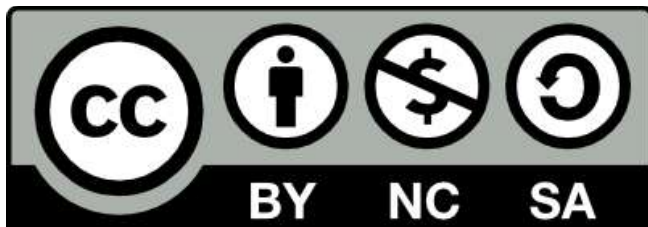


INTERNATIONAL
BIOLOGY
OLYMPIAD e. V.

IBO



All IBO examination questions are published under the following Creative Commons license:



CC BY-NC-SA (Attribution-NonCommercial-ShareAlike) -
<https://creativecommons.org/licenses/by-nc-sa/4.0/>

The exam papers can be used freely for educational purposes as long as IBO is credited and new creations are licensed under identical terms. No commercial use is allowed.

Theoretical1



English (Official)

Question 1

Alfalfa Mosaic Virus (AMV) consists of a capsid and 4 RNA fragments: R1, R2, R3, R4. Capsid protein (CP) is known to play an important role at different stages of the AMV viral cycle. In particular, CP is involved in the initial translation of replication factors encoded by the viral RNA. CP interacts with the atALKBH9B protein of the host cell, which catalyzes the following reaction in the cell (Figure 1).

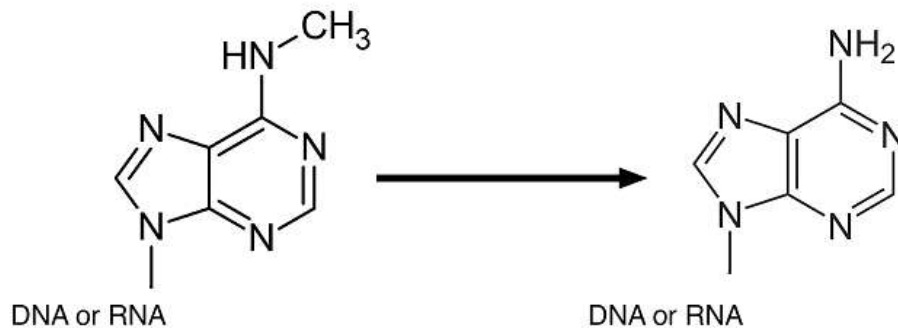


Figure 1. Reaction catalyzed by atALKBH9B

Methylation of the viral RNA in the host cell inhibits viral replication. CP is thought to neutralize this cellular antiviral mechanism by binding to and recruiting atALKBH9B. To test this hypothesis, researchers have grown *Arabidopsis thaliana* individuals with mutations in the atALKBH9B gene (*atalkbh9b*). Then the mutants (*atalkbh9b*; 4, 5, 6 in Figure 2) and wild types (WT; 1, 2, 3 in Figure 2) have been infected with AMV. Separation of viral RNAs by gel electrophoresis was performed in the two studied plant groups 3 and 6 days post infection (dpi). The results of the experiment are presented in Figure 2.

Theoretical1



English (Official)

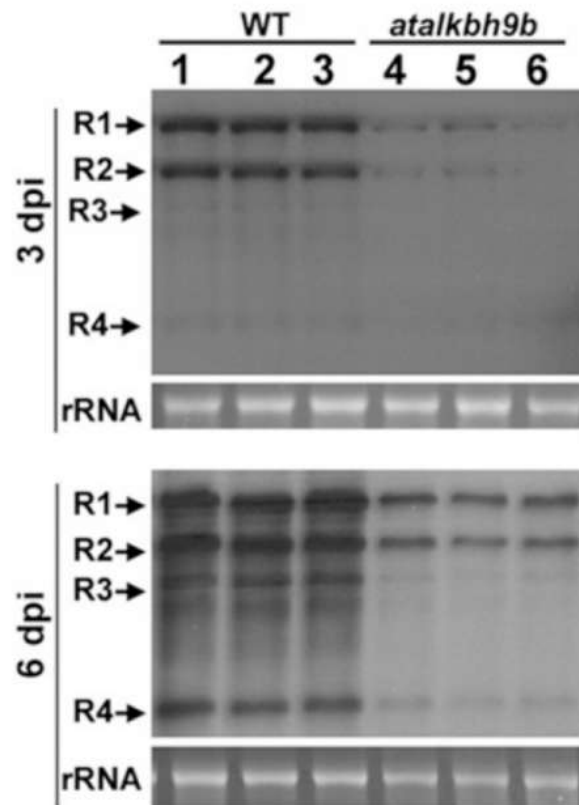


Figure 2: Separation of viral RNAs by gel electrophoresis in the two studied plant groups 3 and 6 days after infection (dpi). rRNA is the ribosomal RNA of the host cell.

Based on the results of the experiment, indicate whether the following statements are true or false:

- A. R1 contains the highest number of nucleotides among the examined viral RNAs
- B. The results of gel electrophoresis do NOT contradict the proposed hypothesis
- C. The results indicate that atALKBH9B directly demethylates viral RNAs
- D. A drug suppressing the atALKBH9B activity may prevent viral RNA methylation in AMV-infected plant cells

Theoretical1

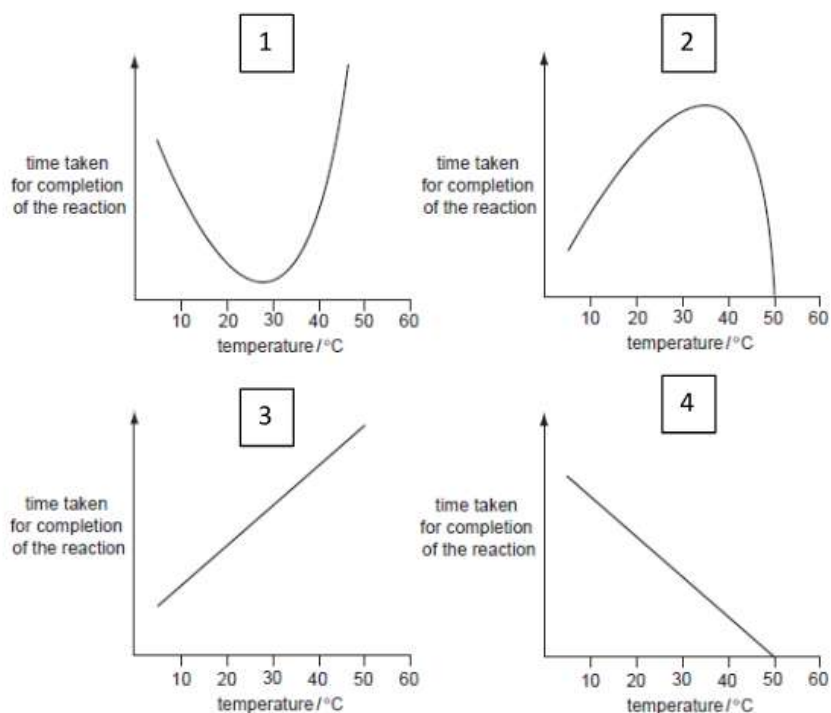


IBO
33rd 2022
ARMENIA

English (Official)

Question 2

Solutions of a specific concentration of enzyme and substrate were mixed to record the rate of the enzymatic reaction. The time required to complete the reaction was measured at various temperatures. The enzyme is completely denatured at 50°C .



time taken for completion of the reaction	
temperature	

For each graph determine if it represents the results of the experiment correctly (true) or not (false)?

- A. Graph 1
- B. Graph 2
- C. Graph 3
- D. Graph 4

Theoretical1

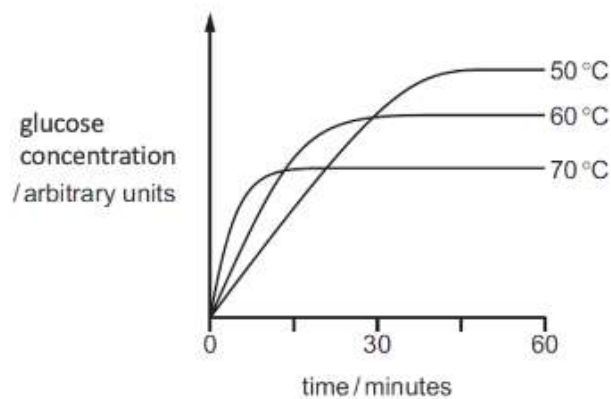


IBO
33rd 2022
ARMENIA

English (Official)

Question 3

The diagram shows experimental data comparing the hydrolysis of starch by amylase at 3 different temperatures.



glucose concentration/arbitrary units	
time/ minutes	

What conclusion can be drawn from these data? Determine whether the following statements are true or false:

- A. 50°C is the optimal temperature for the initial activity of amylase.
- B. At 60°C , all starch is hydrolyzed after 30 minutes.
- C. At 70°C amylase is denatured before hydrolysis is complete
- D. The initial reaction rate of starch hydrolysis at 60°C is higher than at 70°C .

Theoretical1

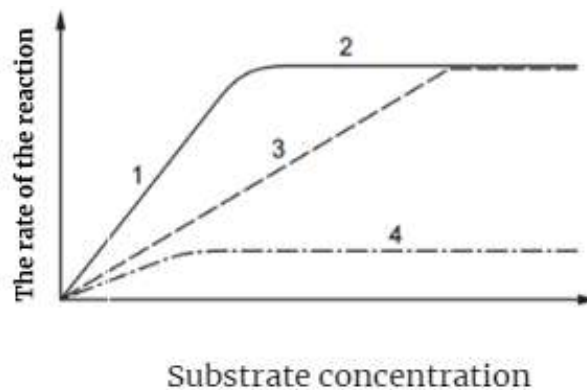


IBO
33rd 2022
ARMENIA

English (Official)

Question 4

The following curves show the effect of substrate concentration on the rate of an enzymatic reaction.



The rate of reaction	
Substrate concentration.	

- The reaction proceeds without an inhibitor
- The reaction proceeds in the presence of inhibitor X
- · - · - The reaction proceeds in the presence of inhibitor Y.

Choose whether the following statements about Sections 1, 2, 3, and 4 of the enzymatic reactions are true or false.

- A. Section 1 is limited by (or depends on) enzyme concentration
- B. Section 2 is limited by enzyme concentration
- C. Section 3 is limited by a competitive inhibitor
- D. Section 4 is limited by an uncompetitive inhibitor

Theoretical1

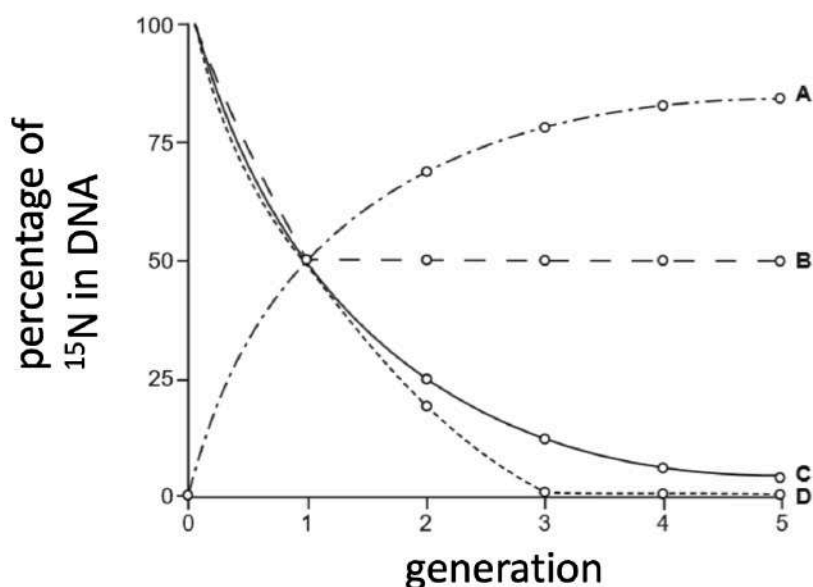


IBO
33rd 2022
ARMENIA

English (Official)

Question 5

To find out how DNA replicates, Matthew Meselson and Franklin Stahl performed the following classical experiment. Bacteria were grown in a medium with heavy nitrogen (^{15}N) until all the DNA was labeled. Then they were grown in a normal nitrogen-containing culture medium (^{14}N) for 5 generations. The number of heavy nitrogen-containing cells in these 5 generations was counted.



percentage of ^{15}N in DNA	
generations	

Using the information and figure, determine whether the following statements are true or false:

- A. Curve A corresponds to semi-conservative DNA replication
- B. Curve B corresponds to dispersive DNA replication
- C. Curve C corresponds to semi-conservative DNA replication.
- D. Curve D corresponds to conservative DNA replication

Theoretical1

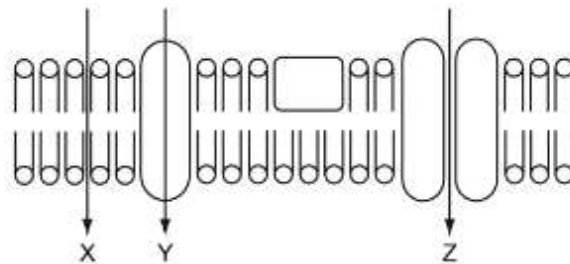


IBO
33rd 2022
ARMENIA

English (Official)

Question 6

There are 3 arrows in the figure: X, Y, Z that show paths of movement of substances through the cell surface membrane.



Using the figure, determine whether the following statements are true or false:

- A. Vitamin D can be transported through X.
- B. Sodium and potassium ions can be transported through X.
- C. Large native globular proteins can be transported through Y.
- D. Water can be transported through Z

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 7

Hypoxia is a hallmark of solid tumors and plays a critical role in different steps of tumor progression. To develop an effective treatment against malignant tumors, it is important to understand how cancer cells that develop under hypoxic conditions, avoid apoptosis. The figure shows the mechanism of apoptosis.

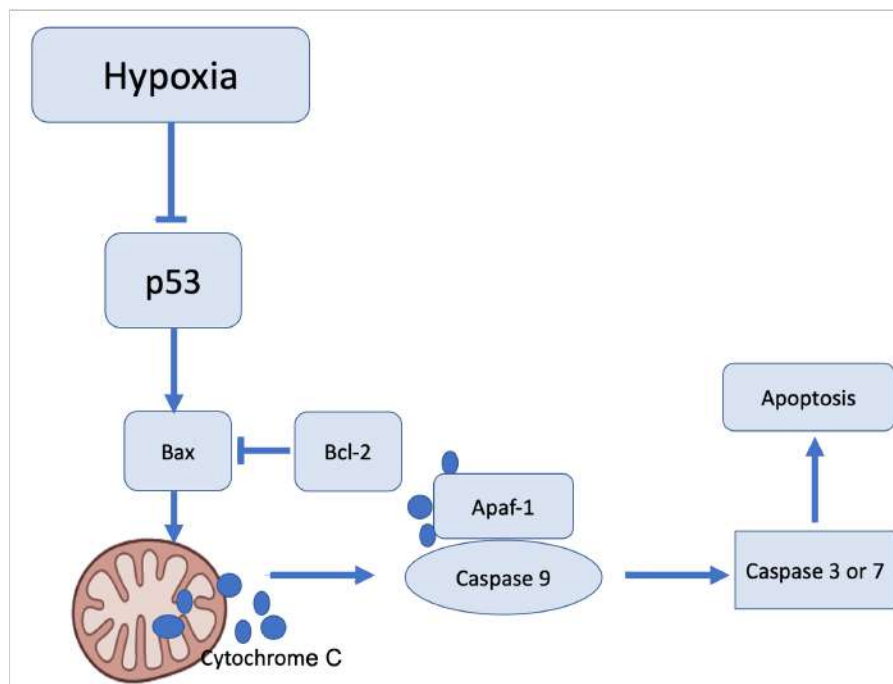


Figure: Mechanism of apoptosis. p53 protein promotes the expression of Bax and its translocation from cytosol to mitochondria which leads to mitochondrial protein cytochrome C release to the cytoplasm, activating the caspase cascade.

Hypoxia	
Bax	
Apaf	
Caspase	
Apoptosis	

Using the information and figure, determine whether the following statements are true or false:

- A. Hypoxia in cancer cells suppresses apoptosis.
- B. Upon Bcl-2 overexpression, the integrity of the mitochondrial membranes is preserved, which in return prevents apoptosis.
- C. It is necessary to suppress p53 to ensure the apoptosis of cancer cells.
- D. Deficiency of Bax protein promotes apoptosis.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 8

Ethidium bromide is a fluorescent dye which can intercalate into double-stranded DNA (Figure 1), resulting in a sharp increase in the fluorescence intensity of ethidium bromide. Ethidium bromide can bind to and intercalate in DNA in different ways (Figure 2).

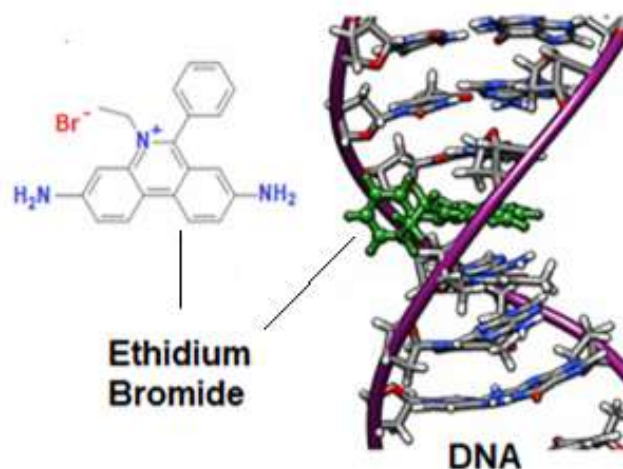


Figure 1. Ethidium bromide and its binding to DNA.

Ethidium Bromide	
------------------	--

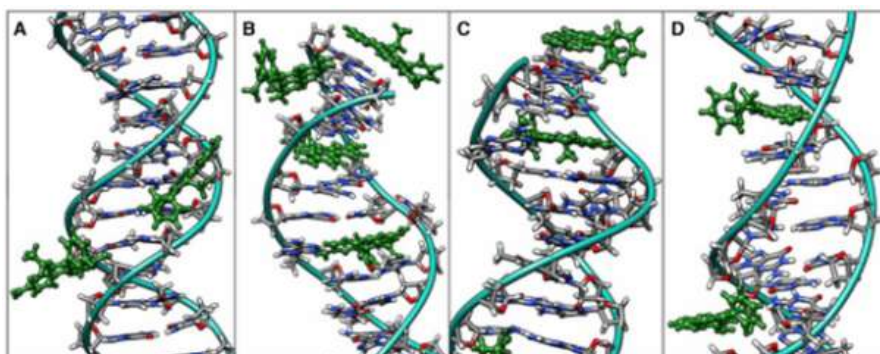


Figure 2. Modes of binding of ethidium bromide to DNA. A-Minor groove binding, B- intercalation of ethidium bromide into DNA and, C- stacking on the terminal base pairs and insertion mode in DNA, D-major groove intercalation between DNA and minor groove binding.

Using Figures 1 and 2, determine whether the following statements are true or false:

A. The study of complexes between ethidium bromide and DNA allows for the detection of major structural DNA damage caused by different stressful situations.

Theoretical1



English (Official)

B. When ethidium bromide is intercalated into a DNA molecule, the base pairs move away from each other to make space for the inserted molecule.

C. In the intercalation shown in Figure 2B, the bases are displaced by overexertion while simultaneously the helix contracts along its axis. This ensures the DNA sugar-phosphate backbone does not rupture during the overexertion.

D. The plane of the intercalated ethidium bromide molecule is approximately parallel to the axis of the DNA helix and perpendicular to the plane of the bases.



Question 9

Tissue engineering is trying to develop miniature blocks of tissue from multiple cell types using an approach called ‘organ-on-a-chip’. This technology enables in vitro testing of patient-specific effects of different drugs or treatments. Cells collected from a patient are first turned into induced pluripotent stem cells (iPSCs). The next step is to perform differentiation, followed by seeding these differentiated cells into specially designed chambers (Figure 2).

Figure 2 shows the concept of ‘lung-on-a-chip’ to model pulmonary oedema progression. Endothelial barrier function was quantified by measuring alveolar-capillary permeability to a fluorescently labeled inulin, a large polysaccharide molecule. Inulin was introduced into the lower chamber together with interleukin 2 (IL-2), one of the major cytokines. Images next to the graph in figure 3 illustrate immunostaining patterns for junctional proteins such as epithelial occludin (green) and endothelial VE-cadherin (red) in control conditions and after exposure to cyclic mechanical strain (10% at 0.2 Hz) along with administration of IL-2 for 3 days. White arrows indicate intercellular gaps.

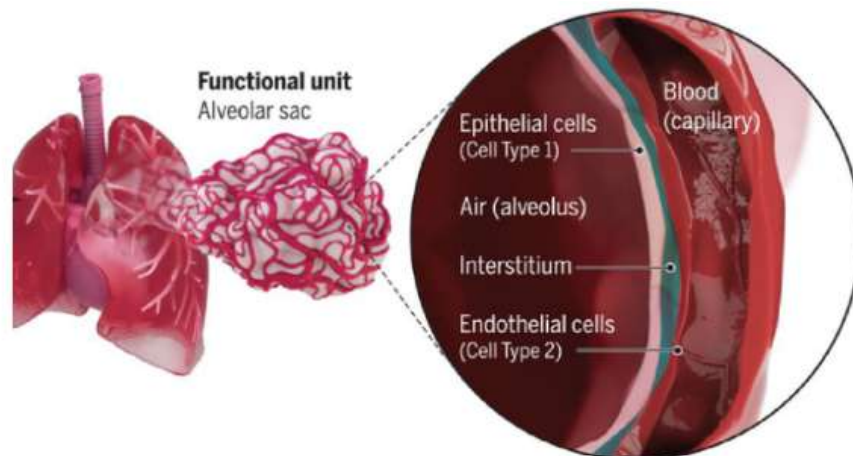


Figure1. The endothelial barrier of alveoli.

Functional unit	
Epithelial cells	
Air (alveolus)	
Interstitium	
Endothelial cells	
Blood (capillary)	

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

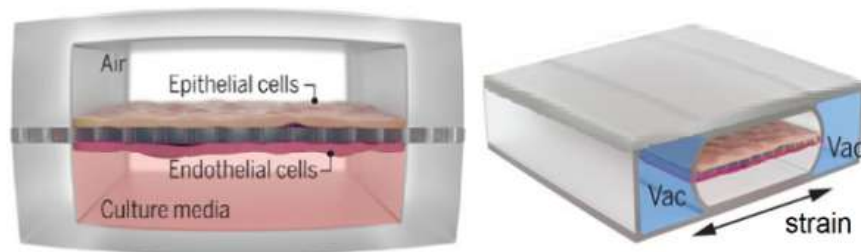


Figure 2. Chambers used in technologies called 'organ-on-a-chip'

Culture media	
Vac	
Strain	

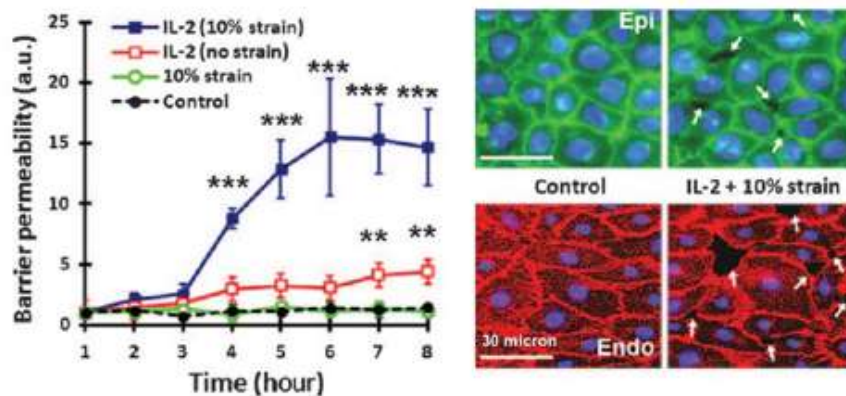


Figure 3. Immunostaining patterns for junctional proteins

Barrier permeability(a. u.)	
Time (hour)	
Control	

Based on data provided, indicate whether the following statements are true or false.

- A. The most likely consequence of increased barrier permeability in vivo is increased blood oxygen saturation
- B. Occludin staining works as a secondary marker to show increased gaps between endothelial cells and as such must be nearly identical to the VE-cadherin staining
- C. Cyclic stretch was used to simulate repetitive breathing patterns and not to mimic repetitive arterial pressure pulsations

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

D. Under conditions of cyclic stretch and the presence of IL-2, the addition of albumin into culture media should not affect the volume of fluid leaving the lower chamber reflecting the oedema model.

Theoretical1



English (Official)

Question 10

To create *in vitro* analogues of live tissue, 3D bioprinters use what is called bioink (Figure 1). Bioink formulations combine live cells with different kinds of biocompatible materials that can be polymerized after extrusion from a printing needle. The latter allows cells to proliferate and form 3D structures. The viability of cells post-printing can be evaluated by daily monitoring of bioluminescence which essentially measures intracellular ATP. Due to shear stress, associated with the extrusion process, cell viability and cell proliferation within printed constructs can be adversely affected by the size of the needle and the extrusion pressure. Bioluminescence data and confocal images, shown here, were acquired from tissue constructs printed with bioink formulations containing either fibroblasts (left) or myocytes (right). After several days of culturing, both types of constructs were stained with the same markers.

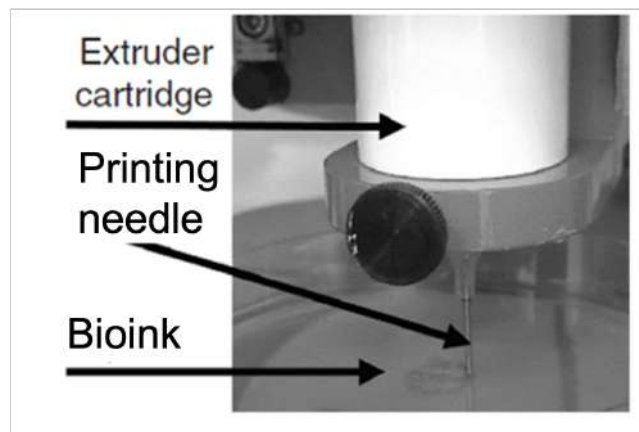


Figure 1. The 3D printer of living tissues.

Extruder cartridge	
Printing needle	
Bioink	

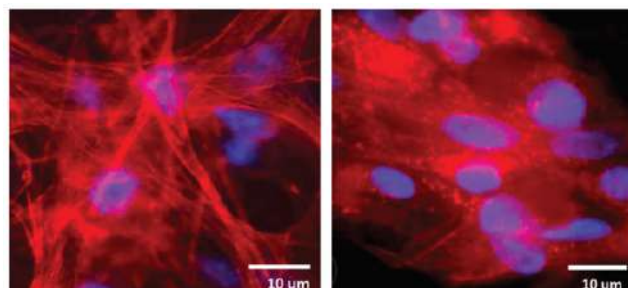


Figure 2. Confocal images shown here were acquired from tissue constructs printed with bioink formulations containing either fibroblasts (left) or myocytes (right). Scale bar change micrometer. Stained with MF20 and DAPI.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

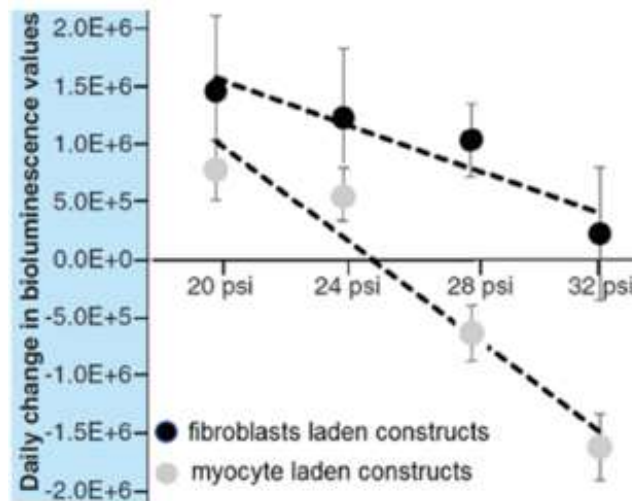


Figure 3. x axis is pressure (psi - pound per square inch), y axis - firefly luciferase activity (Bioluminescence).

Daily change in bioluminescence values	
fibroblasts laden constructs	
myocyte laden constructs	

Using the information and figures, determine whether the following statements are true or false:

- A. After one week of culture, the relative percentage of myocytes in tissue constructs printed using bioink with 50 – 50% myocyte-fibroblast content will be decreased
- B. The most likely meaning of the negative values on the y-scale is decreased cell proliferation
- C. The most likely meaning of the zero values on the y-scale is decreased cell viability
- D. A staining for actin in red and for DNA in blue would lead to confocal images presented.

Theoretical1



English (Official)

Question 11

Decellularization is the process of isolating the extracellular matrix of a tissue from its inhabiting cells. Decellularization of the organs is an important prerequisite for future transplantation of the animal organs cellularized with the patient cells. Heart decellularization can be performed by cannulating the coronary sinus (venous sinus collecting blood from heart) and perfusing it with a decellularization solution (a detergent destroying cell membranes). Figure 1 shows the appearance of the hearts right after they were cannulated and upon completion of the decellularization process. Figure 1A shows the outcomes of an experiment with fish hearts. Fig.1B illustrates a typical appearance of rat hearts before and after the decellularization process.

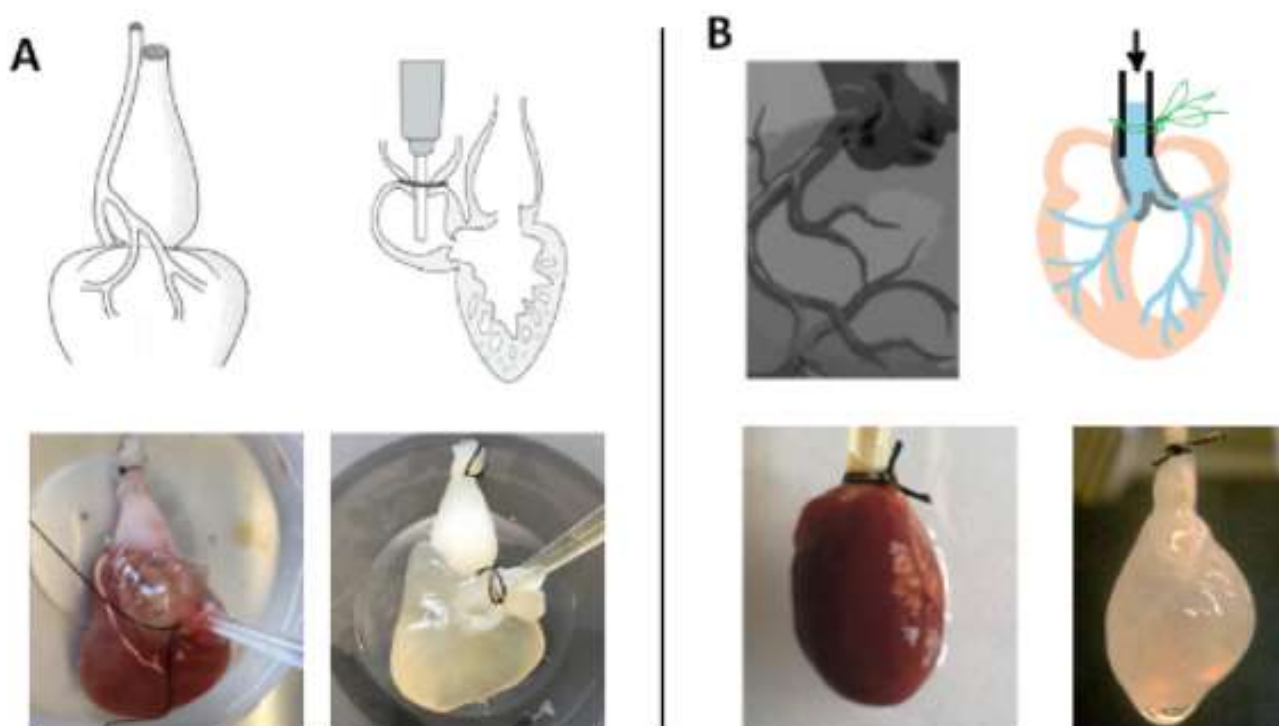


Figure 1. Cannulation process of fish (A) and rat (B) hearts.

Using the information and images, determine whether the following statements are true or false:

- A. The differences in cannulation are due to different numbers of heart chambers between the two species
- B. In mammals, entrances to major coronary vessels are found right behind the cusps of the aortic valve.
- C. Cannulation of fish heart for efficient decellularization can be accomplished by inserting perfusion cannula into bulbus arteriosus (cardiac outflow tract).
- D. The soap solution has ability to destabilize the cell membrane and have the same properties like decellularization reagent

Theoretical1



English (Official)

Question 12

Groundbreaking studies by Shinya Yamanaka's group broke long-standing dogma that differentiated adult cells cannot return to their embryonic state. The creation of what is now known as iPSC (induced pluripotent stem cells) offers the hope that damaged organs can be repaired by a patient's own cells. Multiple labs are currently working on the development of future therapies involving patient-specific iPSC or immortalized lines of human embryonic stem cells (hESC). These include efforts to use pluripotent stem cell-derived cardiomyocyte grafts to re-muscularize scar tissue that forms after myocardial infarction. Images from one of such studies show cross-sections of the ventricular wall of an infarcted heart from a sham-treated monkey (Fig.1) and the one with grafts of cardiac myocytes derived from hESC (Fig.2).

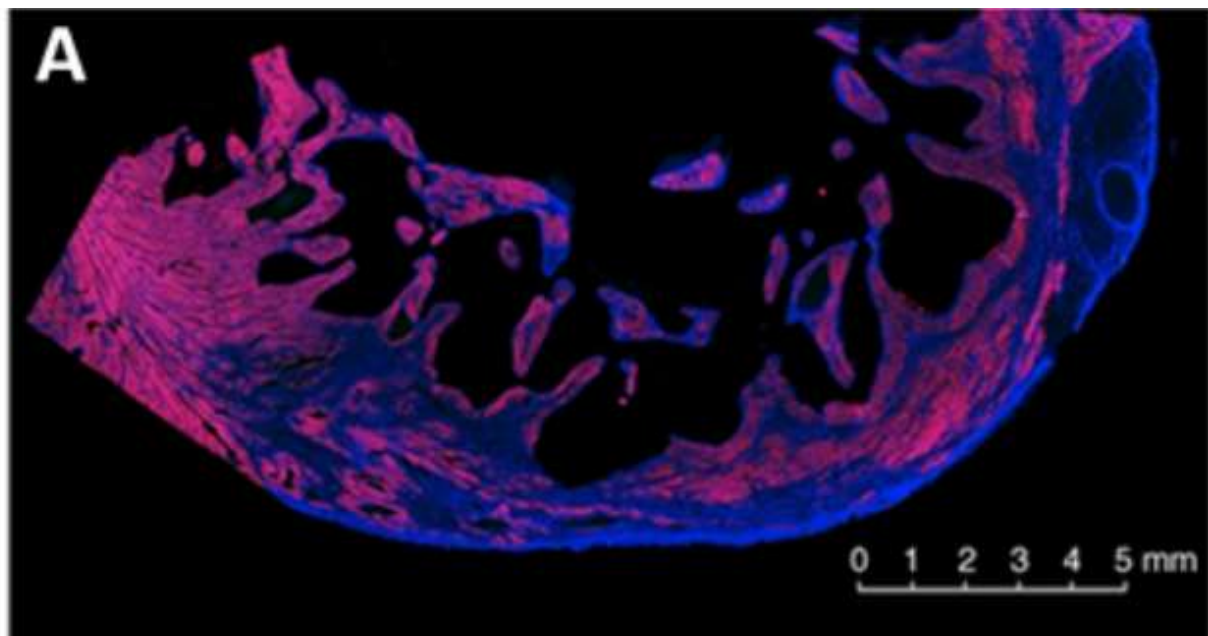


Fig.1. Cross-sections of ventricular wall of infarcted heart from sham-treated monkey.

Theoretical1



English (Official)

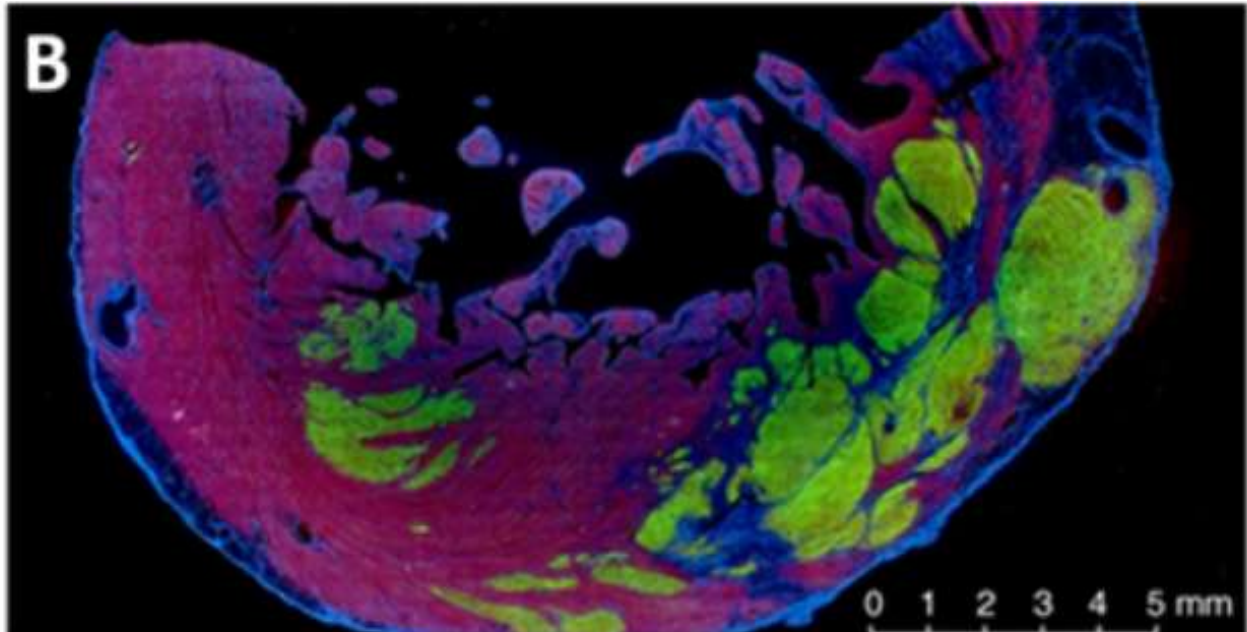


Fig.2. Cross-sections of ventricular wall of infarcted heart from monkey with grafts of cardiac myocytes derived from hESC. iPSc were genetically modified to express "green fluorescence protein" or GFP.

Using the information and figures, determine whether the following statements are true or false:

- A. Let's assume the amount of myocardium lost during typical infarction in human patients is about 1/3 of the left ventricular mass. Let's assume the weight of the left ventricle in humans is about 120 grams. Let's assume the size of an average cardiac myocyte is about $20 \times 20 \times 100 \text{ microns}$. Then the closest number by an order of magnitude of new cells needed to replace the ones that are lost is 10^9 .
- B. Although grafted cells are of human origin, the host animals do not require immunosuppression because transplanted cells were derived from embryonic stem cells.
- C. Protein identified by blue pseudocolour, abundant in heart scar, is also the most common component of connective tissue.
- D. Grafted cardiac myocytes within the host heart can be identified by staining for a cardiac isoform of troponin T.

Theoretical1

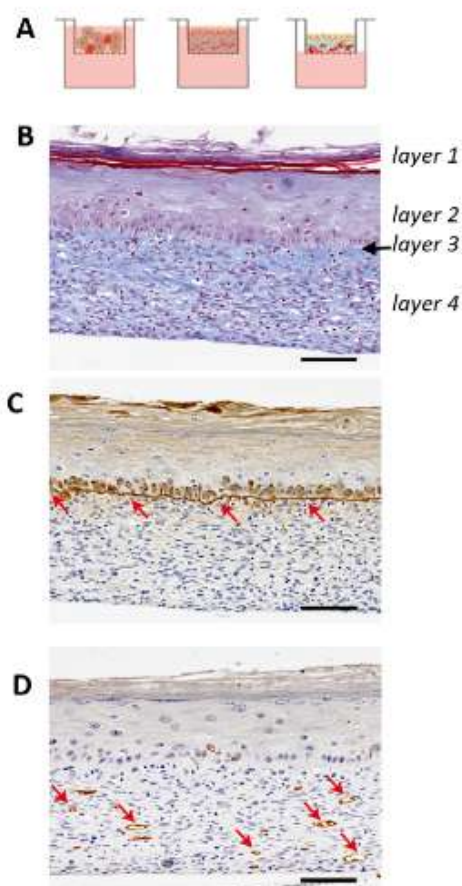


IBO
33rd 2022
ARMENIA

English (Official)

Question 13

For engineered tissue to survive *in vivo* it needs to be vascularized. Current vascularization approaches include, among others, the incorporation of adipose tissue-derived microvascular fragments, induced pluripotent stem cell (iPSC)-derived endothelial cells, three-dimensional bioprinting and a layer-by-layer approach. The figures below show the assembly of multicellular 3D skin substitute by interspersing three types of differentiated cells with thin layers of extracellular matrix film, composed of fibronectin and gelatin, followed by several days of air-liquid interface culturing (Figure A). Figures B-D shows outcomes of staining with B: Masson's trichrome, C: antibodies against laminin, and D: antibodies against PECAM1 (platelet endothelial cell adhesion molecule-1). Masson's trichrome is a stain that highlights collagen fibers. This method is used in histology to differentiate collagen and muscle fibers on tissue sections.



layer	
-------	--

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Using the information and figures, determine whether the following statements are true or false:

- A. Layer 1 corresponds to the lamina of basal membrane.
- B. Red arrows in Fig.C point to a newly formed vasculature.
- C. Endothelial cells and fibroblasts are the key components of layer 4.
- D. Keratinocytes and laminin are major components of layer 3.

Theoretical1

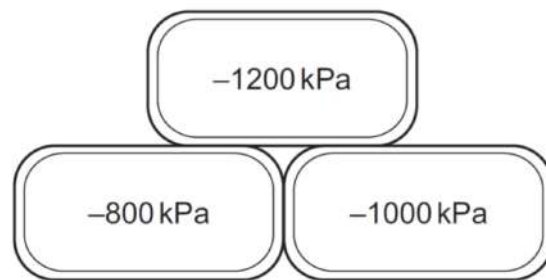


IBO
33rd 2022
ARMENIA

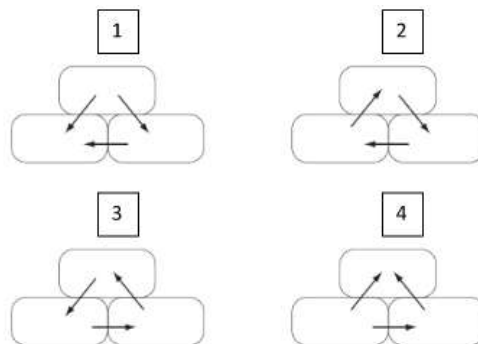
English (Official)

Question 14

The diagram shows the water potentials of 3 adjacent plant cells (the water potential of pure water is 0).



Determine for each of the following figures whether the direction of water movement due to osmosis is depicted correctly (true) or not (false)?



- A. figure 1
- B. figure 2
- C. figure 3
- D. figure 4

Theoretical1

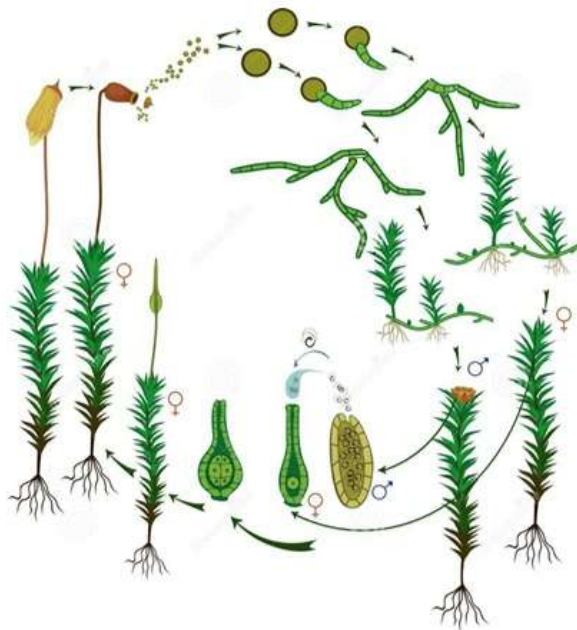


IBO
33rd 2022
ARMENIA

English (Official)

Question 15

The figure here depicts the life cycle of a plant. Using the figure, determine whether the following statements are true or false:



- A. The plant is a heterosporous
- B. The figure depicts the life cycle of a lycophyte
- C. The gametophyte of this plant develops in two forms.
- D. The sporophyte of this plant is capable of living independently.

Theoretical1

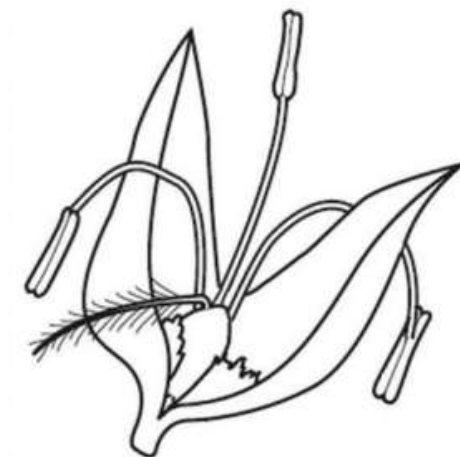


IBO
33rd 2022
ARMENIA

English (Official)

Question 16

The following figure shows the structure of a flower.



Using the figure, determine whether the following statements are true or false:

- A. This is a zygomorphic flower.
- B. This flower belongs to a plant pollinated by wind.
- C. This flower does not have a double calyx.
- D. This is a cleistogamous flower (i.e. does not open).

Theoretical1

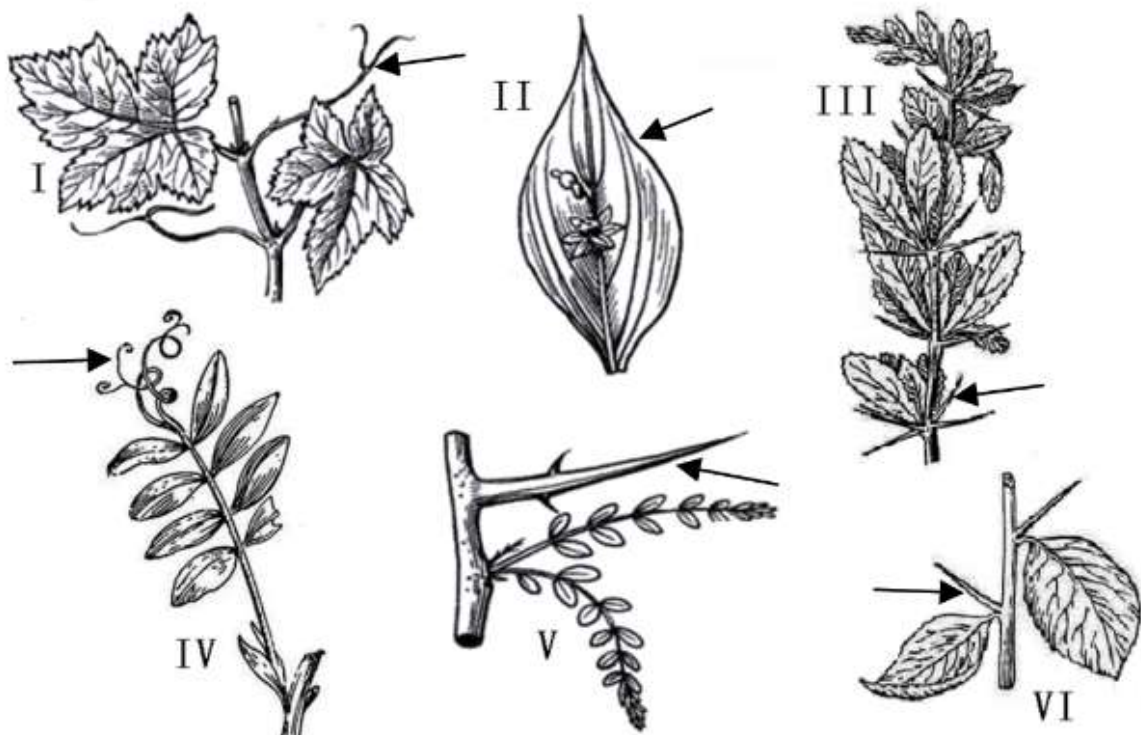


IBO
33rd 2022
ARMENIA

English (Official)

Question 17

The following figures indicate various modifications of plant organs.



Using the information and figures, determine whether the following statements are true or false:

- A. I, II, IV are modifications of the shoot
- B. III, IV are modifications of the leaf
- C. II, V, VI are modifications of the leaf
- D. II, V, VI are modifications of the shoot

Theoretical1

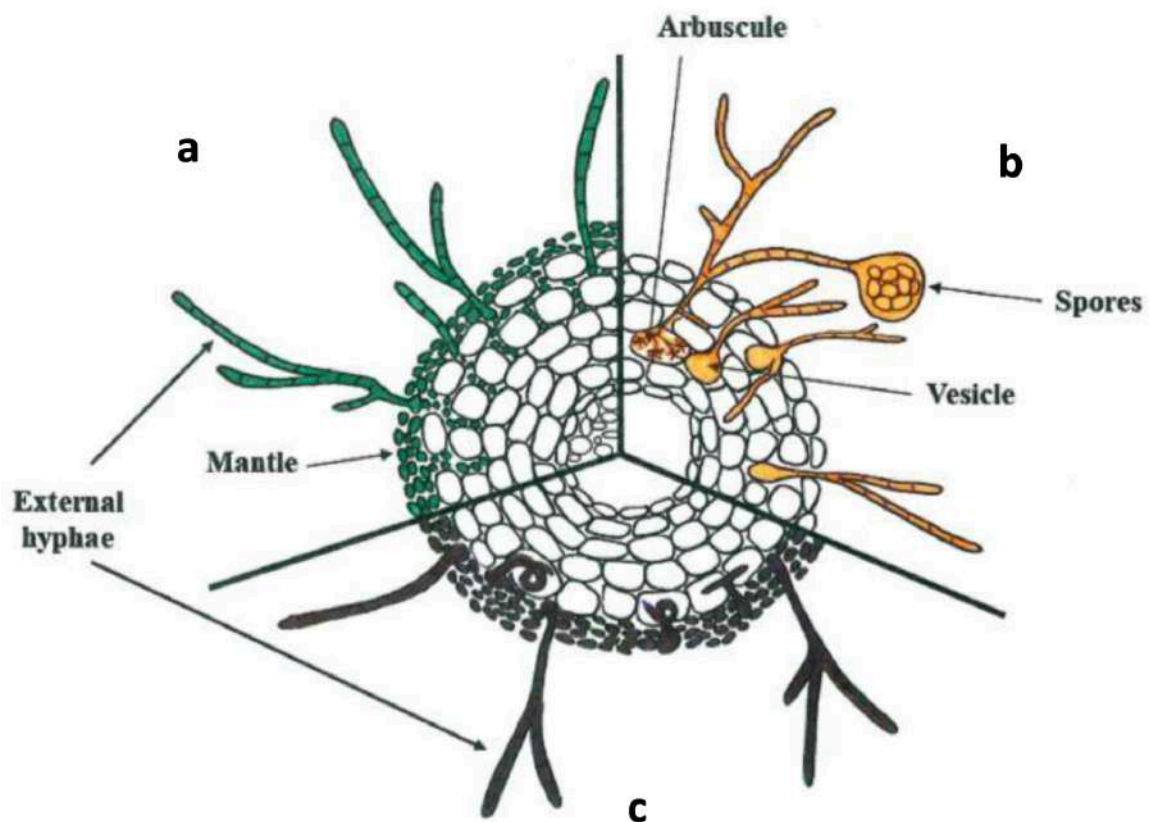


IBO
33rd 2022
ARMENIA

English (Official)

Question 18

The following schematic image shows the transverse cut of root showing symbiosis with 3 different groups of organisms (a, b, and c).



Arbuscule	
External hyphae	
Mantle	
Spores	
Vesicle	

Using the schematic image, determine whether the following statements are true or false.

- Diagram (a) shows ectomycorrhiza.
- Diagram (b) shows endomycorrhiza.
- Diagram (c) shows ectendomycorrhiza.
- One of the diagrams indicates a symbiosis of nitrogen-fixing bacteria and plant.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Theoretical1

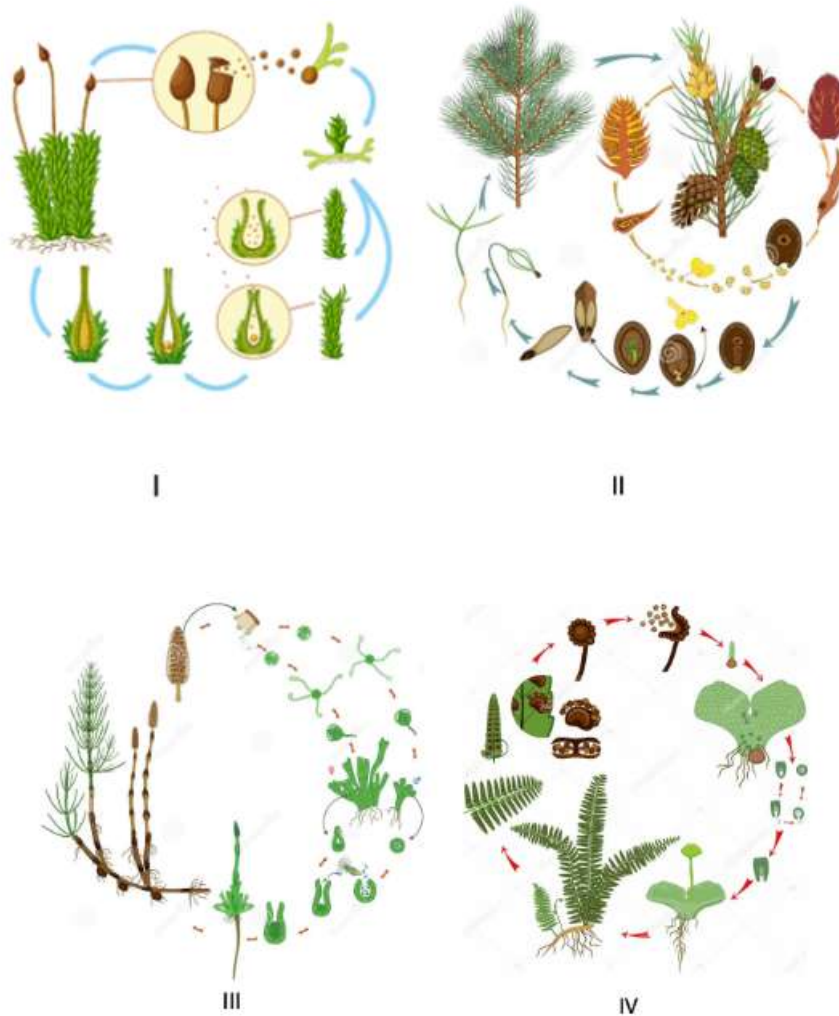


IBO
33rd 2022
ARMENIA

English (Official)

Question 19

The following figures demonstrate the life cycles of some plants. In the presence of water, determine whether the fertilization occurs (true) or not (false) in the following species.



- A. Species I
- B. Species II
- C. Species III
- D. Species IV

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 20

The circumference of the trunk of an oak tree is 282.6cm near its base. The average width of annual rings is 0.5cm , while the thickness of the bark is 2cm . Calculate the age of the tree. Annual rings can be used to determine the age of a tree.



Example of a tree.

Using the information and figures, determine whether the following statements are true or false.

- A. All annual rings have the same width.
- B. Light parts of the wood correspond to wide vessels, which grow during summer.
- C. Bark does not have year rings.
- D. The approximate age of the tree would be 86 years.

Theoretical1

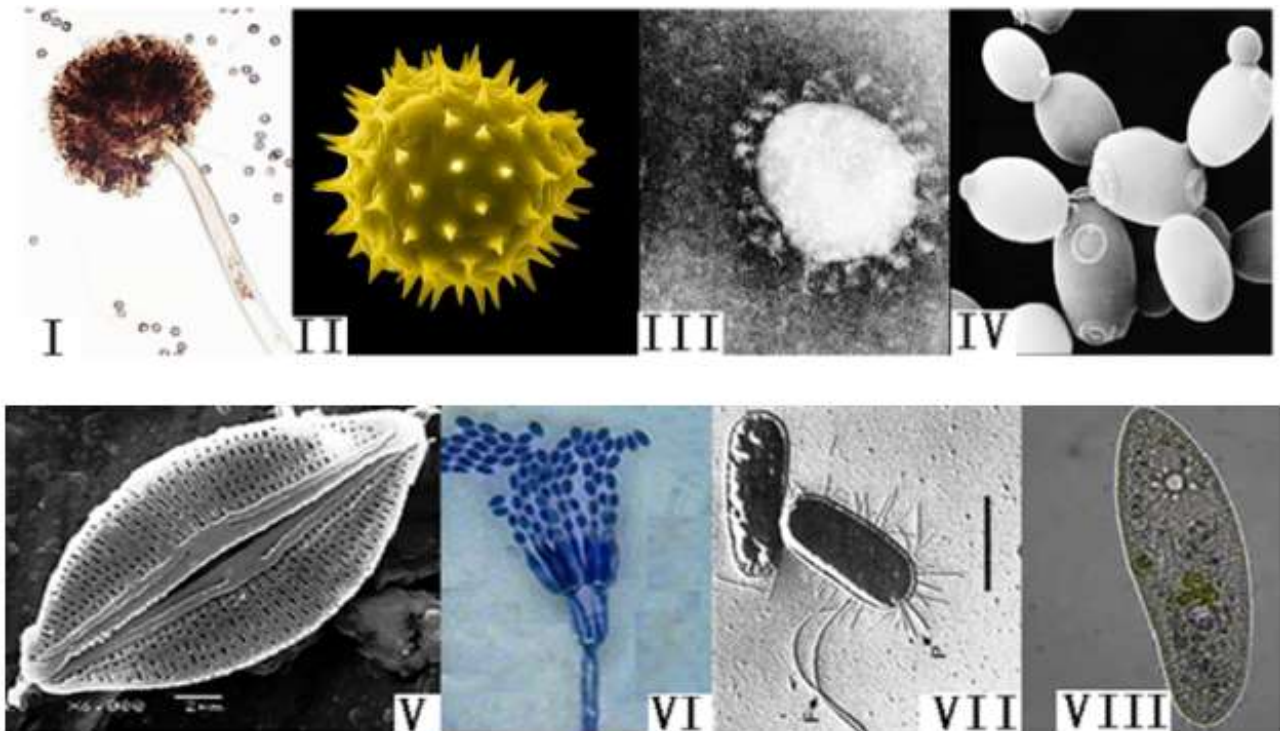


IBO
33rd 2022
ARMENIA

English (Official)

Question 21

The following images depict certain biological samples.



Using the images, determine whether the following statements are true or false:

- A. I, III and VI can cause diseases in humans.
- B. II and IV consist of plant gametophytes.
- C. II, VII and VIII belong to plankton.
- D. II and V belong to autotrophic organisms.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 22

At the basis of the hierarchy/subordination of individuals in a population is a complex system of behavioral and physiological reactions. In mammals, a complex set of reactions called stress response is very important. Experiments on mice have shown that regular changes in behavior are accompanied by regular changes in stress response. Prior to grouping, male mice were kept alone and did not meet one another. The degree of stress expression was determined by measuring suppression of breathing.

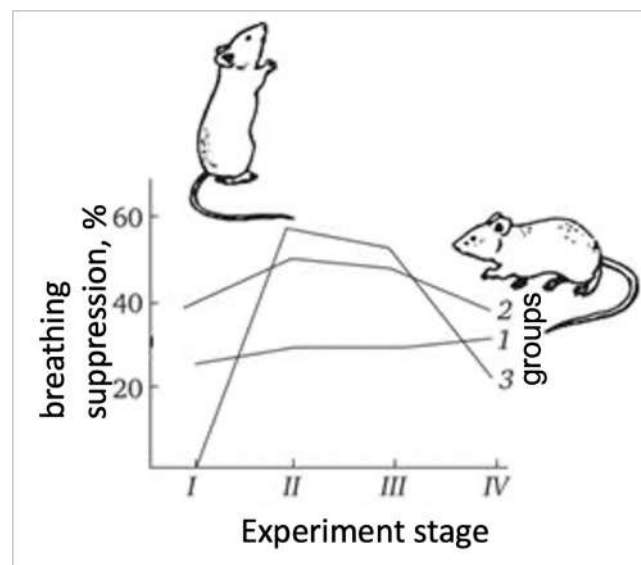


Figure. Dynamics of stress response in males of different social statuses to group formation experiment. The average data of the group is presented.

- 1 - dominants,
- 2 - subdominants,
- 3 - subordinates,

- I - Before group formation, individuals were kept alone/separately
- II - 1st day in the group,
- III - 7th day in the group,
- IV - 2nd day of separation of individual mice from the group

Using the information and graph, determine whether the following statements are true or false:

- A. In all groups, stress is most pronounced on the second day of group formation.
- B. Before and immediately after the experiment, the stress levels are higher in the subdominant group, compared with the dominant group.
- C. The degree of stress expression does not depend on the initial social status of an individual.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

D. As the relationship between individuals improves, the amount of stress response decreases, but remains higher than that observed in solitary individuals.

Theoretical1



English (Official)

Question 23

The gut microbiome comprises a vast ecosystem of commensal bacteria, archaea, fungi, and viruses. The gut modulates CNS (central nervous system) functions by involving a variety of microbiota-derived metabolites, neuroactive substances and gut hormones. Direct microbial invasion beyond the blood-brain barrier (BBB) is also possible. Bacteria can traverse the endothelium through the transcellular pathway via brain endothelial cells, the paracellular pathway via disruption of intercellular junctions, as well as through infected phagocytes (Figure 1, 2).

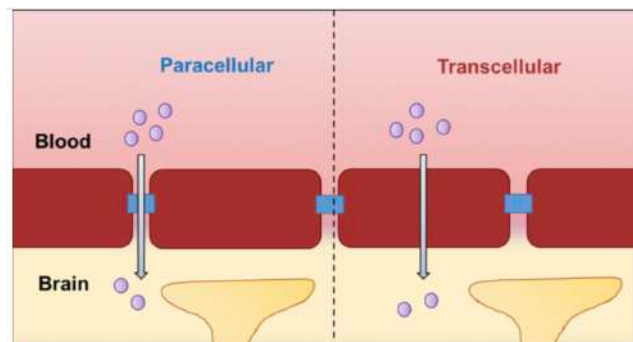


Figure 1: Paracellular and transcellular transport pathways.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

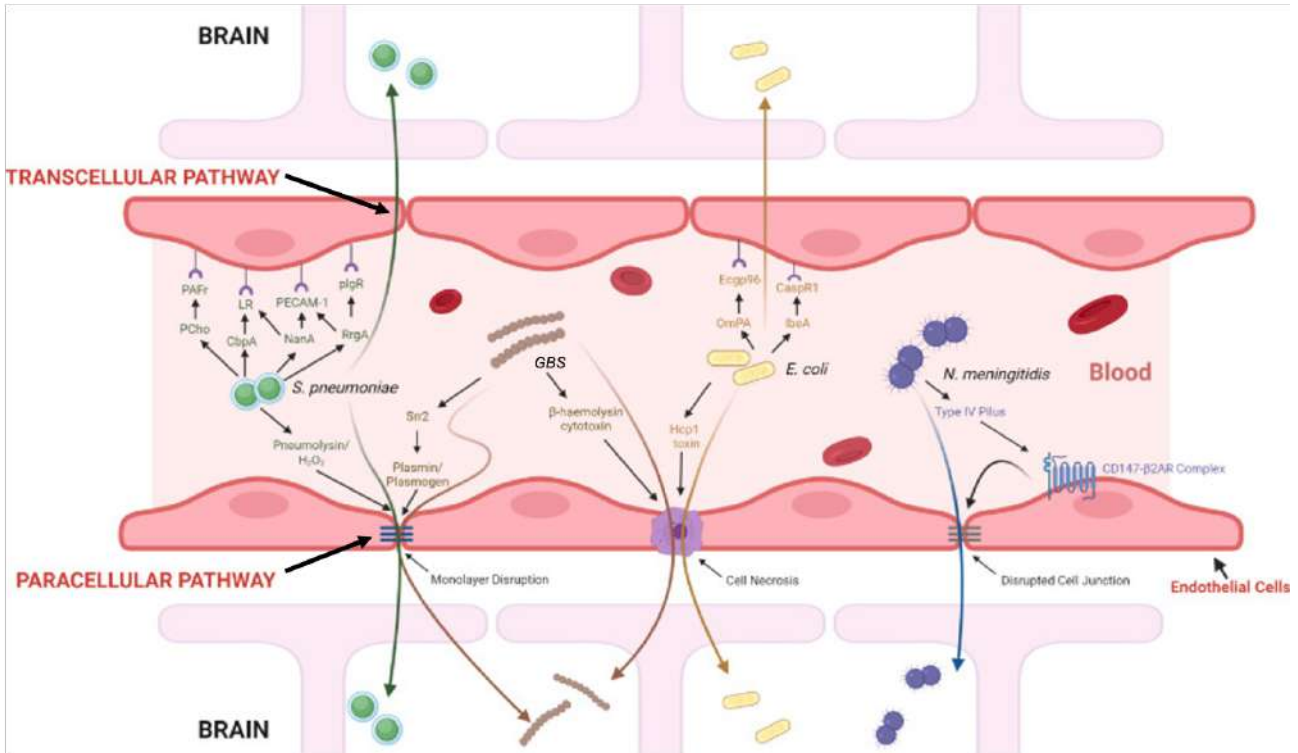


Figure 2. Mechanisms for four common meningitis-causing bacteria to cross the blood-brain barrier: *N. meningitidis*, *E. coli*, Group B *Streptococcus* (GBS) and *S. pneumoniae*.

Using the information and figure, determine whether the following statements are true or false:

- Group B *Streptococcus* (GBS) bacteria can penetrate by endothelial layer breakdown when serine-rich bacterial protein (Srr2) causes rupture of intercellular connections.
- All CNS pathogens have to cross an additional layer of BBB formed by the astrocyte endfeet.
- E. coli* bacteria can cross paracellularly, causing disruption of intercellular connections.
- Bacteria *S. pneumoniae* can either enter transcellularly through endothelial monolayer disruptions caused by the bacterial production of pneumolysin and H_2O_2 or paracellularly via several interactions.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 24

During the evolution of vertebrates, changes in the structure of organs and organ systems have occurred.

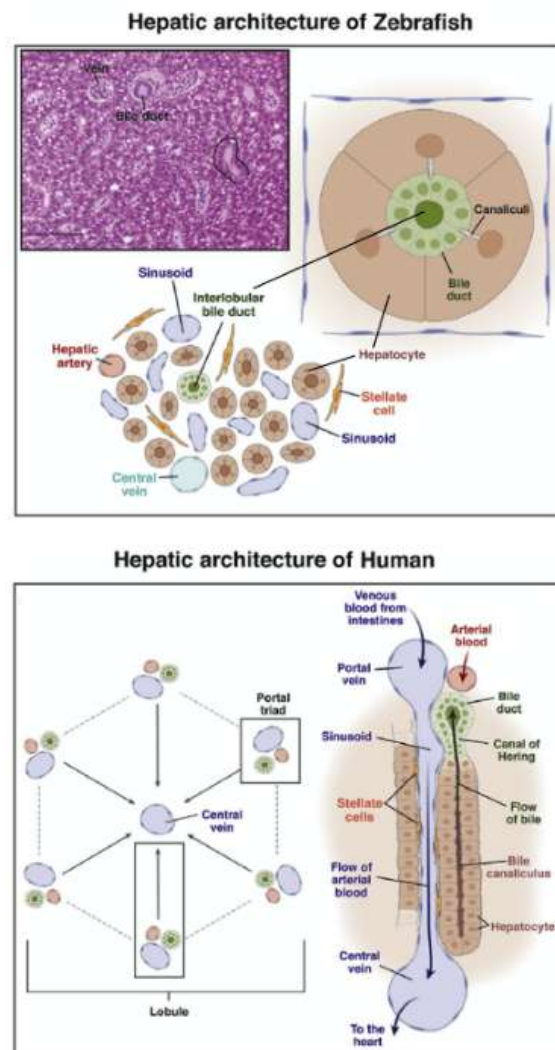


Figure 1 showing liver anatomy of zebrafish and human

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Hepatic architecture of zebrafish	
vein	
Bile duct	
Sinusoid	
Hepatic artery	
Interlobular bile duct	
Central vein	
Sinusoid	
Stellate cell	
Hepatocyte	
Bile duct	
Canaliculi	

Hepatic architecture of Human	
Portal triad	
Central vein	
Lobule	
Venous blood from intestines	
Portal vein	
Arterial blood	
Canal of Hering	
Stellate cells	
Flow of bile	
Flow of arterial blood	
Bile canaliculus	
Hepatocytes	
Central vein	
to the heart	

Based on the figure, determine whether the following statements are true or false.

- A. Like the human liver, zebrafish liver is also characterized by a lobular structure where the bile duct is located in the center of each lobule rather than a central vein as in the human liver.
- B. In contrast to human liver, the blood vessels of zebrafish liver are distributed irregularly in the organ.
- C. All types of cells in the liver of the zebrafish are also present in the human liver.
- D. The hepatocytes of the hexagonal lobules of the human liver differ in oxygen content, with the peri-central cells having a higher oxygen concentration than the periportal cells.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 25

Oxytocin is a neuropeptide that plays a crucial role in shaping social relations and interactions. Oxytocin was thought to be produced in response to tactile contact. Scientists have studied the release of oxytocin in girls aged 7 - 12 years in different experimental conditions. All the girls had to go on stage and take part in a public-speaking contest (stressor). After that, the girls of the first group (control group) were immediately sent to watch a movie with neutral content. The second group (tactile group) of girls had 15 minutes of direct contact with their mothers before watching the movie, and the girls of the third group (vocal group) communicated with their mothers by phone for 15 minutes, after which they watched the same movie. Cortisol (Fig. 1) and oxytocin (Fig. 2) levels were measured in girls in all groups during the observations.

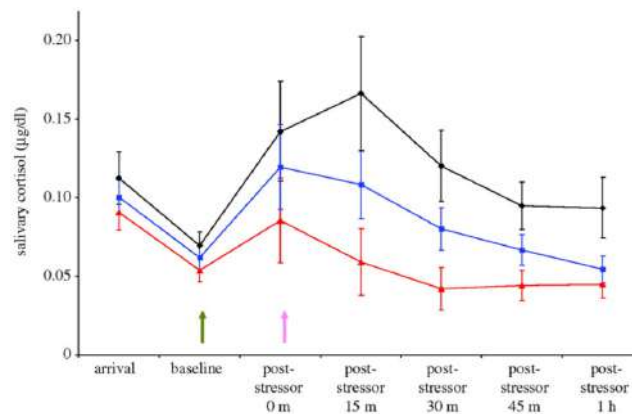


Figure 1. Changes in cortisol levels in girls during observations: green arrow shows the start of public speaking, pink arrow, the end of public speaking. Black (control), Blue (vocal) and Red (tactile). Children in all three conditions exhibited an increase in salivary cortisol from baseline to peak ($p < 0.01$), indicating that the social stressor was effective. However, treatment conditions differed following the stressor ($p < 0.02$). Children receiving no social contact exhibited higher levels of cortisol than the other two groups, even an hour after the stressor was complete ($p < 0.02$). Error bars refer to standard deviation.

salivary cortisol ($\mu\text{g}/\text{dl}$)	
arrival	
baseline	
post-stressor	

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

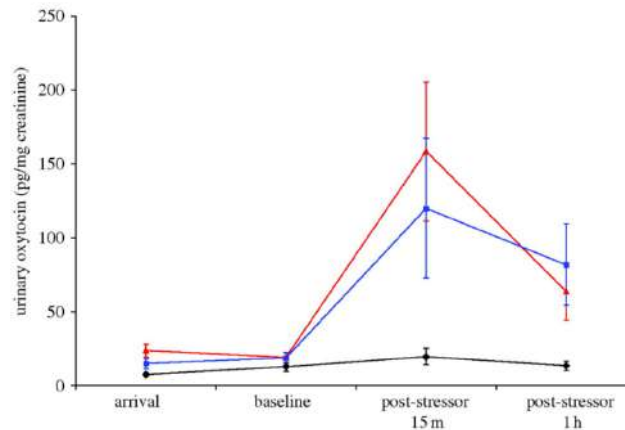


Figure 2. Oxytocin content in the urine, relative to creatinine, of the girls; Black curve (- control) group, Blue (vocal) and Red (tactile). Both physical and speech-only contact affected children's OT levels within 15 min post-stressor and this effect was maintained as long as 1 h post-stressor ($p = 0.02$ and $p = 0.02$, respectively). Error bars refer to standard deviation.

urinary oxytocin (pg/mg creatinine)

Using the information and figures, determine whether the following statements are true or false:

- A. In all groups, cortisol levels rose after the performance, but after an hour they dropped to starting levels.
- B. Oxytocin levels were significantly higher in the tactile group than in the vocal group, so touch is a more potent stimulus for oxytocin production.
- C. Communication with mothers stimulates the production of oxytocin, which decreases cortisol levels and eliminates the effects of stress.
- D. This study establishes a direct link between voice stimulation and neuropeptides that regulate interpersonal relationships.

Theoretical1

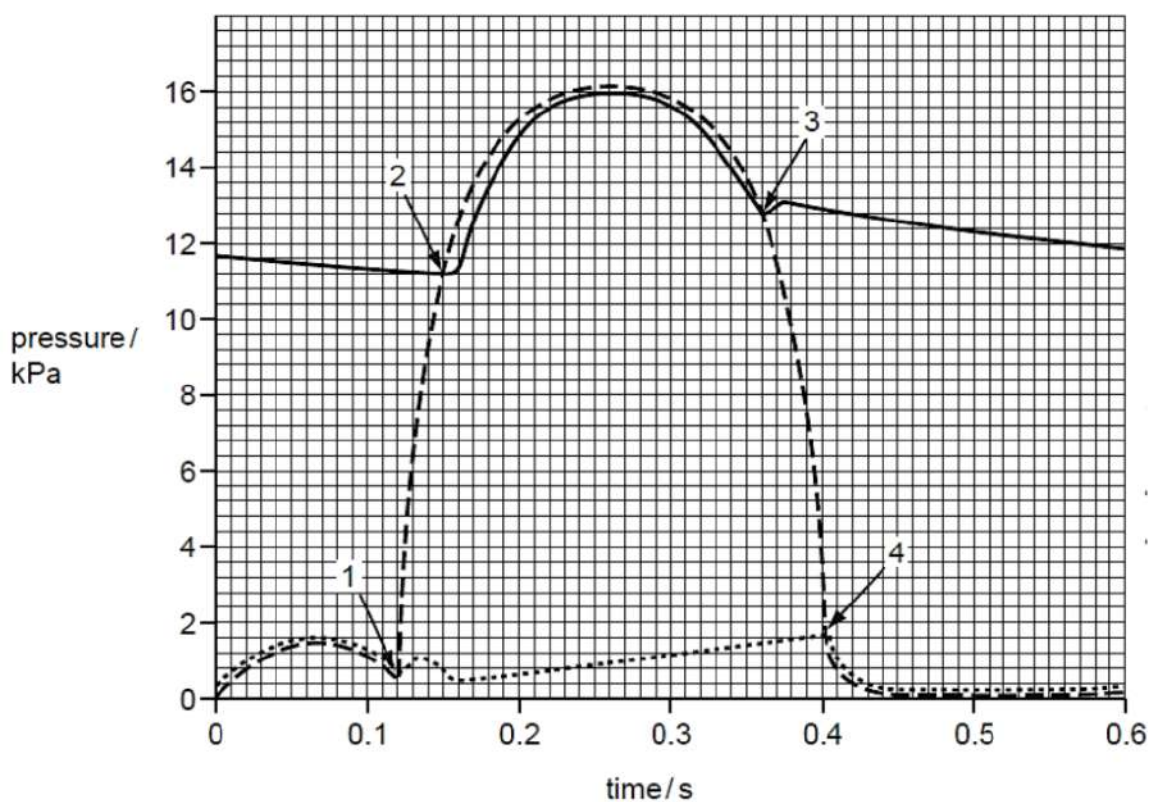


IBO
33rd 2022
ARMENIA

English (Official)

Question 26

The diagram shows the change in pressure over time in the left half of the heart and in the aorta. The duration of this cardiac cycle is 0.6s. At points 1, 2, 3 and 4, the atrioventricular valves and semilunar valves either open or close.



pressure	
time	

- pressure change in the left ventricle
- pressure change in the aorta
- pressure change in the left atrium

Using the information and figure, determine whether the following statements are true or false.

During the cardiac cycle,

A. the atrioventricular and semilunar valves close simultaneously for 0.07 seconds.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

- B. the atrioventricular valves are closed for 0.28 seconds.
- C. the semilunar valves are closed for 0.07 seconds.
- D. the semilunar valves are open for 0.28 seconds.

Theoretical1



English (Official)

Question 27

Saiga, *Saiga tatarica*, live in the deserts, semi-deserts, and steppes of Central Asia and Mongolia, where the climate is very harsh, with cold winters and hot summers. They originally formed large, nomadic herds, with thousands or even tens of thousands of individuals. During migration, they cross large areas, including by swimming across large rivers. They are fast-moving animals and can develop speeds of up to 70km/h , commonly $50 - 60\text{km/h}$. In case of a long-distance run, they lower their heads and in this position can run tens of kilometers, producing large dust clouds in summer.



Figure 1. Male saiga



Figure 2. Female saiga

Theoretical1



English (Official)



Figure. 3. Saigas swim across a river during migration

Using the information and figures, determine whether the following statements are true or false:

- A. The long snout-like nose of saigas is an adaptation to warm up the cold air in the nasal cavity during the winter.
- B. The long snout-like nose of the saigas clears the inhaled air of dust, allowing them to run long distances during summer without suffocating from the dust.
- C. While swimming in the rivers and while avoiding being noticed by predators, saigas immerse their whole body and head underwater, pulling out only their long snout-like nose to breathe.
- D. The long snout-like nose of saigas is typical only for males and serves to attract females and occupy a high social position in the herd.

Theoretical1

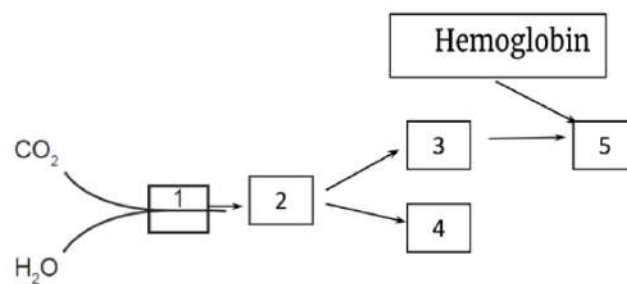


IBO
33rd 2022
ARMENIA

English (Official)

Question 28

The diagram shows the mechanism of transport of carbon dioxide in the blood.



Hemoglobin	
------------	--

Using the information and figure, determine whether the following statements are true or false:

- A. The presented scheme is the only way to transport carbon dioxide via circulatory system to the lungs
- B. Substances 1 and 2 are found in red blood cells
- C. Substance 1 is the enzyme carbonic anhydrase
- D. Substance 5 is carbaminohemoglobin

Theoretical1

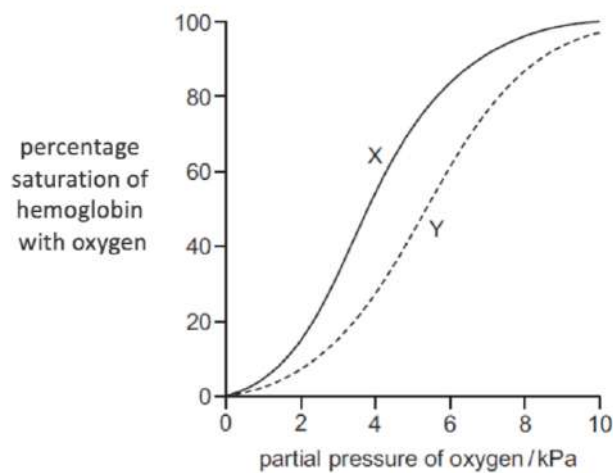


IBO
33rd 2022
ARMENIA

English (Official)

Question 29

The amount of oxygen transported by hemoglobin is affected by the partial pressure of oxygen and carbon dioxide. Under conditions of high partial pressure of carbon dioxide, the process of oxygen release from oxyhemoglobin is stimulated. This is called the Bohr effect, which is shown in the diagram below.



percentage saturation of hemoglobin with oxygen	
partial pressure of oxygen / kPa	

Using the information and graph, determine whether the following statements are true or false:

- A. The change from X to Y is caused by a decrease in oxygen concentration and a high pH
- B. The change from X to Y is due to the decrease in oxygen concentration and low pH
- C. The change from X to Y is due to an increase in the concentration of carbon dioxide and low pH
- D. Y indicates the acclimation in the tissues of alpinists during high-altitude climbs

Theoretical1

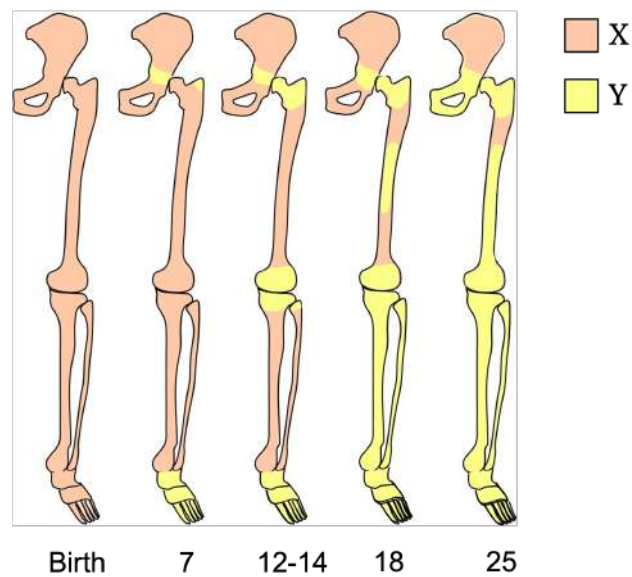


IBO
33rd 2022
ARMENIA

English (Official)

Question 30

The figure below represents the distribution of bone marrow types X and Y in the lower limbs of humans (*Homo sapiens*) at different ages (in years).



Using the information and figure, determine whether the following statements are true or false:

- A. The reduction in marrow type X is initiated in puberty.
- B. A healthy adult does not have a significant amount of marrow type X in his pelvis.
- C. Conversion of marrow type X to Y is reversible.
- D. A patient with leukemia can be assigned for a transplant of bone marrow type Y.

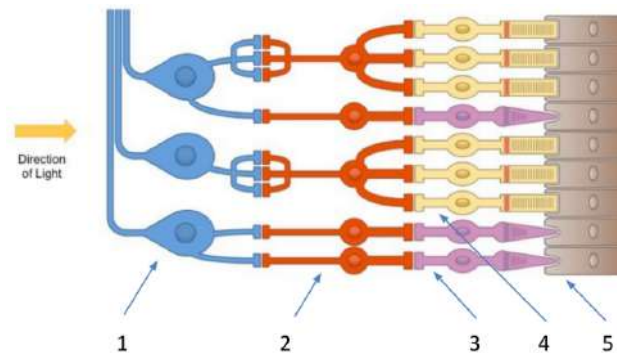
Theoretical1



English (Official)

Question 31

The diagram below shows cell layers in the healthy human retina. By carefully observing the diagram, determine whether the following statements are true or false.



Direction of Light	
--------------------	--

Using the information and figure, determine whether the following statements are true or false:

- A. The first layer of cells through which light passes belongs to type 1. These cells are the photoreceptors.
- B. Cells of type 4 have the lowest threshold of light sensitivity.
- C. Cells of type 2 are always depolarized if the light is present.
- D. Cells of type 2 and 3 communicate via electrical synapses.

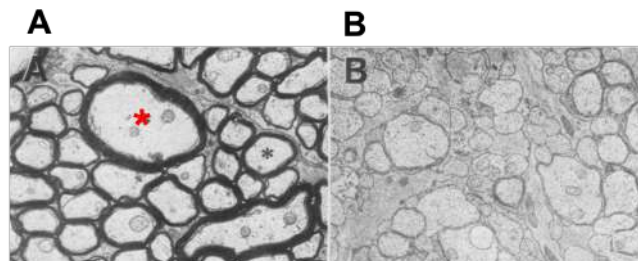
Theoretical1



English (Official)

Question 32

The *shiverer* mutation is known to affect the Central Nervous System (CNS) causing tremors and early death in mice. To investigate its effects, the optic nerve, which, unlike all other nerves, is histologically equivalent to the CNS, was cut transverse and stained for lipids (A - wild type, B - mutant).



Using the information and image, determine whether the following statements are true or false:

- A. Picture A contains multiple Schwann cells
- B. Ion channels of neurons in Picture B were directly affected by the mutation
- C. The *shiverer* mutation severely compromises oligodendrocytes
- D. In Picture A we could see the nucleus in place of the asterisk, if we stained the sample with DAPI

Theoretical1

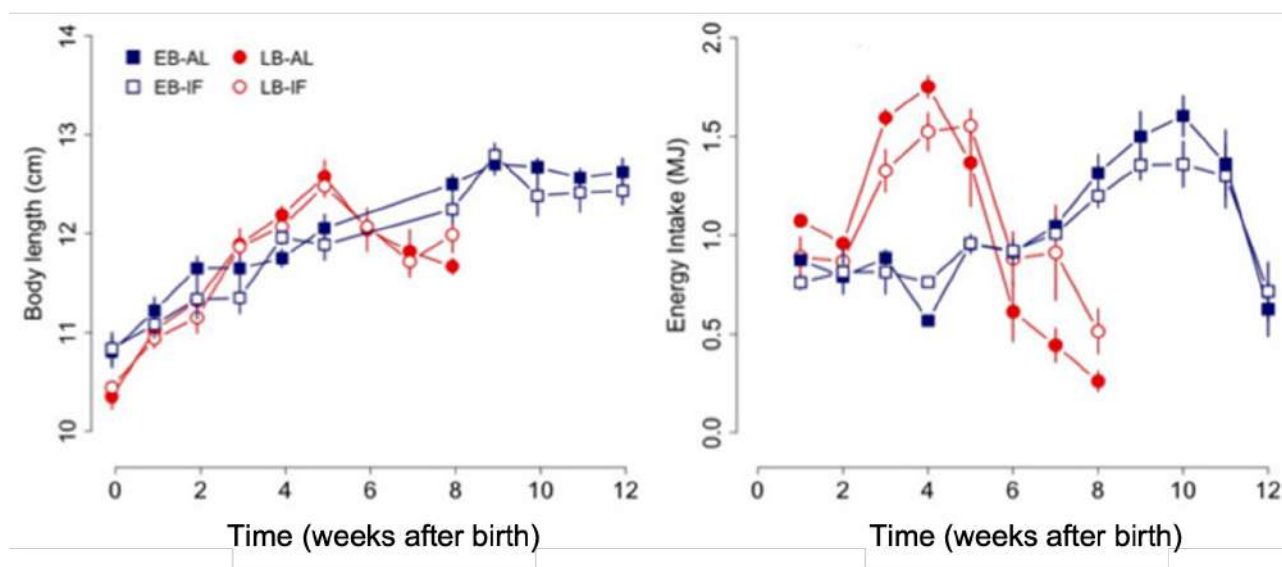


IBO
33rd 2022
ARMENIA

English (Official)

Question 33

The active period of the dormouse *Eliomys quercinus* is 6 - 7 months. During this time, the animals give birth to two litters. It should be taken into account that the gestation period is 1 month and 1 month is spent on feeding the offspring. Therefore, the first litter offspring are two months older than the second litter offspring. And winter comes on schedule for everyone. Scientists studied the effect of the birth date of offspring on a number of physiological parameters during their growth. In one experiment, the growth rate and activity of the first and second litter offspring were observed. Dormice of each age group were divided into 2 subgroups. One group of animals received an unlimited amount of food (AL - ad libitum), and the other - was left without food for 24 hours twice a week (IF - intermittently fasted), the days of which were selected randomly. The growth rate was determined by the body length of the pup, and activity by the metabolic rate, measured in terms of energy consumption (MJ).



Body length (cm)	
Energy consumption (MJ)	
Time (weeks after birth)	

Figure. EB (early-litter) pups, LB (late-litter) pups, AL (ad libitum) unlimited food, IF (intermittently fasted pups)

Using the information and graphs, determine whether the following statements are true or false:

- Late-litter dormice were more susceptible to malnutrition and had significantly lower growth rates than early-born ones.
- The late-litter pups gradually increased their food intake, while the first-litter ones immediately began to eat a lot, stopping eating only before overwintering.
- Late-litter offspring were born smaller but grew faster, reaching the level of early-litter ones in a relatively short period of time.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

D. The metabolism of fasting pups was lower than that of fully fed pups, but as overwintering approached, it gradually decreased in all pups.

Theoretical1



English (Official)

Question 34

Lake Malawi in Africa is home to the cichlid family *Labidochromis caeruleus* fish species, whose females carry their eggs and larvae in their mouths for several weeks before the juveniles become independent. During this time, each adult male of the cichlid individually tries to protect its territory from other males, showing the other males its mouth and opening the gills. Males are also characterized by yellow and round dots on the anal fin that resemble eggs of the species.



Labidochromis caeruleus female



Labidochromis caeruleus male

Using the information and images, determine whether of the following statements are true or false.

- A. The yellow dots on the male anal fins attract females because they signify strength in the male.
- B. Yellow dots are selected for through intersexual selection, i.e. female preference rather than intrasexual selection, i.e. male-to-male competition.
- C. The male of *Labidochromis caeruleus* shows the dots on its anal fin during the breeding season to other males, disrupting their mating behaviour, and thus getting a higher chance to fertilize the eggs of a female.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

D. Females of *Labidochromis caeruleus* can re-enter the reproductive process after the embryo and larvae, which are kept in their mouths for a week, become independent.

Theoretical1



English (Official)

Question 35

Sexual dimorphism is characteristic of Ninespine stickleback *Pungitius pungitius*. Males, in contrast to females, acquire a dark color during the breeding season and begin to build nests from aquatic plants and their remnants, and aggressively do not allow other dark-colored males to approach. At the same time, they invite the females to swim in the nest they have built, where females lay eggs. The laid eggs are then fertilized by the male. However, during the breeding season, some mature males do not look much different in color from females and can be seen in the same schools, not being treated aggressively by males with dark coloration.



Figure 1. Dark colored male of Ninespine stickleback



Figure 2. Ninespine stickleback female. Some adult males also have this coloration.

Using the information and images, determine whether the following statements are true or false.

- A. Males resembling females during the breeding season may be an adaptation for tricking females into complacency before they fertilize the eggs that the females have laid in the dark-colored male's nest.
- B. Males that do not differ in appearance from females are not yet mature, have not acquired a typical coloration of males and cannot yet reproduce.
- C. The absence of sexual dimorphism between the light-colored males and females helps individual males to save energy and participate in reproduction.
- D. Dark-colored males are able to distinguish males that are colored like females and drive them away from their nests.

Theoretical1



English (Official)

Question 36

Aethia cristatella are strictly monogamous birds, forming colonies during the breeding season and laying one egg in a nest under rocks after mating has taken place.

Males of *Aethia cristatella* (Fig. 1), that already have a mate, occupy a highly positioned rock with surrounding areas (up to one meter). Studies show that males spend most of their time on their own stones but also temporarily occupy the stones of other males. Males try to prevent the invasion of other males into their area. At the same time, they try to display themselves in the area of the invading males (Figure 2). The frequency of such behavior is directly proportional to the increase in the number of birds in the area. When there is an increase in the number of birds, active males tend to display themselves more frequently in the area of other males compared to their own.



Figure 1. *Aethia cristatella* with courtship feathers

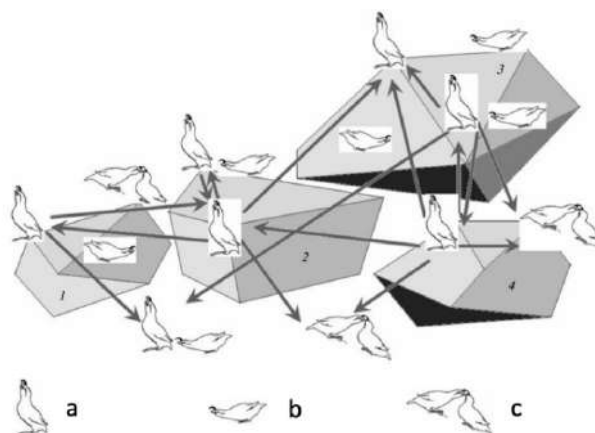


Figure 2. *Aethia cristatella* courtship game diagram in areas with high bird density; a - males displaying themselves in their own territory, b - females searching for a mate, c - mated pairs, 1-4 - rocks. The arrows indicate the movements of the males on rocks.

Using the information and the figures above, determine whether the statements are true or false.

A. Active males of *Aethia cristatella* display themselves on rocks, preferred by other active males, to attract

Theoretical1



English (Official)

and mate with other females.

B. Active males of *Aethia cristatella* display themselves for social interactions.

C. The behavior of the males is aimed to dominate other males and outcompete them from their territory.

D. For females of *Aethia cristatella*, observing the active and regular display behavior of different males is important to evaluate their capacities for caring for the offspring.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 37

There are glycoproteins on the surface of human red blood cells that have antigenic properties called H-antigen. In the presence of the A allele in the human genotype, an enzyme is synthesized, under the influence of which a part of the H-antigen is converted into an A antigen. Thus, the person has an A blood type. If there is a B allele in the genotype, then part of the H-antigen is converted to the B antigen, and the person has a B blood type. The O allele encodes an inactive enzyme, which does not modify the H-antigen.

In some cases (with a probability of 0.0005%) the initial H antigen does not appear on the surface of human erythrocytes (Bombay phenotype). In this case, even in the presence of A and B alleles, i.e. when the necessary enzymes are synthesized in the body, a person does not produce A and B antigens. The synthesis of the initial H antigen is encoded by the H gene, the recessive allele of which is h.

Using the information, determine whether the following statements are true or false.

- A. Parents with genotype *ABHH* and *OOhh* may have a baby with blood type B with a 25% of probability.
- B. If both parents have normal phenotypes (absence of Bombay phenotype), their child cannot have a B blood type.
- C. If a child with AB blood type was born in the family, it is possible that his / her parents' genotypes were *AAHH* and *BBhh*.
- D. If the parents have the *AAhh* and *BBHh* genotypes, then their children will all have blood type AB.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 38

There are different modes of natural selection: stabilizing selection, directional selection and disruptive selection. The figure below shows three different frequency distribution curves (in no particular order) shifting in the course of natural selection.

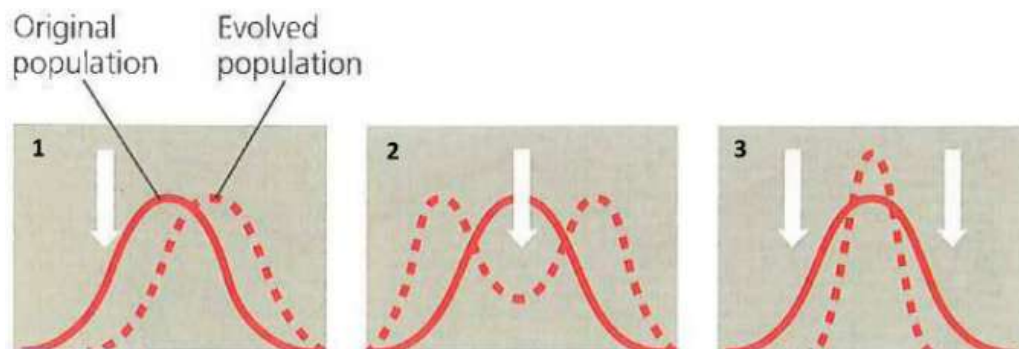


Figure 1: The possible effects of natural selection on frequency distribution for some trait.

Original Population	
Evolved population	

Using the information and images, determine whether the following statements are true or false.

- A. Stabilizing selection is the only mode of selection, where the population median stays the same.
- B. In response to all plants producing harder seeds, a species of finches evolved to have larger beaks, as represented by curve 2.
- C. For a population of finches, the largest seeds and the smallest seeds have become the most abundant as resources. This is represented by curve 2.
- D. The Siberian husky has to evolve enough muscle mass to pull a sledge, but not enough to fall into the snow due to its weight. This evolutionary process is represented by curve 3.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 39

To understand the molecular mechanisms of the origins of adaptation during asexual and sexual reproduction, scientists have studied mutations in asexually and sexually replicating populations of the yeast *Saccharomyces cerevisiae*. All populations were kept in similar conditions, the number of individuals was 100,000, and the duration of the experiment was 100 days (about 1000 generations).

Mutations in the non-coding regions of the genome (intergenic), mutations that do not cause amino acid changes in the protein (synonymous), and mutations that cause amino acid changes in the protein (non-synonymous) were recorded. All the mutations that originated in the population during the whole experiment (All) as well as only those mutations that were recorded at the end of the experiment in all individuals of the population (Fixed) were considered.

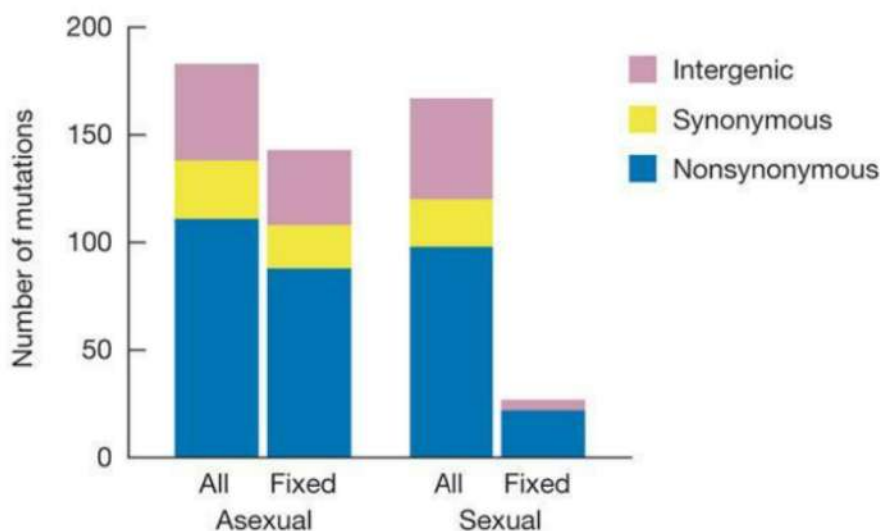


Figure. Mutations in asexual and sexual populations of the yeast *Saccharomyces cerevisiae*.

Number of mutations	
All	
Fixed	
Asexual	
Sexual	
Intergenic	
Synonymous	
Nonsynonymous	

Using the information and analysis, determine whether the following statements are true or false.

- The process of mutagenesis is different in asexual and sexual populations.
- Synonymous mutations are usually neutral and do not get fixed in sexual populations.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

C. The proportion of different mutation types recorded in asexual and sexual populations varies.

D. Due to sexual reproduction, only some useful mutations are fixed in individuals, while in asexual populations their entire "genetic background" is recorded.

Theoretical1



English (Official)

Question 40

Elephants live about as long as humans but cancer occurs in 17% of humans and in only about 5% of elephants. Researchers from the University of Chicago have found that a special "zombie gene", (Leukemia Inhibitory Factor LIF6), helps to prevent cancer in elephants.

Genetic analysis has shown that in humans as well as elephants, the p53 gene suppresses the growth of cancer cells and promotes their apoptosis. It was assumed that the LIF family of genes has lost the ability to encode a protein, but LIF6 is somehow revived in elephants and involved in damaging the mitochondrial membrane in cells with mutations, resulting in rapid destruction of genetically defective cells.

According to scientists, the described changes occurred 25-30 million years ago, when the ancestors of elephants began to grow in size.

Using the information determine whether the following statements are true or false.

- A. The increase in the size of the elephants promoted their survival.
- B. An increase in body size is usually accompanied by a higher probability of developing cancer.
- C. The new function of the LIF6 gene is a key determinant of elephant body size and species survival.
- D. Probability of cancer development increases as the animal ages.

Theoretical1

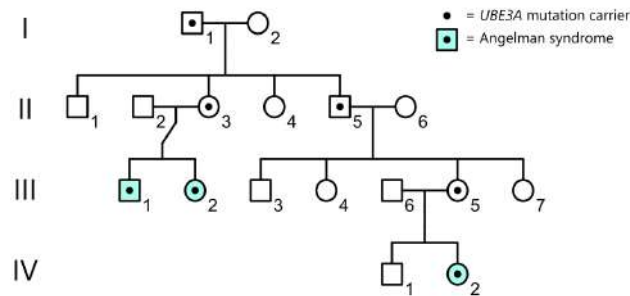


IBO
33rd 2022
ARMENIA

English (Official)

Question 41

Angelman Syndrome (AS) is caused by a mutation of the *UBE3A* gene. Affected individuals display delayed development, impaired cognitive abilities and frequent laughter for no apparent reason. The following pedigree describes the inheritance pattern of the disease in a family of carriers. The mutation is rare enough for us to assume none of the carriers married another carrier. All individuals labeled white are phenotypically healthy.



mutation carrier	
syndrome	

Using the information and pedigree, determine whether the following statements are true or false.

- A. This mutation is recessive and is on an autosomal chromosome.
- B. Mendelian inheritance is insufficient to explain the inheritance of AS.
- C. If II-3 has a third child, then the child will surely have AS, just like II-3's other two children.
- D. If individual III-1 conceived a child with a non-carrier woman, their progeny would have a 50% chance of having AS.

Theoretical1

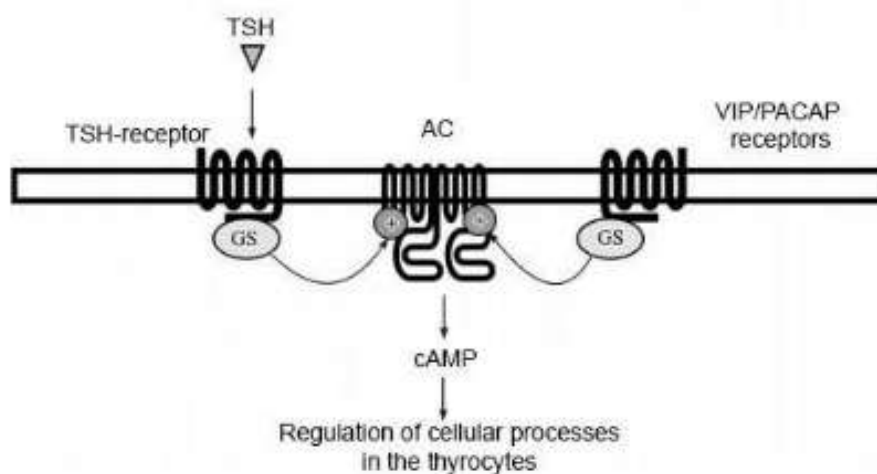


IBO
33rd 2022
ARMENIA

English (Official)

Question 42

The following image depicts the pathways which activate the adenylyl cyclase enzyme in the thyrocytes in the thyroid gland.



TSH	
TSH-receptor	
AC	
cAMP	
Regulation of cellular processes in the thyrocytes	
VIP/PACAP receptors	
GS	

AC - adenylyl cyclase, GS (G protein) - stimulating protein, TSH - thyroid-stimulating hormone

Determine whether the following statements are true or false.

- The activation of AC, which occurs by TSH binding to its receptors, plays a important role in the production of thyroid hormones (TH).
- The peptide hormone PACAP activates AC via VIP/PACAP receptors.
- GS proteins activate AC by catalyzing the synthesis of secondary messenger - cAMP.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

- D. One of the mechanisms of thyroid hypofunction is the increased sensitivity of the thyrocyte AC system to TSH, as well as the increased number of TSH receptors.

Theoretical1



English (Official)

Question 43

Biologists and physiologists have long been interested in a range of height-related adaptations of giraffes, *Giraffa* sp. The immediate ancestors of giraffes, among them the *Samotherium major*, appeared on Earth during the Neogene. Among mammals, extant giraffes have the longest necks, up to 2 meters long. In order for oxygen to reach the brain, the heart of a giraffe must constantly supply blood with blood pressure 2.5 times higher than that of humans. The question of why under such conditions giraffes do not suffer from hypertension has been explored here.

Comparing the genome of Rothschild's giraffe *Giraffa camelopardalis rothschildi* with genomes of other ruminants, particularly *Okapia johnstoni*, scientists have found giraffe-specific mutations, mainly related to the cardiovascular system, bone growth, sensory function, and circadian rhythms. Among them are seven mutations in the giraffe FGFR1 gene that has not been found in any other ruminant.

Mice with the "giraffe" FGFR1 gene become insensitive to hypertension and their bones are more firm. Additionally, compared to okapi, giraffes have been found to have lost at least 53 olfactory genes, and giraffes can sleep only three hours a day due to changes in the genes involved in sleep control.



a.

Theoretical1



English (Official)



b.

The positions of giraffe eating (a) and drinking water (b)

Using the information and images, determine whether the following statements are true or false.

- A. The ancestors of giraffes lived on Earth during the Paleogene
- B. The giraffe *FGFRL1* gene has a pleiotropic effect on the development of both the circulatory and musculoskeletal systems.
- C. The unique mutations in contemporary giraffes probably involve genes that evolved to regulate both skeletal and cardiovascular development in parallel.
- D. As a result of changes in the corresponding genes, the evolutionary advantages of the giraffe are: easy access to drinking water, avoiding predators and a better sense of smell.

Theoretical1



IBO
33rd 2022
ARMENIA

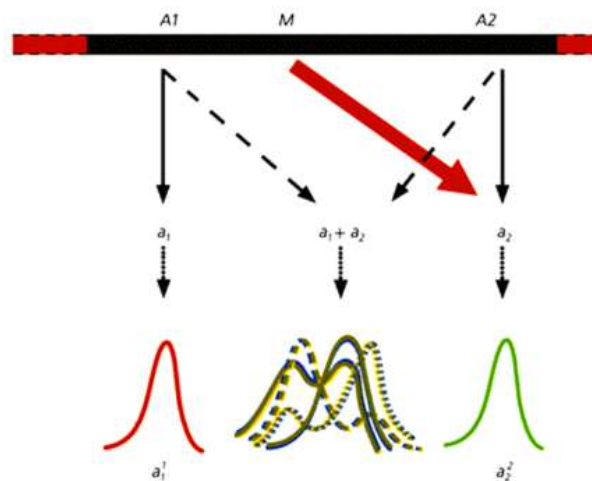
English (Official)

Question 44

One of the possible genetic causes of changes in morphogenesis are macromutations, which cause alterations in gene expression.

The following is a hypothesis of the effect of such mutations on morphogenetic processes.

A1 and A2 are independent genes that, through the synthesis of substances a_1 and a_2 , control the corresponding morphogenetic processes/reactions a_1^1 and a_2^2 , M is the modifying gene. A2 is active only in the presence of the expression of gene M.



Using the information and diagram, determine whether the following statements are true or false.

- If the expression of the A2 gene in the phenotype is not possible, only the a_1^1 morphogenetic process will take place.
- Product a_1 can determine if a_1^1 and a_2^2 morphogenetic reactions take place and determine the diversity of morphogenetic processes by interacting with product a_2 .
- In the case of a loss-of-function mutation in the modifier gene M, reactions a_1^1 and a_2^2 can occur simultaneously, in which case intermediate morphogenetic processes will take place.
- Mutation of a modifying gene can regulate the course of morphogenesis and can be considered a molecular-genetic mechanism of speciation.

Theoretical1



Question 45

Scientists have found that *Drosophila melanogaster* fruit flies have complex innate color preferences depending on the time of day. To study this, the flies were kept for 6 days in separate tubes, and plastic colored filters were attached to these, creating red, blue and green bands, respectively. Flies were kept in test tubes at a constant temperature, humidity and daily rhythm of 12 hours of natural light / 12 hours of darkness. The color preference of flies was determined by the number of individuals found in the respective color zone. In parallel, the motor activity of the flies was observed. The experimental setup is presented in figure 1 and the results are presented in figure 2.

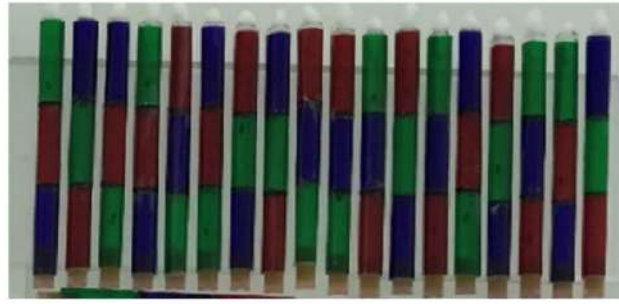
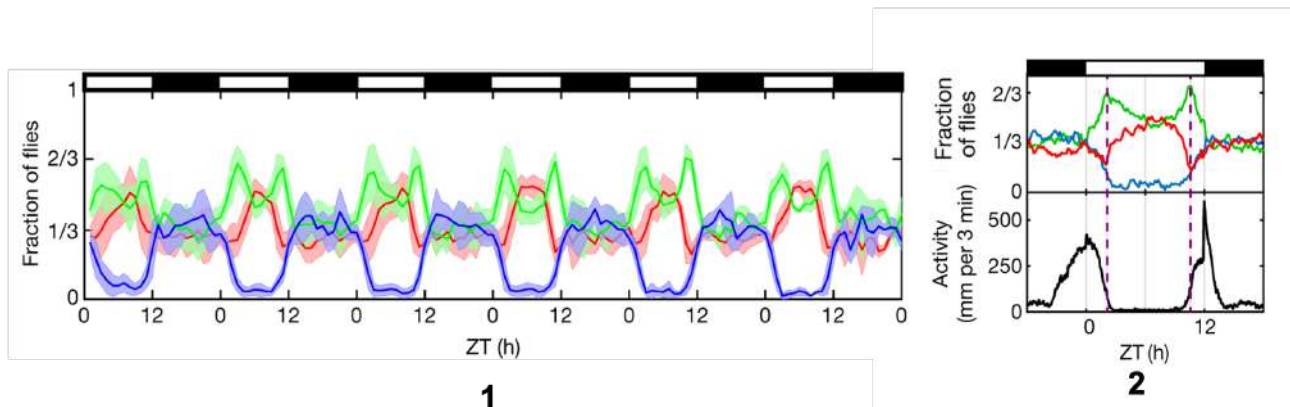


Figure 1: An example of the randomized order of filters



Fraction of files	
Activity (3 mm per min)	

Figure 2. Fruit fly color preferences and motor activity during 6 days. ZT 0 - the start of daylight, ZT 12 - the point of lights being turned off. Panel 1. color preferences of flies. Panel 2. top curve - Proportion of flies in different color bands, bottom black curve - the mobile activity of flies.

Using the information and figures, determine whether the following statements are true or false.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

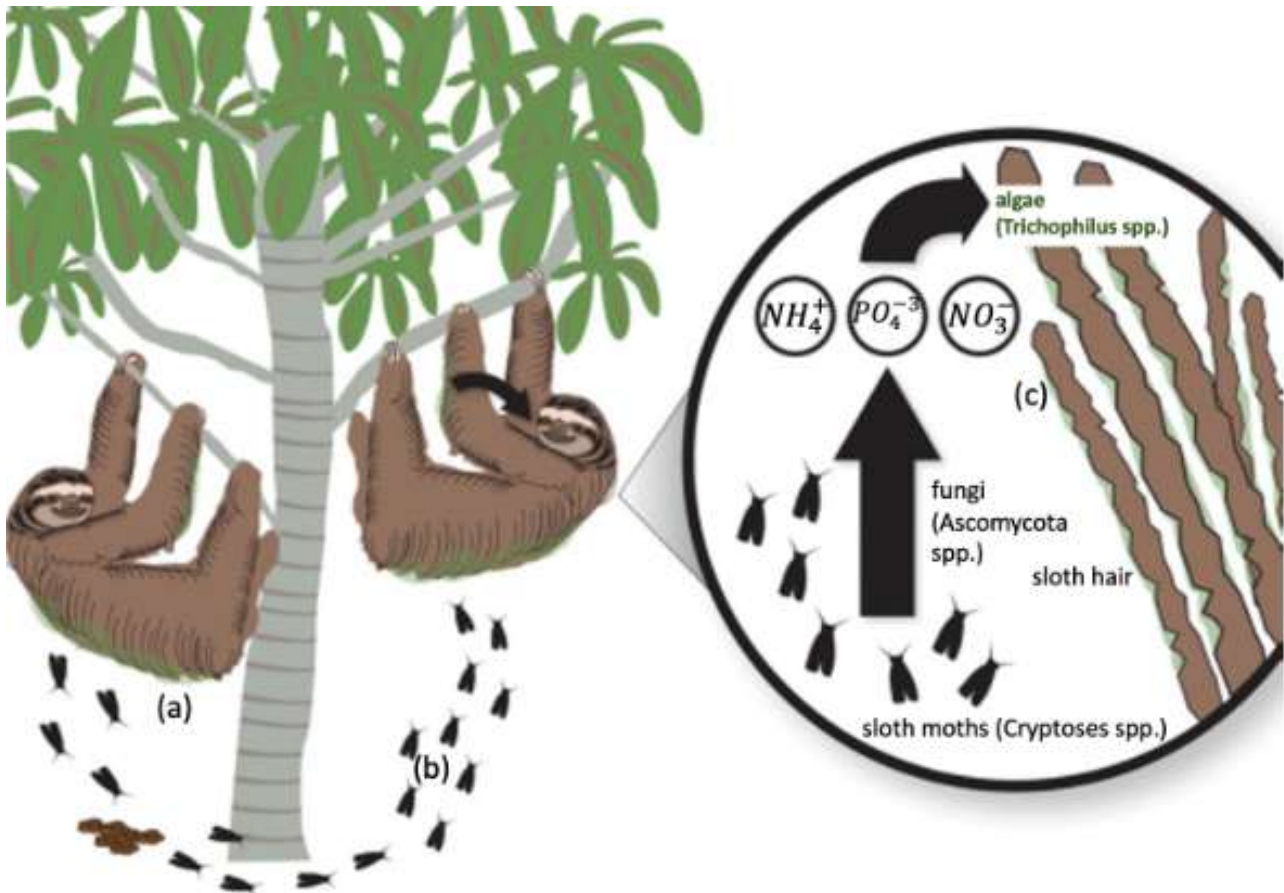
- A. The maximum values of green color preference is related to with the late morning and early evening motor activity.
- B. In the middle of the day, flies occur with equal frequency in green and red bands.
- C. Based on the given data individual fruit flies tend to remain in one colour band during the night (from ZT 12 to ZT 0).
- D. In the dark, flies are randomly distributed between color bands and occur with equal frequency in all bands.

Theoretical1



Question 46

Three-toed sloths *Bradypus sp.*, found in South and Central America, are sluggish animals that spend their entire lives in the foliage of trees (Figure 1), descending to the ground only once a week to defecate. *Cryptoses choloepi* moths live in the fur of sloths (a) and this defends them from the attacks of insectivorous birds. In addition, they move with sloths and lay their eggs on the feces of sloths. The larvae that hatch from the eggs feed on the feces. Adult moths (b) climb up on sloths again. In addition to moths, algae of the genus *Trichophyllus* (c) grow in the fur of sloths, which when in large quantities, serve as food for sloths. The algae turn the sloth fur color to greenish, making the sloth inconspicuous to enemies, when in the foliage. Ascomycota fungi also grow in the fur of sloths, decomposing dead moth bodies, and producing nutrition for the algae.



algae (<i>Trichophilus</i> spp.)	
fungi (<i>Ascomycota</i> spp.)	
sloth hair	
sloth moths (<i>Cryptoses</i> spp.)	

Figure 1. Relationships between the three-toed sloth and the organisms living in its fur

Theoretical1



English (Official)

Using this information, whether the following statements are true or false:

- A. The interaction between the sloth and *Cryptoses choloepi* moths is mutualism.
- B. *Cryptoses choloepi* moths and fungi, living in sloth fur, have a commensal relationship with the sloth when the indirect effect on the algae is not taken into consideration.
- C. Algae, living on sloth fur, and sloths are amensal.
- D. Algae and fungi, living in the fur of sloths, have a commensal relationship with each other.

Theoretical1



IBO
33rd 2022
ARMENIA

English (Official)

Question 47

Codling moth *Cydia pomonella* is a serious pest in agriculture. From time to time, favorable environmental conditions can cause population outbreaks. In an experiment, the minimum and maximum values for the survival to different heat and humidity conditions of codling moth pupa were studied (Tables 1, 2).

Analyze the risk of mass bursts of large numbers of codling moths on the basis of these data in the coordinate space of the two-dimensional ecological niches formed in the zones marked with the letters X and Y (Figure 1).

Table 1.

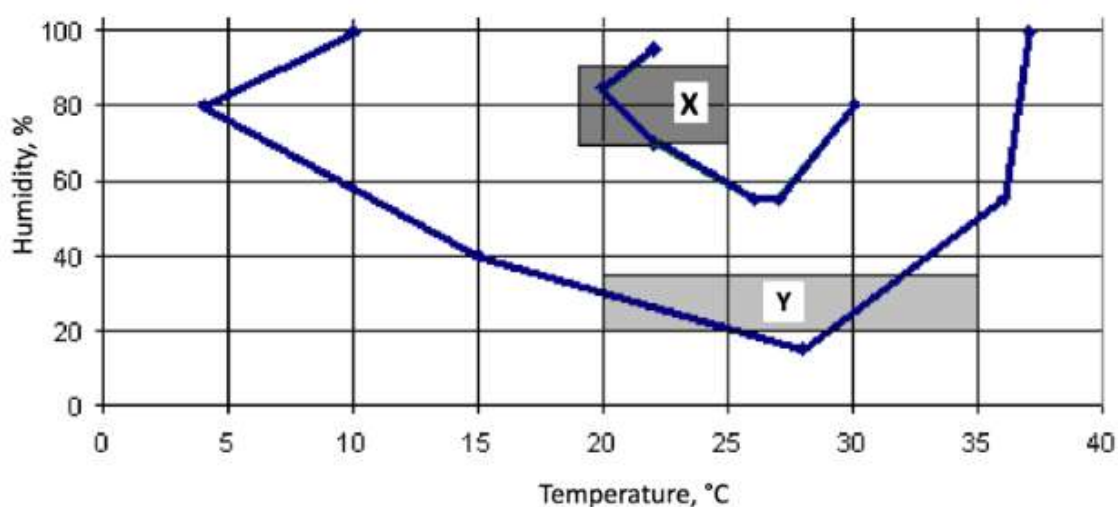
100% mortality of codling moth pupae is observed in the case of the following combinations of temperature and humidity.

Temperature, °C	+10	+4	+15	+28	+36	+37
Humidity, %	100	80	40	15	55	100

Table 2

The lowest mortality of codling moth pupae (less than 10%) is observed in these combinations of temperature and humidity.

Temperature, °C	+20	+22	+27	+26	+22	+30
Humidity, %	85	95	55	55	70	80



Temperature	
Humidity	

Theoretical1



English (Official)

Figure 1: Diagram of the coordinate space of the two-dimensional ecological niches of codling moth
Using the information and data, determine whether the following statements are true or false.

- A. Viability of codling moth pupae is low in zone X.
- B. Zone Y corresponds to the range of 18 – 25 °C air temperature, and 70 – 90% humidity.
- C. Adult moths are unable to survive temperatures of 15 °C, when the humidity is lower than 40%.
- D. 20 – 30 °C is optimal for survival of moth pupae if the air humidity is above 50%.

Theoretical1



English (Official)

Question 48

Sockeye salmon (*Oncorhynchus nerka*) is a Far East salmon species that spends its initial life stage in rivers, then migrates to the ocean, where it has more favorable conditions for feeding, and after a while returns to the rivers to breed. During this time, the color of its body changes (Figure).

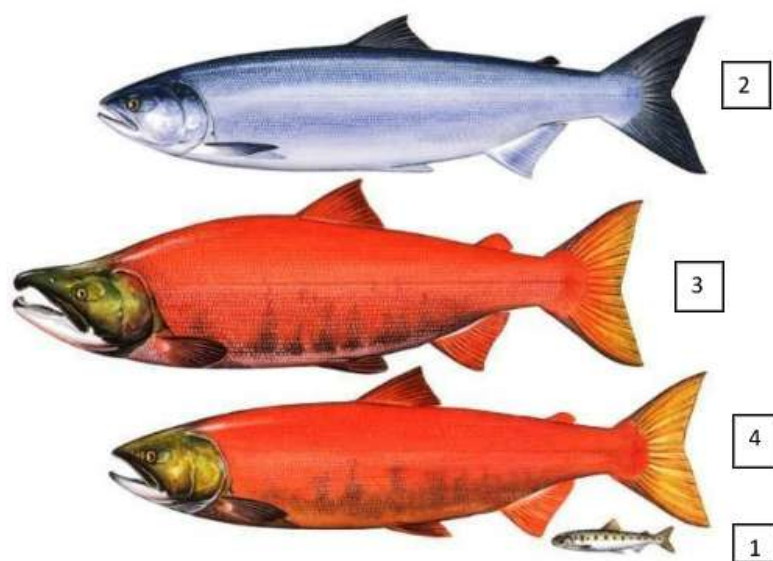


Figure. Peculiarities of sockeye salmon coloring at different stages of life. 1- river phase (newborn period), 2 - ocean phase, 3 - male during the breeding season, 4 - female during the breeding season

Sockeye salmon distribution area includes the rivers of the east coast of Eurasia and west coast of North America, and north of the Pacific Ocean. The Chukchi Peninsula is the northernmost region of the sockeye salmon distribution area, where its populations are characterized by complex age groups of breeding schools, longer marine lifespan, a predominance of early maturing females, and a predominance of males in older age groups.

Using the information and images, determine whether the statements are true or false.

- A. The complex age composition of the sockeye salmon's Chukchi populations is directed to neutralize the potential impact of less favorable conditions during the river life stage.
- B. In the Chukchi sockeye salmon populations, color changes at different stages of life lead to a predominance of males in the older age groups of breeding schools.
- C. The complex age composition of the sockeye salmon's Chukchi populations may have conferred a selective advantage to the population by minimizing the impact of less favorable conditions during the river life stage.
- D. Sockeye salmon entering rivers from the ocean is characterized by sexual dimorphism, while the salmon living in the ocean do not have it.

Theoretical1



English (Official)

Question 49

Only some bacteria and archaea are capable of performing biological nitrogen fixation. Organisms that grow on N_2 as a sole nitrogen source are called diazotrophs and play an essential role in the biosphere.

Determine whether the following statements are true or false.

- A. Diazotrophs fix nitrogen in the form of nitric acid.
- B. The process of nitrogen fixation consumes a lot of energy.
- C. The enzyme nitrogenase which catalyzes nitrogen fixation requires an organic source of nitrogen as a substrate for catalytic activity.
- D. Nitrogen fixation requires molecular oxygen.

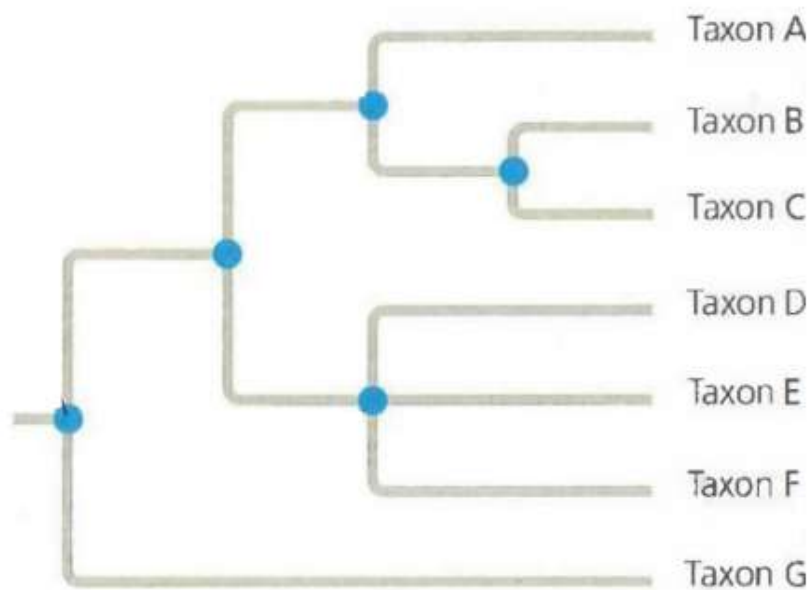
Theoretical1



English (Official)

Question 50

The following rooted cladogram represents the evolutionary relationship between seven biological species. Carefully observe the phylogenetic tree and choose the correct statement(s).



Taxon	
-------	--

Using the phylogenetic tree, determine whether the following statements are true or false.

- A. There is a monophyletic group with four members which includes C but not B.
- B. Taxons A and C can form a paraphyletic group with their last common ancestor.
- C. Branches for Taxa B and C have the same length; thus, they have diverged from their last common ancestor at the same speed.
- D. Taxon G shows no branching events; thus, it has the closest resemblance to the last common ancestor of Taxa A-G.

End of Exam