USABO Competition

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1.

To characterize eukaryotic genes of interest, a researcher uses a sequencing method in which a hyperactive mutant transposon is added to the cell culture. The transposon cleaves genomic DNA and tags it with sequencing adaptors allowing these fragments to be purified, amplified, and sequenced. Which of the following would be sequenced LEAST effectively with this method?

A. A region that experiences a high rate of spontaneous mutation.
B. A protein-coding region of a gene whose transcriptional activity is high.
C. A noncoding region of a gene whose transcriptional activity is high
D. A DNA region located near many acetylated histones.
E. A DNA region located near many deacetylated histones.

2.

Nithin decides to examine the properties of the unusual bacterial protein Rha5. From previous structural studies, he knows that the protein binds to dsDNA. He decides to test whether Rha5 functions as a monomer or as a dimer. He allows Rha5 to translocate on a single-stranded DNA hairpin (example shown below) and collects the following data from a single-molecule fluorescence experiment:

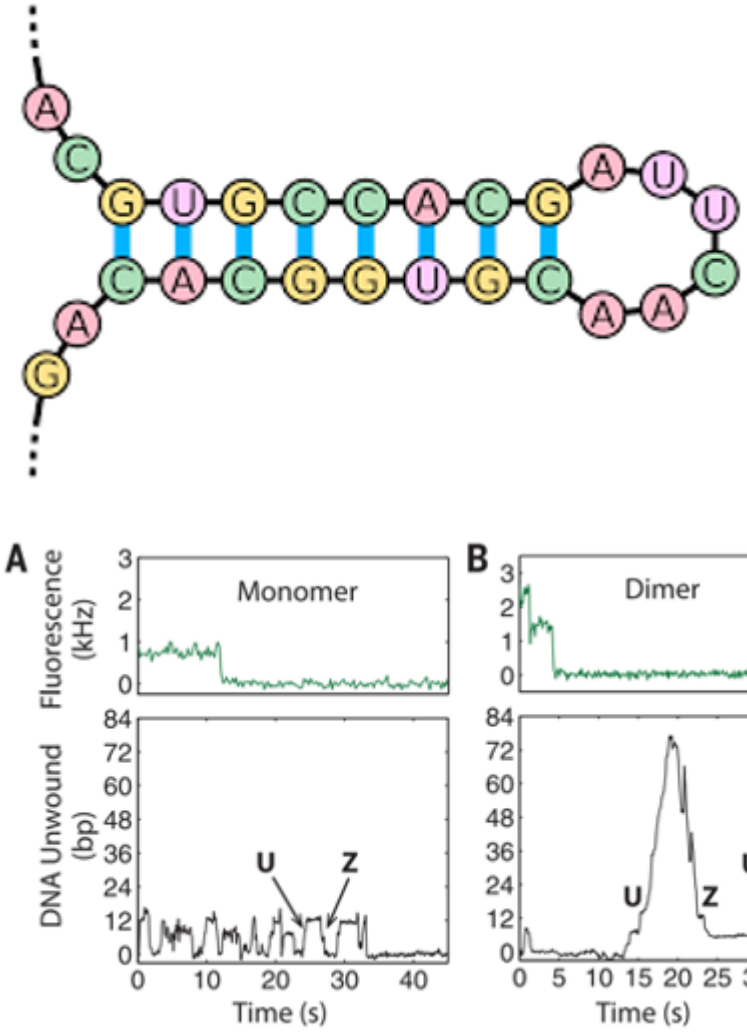


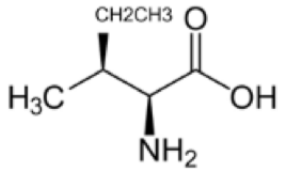
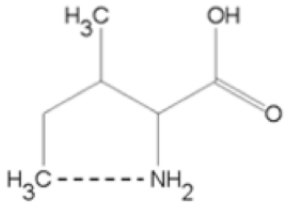
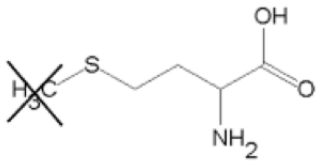
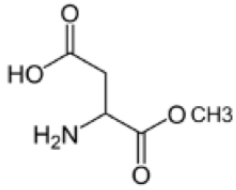
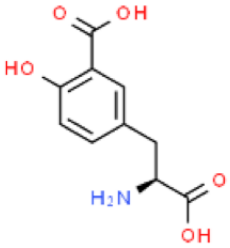
Image sources: Wikipedia, Comstock et al. (2015) & Science (17 April 2015).

In the lower panels of A and B, the horizontal axis corresponds to time, while the vertical axis is the unwound DNA that corresponds to the number of base pairs whose hydrogen bond interactions have been broken. What type of protein is Rha5, and in what form is it most likely found in the cell?

A. Topoisomerase II monomer.
B. Topoisomerase II dimer.
C. Helicase monomer.
D. Helicase dimer.
E. DNA polymerase monomer.

3.

You are a biochemist attempting to determine which amino acid modifications are tolerable to the cell. You perform the following chemical modifications on the side chains of amino acids and add them to cell cultures to be assimilated. Which of the following modifications is INCORRECTLY matched with its predicted effect?

	Amino Acid	Modification	Effect
A.	Threonine	 Replacement of the hydroxyl group with an ethyl group	Impaired ability to be phosphorylated
B.	Isoleucine	 Formation of a new C-N bond indicated by the dotted line	Impaired ability to be incorporated in alpha helices
C.	Methionine	 Replacement of the crossed-out methyl group with a hydrogen atom	Gains the ability to form disulfide bonds
D.	Aspartic acid	 Addition of a methyl group to the carboxylic acid to form an ester	Increases likelihood to be found in the interior region of a globular protien
E.	Tyrosine	 Addition of a carboxyl group adjacent to the hydroxyl group	Increased pH at which the isoelectric point occurs

4.

Upon completing a Western blot, you observe no fluorescence on your nitrocellulose membrane. Which of the following are possible errors that could have produced this result?

I. **Acrylamide concentration of the gel is too high.**
II. **Failure to coat the membrane with nonspecific protein.**
III. **Failure to add primary antibody.**
IV. **Insufficient transfer time between gel and nitrocellulose membrane.**

A. I and II.
B. I and III.
C. II and III.
D. II and IV.
E. III and IV.

5.

Professor Goon has tasked you with developing a microorganism that can detect toxins affecting humans. You design a genetic circuit in *E. coli* that dynamically regulates the expression of the reporter protein, green fluorescent protein (GFP) that is isolated from jellyfish in response to metabolic toxins. GFP levels are easily visualized in fluorescence microscopy. The anticipated results are that the fluorescence measured will be high in the presence of metabolic toxins and low in the absence of toxins. Which of the following is a valid design consideration for your hypothetical genetic circuit?

A. GFP expression is dependent on cellular energy state, so a metabolic toxin could have false negative results with your engineered organism.
B. Eukaryotic proteins like GFP cannot be expressed in prokaryotic cells because they lack a rough ER.
C. An introduced genetic circuit should have a constitutive promoter paired to GFP, which would result in easy visualization due to high GFP expression.
D. Since *E. coli* is a Gram-negative bacterium, it will not efficiently take up foreign genetic material from the environment.
E. GFP expression should be under the control of a repressible promoter using co-repressors that bind to metabolic toxins.

6.

The following free-energy diagram plots Gibbs' free energy as a function of reaction coordinate for a reaction. The upper curve with a single peak (black) represents the free energy of the normal reaction, while the lower curve with two peaks (red) represents free energy of the reaction in the presence of an enzyme.

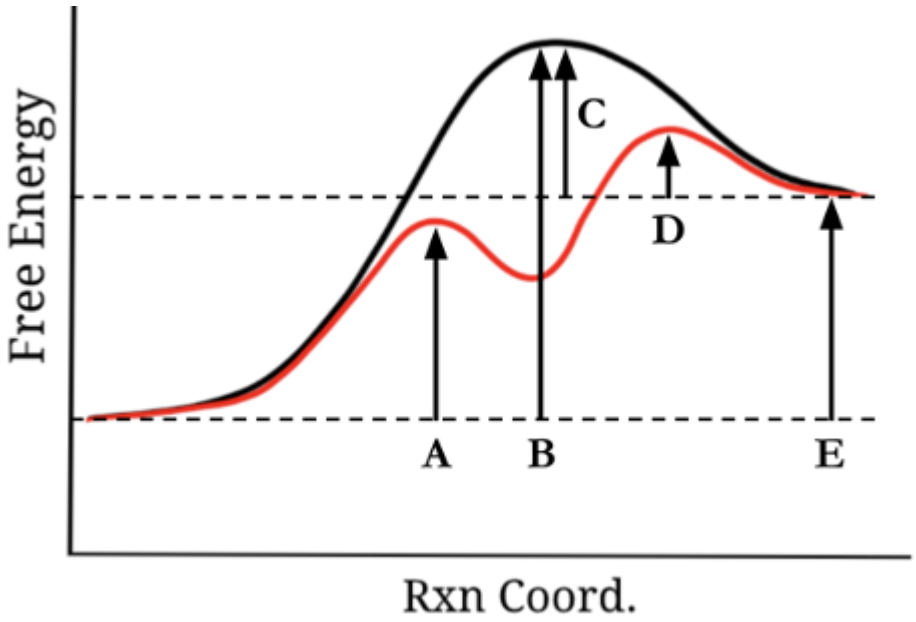


Image source: J. Dong & C. Wang.

Which of the following statements about this free-energy diagram is FALSE?

A. Arrow A represents the activation energy of the overall forward reaction in the presence of the enzyme.
B. Arrow B represents the activation energy of the overall forward reaction in the absence of the enzyme.
C. Arrow C represents the activation energy of the overall reverse reaction in the absence of the enzyme.
D. Arrow D represents the activation energy of the overall reverse reaction in the presence of the enzyme.
E. Arrow E represents the change in free energy ΔG of the overall forward reaction, regardless of the presence or absence of the enzyme.

7.

Telomeres are repetitive sequences found at the end of linear eukaryotic chromosomes. Which of the following statements about telomeres is FALSE?

A. When mammalian cells are cultured *in vitro*, each generation of cells possesses shorter telomeres than the previous generation.
B. Genes involved in telomere elongation are frequently non-functional or lost in the genomes of most types of vertebrate cancers.
C. In physiological conditions, proteins that extend telomeres ("telomerases") are expressed in the germline of vertebrates and not expressed in most somatic cells.
D. The cell's DNA-damage response to double-stranded breaks is not triggered by the staggered end of the linear chromosome.
E. Telomerase enzymes use an RNA template complexed with the enzyme to synthesize the DNA repeats.

8.

In a bacterial species, Mutants 1 to 4 are each defective in one gene and are unable to synthesize an essential compound G. Compounds D to F are intermediates in the biosynthetic pathway for G. The mutants were supplied with minimal media supplemented with one of either D, E, F, G. The results were as follows (``+" indicates growth):

	Growth on compound			
Mutants	D	E	F	G
1		+		+
2		+	+	+
3				+
4	+	+	+	+

If the defective genes in Mutants 1 to 4 are named Genes 1 to 4 respectively, then the order in which the genes act in this biosynthetic pathway is:

A. $1 \rightarrow 3 \rightarrow 2 \rightarrow 4.$
B. $3 \rightarrow 1 \rightarrow 2 \rightarrow 4.$
C. $3 \rightarrow 4 \rightarrow 1 \rightarrow 2.$
D. $4 \rightarrow 2 \rightarrow 1 \rightarrow 3.$
E. $4 \rightarrow 3 \rightarrow 2 \rightarrow 1.$

Time Remaining: **6:53**
Problems Answered: **50/50**
Status: Answers Saved ✔

9.

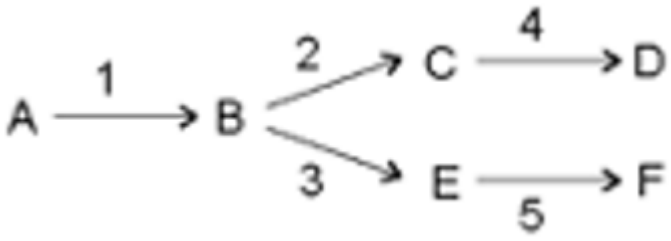
In the electron transport chain, the degree of reduction of each carrier is determined by internal mitochondrial conditions. Dr. Jain subjects cultured cells to various conditions and predicts the state of oxidation of cytochrome *c* compared to the normal resting state. Cytochrome *c* transfers electrons from Complex III to Complex IV in the electron transport chain. Which of Dr. Jain's predictions are consistent with the structure of the electron transport chain?

I. **When the cells are subjected to increased O_2 levels and decreased NADH levels, cytochrome *c* will become more oxidized.**
II. **When the cells are subjected to the addition of potassium cyanide (a Complex IV inhibitor), cytochrome *c* will become more oxidized.**
III. **When the cells are subjected to the addition of oligomycin (an ATP synthase inhibitor), cytochrome *c* will become more oxidized.**

A. I only.
B. III only.
C. I and II.
D. I and III.
E. II and III.

10.

A branched biochemical pathway synthesizes two amino acids D and F, both of which are essential for survival and reproduction:



A, B, C, and E are intermediates in this pathway. 1, 2, 3, 4, and 5 represent enzymes that are necessary for each step, each encoded by a separate gene. Which of the following statements is true about mutants lacking one enzyme?

A. A mutant for Enzyme 1 could survive on minimal media supplemented with Intermediate C.
B. A mutant for Enzyme 2 could survive on minimal media supplemented with Intermediate E.
C. A mutant for Enzyme 3 could survive on minimal media supplemented with Amino acid F.
D. A mutant for Enzyme 4 could survive on minimal media supplemented with Intermediate B.
E. A mutant for Enzyme 5 could survive on minimal media supplemented with Amino acid D.

11.

The glyoxylate cycle, which converts lipids to carbohydrates, is an important biochemical process in seed germination. Since seeds are unable to perform photosynthesis, much of the energy required for germination is derived from the glyoxylate cycle. If you were to track a single lipid molecule in a seed, where would that lipid be stored in the dormant seed, and where would it likely end up during germination?

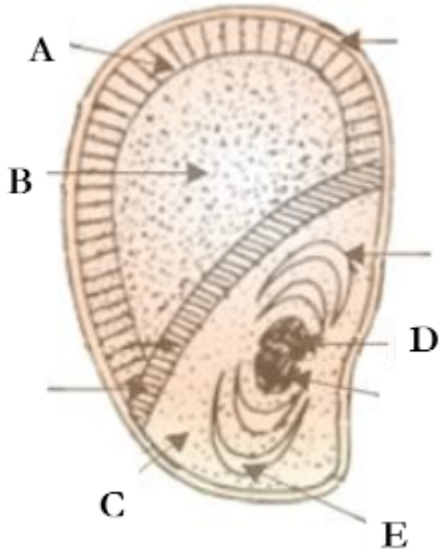


Image source: enmuangplanting.blogspot.com.

A. Stored at A, end up at C.
B. Stored at B, end up at D.
C. Stored at B, end up at E.
D. Stored at C, end up at D.
E. Stored at C, end up at E.

12.

Phenylurea is an herbicide used on corn fields to injure and kill dicot weeds after the seeds germinate. This herbicide functions by irreversibly binding to the D1 quinone-binding protein of Photosystem II (PSII) and inhibiting the movement of electrons to plastoquinone, thereby shutting off the linear photosynthesis pathway. How will the pH of space between the stroma and the thylakoid change after a leaf cell takes up phenylurea?

A. The stromal pH and the pH of the thylakoid space will both increase.
B. The stromal pH and the pH of the thylakoid space will both decrease.
C. The stromal pH will increase, and the pH of the thylakoid space will decrease.
D. The stromal pH will decrease, and the pH of the thylakoid space will increase.
E. The stromal pH will remain unchanged, and the pH of the thylakoid space will decrease.

13.

You are experimenting with a type of *Fabaceae*, which normally have complete flowers. You wish to create a strain of ``super-breeder" flowers that only express a combination of stamens and carpels across all whorls, with no petals or sepals. Based on your knowledge of the ABC hypothesis, which of the following changes would produce a ``super-breeder"?

I. **Deletion of Gene A in parts of the flower that normally express Gene B.**
II. **Overexpression of Gene A throughout the entire flower.**
III. **In a mutant flower with the phenotype "sepal, petal, petal, sepal" (outer whorl to inner whorl), replacement of all Gene A expression with Gene C expression.**

A. I only.
B. III only.
C. I and III.
D. II and III.
E. None of these.

14.

Which of the following plants are most likely to flower?

I. **A short-day plant that receives a 660-nm light flash in the middle of its dark period.**
II. **A short-day plant that receives a 750-nm light flash in the middle of its dark period.**
III. **A long-day plant that receives a 660-nm light flash in the middle of its dark period.**
IV. **A long-day plant that receives a 750-nm light flash in the middle of its dark period.**

A. I and III.

B. I and IV.
C. II and III.
D. II and IV.
E. III and IV.

15.

In the flower shown below, you specifically block the transport of one particular hormone at the location indicated by the arrow. The hormone you targeted is unable to move past the block, but other molecules in the plant are still free to move throughout the plant. After adding the block, you observe the following in your trusty flower.

1. **Delayed wound healing and formation of new vascular tissue if the plant is injured below the block, but not if the plant is injured above the block.**
2. **Decreased formation of fruit below the block.**
3. **Decreased growth of the cells immediately above the block.**

Which of the following hormones did you most likely target?

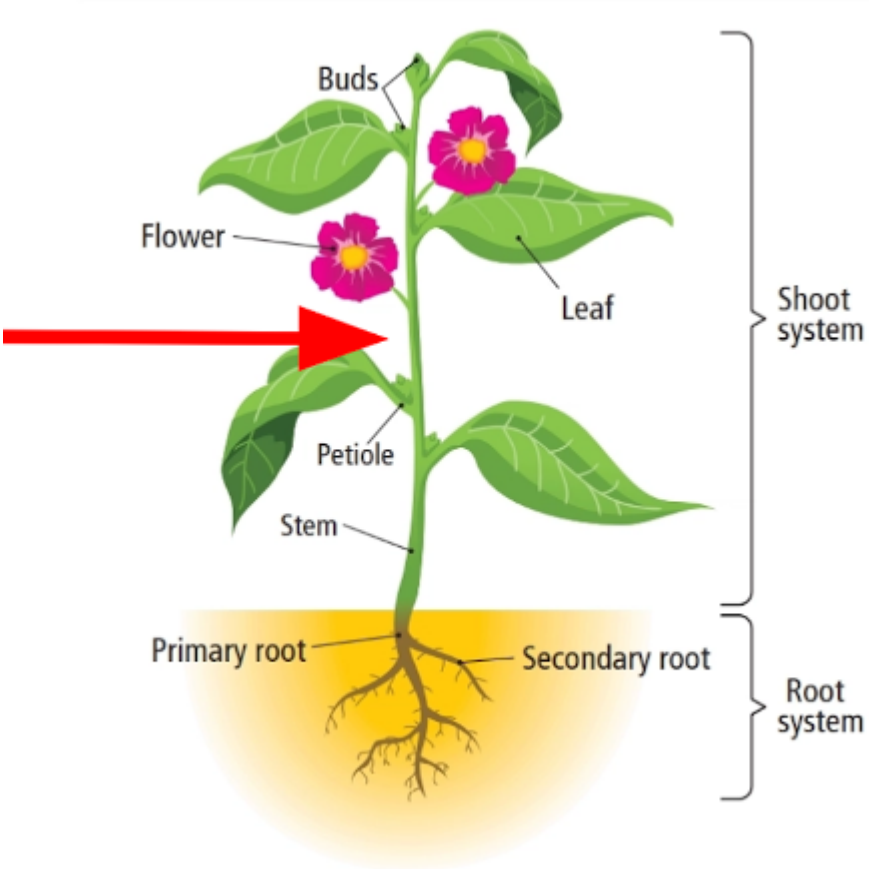


Image source: leavingcertbiology.net.

A. Auxin.
B. Cytokinin.
C. Gibberellin.
D. Strigolactone.
E. Ethylene.

16.

Your good friend Dr. Zhang needs your help in identifying the characteristics of a particular plant and provides you with the following images, both from the same specimen:

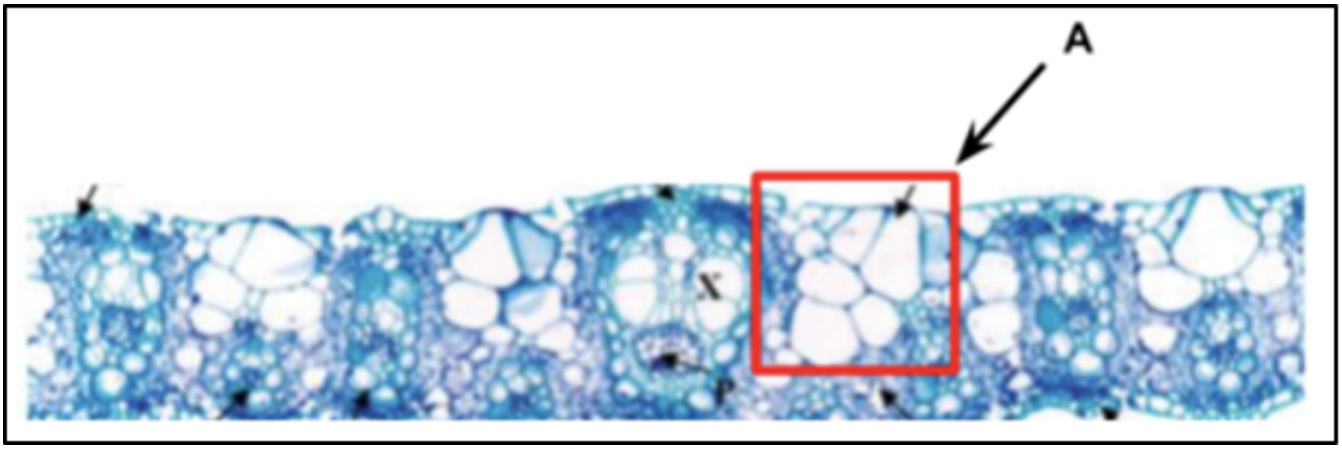


Image sources: Figueiredo et al. (2015), Ferreira et al. (2007).

Using the images above, identify which of the following statements are TRUE.

I. **The plant is a monocot.**
II. **The plant is a C_4 plant.**
III. **This plant has a thick cuticle and is well adapted for arid climates.**
IV. **The structures labeled A are thin-walled parenchyma cells and will lose turgidity in response to decreased water potential outside the cell.**

A. I, III.
B. I, II, III.
C. I, II, IV.
D. II, III, IV.
E. I, II, III, IV.

17.

One day while hiking, you come across a young woody plant undergoing secondary growth. You decide to cut the plant in half (transverse section), and sample the ages of different parts of the plant starting from the center. You plot the ages as a function of distance from the center (increasing toward the right). What tissue likely corresponds to the circled portion of the graph?

Image source: J. Zhang.

A. Cork.
B. Cork cambium.
C. Secondary xylem.
D. Secondary phloem.
E. Phelloderm.

18.

You're bored one day and decide to isolate equal amounts of xylem, phloem, parenchyma, sclerenchyma, and collenchyma from a plant in your house. You forget to label your samples and want to confirm the identity of each tissue. You evaluate different relative characteristics of the tissues and obtain the results below. What is the identity of Tissue II?

Tissue	Pressure	Water Potential	Monosaccharides/ Disaccharides	Starch Content	O_2 Production
I	Positive	Negative	Moderate	High	High
II	Positive	Negative	Moderate	Low	Moderate
III	Negative	Negative	Low	Low	None
IV	Positive	Negative	High	Low	Minimal
V	Zero	Zero	None	Low	None

A. Xylem.
B. Phloem.
C. Parenchyma.
D. Sclerenchyma.
E. Collenchyma.

1(

You are a clinician whose patient has two copies of the Glu to Val mutation responsible for sickle cell disease. However, your patient also has a deletion in a regulatory region which causes fetal hemoglobin expression to persist into adulthood. When examining the patient's oxygen-hemoglobin dissociation curve and clinical symptoms, which of the following is TRUE?

A. Left-shifted curve; reduced symptoms.
B. Left-shifted curve; increased symptoms.
C. Right-shifted curve; reduced symptoms.
D. Right-shifted curve; increased symptoms.
E. Right-shifted curve; typical symptoms.

20.

β-catenin is a transcription factor that is evenly distributed throughout the cytoplasm of frog eggs. GSK-3, a protein kinase, is also evenly distributed throughout the egg cytoplasm and phosphorylates β-catenin, marking it for degradation. Before fertilization, vesicles containing a GSK-3 inhibitor are concentrated at the vegetal pole. Following fertilization, the vesicles migrate across the cell and release their contents, the distribution of β-catenin throughout the cell becomes uneven, and the side of the zygote with a higher β-catenin concentration develops into the dorsal side of the organism. Which statement accurately describes the relationship between sperm entry, vesicle migration and release, and development of the dorsal-ventral axis?

A. The vesicles containing the GSK-3 inhibitor migrate to the side of the cell where sperm entry occurred and release their contents. This site of release develops into the dorsal side.
B. The vesicles containing the GSK-3 inhibitor migrate to the side of the cell where sperm entry occurred and release their contents. This site of release develops into the ventral side.
C. The vesicles containing the GSK-3 inhibitor migrate to the side of the cell opposite sperm entry and release their contents. This site of release develops into the dorsal side.

D. The vesicles containing the GSK-3 inhibitor migrate to the side of the cell opposite sperm entry and release their contents. This site of release develops into the ventral side.
E. The vesicles containing the GSK-3 migrate to the animal pole and release their contents, regardless of the site of sperm entry. This site of release develops into the dorsal side.

21.

A patient walks into your endocrinology clinic with symptoms of low blood pressure, low blood sugar, low plasma sodium levels, fatigue, and depressed mood. You discover that all of the hormones produced by one gland are present in the plasma at abnormally low levels, which is consistent with all of the patient's symptoms. Which gland is affected?

A. Thyroid.
B. Adrenal cortex.
C. Adrenal medulla.
D. Posterior pituitary.
E. Pancreas.

22.

The transport maximum for glucose in the kidneys is 375 mg/min. If the plasma concentration of glucose is 300 mg/100 mL, the glomerular filtration rate is 140 mL/min, and the urine output is 1.8 L per day, what is the concentration of glucose in the urine?

A. 0 mg/mL.
B. Between 0 mg/mL and 15 mg/mL.
C. Between 15 mg/mL and 30 mg/mL.
D. Between 30 mg/mL and 45 mg/mL.
E. Greater than 45 mg/mL.

23.

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Multiple myeloma is a plasma cell cancer initiated by one or more alterations to the DNA of a single stem cell in bone marrow, which causes damage to bone and bone marrow. Which of the following is a complication of multiple myeloma?

A. Increased calcium levels in the blood.
B. Increased levels of red blood cells.
C. Increased levels of healthy white blood cells.
D. Decreased protein levels in the blood.
E. Decreased susceptibility to infection.

24.

Which of these organisms is INCORRECTLY matched to its heart structure and mode of lung ventilation, respectively?

A. Garter snake: three-chambered; negative pressure.
B. Blue-jay: four-chambered; negative pressure.
C. Crocodile: four-chambered; negative pressure.
D. Toad: four-chambered; positive pressure.
E. Panda bear: four-chambered; negative pressure.

25.

Consider a neuron whose Nernst (equilibrium) potential for the chloride ion is -40 mV. The valence of a chloride ion is -1. The Nernst potential is given by the equation below. Which of the following statements is TRUE about this neuron?

$$V_{\text{Eq.}} = \frac{RT}{zF} \ln \left(\frac{[X]_{\text{out}}}{[X]_{\text{in}}} \right)$$

($V_{\text{Eq.}}$ = Nernst potential, R = ideal gas constant, T = absolute temperature, z = ion valence (charge), F = Faraday constant. $[X]_{\text{out}}$ = extracellular ion concentration, $[X]_{\text{in}}$ = intracellular ion concentration.)

A. The concentration of chloride ions is greater inside the cell than outside the cell.
B. If the membrane voltage is equal to +40 mV, then there will be no net flux of chloride ions in or out of the cell.
C. At the resting membrane potential, the net flow of chloride ions is from the extracellular fluid into the intracellular space.
D. If the extracellular chloride concentration is constant for all neurons, then this neuron has a higher intracellular chloride concentration than a neuron with a typical chloride Nernst potential of -90 mV.
E. Binding of GABA to receptors on this neuron would lead to an inhibitory postsynaptic potential.

26.

A patient who walks into your clinic is suffering from congestive heart failure (CHF). He presents all of the normal symptoms associated with CHF. Which statement is FALSE regarding treatment or symptoms?

A. He presents with a diastolic low-frequency sound which is caused by excessive blood passing into the left ventricle.
B. He presents with pulmonary rales and shortness of breath due to fluid being pushed into the alveoli in the lungs.
C. You should perform an echocardiogram initially.
D. You should prescribe both vasodilators and diuretics during treatment dependent on fluid accumulation or redistribution.
E. You should prescribe calcium channel inhibitors to prevent further complications and re-hospitalization.

27.

The following graph shows the proportion of undigested carbohydrates, lipids, and proteins as a function of time after entering the alimentary canal (not drawn to scale). Between Curves A (green), B (orange), and C (blue), which ones correspond to carbohydrates, lipids, and proteins?

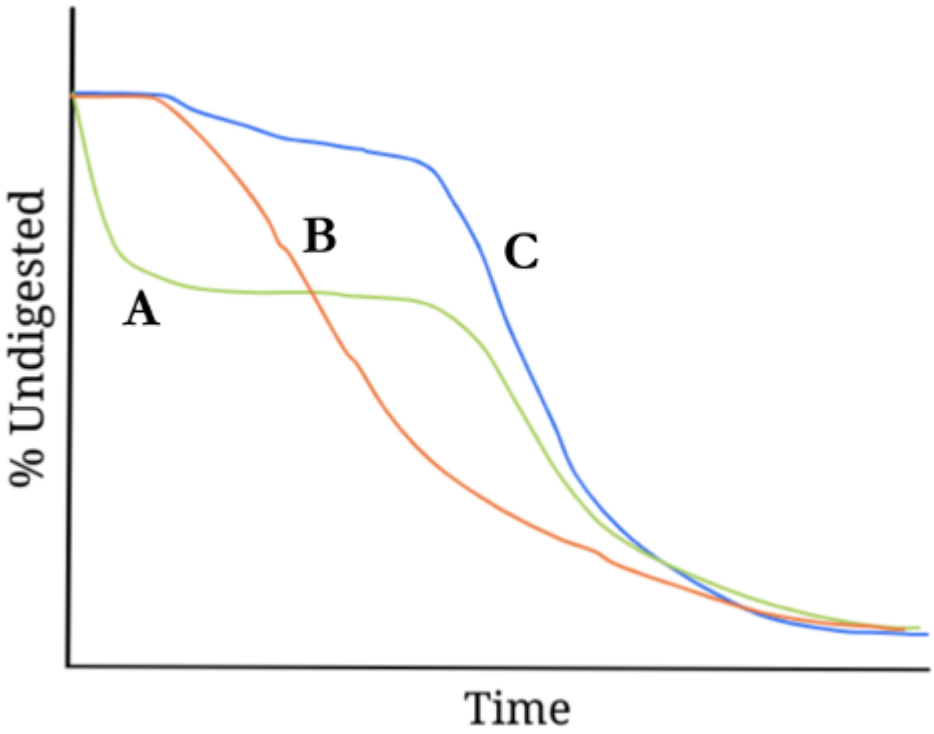


Image source: J. Dong & C. Wang.

A. A = carbohydrates, B = lipids, C = proteins.
B. A = carbohydrates, B = proteins, C = lipids.
C. A = proteins, B = carbohydrates, C = lipids.
D. A = proteins, B = lipids, C = carbohydrates.
E. A = lipids, B = proteins, C = carbohydrates.

28.

Which of the following is NOT an example of an interaction that happens in the immune response to a virus?

A. Dendritic cells congregate at lymph nodes and present viral antigens to lymphocytes, triggering the adaptive immune response.
B. Natural killer cells trigger apoptosis in infected cells as part of the rapidly acting innate immune response.
C. B lymphocytes proliferate and secrete IgM and IgG antibodies that target viral particles.
D. T lymphocytes identify cells with abnormal antigens displayed in their MHC II surface proteins and trigger lysis in these cells.
E. Infected cells secrete signaling molecules that cause nearby cells to increase their defenses against viral infection.

29.

You want to engineer QuickMuscles^{TM} that actuate very rapidly and contract with more force relative to human skeletal muscles. A diagram of a single muscle twitch is depicted below. The latent period represents the time from an action potential arriving at a motor neuron synapse to the onset of muscle contraction.

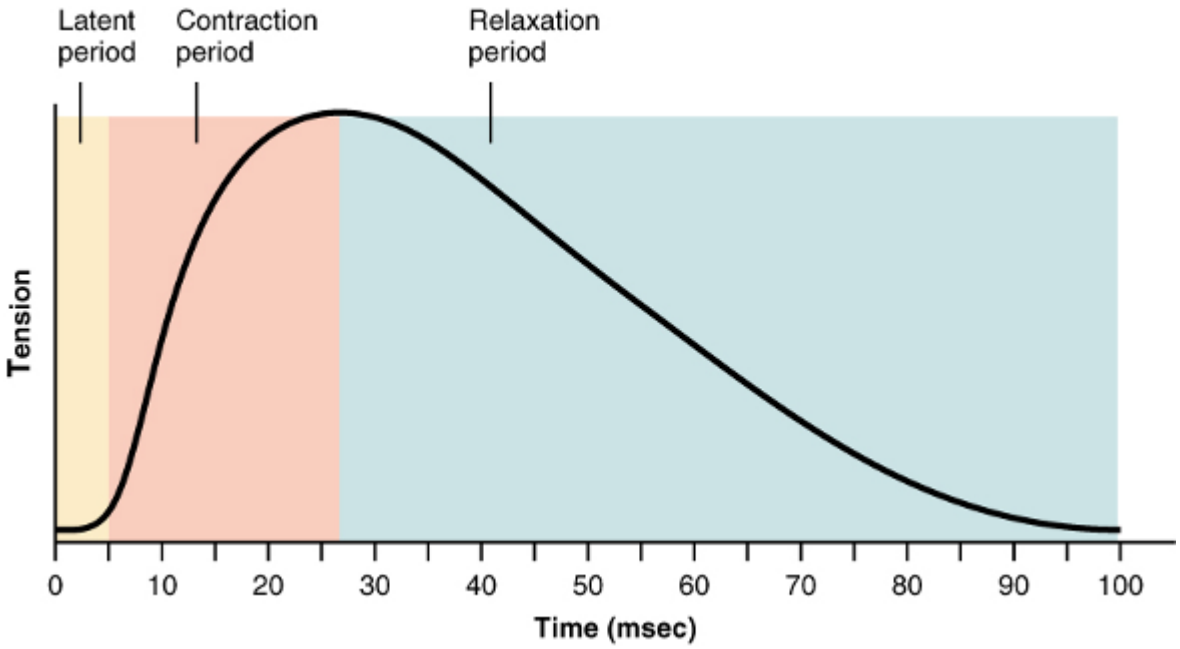


Image source: Anatomy and Physiology *OpenStax textbook.*

Which of the following statements is TRUE?

A. An increase in the width of the synaptic cleft would shorten the duration of the latent period.
B. Blocking the activity of acetylcholinesterase at the neuromuscular junction would decrease the maximum tension of muscle contraction.
C. An increase in the diameter of the T-tubules would increase the duration of the latent period prior to muscle contraction.
D. Blocking Ca^{2+} binding sites on troponin would increase the maximum tension of muscle contraction.
E. Blocking Ca^{2+} ATP-ases in the sarcoplasmic reticulum membrane would prolong the duration of the relaxation period.

30.

Muscles in the body act as levers with an applied effort (input force) resulting in an output force that acts against a load. There are three classes of levers:

- **First-class levers act with the effort and load on opposite ends of the fulcrum (pivot).**
- **Second-class levers act with the load positioned between the effort and the fulcrum.**
- **Third-class levers act with the effort applied between the load and the fulcrum.**

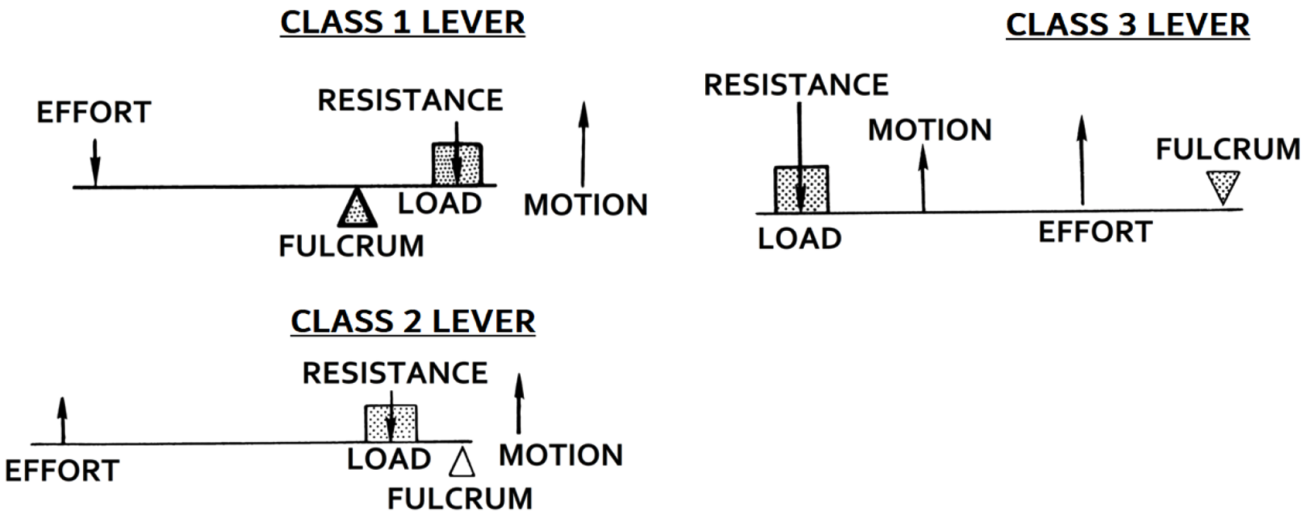


Image source: Pearson Scott Foreman, Wikipedia.

Which of the following statements about muscle levers in the body is TRUE?

A. The output movement speed of a first-class lever is maximized when the effort arm is long and the load arm is short.
B. With equal effort, a third-class lever can move a greater load than a second-class lever.
C. When kicking a ball, the quadriceps muscle (thigh) and knee joint act as a second-class lever.
D. When throwing a ball, the triceps muscle (upper arm) and elbow joint act as a third-class lever.
E. When arm-wrestling, the biceps muscle (forearm) and elbow joint act as a third-class lever.

31.

In a particular bird species, all individuals attempt to breed independently at the beginning of each breeding season. However, some individuals fail to breed and end up becoming ``helpers" for other breeders by helping them raise their offspring. You hypothesize that this ``helper" behavior evolved due to kin selection. All of the following observations would support your hypothesis EXCEPT:

A. This bird species exhibits a monogamous system of mating.
B. Offspring survival rate for a given nest increases as the number of helpers raising the chicks in that nest increases.
C. Birds can distinguish between the calls of its relatives and those of other individuals.
D. Female birds who become helpers gain the ability to lay some of their own eggs in the nest at which they are helping.
E. Birds who fail to breed and become helpers in their first breeding season are likely to remain as helpers for the rest of their lifespan without ever successfully breeding.

32.

A marine biologist conducted a series of time-lapsed photographs that recorded the schooling behavior of the fish *Pagrus major*. Food was added to water at two different locations via a time released mechanism. The data is shown graphically below.

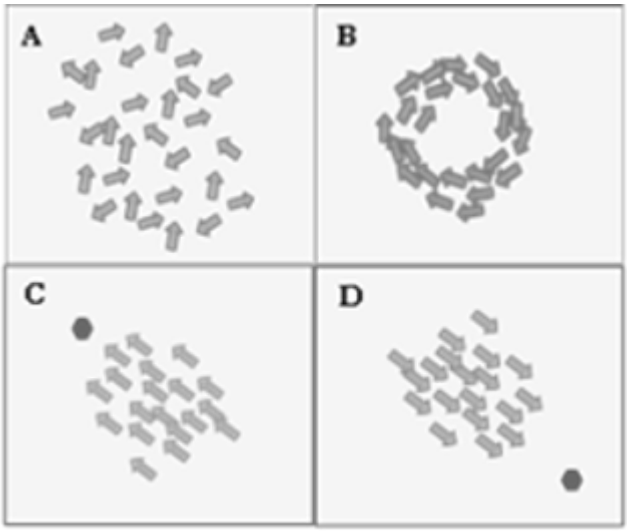


Image source: Cousin et al.

***Graphs A and B*: Fish behavior before the stimuli was added. *Graphs C and D*: After the food was added at two different locations (shown in dark grey hexagons) of the test area.**

Which of the following behaviors is demonstrated here?

A. Short-term habituation.
B. Collective cognition.
C. Operant conditioning.
D. Phenotypic plasticity.
E. Redirected behavior.

33.

Lakshay is observing his herd of *Alces alces* and notes that they appear to optimize their foraging based on the type of food. To test this, he creates a habitat with two foods of different availabilities. FOOD1 is abundant, but only nets an individual 100 calories and takes 30 minutes to eat (during which the organism cannot move). FOOD2 is far less abundant, but nets 1,000 calories and takes 180 minutes to eat. The search time for FOOD1 is 0 minutes once it is encountered. The search time for FOOD2 is 80 minutes 80% of the time, and 150 minutes the other 20% of the time. An *A. alces* individual encounters FOOD1. To maximize its overall rate of energy gain, should it eat FOOD1 or leave to search for FOOD2. Why?

A. Leave. The profitability of FOOD2 is greater than FOOD1 even in the worst-case search time.
B. Leave. The profitability of FOOD2 at the expected search time is greater than FOOD1, even though the profitability of FOOD2 in the worst-case search time is less.
C. Eat FOOD1. The profitability of FOOD2 in the worst-case search time is less than the profitability of FOOD1.
D. Eat FOOD1. The profitability of FOOD2 at the expected search time is less than FOOD1, even though the profitability of FOOD2 in the best-case search time is greater.
E. Eat FOOD1. The profitability of FOOD2 is less than FOOD1 even in the best-case search time.

34.

Professor Bonzu studies sky bison, which are very attentive to the high-pitched sound of a bison whistle. Seeking to better understand the inheritance of the whistle-attentive gene, denoted by ``*W/w*", he crosses a true-breeding whistle-attentive male with a true-breeding non-whistle-attentive female. All offspring of this cross are whistle-attentive. Then, Professor Bonzu crosses two F_1 bison to produce 1600 F_2 offspring. In this F_2 generation, there are 1300 whistle-attentive bison and 300 non whistle-attentive bison. Which of the following mechanisms reasonably explains Professor Bonzu's results?

A. There is a dominant activator gene (*A/a*) in addition to the *W* gene that is capable of reversing the recessive phenotype at *W*. The parental generation male shows the genotype *AA*, while the parental generation female shows the genotype *aa*.
B. There is a recessive suppressor gene (*S/s*) in addition to the *W* gene that is capable of reversing the recessive phenotype at *W*. The parental generation male shows the genotype *ss*, while the parental generation female shows the genotype *SS*.
C. The parental generation male shows a normal upstream enhancer sequence for the whistle response gene, but the parental generation female has a loss-of-function mutation in the enhancer sequence. Assume that the enhancer sequence is passed down in a simple Mendelian-like manner in this case.
D. The *W* locus is affected by another gene product (*D/d*) that acts as a dominant negative mutation. The parental generation male shows the genotype *dd*, while the parental generation female shows the genotype *DD*.
E. The *w* allele is approximately 15% penetrant into the whistle response phenotype.

35.

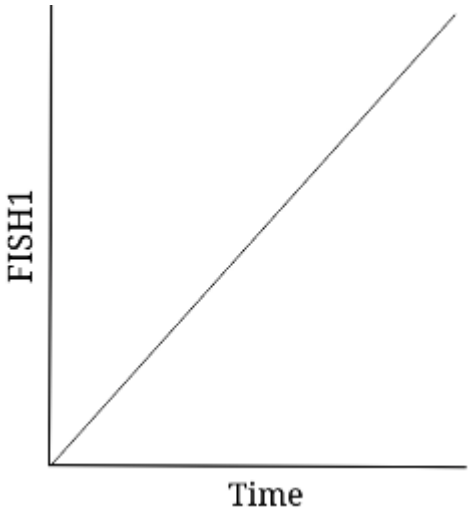
HindIII is a restriction enzyme that cuts at the palindromic site $5'$-AAGCTT-$3'$. You add HindIII to a chromosome that is 6×10^6 bp long and has 80% G-C content. If base pairs are distributed randomly throughout the chromosome, which of the following is closest to the number of cuts that you would expect HindIII to make?

A. 1.
B. 10.
C. 100.
D. 1,000.
E. 10,000.

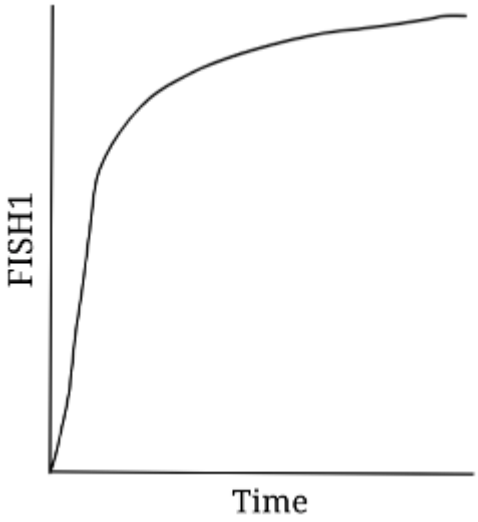
36.

You are studying a newly evolved fish species and discover that there are two phenotypes for aggressiveness: FISH1 and FISH2. The FISH1 allele is dominant to the FISH2 allele and is more advantageous because FISH1 fish outcompete FISH2 fish for food. The frequency of the FISH2 allele in the population initially starts at 1, and then a mutation occurs that causes a small number of offspring to inherit the FISH1 allele. Which of the following graphs accurately shows how the frequency of FISH1 changes over time?

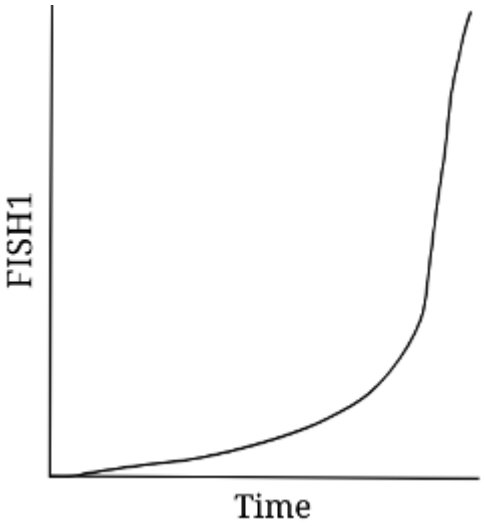
A.



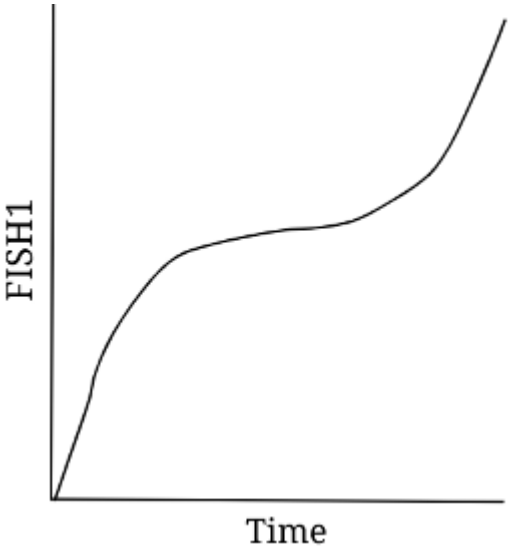
B.



C.



D.



E.

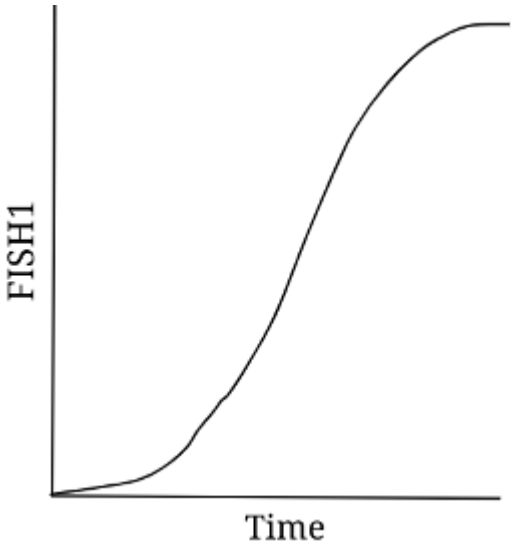


Image source: J. Dong.

37.

A plasmid carries genes for streptomycin (StrR), ampicillin resistance (AmpR), and erythromycin resistance (EryR). The AmpR gene is cut with restriction enzymes, and donor DNA treated with the same enzymes is added. Which genotype needs to be selected to show evidence of transformation? (R = resistant, S = susceptible)

A. StrR AmpR EryR.
B. StrR AmpR EryS.
C. StrR AmpS EryR.
D. StrS AmpS EryS.
E. StrS AmpR EryS.

38.

Which of the following examples is paired INCORRECTLY with its type of selection?

A. Directional selection: The tusk length of elephants in response to poaching.
B. Stabilizing selection: The clutch size of birds.
C. Disruptive selection: The fur color of mice in response to a volcanic eruption that wipes out most of the population.
D. Frequency-dependent selection: The aposematic coloring of poison dart frogs.
E. Heterozygote advantage: One copy of the cystic fibrosis allele decreases susceptibility to tuberculosis infection.

39.

Genes A, B, C, and D are linked on the same chromosome. Genes A and B have a recombination frequency of 5%, genes A and D have a recombination frequency of 11%, genes B and C have a recombination frequency of 17%, and genes C and D have a recombination frequency of 23%. Which of the following is the most likely order of these genes on the chromosome?

A. ABCD.
B. ACBD.
C. BCAD.
D. CABD.
E. CBAD.

40.

Which of the following mechanisms leads to gene duplication and gene evolution over time in diploid organisms such as humans?

A. Unequal crossing over of misaligned chromosomes in germline cells.

B. Epigenetic chromosomal changes in germline cells.
C. Epigenetic chromosomal changes in somatic cells.
D. Telomere shortening of chromosomes in somatic cells.
E. Translocation between nonhomologous chromosomes in somatic cells.

41.

Lesch-Nyhan syndrome is a recessive X-linked disorder. People with Lesch-Nyhan syndrome exhibit high uric acid levels and neurological symptoms like chewing their fingers and lips. A woman whose parents are healthy and whose brother has Lesch-Nyhan syndrome marries a normal man. What is the probability that her first child will have Lesch-Nyhan syndrome?

A. 0%.
B. 6.25%.
C. 12.5%.
D. 25%.
E. 50%.

42.

The following pedigree shows the inheritance of a rare disorder over three generations. Assuming complete penetrance, which of the following disorders could this represent?

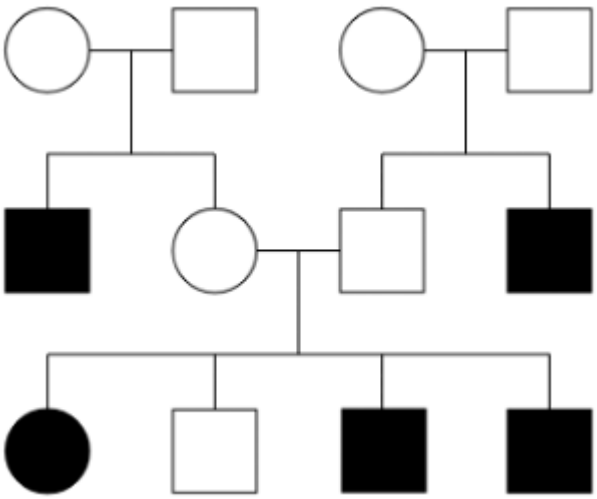


Image source: C. Wang.

I. **Tay-Sachs disease.**
II. **Duchenne muscular dystrophy.**
III. **Achondroplasia.**

A. I only.
B. II only.

C. I or II.
D. I or III.
E. II or III.

43.

A wild population of mice exhibits three coat colors: black, gray, and brown. Coat color is controlled by a single locus, where the black allele is dominant to the gray allele and the gray allele is dominant to the brown allele. The population of mice is in Hardy-Weinberg equilibrium for coat color and contains 510 black mice, 240 gray mice, and 250 brown mice. Which of the following lists the three alleles in increasing order of frequency?

A. Black $<$ gray $<$ brown.
B. Black $<$ brown $<$ gray.
C. Gray $<$ black $<$ brown.
D. Gray $<$ brown $<$ black.
E. Brown $<$ gray $<$ black.

44.

You obtain a water sample from Yellowstone's Grand Prismatic Spring, streak a portion of the sample onto nutrient agar, and incubate the dish at 55°C for 36 hours with a standard atmospheric composition of gases. Green and gray colonies appear on the agar at the end of the incubation period. Which of the following descriptions is MOST accurate for these colonies?

A. Thermophilic and aerobic.
B. Mesophilic and aerobic.
C. Cryophilic and aerobic.
D. Thermophilic and anaerobic.
E. Mesophilic and anaerobic.

45.

Farmer John has been using inorganic fertilizer containing nitrogen and phosphorus to grow his crops. Recently, a massive rainstorm caused large amounts of fertilizer from his farm to enter a local freshwater ecosystem *via* runoff. One month later, which of the following values would you expect to have increased in the freshwater ecosystem?

I. **The dissolved oxygen levels of the freshwater ecosystem.**
II. **The turbidity of the freshwater ecosystem.**
III. **The net primary productivity of the freshwater ecosystem.**
IV. **The biodiversity of the freshwater ecosystem.**

A. I, II.

B. II, III.
C. III, IV.
D. I, II, III.
E. I, II, III, IV.

46.

Christopher the Explorer surveys his ecologically diverse plot of land and plots the location of every individual for five tree species: [Poplar, Birch, Oak, Fig, and Pine].

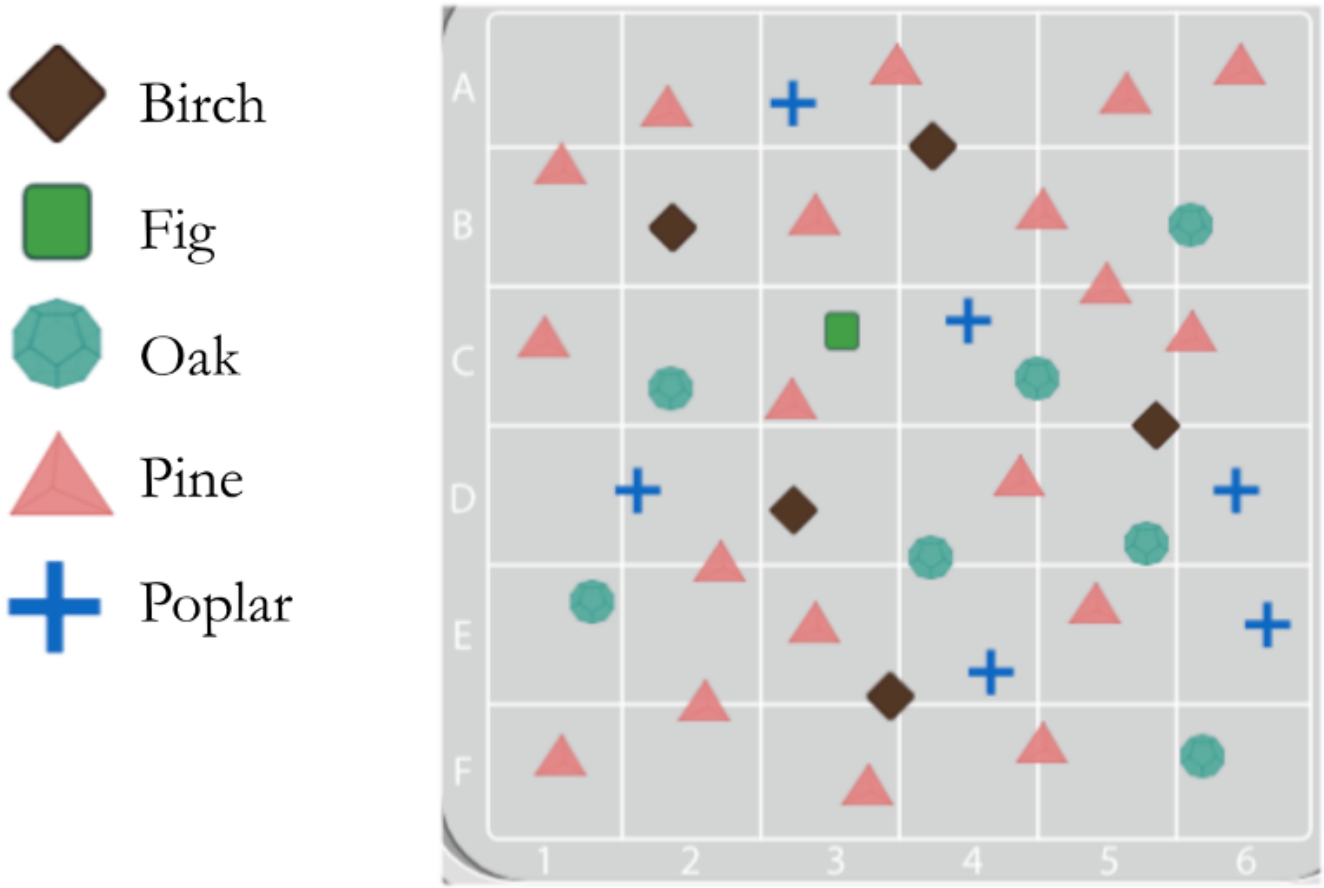


Image source: N. Parson.

The Shannon diversity index can be used to quantify diversity of species in a plot. The formula below is used to calculate the value (H') for the Shannon diversity index: }

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

(R = number of species; p_i = proportion of individuals belonging to a particular species)

Which of the following scenarios would increase the Shannon diversity index of this plot?

I. **An invasive pine weevil kills 50% of the pine tree population.**
II. **Chris plants 5 additional fig trees as a gift to his romantic interest.**
III. **Chris saws down 4 poplar trees to build himself a log cabin.**

A. II only.
B. III only.
C. I and II.
D. I and III.
E. II and III.

47.

Which of the following is LEAST likely to be true of a pioneer species in an area devastated by a volcanic eruption?

A. Semelparous.
B. r-selected.
C. Type I survivorship curve.
D. Low soil nutrient requirements.
E. Population is controlled primarily by density-independent factors.

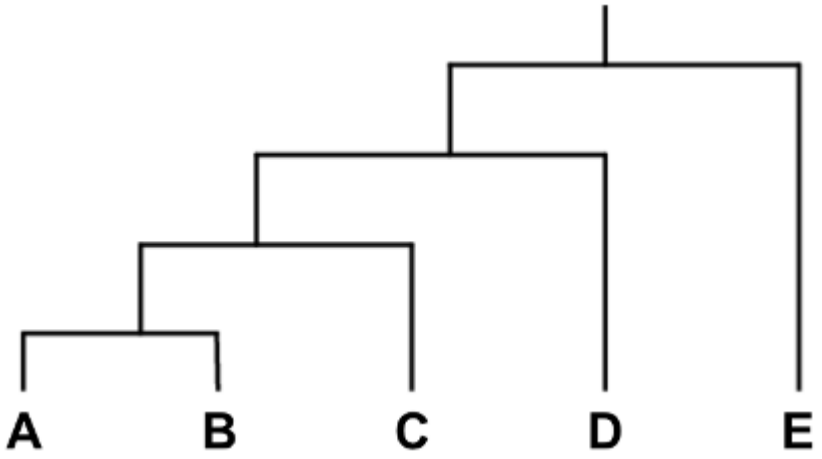
48.

You study the remains of an unknown animal. You find that, compared to other closely related species in other habitats, this animal's body size is larger, its limbs are shorter, and its hemoglobin binds oxygen with higher affinity. In what habitat does this species live?

A. Temperate broadleaf forest.
B. Chaparral.
C. Tropical rainforest.
D. Alpine tundra.
E. Freshwater lake.

49.

The following phylogenetic tree displays the evolutionary relationships between five species: A, B, C, D, and E. The character table on the right states whether species A, B, D, and E have each of three different traits. A ``1" means that the species exhibits the trait; a ``0" means that the species lacks the trait. According to the principle of maximum parsimony, which traits would you expect Species C to have?



	A	B	D	E
Trait I	1	1	1	0
Trait II	1	0	1	1
Trait III	0	0	1	0

Image source: C. Wang.

A. I only.
B. I and II.
C. I and III.
D. II and III.
E. I, II, and III.

50.

Dr. Dumfler, world-renowned star chef on his cooking show *The Great American Snake Off*, is testing out fanmade recipes that require premium select bush meats. The recipe he's testing today requires `` lb. of ground deuterostome." Which of the following organisms below should he use?

A.

Image Source: NOAA.

B.

Image Source: Wikimedia.org.

C.

Image Source: Eurekalert.org.

D.

Image Source: I.guim.co.uk.

E. *Image Source: Amazonnaws.com.*

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USABO/USACN 2021 - Reference key

Version 1 (AoPS) | Questions 1-50 | Independently prepared by Jimlaoshi

1	**E**	11	**B**	21	**B**	31	**D**	41	**C**
2	**D***	12	**D**	22	**D**	32	**B**	42	**A**
3	**E**	13	**B**	23	**A**	33	**B**	43	**C**
4	**E***	14	**C**	24	**D**	34	**B**	44	**A**
5	**A**	15	**A**	25	**D**	35	**C**	45	**B**
6	**A**	16	**C**	26	**E***	36	**B**	46	**C**
7	**B***	17	**E**	27	**B**	37	**C**	47	**C**
8	**D**	18	**E**	28	**D**	38	**C**	48	**D**
9	**A**	19	**A**	29	**E**	39	**D**	49	**B**
10	**C**	20	**C**	30	**E***	40	**A**	50	**A**

* See item notes on the following pages. N/A means the source does not support a unique answer.

These are authored reference answers, not a CEE or ASDAN official mark scheme.

Item notes

Q2. D is the functional inference from these in-vitro traces, not proof that every cellular molecule must always be dimeric. The illustrative hairpin incorrectly contains U despite the DNA stem; the supplied unwinding data determine the answer.

Q4. E is the intended choice. An excessively high gel acrylamide percentage (I) can also impede protein transfer, especially for high-molecular-weight targets; no option includes I, III and IV, so the literal possible-causes wording is not uniquely well formed.

Q7. B is the intended false statement. A is a generalization applicable to ordinary telomerase-negative somatic-cell cultures, not literally every cultured mammalian cell: telomerase-positive or immortalized lines need not shorten telomeres in each generation.

Q26. E is false as a blanket CHF treatment recommendation. Do not generalize this to every calcium-channel blocker in every heart-failure phenotype; amlodipine can be safe for another indication, and nondihydropyridines are the main cardiac-depressant concern.

Q30. E correctly describes the biceps-elbow lever, although biceps is anatomically in the upper arm, not the forearm as the option labels it.

Selected references

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