

USA
BIOlympiad

2010

USABO OPEN EXAMINATION
FEBRUARY 8-17 2010

- 1. Both amino acids and nucleotides form complex chains. Select all the answers below that are accurate.**
 - A. The chains formed by both have polar phosphate groups.
 - B. Both contain peptide bonds.
 - C. Both contain nitrogen.
 - D. The chains formed by both can be lysed by trypsin.
 - E. The sequence of chains both form from preexisting templates.

- 2. When a population is in Hardy-Weinberg equilibrium, which of the following is *true*?**
 - A. All of its recessive lethal genes are wiped out, leaving only healthy dominant genes.
 - B. $dN/dt = 0$, $N =$ population size.
 - C. Mutations occur at five times the normal rate to balance the loss of genes by way of natural selection.
 - D. The frequencies of the alleles in the population change over time.
 - E. The frequencies of genotypes in the population are stable over time.

- 3. Which of the following is *NOT* an accurate description of protein synthesis and folding?**
 - A. All protein synthesis is initiated in the cytoplasm.
 - B. Many copies of a protein can be synthesized simultaneously from the same mRNA.
 - C. The 3D shape of a protein is determined largely by its amino acid sequence.
 - D. The entire chain of amino acids exits the ribosome before it begins folding into its 3D shape.
 - E. The first encoded amino acid in every protein is methionine.

4. Neurotransmitter released at the synapse binds to two classes of receptors. Select the correct response(s).

- A. Metabotropic receptors that do not form an ion pore are linked with signal transduction mechanisms and can alter neuron function for seconds to minutes.
- B. Receptor tyrosine kinases that activate signal transduction mechanisms and change gene transcription that can last for hours to days.
- C. Ionotropic receptors that do not form an ion pore are linked with signal transduction mechanisms and can alter neuron function for seconds to minutes.
- D. Ionotropic receptors that are directly linked to an ion pore and are opened within milliseconds in response to neurotransmitter.
- E. Steroid hormone receptors that can activate changes in gene transcription that can last for hours to days.

5. Many proteins are transported around cells in vesicles. Which of the following determines the specificity or directionality of vesicle transport?

- A. Clathrin coat proteins.
- B. v-SNARES and t-SNARES.
- C. Flippase.
- D. Myristoylation.
- E. Hydrophobic domains.

6. The primary energy source of the brain is

- A. Arabinose.
- B. Creatine.
- C. Fructose.
- D. Glucose.
- E. L-serine.

7. Which set of the following statements are correct?

- 1. Osmosis can be used to measure the molecular weight of macromolecules.**
- 2. Aquaporins affect the rate of water transport across membranes.**
- 3. Antidiuretic hormone (ADH) controls aquaporins and the reabsorption of water in the kidney.**
- 4. Reverse osmosis is a process that uses a pressure greater than the osmotic pressure to force the solvent through a semi-permeable membrane from the side with a high solute concentration.**
- 5. Passive proton pumps in plant cell membranes establish proton gradients.**

- A. Only statements 2, 3 & 4 are correct.
- B. Only statements 5, 2 & 3 are correct.
- C. Only statements 1, 2 & 3 are correct.
- D. Only statements 1, 2, 3, & 4 are correct.
- E. All statements are correct.

8. If two animals with the genotype AaBb X AaBb are mated, what is the probability of generating an offspring with the genotype AABb? Assume there is no linkage between the two genes.

- A. 1/8
- B. 1/4
- C. 3/8
- D. 1/2
- E. 5/8

9. Glycogenesis and glycogenolysis are controlled primarily by two hormones.

- A. Fructose kinase and glucose hydrolyase
- B. Glucagon and glucose hydrolyase
- C. Glycogen synthetase and insulin
- D. Insulin and glucagon
- E. Pentose kinase and insulin

10. What is the pH of a solution where the concentration of hydrogen ions is 2×10^{-6} molar? (Hint: You don't need a calculator!)

- A. 2
- B. 2E-6
- C. 5.7
- D. 6
- E. 6.4

11. Phospholipids are important components of cell membranes because they

- A. are completely insoluble in water.
- B. can be easily phosphorylated by ATP.
- C. can transport sodium and potassium ions across the membrane.
- D. form a layered structure that can interface with water on two surfaces.
- E. form a lipid bilayer with their hydrophobic surface facing outward.

12. A homozygous black-eye, white-coat, short-hair mouse is mated to a homozygous brown-eye, brown-coat, long-hair mouse. One of the resulting F1 animals is mated to a homozygous brown-eye, brown-coat, long-hair mouse. Given the following offspring from the second mating, what is the recombination frequency with respect to eye and coat color?

- 243 black-eye, white-coat, short-hair
- 220 brown-eye, brown-coat, long-hair
- 200 brown-eye, brown-coat, short-hair
- 187 black-eye, white-coat, long-hair
- 49 brown-eye, white-coat, short-hair
- 42 black-eye, brown-coat, long-hair
- 36 brown-eye, white-coat, short-hair
- 23 black-eye, brown-coat, short-hair

- A. 5%
- B. 15%
- C. 25%
- D. 46%
- E. 75%

13. Which of the following best describes the fluorophore in the green fluorescent protein?

- A. A molecular component of the protein that is energized by a specific wavelength of light and dissipates the energy by emitting light at a longer wavelength.
- B. A molecule that generates light by hydrolysis of ATP.
- C. A molecule that generates light by oxidation/reduction .
- D. A molecule that is energized by a specific wavelength of light and dissipates the energy by emitting light at a shorter wavelength.
- E. Excess energy in a fluorophore is emitted as light upon increasing the temperature of the molecule.

14. Which of the following is required by a phototropic organism?

- A. Ample supply of metabolites.
- B. Energy supplied by photosynthesis.
- C. Melanin.
- D. Photoactivated mitochondria.
- E. Rhodopsin.

- 15. Which of the following would promote *allopatric* speciation?**
- A. An error in cell division that generates diploid gametes.
 - B. The flooding of a valley that splits one population into two that inhabit different sides of the valley.
 - C. The migration of a segment of a population to a new location, and then failure of the migrants to resume contact with the original population.
 - D. All of the above would promote allopatric speciation.
 - E. Only B and C above would promote allopatric speciation.
- 16. Which of the following carbohydrates contain α -1, 4-linkages?**
- A. amylose
 - B. Cellulose
 - C. Deoxyarabinose
 - D. Glucose
 - E. Hexose
- 17. Genetic Drift is best described as:**
- A. A random change in allele frequencies that benefits the population.
 - B. Changes in the proportion of homozygous recessive individuals due to random mating
 - C. Evolutionary change due to natural selection.
 - D. Evolutionary change due to non-random events.
 - E. Evolutionary change due to random events.
- 18. Which of the following is used to develop a phylogenetic tree?**
- A. An analysis of the differences between different groups or species of organisms.
 - B. A recent shared common ancestor.
 - C. A species comparison of the amino acid and/or base sequences from known proteins and/or nucleic acids.
 - D. Shared characteristics.
 - E. All of the above.
- 19. When the temperature increases, which of the following statements is *not* true?**
- A. Dissolved oxygen decreases at higher temperatures and higher salinity.
 - B. Many corals die when the temperature exceeds 86°F.
 - C. Metabolic reactions are less likely to achieve their activation energy.
 - D. The amount of carbon dioxide that can be absorbed by the ocean decreases.
 - E. Zooxanthellae are released from the coral and thrive when the temperature exceeds 86°F.

- 20. The biodiversity of a community is measured by the following:**
- A. Ratio of plant to animal species.
 - B. Relative abundance.
 - C. Species richness.
 - D. Total biomass in a given area.
 - E. Both A and B are metrics of biodiversity.
- 21. A short-day plant has a critical night length of 6 hours. Which of the following 24-hour light/dark cycles would not initiate flowering?**
- A. 4 hours light/8 hours dark, 4 hours light/8 hours dark
 - B. 6 hour light/6 hour dark, 6 hour light/6 hour dark
 - C. 6.5 hour light/5.5 hour dark, 6.5 hour light/5.5 hour dark
 - D. 7 hour light/5 hour dark, 7 hour light/5 hour dark
 - E. 8 hours light/16 hour dark
- 22. Which of the following statements is *not* true?**
- A. Insects, birds, and many reptiles excrete nitrogenous waste in the form of urea.
 - B. Neurons have evolved to speed the communication between distant cells in multi-cellular organisms.
 - C. Synapses are specialized connections between neurons to facilitate the formation of complex neuronal networks.
 - D. The regulatory proteins tropomyosin and troponin control the contraction of contractile filaments, actin and myosin.
 - E. Vitamin A is the chromophore in the visual pigment, rhodopsin.
- 23. The chemical EDTA is routinely used in many experiments. For example, EDTA is used in electrophoresis buffer solutions. Which of the following statements is *not* true?**
- A. EDTA has a strong binding affinity for divalent and some trivalent cations.
 - B. EDTA is a catalyst for polymer formation and essential for protein and nucleic acid polymerization.
 - C. EDTA is a chelator.
 - D. EDTA is used to help denature proteins and weaken cell membranes.
 - E. EDTA protects DNA from restriction enzymes by removing magnesium ions from the solution.
- 24. Positive cooperativity is an emergent property of what type of enzymatic regulatory mechanism?**
- A. Allosteric interactions.
 - B. Cellular compartmentalization.
 - C. Genetic regulatory mechanisms.
 - D. Second messenger systems.
 - E. None of the above.

- 25. Select ALL of the following associations that are accurate.**
- A. Tryptophan, tyrosine and phenylalanine – aromatic amino acids which absorb UV light.
 - B. L-Isoleucine – most hydrophobic.
 - C. L-Histidine – side chain can shift pKs, at physiologic pH can act as either an acid or a base.
 - D. L-Lysine -amphipathic
 - E. L-Proline is known as an “ α -helix breaker” and is found in tight turns.
- 26. Using accelerator mass spectrometry, the ^{14}C atoms in a 2 mg bone fragment were directly counted and found to be 1/8 of those that would be present in a 2 mg bone fragment in 1950. What is the approximate age of this specimen? The half-life of ^{14}C is 5,730 years.**
- A. 1,540 years BP (before present)
 - B. 5,730 years BP
 - C. 17,190 years BP
 - D. 22,920 years BP
 - E. 45,840 years BP
- 27. Which of the following molecules are involved in directing the growth of axons in the nervous system?**
- A. Cell adhesion molecules (CAM)
 - B. Netrin-1
 - C. Slit
 - D. B & C
 - E. A, B, & C
- 28. Select ALL statements that are true concerning the Photosynthesis Reaction Center (Photosystem II)?**
- A. The Photosynthesis Reaction Center contains chlorophyll and sometimes Fe-heme groups.
 - B. It is a globular protein found in the cytoplasm where it acts as an antenna protein.
 - C. It oxidizes carbon dioxide and produces H_2O .
 - D. It transfers high-energy electrons to an acceptor nearby in the thylakoid membrane.
 - E. The Photosynthesis Reaction Center is usually a heterotetramer, but may be a heterotrimer in some species of cyanobacteria.

29. Blood entering the kidney is filtered by the Bowman's capsule. In what order does the filtrate pass through the following structures of the nephron?

- (1) Ascending limb of the Loop of Henle
- (2) Distal convoluted tubule
- (3) Descending limb of the Loop of Henle
- (4) Proximal convoluted tubule
- (5) Collecting duct

- A. 1, 3, 4, 2, 5
- B. 2, 1, 3, 4
- C. 2, 3, 1, 4, 5
- D. 4, 1, 3, 5
- E. 4, 3, 1, 2, 5

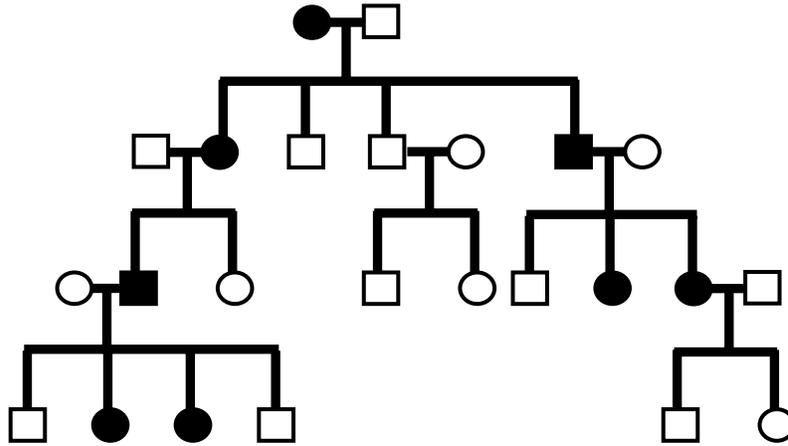
30. Select ALL of the following that are accurate statements concerning ecosystems?

- A. Energy flow tends to be from the sun, to producers, then consumers, and finally back to the sun.
- B. Energy flow from trophic level to trophic level is 90% efficient.
- C. Energy may only flow from the biotic to the abiotic portions of ecosystems.
- D. Heterotrophs supply 10% of the energy needed by autotrophs.
- E. Some energy lost during transfers from trophic level to trophic level is in the form of heat.

31. Select ALL of the structure/function relationships in the CNS that are not accurate?

- A. Cerebellum: Control of motor functions
- B. Cerebrum(limbic system): Long term memory
- C. Hypothalamus: Circadium rhythms
- D. Medulla oblongata: Breathing
- E. Spinal cord: Short term memory of motor functions

32. Below is a human pedigree depicting the inheritance of a rare disease:



What is the most likely mode of inheritance?

- A. Autosomal recessive
 - B. Autosomal dominant
 - C. X-linked recessive
 - D. X-linked dominant
 - E. Y-linked dominant
33. Which of the following interactions is most responsible for the structural stability of soluble globular proteins?
- A. Dipole-dipole interactions.
 - B. Electrostatic interactions.
 - C. Hydrogen bonds.
 - D. The Hydrophobic Effect.
 - E. Van der Waal force.
34. Select the description that most correctly describes the term recessive:
- A. A weak phenotype.
 - B. An allele that confers a weak phenotype.
 - C. A phenotype conferred when only one copy of an allele is present.
 - D. a weak allele.
 - E. A phenotype conferred when two copies of an allele are present.

- 35. Select ALL the following associations that are *not* correct?**
- A. Brain: Pineal Gland: Melatonin: Biological rhythms – light dark cycles.
 - B. Hypothalamus: Posterior Pituitary Gland: Oxytocin: Ovary & follicular growth.
 - C. Kidney: Adrenal Gland: Adrenal Cortex: Cortical: Manage Stress and Anxiety: Increase blood pressure and blood sugar levels and reduce immune response.
 - D. Pancreas: Glucagon: Increases blood glucose levels.
 - E. Parathyroid: calcitonin: stimulates osteoblasts and calcium deposit in bone.
- 36. Which of the following is *not* an action of epinephrine or norepinephrine?**
- A. Glycogen broken down to glucose.
 - B. Increased gastric motility and secretion.
 - C. Increased blood pressure.
 - D. Increased heart rate.
 - E. Increased salivation.
- 37. Arthropods are the most numerous of all animal groups. This diversity in numbers may be the consequence of the presence of ancient regulating genes present prior to the division of the protostome-deuterostome group. The evolution of increased morphological change in the basic body plan of arthropods is attributed to the:**
- A. Differential success of alternate developmental variations.
 - B. Flexible modular body plan.
 - C. Genetic peculiarity among arthropods.
 - D. Plasticity of regulatory genes.
 - E. All of above.
- 38. The majority of proteins exist as homo-oligomers rather than hetero-oligomers. That is, their quaternary structure is composed of two or more identical polypeptides rather than two or more different polypeptides. Which of the following is not a reason that quaternary structures are homo-oligomers?**
- A. Aggregation of identical subunits gives rise to symmetry and possible allosteric interactions.
 - B. A slow post-translational process favors a quaternary structure with the homo-oligomers held together by covalent bonds.
 - C. Homodimers may increase binding specificity and stability.
 - D. Homo-oligomerization results in a genetic savings with lower energy demand.
 - E. The presence of two identical catalytic subunits in a single protein may lower the activation energy of the reaction.

- 39. Zooxanthellae are protozoa which live inside the cells of some marine animals as endosymbionts. They supply nutrients and synthesize other beneficial chemical compounds. Which of the following statements is *not* true?**
- A. Amino acid-like mycosporines prevent thymine dimmer formation.
 - B. Mycosporines are amino acid-like compounds produced by zooxanthellae to reduce UV damage to the cells.
 - C. Mycosporines are produced by many organisms, which exist in intense sunlight.
 - D. Zooxanthellae can supply up to 90% of a coral's energy requirements.
 - E. None of the above is correct.
- 40. During the late Carboniferous period, terrestrial arthropods such as Hexapoda, Myriapoda, and Arachnida showed great diversity in form and size. An example is the giant dragonfly, *Meganeura*, with a wing span of over 70 cm. Our modern day dragonflies and other arthropods are much smaller than their Carboniferous ancestors because:**
- A. The amount of nutrients is less today than in the Carboniferous.
 - B. The amount of free carbon is greater today.
 - C. The competition among organisms for existing habitats is greater today and small size provides a competitive edge.
 - D. The thickness of the exoskeleton required in large Carboniferous insects limited the ability of the arthropods to successfully molt and subsequently to compete with smaller forms.
 - E. The volume of oxygen in the atmosphere is much lower today than in the Carboniferous.
- 41. If active transport is inhibited, the passive sodium and potassium ion fluxes across the plasma membrane are still coupled. What makes these two passive ion fluxes dependent on each other?**
- A. The membrane potential.
 - B. The potassium channels.
 - C. The pumping ratio of the Na⁺/K⁺ ATPase.
 - D. The ratio of cholesterol to phospholipids in the membrane.
 - E. The ratio of the extracellular sodium ion concentration to the intracellular potassium ion concentration.

- 42. Arrange the following five events in the order that explains the bulk flow of substances in the phloem.**
1. Sugar moves down the stem.
 2. Leaf cells produce sugar by photosynthesis.
 3. Sugar is transported from cell to cell via the apoplast and/or symplast.
 4. Solutes are actively transported into sieve elements.
 5. Water diffuses into the sieve tube elements.
- A. 1,2,3,4,5
B. 2,1,4,3,4
C. 2,3,4,1,5
D. 2,4,1,3,5
E. 4,2,1,3,5
- 43. The Henderson Hasselbalch equation describes the relationship between pH, pK and the ratio of base to acid concentration, $\text{pH} = \text{pK} + \log ([\text{B}]/[\text{A}])$. It is useful when determining the amount of weak acid and weak base to weigh out for a buffer system. It is also useful to determine percent of a functional group in it's ionized state. If a carboxylic acid has a pK of 3.9, what percentage of the functional group will carry a negative charge at pH 4.9?**
- A. 10%
B. 90.9%
C. 9.09%
D. 50%
E. 18.18%
- 44. An inbred strain of plants has a mean height of 24 cm. A second strain of the same species also has a mean height of 24 cm. When these plants are crossed, the F_1 are also 24 cm in height. However, when the F_1 plants are crossed, the F_2 plants show a wide range of heights; the greatest number are similar to the P_1 and F_1 , but approximately 4 of 1000 are only 12 cm tall and 4 of 1000 are 40 cm tall. What fraction of the F_2 plants will be approximately 28 cm in height? [Assume that each of the alleles involved in determining increase in plant height contributes the same amount.]**
- A. $3/4$
B. $9/16$
C. $56/256$
D. None
E. Cannot be determined from the information given

- 45. Your parents built a tree house for you when you were 8 years old and 4 feet tall. They placed the tree house on a branch of a tree that was 5 feet above the ground in a tree that was 20 feet tall. You are now 17 years old and 6 feet tall. The tree has grown to be 50 feet tall. How high above the ground is the branch on which the tree house is resting now?**
- A. 4 feet
 - B. 5 feet
 - C. 17 feet
 - D. 20 feet
 - E. 35 feet
- 46. In plant cells grown in the presence of a metabolic poison that specifically inhibits mitochondrial F_1ATP synthase, one would expect:**
- A. the pH difference across the cristae to be greater than normal.
 - B. the pH difference across the cristae to be less than normal.
 - C. the electron transport chain to become inoperative.
 - D. oxygen consumption to cease.
 - E. water to move out of the mitochondria by osmosis.
- 47. While walking to school one day, you notice a group of purple ants who all walk sideways. Excited by your discovery, you decide to classify your ants. Which of the following characteristics would classify the purple ants as a new subspecies or strain of ants and NOT a new species?**
- A. The purple ants have a similar DNA polymerase as the tropical fire ant *Solenopsis geminate*.
 - B. The purple ants may produce fertile offspring when crossed with *Solenopsis geminate*.
 - C. The purple ants have ribosomal subunits of the same size as *Solenopsis geminate*.
 - D. The purple ants are found to inhabit similar areas as *Solenopsis geminate*.
 - E. Both b and d are necessary characteristics.

48. The membrane potential across a cell membrane is determined by the relative permeabilities and concentration gradients of electrolytes across its cell membrane.

The intracellular/extracellular concentration of sodium ions is 14 mM/140 mM.

The intracellular/extracellular concentration of potassium ions is 120 mM / 4 mM.

The chemical potential or equilibrium potential = $(RT/zF) \ln ([x]_o/[x]_i)$. Given the gas constant, $R = 8.31 \text{ JK}^{-1}\text{mol}^{-1}$, the temperature, T , needs to be in Kelvin, °K.

The Faraday constant, $F = 9.65 \text{ coulombs mol}^{-1}\text{m}$, and z is the valency of the cation or ion.

At 25°C, the _____ equals +58 mVs.

- A. calcium equilibrium potential
- B. chloride equilibrium potential
- C. membrane potential
- D. potassium equilibrium potential
- E. sodium equilibrium potential

49. Scientists have determined that three classes of genes (named A, B, and C) control development of the four flower parts: Sepals, Petals, Stamen, and Carpels. Genes A and C mutually repress each other. Gene B is not regulated by either gene A or C. The expression pattern of these genes in wild-type flowers is shown below, where +++ indicates gene activity.

Flower Formation				
	Sepals	Petals	Stamens	Carpels
Gene A	+++	+++		
Gene B		+++	+++	
Gene C			+++	+++

A mutation in Gene C, which prevents its expression, will result in which of the following floral patterns?

- A. Sepals-Petals-Stamen-Carpels
- B. Sepals-Petals-Petals
- C. Sepals-Petals-Petals-Sepals
- D. Sepals-Petals-Petals-Carpels
- E. Sepals-Petals-Stamen

50. With proofreading, which of the following is the error rate of DNA polymerase?

- A. One error in 1×10^1 bases.
- B. One error in 1×10^2 bases.
- C. One error in 1×10^3 bases.
- D. One error in 1×10^6 bases.
- E. One error in 1×10^9 bases.