USABO Open Exam
February 5 to 15, 2019

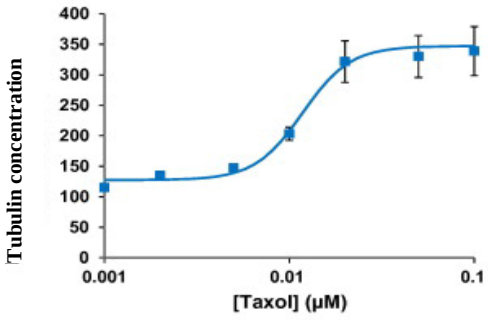
20% Cell Biology (10 Questions)

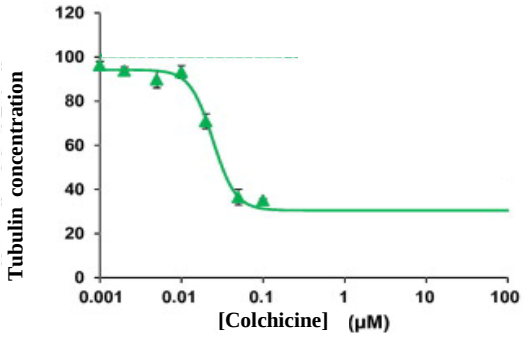
1. **A student in lab is characterizing an unknown chain of amino acids and finds large numbers of lysine residues. Which of the following would be the location of their discovery?**

   A. Alpha-helix interior.
   B. Histone tail.
   C. Magnesium-associated domain.
   D. Steroid center.
   E. Transmembrane domain.

2. **Based on Graphs A and B below, would Taxol or colchicine be more likely to have a positive effect on cell division?**

   A. Colchicine. It increases the amount of tubulin, so the spindle cannot form.
   B. Taxol. It increases the amount of tubulin, so the spindle cannot form.
   C. Colchicine. It decreases the amount of tubulin, so the spindle can form.
   D. Taxol. It increases the amount of tubulin, so the spindle can form.





Graph A. The effect of Taxol on tubulin formation. *Graph B. The effect of colchicine on tubulin formation.*

3. **Polypeptides like membrane transport proteins have a 3-D structure. Hydrogen bonding between the amino and carboxyl groups of individual amino acids most likely affects:**

   A. Polar interactions between R-groups.
   B. Polar interactions in the tertiary structure.
   C. Primary structure via non-polar interactions.
   D. Primary structure via covalent bonding.
   E. Secondary structure via polar interactions.

4. **The molecule shown below is the substance pumiliotoxin produced by poison dart frogs. At which arrow could a hydrogen bond form?**

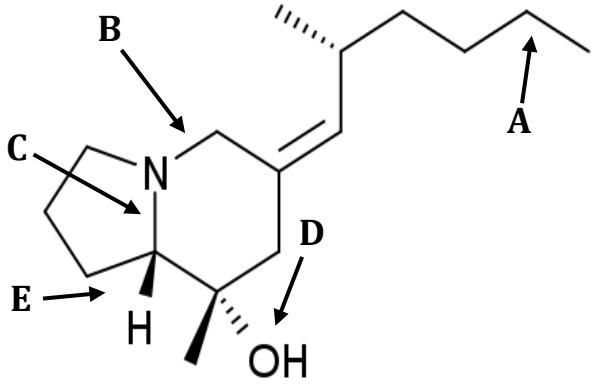
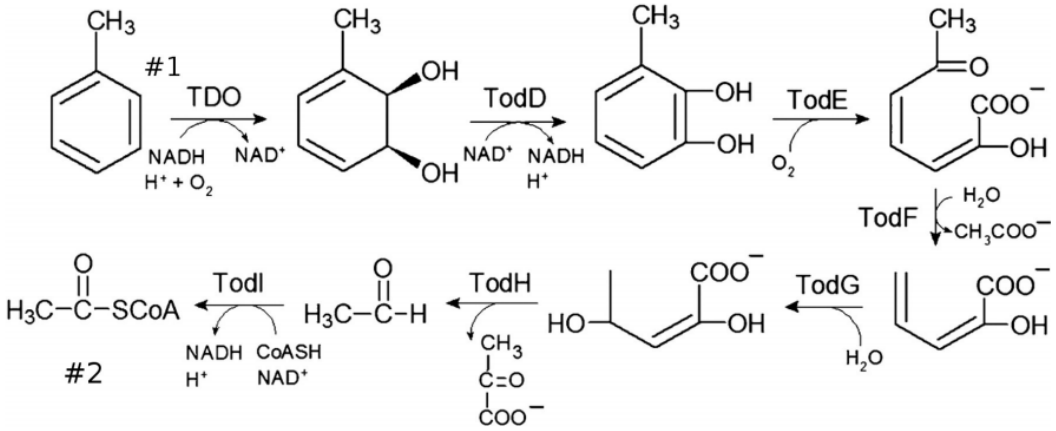


Image pumiliotoxin: https://en.wikipedia.org/wiki/File:Pumiliotoxin251D.png

5. **Consider the pathway below showing the degradation of toluene—a colorless liquid with a low to moderate water solubility. Toluene affects the central nervous system, but animals exposed to moderate to high levels of toluene also show harmful effects in their liver, kidneys, lungs and impaired immune function.**



Considering the general principles of energy metabolism, which of the following statements is TRUE regarding the pathway shown above?

A. #1 in the pathway is an ATP generating step.
B. # 1 in the pathway is a redox reaction; toluene is reduced.
C. The product of the toluene degradation at #2 is further degraded using glycolysis.
D. The product of the toluene degradation pathway #2 is further degraded using beta-oxidation.
E. The microorganism capable of utilizing this pathway cannot be used for bioremediation due to anabolism of toxic chemicals using toluenes as monomers.

6. **A literature search reveals that NOX2 is an important protein complex responsible for generating the reactive oxygen species (ROS) in natural killer (NK) cells. RNA interference (RNAi) was used against NOX2 in NK cells. ROS production was measured with a general fluorescent ROS probe and compared to the control NK cells. The general ROS probe fluorescence intensity was significantly lower in the experimental group when compared to the control NK cells. Your lab is attempting to uncover the intracellular mechanism of ROS production in NK cells. The graduate student conducting the experiment insists that NOX2 was functionally knocked out in the cell line using synthetic single-stranded RNA for RNAi and concludes that the functional removal of NOX2 by RNAi results in no ROS production. Your guidance to your graduate student is**

I. DNA interference should be used in lieu of RNAi.
II. A specific inhibitory peptide to NOX2 translation (protein interference) should be used in lieu of RNAi.
III. RNAi is not 100% efficient and there may be some NOX2 mRNAs that are not degraded.
IV. Synthetic double-stranded RNA should have been used for RNAi, not single-stranded RNA

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

7. **Superantigens (SAgs) are a group of antigens that produce non-specific activation of T-cells which cause the activation of polyclonal T cells and the release of massive amounts of cytokines. Which of the following statements is TRUE regarding SAgs?**

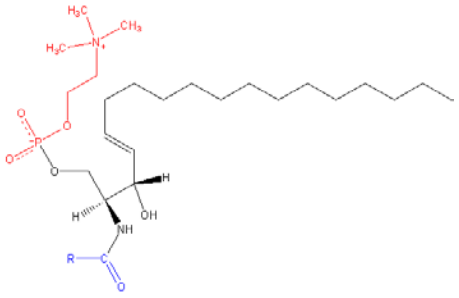
I. They are types of exotoxins.
II. They physically link T cell antigen receptor to antigen-binding domain of MHC class II.
III. They are being presented at the antigen-binding groove of MHC-II with longer peptides.
IV. They physically link T cell antigen receptor to non-antigen-binding domain of MHC class II molecules.

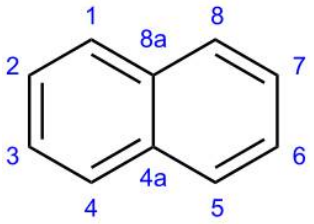
A. I and II.
B. I, II, and IV.
C. I, II, III, and IV.
D. I and IV.
E. II and III.

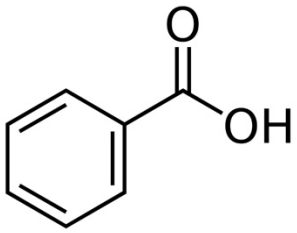
8. **Collagen is usually a triple helix made of three peptide strands with an amino acid motif of either Gly-Pro-X or Gly-X-Hyp, where X is any amino acid and Hyp is hydroxyproline. Which of the following explanations of collagen chemistry is TRUE?**

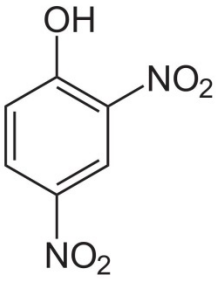
A. A mutation of glycine to a different amino acid in the collagen gene will be recessive because of its limited effects on wild-type collagen molecules.
B. Glycine side chain increases hydrogen bonding between the helices due to its small size.
C. Hydroxyproline's additional hydroxyl group allows the formation of hydrogen bonds to stabilize tight left-handed helices.
D. Non-motif regions of collagen are dedicated to cross-linking within collagen to help the triple helices to coil together in a superhelix.
E. The high proline content allows the three alpha-helices in collagen to bond into a triple helix.

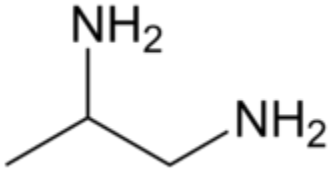
9. **DNP is used as a dangerous weight loss drug due to its ability to increase metabolic activity. The chemical disrupts the proton gradient by binding H+ and diffusing across the inner mitochondrial membrane. Given these constraints, which of the following molecules is DNP?**

A. 

B. 

C. 

D. 

E. 

10. **There have been multiple large-scale outbreaks of Ebola virus in West and Central Africa over the past couple years. The majority of people who are infected with Ebola die from the disease, but some**

will survive and make a full recovery. Researchers found that in some survivors the virus persisted in immunologically protected sites in their bodies well after they had recovered from their initial infection. Which statement below does NOT describe a consequence of this persistence?

A. The virus can persist in high amounts in the inside of the eyeball and cause temporary blindness.
B. The virus can persist in the liver and reinfect the person and then be transmitted to others.
C. The virus can persist in mammary glands of women and be passed down to a child through breastfeeding.
D. The virus can persist in the testes, and if a man has unprotected sex he could infect his partner.
E. The virus can persist in urine, saliva.

15% Plant Anatomy and Physiology (8 Questions)

11. Which of the following statements are TRUE regarding cell junctions in animals and plants?

I. Desmosomes are made of sturdy keratin proteins, which attach myocytes to each other.
II. Plasmodesmata are different from gap junctions because of their unique ability to transport proteins.
III. Gap junctions are different from plasmodesmata because gap junction pores are lined with the membrane.
IV. Plasmodesmata are different from gap junctions because of their unique ability to transport nucleic acid, such as RNA and viruses.
V. If there is a polypeptide chain that makes up a tight junction that weaves back and forth through the membrane four times, with two extracellular loops, and one loop plus short C-terminal and N-terminal tails in the cytoplasm, you would predict that polar amino acids in the four regions that go through the membrane between the tails and loops.

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

12. Which of the following is NOT a characteristic of the majority of plant hormones?

A. Exist as small water-soluble molecules.
B. Function at low concentrations.
C. Modify plant responses to stress.
D. Penetrate easily between cells.
E. Regulate each stage of the plant life cycle.

13. Isoxazolidinones are herbicides. When plants are exposed to the weed killer, the chloroplasts have a high level of ADP and the leaves are translucent (nearly see-through). Based on this information, what concentration of other molecules might you expect to find?

A. Low levels of oxaloacetate.
B. Low levels of rubisco.
C. High levels of NAD^+.
D. High levels of $NADP^+$.
E. High levels of RuBP.

Questions 14 and 15: A Wisconsin gardener notes that the plants immediately bordering a walkway are stunted compared with those farther away. Suspecting that the soil near the walkway may be contaminated from salt added to the walkway in winter, the gardener tests the soil. The composition of the soil near the walkway is identical to that farther away except that it contains an additional 50 mM NaCl. Please answer the following two questions.

14. Assuming that the NaCl is completely ionized, calculate how much it will lower the solute potential of the soil at 20°C using the solute potential equation: $\Psi S = -iCRT$ where i is the ionization constant (2 for NaCl), C is the molar concentration (in mol/L), R is the pressure constant [R = 0.00831 L • MPa/(mol • K)], and T is the temperature in Kelvin (273 + °C).

A. +243.483 MPa.
B. –243.483 MPa.
C. –0.243 MPa.
D. –0.122 MPa.
E. –0.017 MPa.

15. How would this change if the solute potential of the soil affects the water potential of the soil and the movement of water in or out of the roots?

A. The water potential of the soil will be equal, which does not affect water absorption.
B. The water potential of the soil will be higher, promoting water absorption by the root system.
C. The water potential of the soil will be higher, promoting water loss from the root system.
D. The water potential of the soil will be lower, promoting water absorption by the root system.
E. The water potential of the soil will be lower, promoting water loss from the root system.

16. Which of the following statements is NOT true regarding plant development?

A. A tropical tree will not have distinct growth rings due to little seasonal temperature variation.
B. Preprophase band disappears before metaphase and predicts the future plane of cell division.
C. Primary and secondary growth cannot occur simultaneously in the same plant.
D. Roots and stems grow indeterminately but leaves do not.
E. Vascular tissue system enables leaves and roots to function together in supporting growth and development of the whole plants.

17. **While working with a population of experimental plants, you observe plants in Plot I that look like the image below. You suspect that this may be due to the soil quality and ion deficiency. What ion deficiency is a likely cause?**



https://www.google.com/search?q=images+for+boron+ion+soil+deficiency&rlz=1C1SFXN_enUS786US786&tbm=isch&source=iu&ictx=1&fir=_OsTUONpBHMJoM%253A%252Cj9wJ-2Ce_AAbuM%252C_&usg=AI4_-kRE34gXHnWCAYCpK5CpbdlbKF6u8w&sa=X&ved=2ahUKEwjvzp658LXeAhXiw1kKHRp6BuoQ9QEwBHoECAQQDA#imgrc=HAhfRhOrSe4YCM: Fair use.

A. Boron ions.
B. Chlorine ions.
C. Iron ions.
D. Manganese ions.
E. Zinc ions.

18. **Which of the following characteristics and/or functions is NOT associated with parenchyma cells?**

A. Incorporated into vascular tissue.
B. Globular, thin-walled, more or less undifferentiated cells.
C. One cell type composition.
D. Play a role in wound healing and vegetative regeneration.
E. Retain the ability to divide throughout their lives.

25% Animal Anatomy and Physiology (12 Questions)

19. Which of the following mammals would you expect to have the shortest small intestine relative to body size?

A. Cow.
B. Human being.
C. Horse.
D. Lion.
E. Rabbit.

20. Which of the following does NOT distinguish cardiac muscle from skeletal muscle? Cardiac muscle

A. Contains intercalated discs.
B. Contains ryanodine receptors.
C. Has centrally located nuclei.
D. Has a stiffer length-tension curve.
E. Is mononucleated.

21. An epinephrine-mediated increase in heart rate is primarily mediated through which of the following receptor/second-messenger pairs?

A. ß-1, Ca^{2+}.
B. ß -1, cAMP.
C. ß -2, Ca^{2+}.
D. ß -2, cAMP.
E. ß -2, cGMP.

22. A healthy young woman volunteers for a normal physiology study. For one week, she ingests a known diet that contains 150 millimoles of Na^+ a day. On Day 7 of the study, the woman's urine is collected over a 24-hour period. Her urine sample contains 1.2 liters of urine with a Na^+ concentration of 125 mM. Using the tracer molecule inulin injected into her intravenously, researchers calculate that her kidneys filter 180 liters of blood a day (glomerular filtration rate). The concentration of Na^+ in her blood plasma on Day 7 is 140 mM. In an average nephron of hers, what fraction of Na^+ ions crossing the glomerular capillary wall is excreted in the urine?

A. <1 percent.
B. 2 percent.
C. 15 percent.
D. 78 percent.
E. 100 percent.

23. Cortical rotation after fertilization is important for subsequent development in amphibians. To address key aspects of cortical rotations and fertilization, four independent experiments were performed:

***Experiment 1*: Cortical rotation is allowed to occur followed by a forced opposite rotation in the frog embryo.**
***Experiment 2*: Frog eggs are treated with ultraviolet (UV) light for 1 hour.**
***Experiment 3*: Fluorescent spots are placed on the surface the egg of an amphibian species that does not exhibit a visible gray crescent (that is, not a frog.)**
***Experiment 4*: Amphibian zygotes are treated with nocodazole (microtubule depolymerizing agent) within a few minutes after fertilization.**

Which of the following statements is FALSE regarding your designed experiments?

A. The resulting embryos from *Experiment 2* would have axis defects.
B. The resulting embryo from *Experiment 1* would be a two-headed embryo.
C. In *Experiment 4*, this will result in excess ventral and posterior structures.
D. In *Experiment 1*, forcing the opposite rotation cancels out the establishment of the backside by the first rotation.
E. In *Experiment 3*, if after fertilizing the eggs, the spots move in a similar way to frogs, this means that cortical rotation nevertheless occurs in a rare amphibian species.

24. Mice are infected with smallpox viruses which prime the smallpox-specific CD8 T cells. The mice are euthanized and the spleens and lymph nodes are removed and processed. Next, CD8 T cells are extracted and purified from these mice using positive selection. Assuming the complete genetic background of these mice is known, which of the following statements is TRUE regarding a follow-up experiment?

A. To further purify smallpox-specific CD8 T cells, you will have to incubate them with the same family of viruses, such as cowpox.
B. If you further purify smallpox-specific CD8 T cells, you have to incubate with anti-smallpox viruses and purify using a similar strategy (positive selection) described above.
C. If you incubate the purified CD8 T cells with uninfected B cells expressing the MHC class II molecules from any other mice, the CD4 T cells can be destroyed.
D. If you incubate the purified CD8 T cells with dendritic cells infected with smallpox expressing the MHC class II molecules from any other mice, CD4 T cells can be destroyed.
E. If you incubate the purified CD8 T cells with infected CD4 T cells expressing the MHC class I molecules from the same mouse, CD4 T cells can be destroyed.

25. Which of the following statements about digestion is FALSE?

A. A major function of the large intestine is water reabsorption.
B. Digestive enzymes do not digest their respective secretory cells.
C. In many mammals, the digestion of starch begins in the mouth and ends in the small intestine.
D. Stomach acids act to hydrolyze proteins.
E. Villi and microvilli in the small intestine increase absorptive surface area.

26. Which statement about the circulatory system is FALSE?

A. Active transport of water across capillary walls regulates osmotic pressure.
B. Blood flows faster in the arterioles than in the capillary bed.
C. Blood pressure in the arteriole is higher than in the capillary bed.
D. Reabsorption of water into capillaries is by osmosis.
E. The water content of blood is regulated by the blood protein concentration.

27. When the levels of adrenal cortical hormones are low:

A. Nervous stimulation to the adrenal gland from the sympathetic nervous system will increase.
B. The hypothalamus and anterior pituitary are inhibited.
C. The secretion of ACTH from the anterior pituitary will increase.
D. The secretion of CRH from the hypothalamus will decrease.
E. The synthesis of carbohydrate from protein and fat will increase.

28. Which of the following effects would be least effective for a tranquilizer?

A. Blocks receptor site for noradrenalin on postsynaptic membranes.
B. Enhances the sensitivity of neurons to noradrenalin.
C. Interferes with synthesis of noradrenalin in nerve cells.
D. Interferes with the uptake of noradrenalin into synaptic vesicles.
E. Prevents release of noradrenalin from synaptic vesicles.

29. Two electrical recording instruments have been set up to record any electrical changes that may occur in a single neuron 10 cm in length. A recording instrument is placed at each end of the neuron. If the magnitude of the action potential at the first pair of electrodes is recorded at 100mV, what will be the magnitude of the action potential when it reaches the second pair of electrodes at the end of the 10-cm neuron?

A. 10 mV.
B. Less than 100 mV, but cannot be more exact.
C. 100mV.
D. More than 100mV, but cannot be more exact.
E. 1000 mV.

30. The proper metamorphosis of the moth *Cecropia* and presumably many other insects involves the antagonistic interaction of which two hormones?

A. Brain cell hormone and corpora allata hormone.
B. Brain cell hormone and ecdysone.
C. Brain cell hormone and prothoracic gland hormone.
D. Juvenile hormone and ecdysone.
E. Thyroxin and a pituitary hormone.

5% Ethology (3 Questions)

31. Flatworms respond to an electric shock by contracting their body muscles. If the worms are exposed to 50 or 100 electric shocks and a beam of light as the same time, the worms will learn to contract immediately upon presentation of the light bean even if no shock is present. This is an example of:

A. Classical conditioning.
B. Cultural learning.
C. Habituation.
D. Imprinting.
E. Trial and error.

32. Certain species of dung beetles dig burrows under piles of dung and take the dung into the burrows to fee their larvae. When a female dung beetle finishes digging and stops to bring up soil from the underground burrow, the male seizes a piece of dung with his front legs and bears down into the burrow. When the tip of abdomen strikes the females' head, he drops his load and returns to the surface for more. In this case, the striking of the female's head by the male's abdomen is most like an example of a(n):

A. Kinesis.
B. Sexual selection.
C. Sign stimulus.
D. Supernormal stimulus.
E. Tropism.

33. If mice are kept in a cage for several weeks and replaced by another set of mice, the new mice become temporarily sterile and gain weight. What type of communication is involved?

A. Hormones.
B. Litter composition.
C. Pheromones.
D. Releasers.
E. Sign stimuli.

20 % Genetics and Evolution (10 Questions)

34. An evolutionary development that parallels cephalization in animals is

A. Concentration of major sense organs in the head region.
B. Development of efficient locomotor appendages in higher animals.
C. Development of the nerve net.
D. Increased coordinating ability of the endocrine system.
E. Increased size and length of the spinal cord.

Questions 35 to 36. Verne is interested in whether selection has influenced a population of warthogs over the course of two generations. In the first year, Verne counts 200 warthogs and finds:

95 *AA* (long tusks) **35 *Aa* (medium length tusks)** **70 aa (short tusks)**

35. What is the OBSERVED genotype frequency for the heterozygotes in Verne's warthog population?

A. 0.175.
B. 0.246.
C. 0.475.
D. 0.563.
E. 0.35.

36. What is the OBSERVED frequency of the *A* allele in Verne's warthog population?

A. 0.437.
B. 0.475.
C. 0.531.
D. 0.563.
E. 0.689.

37. Verne sampled 100 individuals from a population of salamanders. Based on the number of spots on their backs, Verne found 49 were homozygous for the allele *A* that codes for many, small spots and 16 were homozygous for a second allele *A′* that codes for few, large spots. The remaining salamanders were heterozygous. Based on the sample, what is the frequency of the allele *A*? (You may round up.)

A. 0.34.
B. 0.4.
C. 0.49.
D. 0.67.
E. 0.7.

38. Your mother has two different alleles for eye color. During meiosis, replication of one of her DNA strands resulted in a missense mutation to this eye color locus. How many unique eye color gene versions can she pass to her offspring?

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

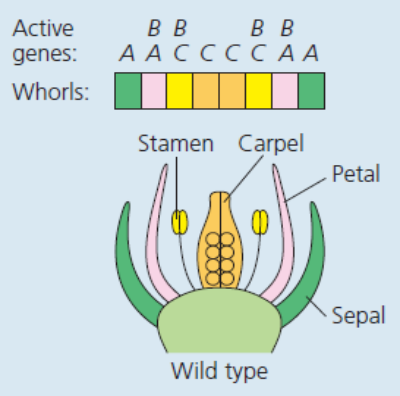
39. To determine germ cell fate in *C. elegans*, antibodies raised from a goat specific for *C. elegans* P granule protein were used. Secondary antibodies that bound to the P granule protein antibodies and emitted green fluorescence under green-blue laser were also used. How would the distribution of this green signal change over time, starting from newly fertilized zygotes to four-cell embryos?

A. P granules will translocate from posterior to anterior end of the embryo.
B. P granules will be distributed throughout the embryo and it will be more concentrated toward posterior end of the embryo.
C. P granules will be initially concentrated toward anterior end of the zygote and will slowly be diffused throughout the embryo.
D. P granules will be initially concentrated toward posterior end of the zygote and will slowly be diffused throughout the embryo.
E. P granules will be distributed throughout the embryo and it will be more concentrated toward anterior end of the embryo.

40. The commonly known nitrogenous bases are adenine, thymine, cytosine, guanine, and uracil. However, there is a sixth base found in the cell known as inosine. Given the knowledge that inosine is responsible for the phenomenon of wobble, which type of molecule would you expect to find inosine a part of?

A. mRNA.
B. rRNA.
C. RNAi.
D. snRNA.
E. t*RNA*.

41. The figure shown below is representative of the ABC hypothesis in plants.



Based on this model, if both Genes A and B are inactivated using the CRISPR/cas9 method, which statement best describes the appearance of the flower?

A. There will be no floral components.
B. The flower would consist of all the components except for petals.
C. The flower would consist of nothing but carpels.
D. The flower would consist of nothing but carpels and partial petal structures.
E. The flower would still be complete because of the complementary gene interactions.

42. The frequency of crossing over between linked genes A and B is 35 percent; between B and C, 10 percent, between C and D 15 percent; between C and A, 25 percent; between D and B, 25 percent. What is the sequence of the genes on the chromosome?

A. ABCD.
B. ABDC.
C. ACBD.
D. ACDB.
E. ADCB.

43. A genetic disease known to Marfan's syndrome is caused by a dominant allele. In this disease, the fingers and toes are excessively long. This and other skeletal defects are often accompanied by a misplaced eye lens and heart defects. Some individuals with this syndrome may have all these defects; others show only one or two of the defects yet may have children with all. Suppose a normal woman marries an affected man whose mother was normal. If this trait has 90 percent penetrance, what percentage of their children will be expected to express this trait?

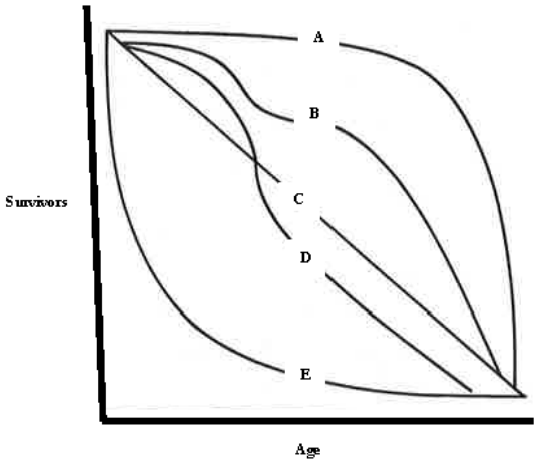
A. 22.5 percent.
B. 45 percent.
C. 50 percent.
D. 67.5 percent.
E. 90 percent.

10 % Ecology (5 Questions)

44. A coelenterate such as a sea anemone could best be described as an

A. Absorptive heterotroph.
B. Autotroph.
C. Herbivore.
D. Ingestive heterotroph.
E. Omnivore.

45. A certain fish species lives in large lakes. It feeds on small insects and other invertebrates. Spawning occurs in late spring, when males and females congregate in shallow water and engage in brief courtship display, after which they release gametes in great clouds. The adult fish then swim back to deeper water. Young fish become sexually mature when they are three years old. Which survivorship curve in the diagram below is most likely to apply to this species? E



46. Sea otters were hunted to near extinction in the 19th century, which drove the expansion of sea urchin populations, leading to the formation of urchin barrens with the loss of kelp forests in Alaska and the Pacific Northwest. However, the more biodiverse Southern California ecosystems stayed intact and continued to have healthy kelp forest ecosystems without sea otters. Southern California's ecosystems were resilient to overharvesting because of…

A. Mutualism.
B. Keystone species.
C. Functional redundancy.
D. Predator release.
E. Trophic cascade.

47. Tasmanian devils have been in significant decline since the spread of a contagious facial cancer, leading to extensive conservation measures including captive breeding and transport of remaining healthy individuals to a remote island. Recent reintroduction efforts have shown signs of success because of the use of a novel anti-cancer vaccine. The vaccine helps the Tasmanian devil survive in the wild by enhancing which of the following….

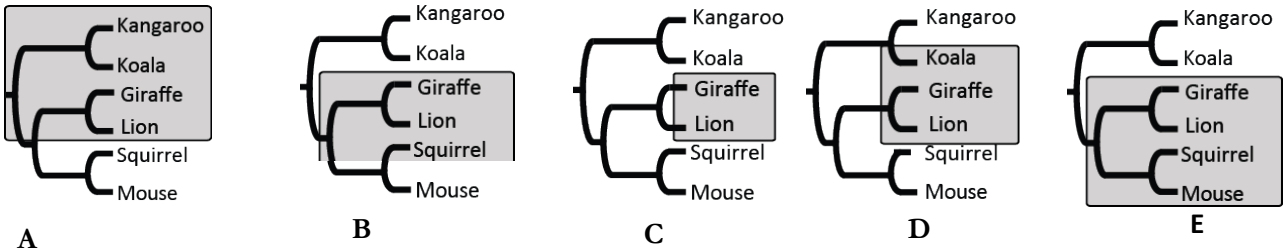
A. Immunosuppression.
B. Passive immunity.
C. Activated T cell transfer.
D. Innate immune system.
E. Secondary immune response.

48. Corals living in high-heat pools were transplanted into a cool pool, while corals of the same species living in the cool pool were transplanted into the high-heat pool. Corals from the cool pool grew just as fast as the high-heat corals in the heat stressed pool. This is an example of….

A. Adaption.
B. Coevolution.
C. Convergent evolution.
D. Phenotypic plasticity.
E. Natural selection.

5 % Biosystematics (2 Questions)

49. Using the trees below, identify the gray shading that shows a monophyletic group.



50. Which statement explains how an annelid differs from a nematode? Annelids

A. Are exclusively free-living, while nematodes are exclusively parasitic.
B. Have a complete digestive tract, while nematodes do not.
C. Have circular muscles, while nematodes have only longitudinal muscles.
D. Have a mouth derived from the blastopore, while nematodes have an anus derived from the blastopore.
E. Have a pseudocoelom, while nematodes are acoelomate.