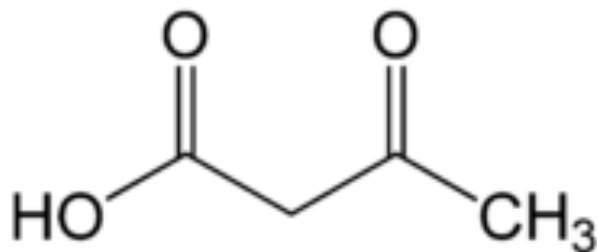
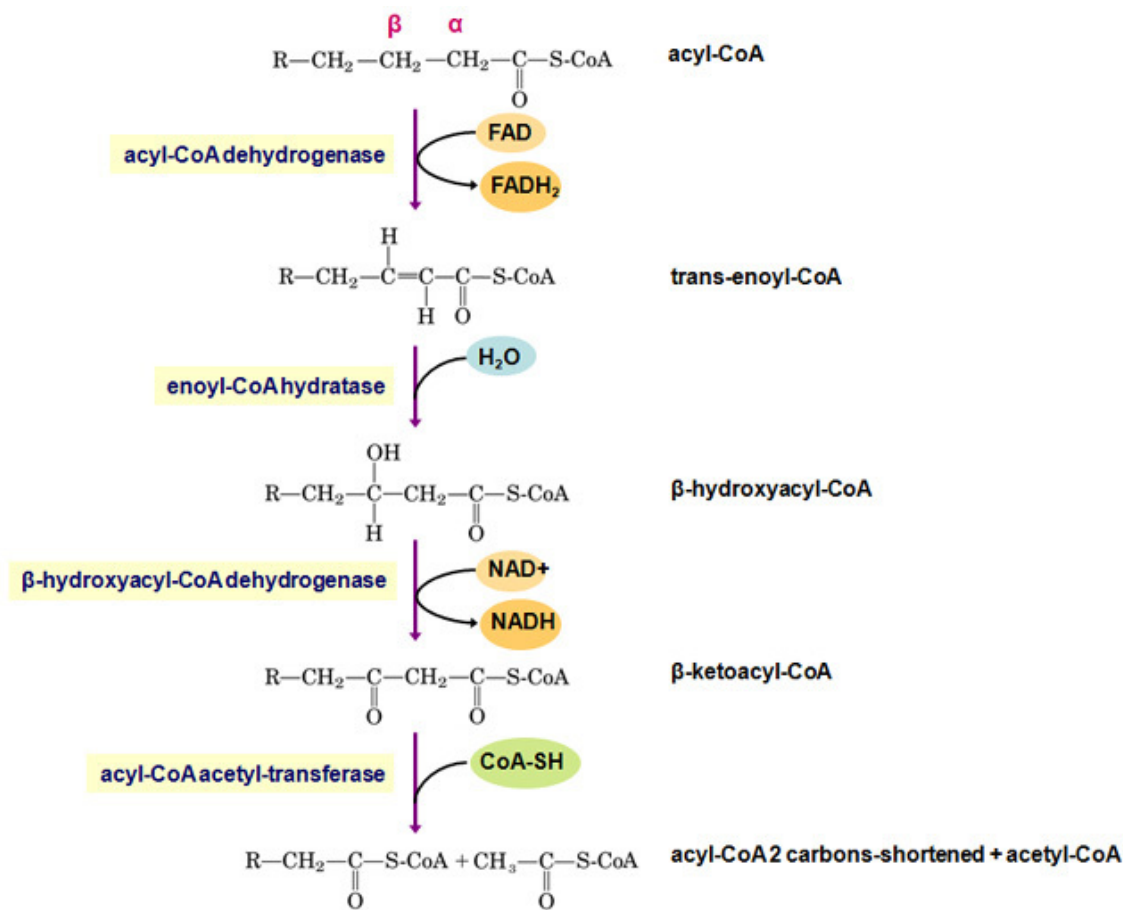


Cell and Molecular Biology

1. Glycolysis is a key biochemical in all living cells. The primary enzyme regulated in glycolysis is phosphofructokinase I (PFK-1). Which of the following molecules modulate the activity of phosphofructokinase? (Select all that apply)
 - A. ATP
 - B. AMP
 - C. Citrate
 - D. Mg^{++}
 - E. Fructose 2,6 Biphosphate
2. Action potentials in animal nerve cells are generated by a different mechanism than in plants. In animals, action potentials are generated by an influx of sodium ions followed by efflux of potassium. In plants, action potentials are generated by an efflux of chloride ions followed by the efflux of potassium. Which of the following statements are true? (Select all that apply)
 - A. Generation of action potential in plant cells is not osmotically neutral
 - B. Action potentials generated in plants, in contrast to animals, result in hyperpolarization followed by repolarization.
 - C. The efflux of chloride ions leads to hyperpolarization in plants.
 - D. In contrast to animal cells, plant cells have higher concentrations of chloride ions within the cytosol than outside the cell.
 - E. In contrast to animal cells, plant cells have lower levels of potassium ions in cytosol than outside the cell.
3. What phase of mitosis is the shortest?
 - A. Prophase
 - B. Metaphase
 - C. Anaphase
 - D. Telophase
4. What is the approximate charge of the following peptide at neutral pH (7.0) Glu-Glu-Asp-Tyr-Ile?
 - A. -3
 - B. -2
 - C. -1
 - D. 0
 - E. 3

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5. The following diagram shows the steps of Beta-oxidation on a generic fatty acid. Using the diagram, approximately how many molecules of ATP are generated by the oxidation of acetoacetate-CoA (the structure of acetoacetate is shown below)? (Hint: One molecule of acetyl-CoA generates approximately 10 molecules of ATP) Assume throughout the question that 1 molecule of NADH generates 2.5 molecules of ATP and molecule of FADH₂ generates 1.5 molecules of ATP.



- A. 20
B. 22.5

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- C. 24
- D. 26
- E. 28.5

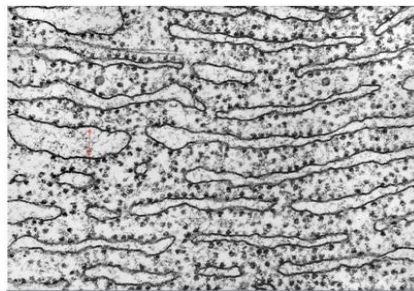
6. Varun is running differential-centrifugation on a cell lysate. Which of the following organelle(s) will precipitate along with the mitochondria (select all that apply)?

- A. Peroxisomes
- B. Chloroplasts
- C. Lysosomes
- D. Ribosomes
- E. Disrupted ER vesicles

7. The reaction of $\text{fumarate} + 2\text{H}^+ + 2\text{e}^- \longrightarrow \text{succinate}$ has electrical potential of 0.030V while the reaction $\text{FAD} + 2\text{H}^+ + 2\text{e}^- \longrightarrow \text{FADH}_2$ has electrical potential of -0.180V. What can you conclude about the reaction $\text{succinate} + \text{FAD} \longrightarrow \text{fumarate} + \text{FADH}_2$ catalyzed by the succinate dehydrogenase enzyme?

- A. The reaction is highly energetically unfavorable and is only made possible by coupling with later more energetically favorable reactions.
- B. The reaction is highly energetically unfavorable but is made energetically favorable by the succinate dehydrogenase enzyme.
- C. The reaction is highly energetically favorable and will likely occur rapidly even without the addition of the succinate dehydrogenase enzyme.
- D. The reaction is highly energetically favorable and equilibrium greatly favors the products.

8. What is the primary function of the organelle pictured above?



- A. Synthesis of Proteins
- B. Synthesis of Lipids
- C. Degradation of waste molecules
- D. Packaging and exportation of molecules outside.
- E. Production of Nuclear Membrane

9. Select all of the following that are function of EDTA.
- A. Treatment of hard water
 - B. Degradation of the ECM
 - C. Inhibition of DNAases
 - D. Degradation of Proteins
 - E. Degradation of RNA
10. Which of the following amino acid is least likely to show up in alpha helix?
- A. Glycine
 - B. Alanine
 - C. Tryptophan
 - D. Serine
 - E. Tyrosine

Genetics

Consider the following lac operon system: Questions 11 - 15 deal with the system. The lac operon can be quickly written in the form P_1 I CAP P_{lac} O Z Y A where each of the letters denotes a different portion of the lac operon system. You create hemizygous *E. coli* by also adding the lac operon to a plasmid.

11. What is the function of the Lac Y gene?
- A. It catalyzes the breakdown of lactose into galactose and glucose.
 - B. It catalyzes the transacylation of lactose.
 - C. It allows lactose to permeate across the cell membrane.
 - D. It catalyzes the conversion of galactose into glucose.
12. Abhijit has recently encountered a species of bacteria that does not metabolize lactose under any conditions. He transforms all the bacteria in the colony with a plasmid containing the normal lac operon (have functional P_1 I CAP P_{lac} O Z Y A portions) but to his surprise, the bacteria continues to be unable to metabolize lactose. The bacteria have a mutation on which portion of the lac operon?
- A. I
 - B. CAP
 - C. P_{lac}

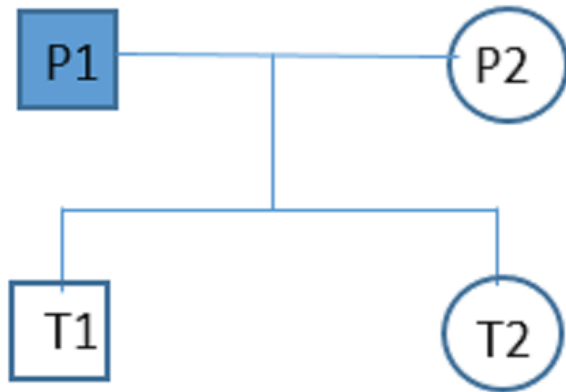
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- D. O
E. Z
13. Consider a bacteria with genotype $P_I^+ I^+ CAP^+ P_{lac}^+ O^+ Z^+ Y^+ A^+ / P_I^+ I^+ CAP^+ P_{lac}^+ O^- Z^+ Y^+ A^+$. What would you expect to be the bacteria's expression of the LacZ gene under low glucose concentration and under low and high lactose levels respectively?
- A. + / +
B. + / -
C. - / +
D. - / -
14. Consider a bacteria with genotype $PI^+ I^+ CAP^+ Plac^- O^+ Z^+ Y^+ A^+ / PI^- I^- CAP^+ Plac^+ O^+ Z^+ Y^+ A^+$. What would you expect to be the bacteria's expression of the LacZ gene under low glucose concentration and under low and high lactose levels respectively?
- A. + / +
B. + / -
C. - / +
D. - / -
15. Consider a bacteria with genotype $PI^+ I^+ CAP^- Plac^- O^+ Z^+ Y^+ A^+ / PI^+ I^+ CAP^- Plac^+ O^+ Z^+ Y^+ A^+$. What would you expect to be the bacteria's expression of the LacZ gene under low glucose concentration and under low and high lactose levels respectively?
- A. ++
B. +-
C. -+
D. --
16. In fruit flies, normal body size is dominant to dwarf body size, and red eye color is dominant to sepia eye color. Both genes are autosomally inherited. A wild-type, true-breeding male fly mates with a dwarf, sepia-eyed female fly. One of the male offspring then mates with another dwarf, sepia-eyed female. The F2 generation has the following distribution:
815 normal, red | 205 normal, sepia | 795 dwarf, sepia | 185 dwarf, red

What is the recombination frequency between the two genes?

- A. Genes are unlinked
B. 10%
C. 20%

- D. 30%
- E. 40%



17. A pedigree for an autosomal dominant inherited disease is shown above, where a shaded box or circle indicates expression of the disease phenotype. Through previous pedigree analysis, it was found that the father has a $1/4$ probability of being homozygous dominant for the disease. The parents (P1 and P2) give birth to twins (T1 and T2). What is the probability that both children have the disease?

- A) $1/16$
- B) $1/4$
- C) $7/16$
- D) $25/64$
- E) 1

18. In a population of 2500 mice, light-colored fur is dominant to dark-colored fur. 2400 mice originally have light-colored fur. However, an owl species moves into their environment, preying mainly upon the light-colored mice as they are easier to spot when hunting at night. When the owls finally leave, 80% of the dark-colored mice are left, and only 10% of the light-colored mice. After many generations, Hardy-Weinberg equilibrium is reestablished. Approximately what percentage of mice now have dark-colored fur?

- A) 10%
- B) 15%
- C) 20%
- D) 25%
- E) 30%
- F) 35%

19. In fruit flies, normal body size is dominant to dwarf body size, and red eye color is dominant to sepia eye color. Both genes are autosomally inherited. A wild-type, true-breeding male fly mates with a dwarf, sepia-eyed female fly. One of the male offspring then mates with another dwarf, sepia-eyed female. The F2 generation has the following distribution:
815 normal, red | 205 normal, sepia | 795 dwarf, sepia | 185 dwarf, red
What is the recombination frequency between the two genes?

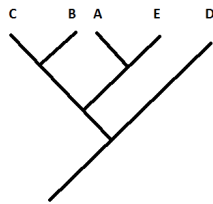
- A) Genes are unlinked
- B) 10%
- C) 20%
- D) 30%
- E) 40%

Biodiversity and Systematics

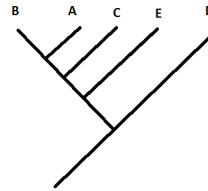
20. You are a pokemon professor working in the newly discovered (i.e. released) region Usabo. You discover a new type of pokemon. It has hard skin, and a four chambered heart. You take it to the Day-care and let it breed, and after large amounts of testing, you also discover that this new pokemon's offspring have temperature dependent gender-determination. Which of the following pokemon names is most suitable for this pokemon?
- A. Gedniturtle (relative of Blastoise, a turtle/tortoise)
 - B. Frameraligator (relative of Feraligatr, an alligator)
 - C. Dunviary (relative of Pidgeot, a bird)
 - D. Mangalickzard (relative of Sceptile, a lizard)
 - E. Yilunape (relative of Mankey, a mammal)
21. In the last Solympiad, test-takers determined that ghouls of Tokyo (depicted to the right) are echinoderms (let's not get into half-ghouls). However, recent phylogenetic studies have determined that they are in fact molluscs with closed circulatory systems and highly reduced shells. Given that they are molluscs, select all following "characteristics" that are likely shared?
- A. Their foot is most likely used to trap prey
 - B. Their foot is most likely used for locomotion and anchorage
 - C. The creature likely uses hemocyanin as a blood pigment to bind oxygen
 - D. The creature likely has 3 hearts
 - E. The creature likely has a network of respiratory tubes across its skin that allow air in

22. The DNA sequence of a homologous gene was sequenced for five different species (A-E). The table shows the number of base pair differences for the gene between species (e.g. species B and C differed by a total of 14 base pairs for the gene). Which of the following phylogenetic trees is most accurate?

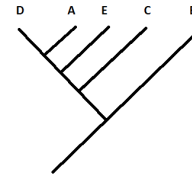
	A	B	C	D	E
A	-	4	15	35	17
B	-	-	14	32	18
C	-	-	-	29	10
D	-	-	-	-	31
E	-	-	-	-	-



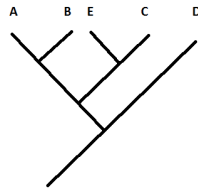
A.



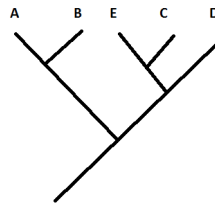
c.



d.



B.



e.

Plant Anatomy and Physiology



23. This is most probably the section of what part of a plant?
- A. Stem Section of a Dicot
 - B. Stem Section of a Monocot
 - C. Root Section of a Dicot
 - D. Stem Section of a Gymnosperm
 - E. Stem Section of a Fern
24. Select all of the following effects that induced by increased ethylene levels.
- A. The triple response (simultaneous slow down in elongation, thickening of stem and increased curvature)
 - B. Leaf Senescence
 - C. Apoptosis
 - D. Thickening of Cell Walls
 - E. Increased Cellulose Synthesis
25. When compared to plants grown in normal soils, plants grown under soil that is partially waterlogged would have which of the following characteristics?
- A. Concentrations of ethanol in water surroundings of the plants are higher in waterlogged plants.
 - B. Plants will have much less total root surface area
 - C. The density of roots will be higher than that of normal plants
 - D. Plants will often higher levels of hydrogen sulfide surrounding their roots
 - E. Plant roots will often contain thicker layers of suberin.

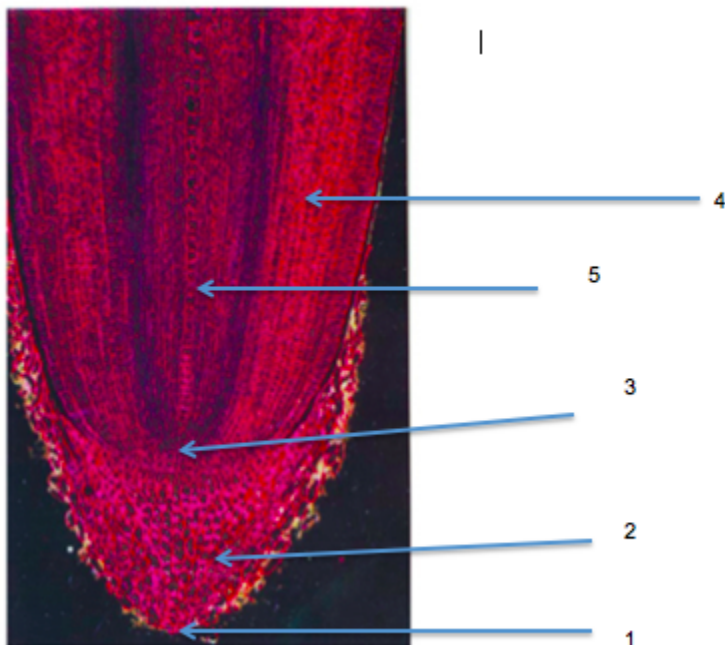
26. Flowers attract different pollinators using different colors and smells to attract different types of pollinators. You have recently discovered a yellow colored flower with faint sweet smell. The flower contains a long floral tube and is irregular. What is the most likely method of pollination?

- A. Beetles
- B. Bees
- C. Hummingbirds
- D. Bats
- E. Wind

27. Select all of the following that are similarities of both plants and charophytes?

- A. Alternation of Generations
- B. Rossete shaped cellulose synthesizing enzymes
- C. Peroxisome Enzymes
- D. Formation of Phragmoplast
- E. Presence of Sporopollenin

28. Consider the plant root section. Where is gravity sensed?



- A. 1

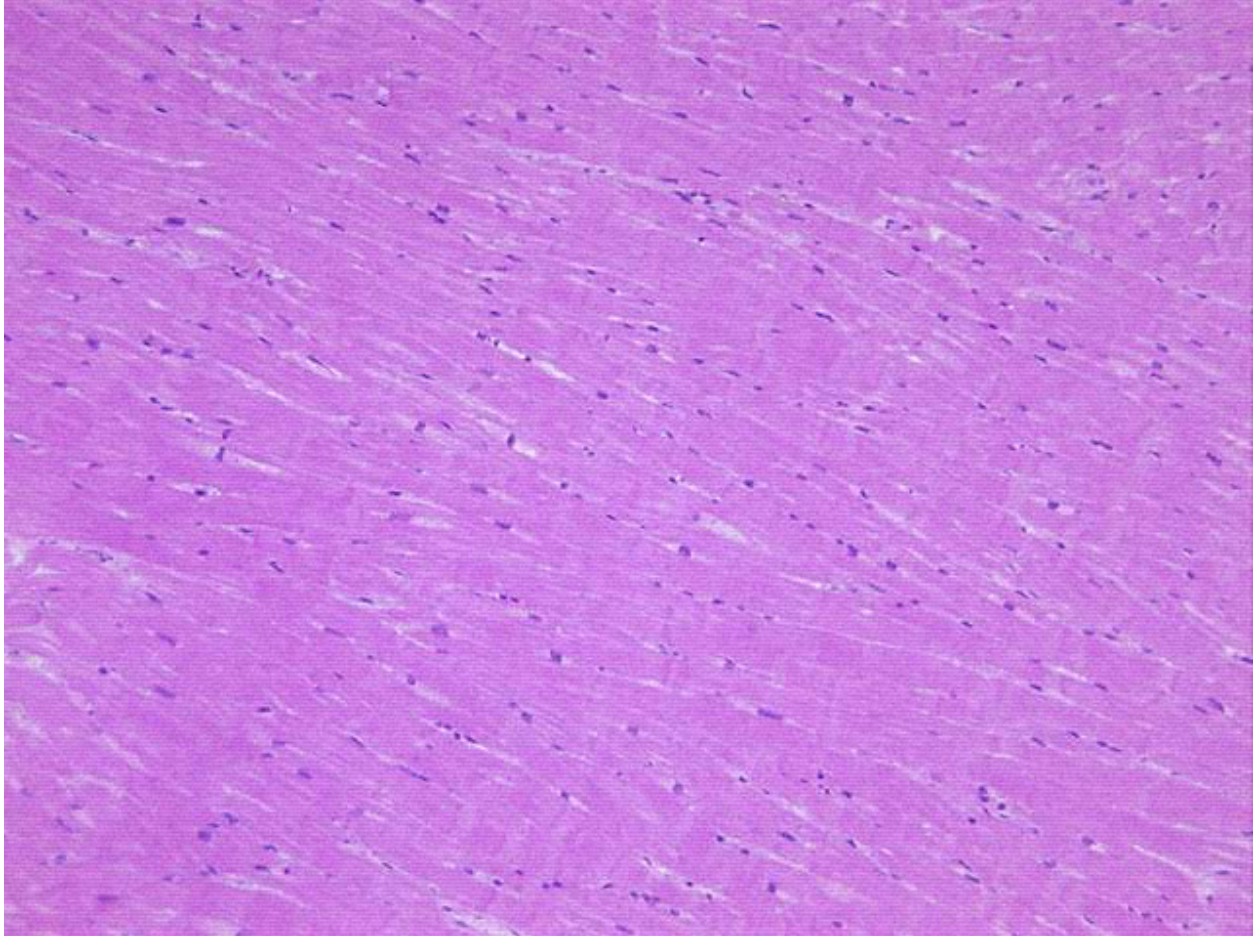
- B. 2
 - C. 3
 - D. 4
 - E. 5
29. Auxin and cytokinin both induce cell division. However different treatments of auxin and cytokine have very different effects on plants. Select all of the following statements that are correct about auxin and cytokine.
- A. Treatment of plant cells with just auxin will lead to formation of root cells.
 - B. Treatment of plants cells with just cytokine will induce formation of many very small cells
 - C. Treatment of plant cells with high levels of cytokine and low levels of auxin will lead to formation of stem tissue
 - D. Treatment of strawberry fruits with auxin will lead to much larger strawberries.
 - E. Treatment of grapes with cytokines will lead to larger grapes such as seen in Thompson grapes.
30. In contrast to animals which can move, plants must get all their minerals from the surrounding soil. As a result plants must alter their look enviroment including the pH of the surrounding soil. Which of the following statements about nutrition of plants from their surrounding soil is correct?
- A. Mineral anions such as nitrates are much more available to plants then cations although they also tend to be leached easier.
 - B. By lowering the pH of the surrounding soil, plants are able to more efficiently absorb cations.
 - C. Many micronutrients of plants, such as iron, are more available at higher pH
 - D. Low pH soil can lead to aluminum toxicity in plants
 - E. Optimal nutrient absorption for plants is at neutral pH.
31. There are several routes plants can take to perform photosynthesis. C3 plants are most common, fixing CO₂ via Rubisco and performing the Calvin Cycle all in one cell. C4 plants are slightly less common, fixing CO₂ via a different enzyme, and then shipping the product to a second cell type to perform photosynthesis. How might you expect the relative abundance of C3 and C4 plants to change in the presence of rising global temperatures and CO₂ levels?
- A. Depends. Both plants benefit equally from the increased availability of CO₂ and the increased temperature to speed up reactions.
 - B. C3 plants will increase because they are able to fix CO₂ more efficiently.

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- C. Depends. C3 plants benefit more from the increased CO₂ levels, but C4 plants benefit more from the increased temperatures.
- D. C3 plants will increase because they can better adjust to changes in temperature.
- E. C4 plants will increase because they can better absorb the increased amount of sunlight.

Animal Anatomy and Physiology

32. Hemoglobin is the primary oxygen transporter in vertebrates. Select all of the following statements about hemoglobin affinity to oxygen in different species that is correct.
- A. Larger mammals tend to have hemoglobin with higher oxygen affinity than smaller mammals
 - B. Warm blooded vertebrates tend to have hemoglobin with higher oxygen affinity than cold blooded vertebrates
 - C. Hemoglobin has higher oxygen affinity at higher temperatures
 - D. Animals that live at high elevation have hemoglobin with higher oxygen affinity than animals at lower elevation
 - E. When humans acclimatize to higher altitudes hemoglobin has decreased affinity to oxygen so that it can more efficiently deliver oxygen to muscle cells
33. While in Denmark for the 2015 IBO, Peter has become overcome with the desire for traditional “Denmarkian” food. Which of the following traditional “Denmarkian” foods found at a local seaside cafe would utilize the lymphatic system the most?
- A. Nachos and cheese
 - B. Grilled cheese sandwich
 - C. Salad
 - D. Hamburger
 - E. Italian Sandwich



34. What type of tissue section is given above?

- A. Smooth Muscle
 - B. Cardiac Muscle
 - C. Skeletal Muscle
 - D. Fibers
 - E. Cartilage
35. Abijihit has been eating very unhealthily in the college dining hall. He is suffering from anemia and depression. Composition of excess folate appears to help ameliorate his symptoms but the preliminary analysis finds that Abijihit has normal levels of folate in his body. What vitamin deficiency does Abijihit most likely have?

- A. Cobalamin
- B. Pyridoxine
- C. Niacin
- D. Riboflavin
- E. Folic Acid

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36. Which of the following descriptions of central nervous organs are matched with their correct function

- A. Amygdala-Processing of emotions such as fear
- B. Hippocampus- Formation of new memories
- C. Cerebellum- Decision Making
- D. Medulla Oblongata- Breathing and other involuntary actions
- E. Spinal Cord- Short Term Memory Formation

37. Order the following parts of an earthworm digestive system in order:

- I. Esophagus
- II. Gizzard
- III. Crop
- IV. Intestine
- V. Pharynx
- VI. Mouth

- A. VI, I, V, II, III, IV
- B. VI, V, I, II, III, IV
- C. VI, I, V, III, II, IV
- D. VI, V, I, III, II, IV

38. What developmental tissue are the lens cells of the eyes derived from?

- A. Endoderm
- B. Mesoderm
- C. Ectoderm

39. Select all of the following symptoms will occur following acclimatization to high elevation in both a short time period or long periods of time?

- A. Increased pH of blood in the short time period
- B. Increased levels of urine in the short time period
- C. Hypertrophy of the left ventricle in the long time period
- D. Decreased levels of 2,3 BPG to increased affinity of hemoglobin in the short term
- E. Increased levels of hemocrit in a long period

40. Which of the following bone pairs form a hinge joint?

- A. Humerus and Ulna

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- B. Humerus and Scapula
 - C. Joint between adjacent vertebrae
 - D. Pelvic joint
41. The axon of a neuron is artificially stimulated at both ends, causing action potentials occur at each site of stimulation. What will happen when the two waves of action potentials meet in the middle of the axon?
- A) The two waves will never meet. Action potentials can only propagate in one direction down an axon.
 - B) The two waves will stop.
 - C) The wave with the stronger action potential will continue, and the other will stop.
 - D) The waves will both continue past each other.
 - E) The waves will rebound and go back in the direction they came from.
42. Brown fat is a type of adipose tissue found in mammals. Its primary function is to produce body heat without shivering. This capability is due to a high concentration of the protein thermogenin in the inner membrane of mitochondria, which provides a channel for protons to flow across. Which of the following statements about brown fat is FALSE?
- A) Hibernating mammals have an especially high prevalence of brown fat cells.
 - B) ATP production in the mitochondria is decreased.
 - C) The energy for heat production comes from the proton motive force.
 - D) The intermembrane space of the mitochondria has a higher than normal pH.
43. A student isolated cultures of 3 different human cell types, but forgot to label them and now can't remember what type of cells each culture is. Using a microscope, he was able to determine that cells in culture 1 had abundant smooth ER, cells in culture 2 had abundant rough ER, and cells in culture 3 had abundant peroxisomes. Which of the following cells might be in each culture?
- A) 1 = Muscle Cells, 2 = Plasma B Cells, 3 = Gonad Cells
 - B) 1 = Red Blood Cells, 2 = Liver Cells, 3 = Macrophages
 - C) 1 = Liver Cells, 2 = Macrophages, 3 = Pancreatic Cells
 - D) 1 = Gonad Cells, 2 = Pancreatic Cells, 3 = Liver Cells
 - E) 1 = Pancreatic Cells, 2 = Muscle Cells, 3 = Red Blood Cells

44. Split-brain surgery is a procedure designed to alleviate epileptic seizures. In the procedure, the patient's corpus callosum is severed, limiting communication between the two hemispheres of the brain. Though patients appear mostly normal after the surgery, certain lateralized functions can be affected. Language processing has been shown to be a primarily left-dominated function. An experiment is set up, in which two words are flashed to a split-brain patient simultaneously. The word "cat" appears in his left visual field, and the word "dog" appears in his right. What will the patient respond when asked which words he saw?

- A) Cat
- B) Dog
- C) Cat and Dog
- D) Nothing

Ethology

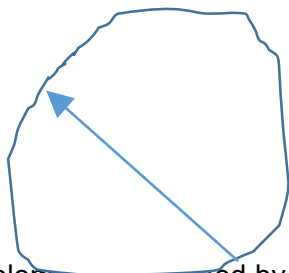
45. Which of the following studies would be ethological study(select all that apply)?

- A. Studying bees outside a manmade beehive
- B. Studying polar bears in the Denver zoo
- C. Studying gorilla's interaction with little children
- D. Studying polar bears in the Artic Ocean
- E. Study mountains lions in the Rocky Moutains

46. What is the correlation coefficient between first cousins?

- A. $\frac{1}{8}$
- B. $\frac{1}{4}$
- C. $\frac{1}{2}$
- D. $\frac{2}{3}$
- E. $\frac{1}{6}$

47. Examine the diagram showing the direction of a bee's waggle dance. If this dance occurred at 12pm in the at a latitude of 50°N, in which direction does the food source lie?



- A. SE
- B. S
- C. NW
- D. NE
- E. N

Ecology

48. The Lotka-Volterra equations (see image) are a pair of equations that describe the population changes over time in a predator-prey interaction. In these equations:

$$\frac{dx}{dt} = \alpha x - \beta xy$$

$$\frac{dy}{dt} = \delta xy - \gamma y$$

x is number of prey.

y is number of predators.

dx/dt and dy/dt are the growth rates of the populations.

t is time.

α , β , δ , γ are positive constants that describe the interaction between the species.

Which of the following correctly associates a constant and the aspect of the interaction it describes?

- A) α represents growth of the predator by eating prey.
 - B) β represents natural death rate of the prey when predator is not present.
 - C) δ represents death of prey to predator.
 - D) γ represents natural death rate of predator when prey is not present.
49. What is the best definition of a keystone species?
- A. A species that generates most of the biomass in an ecosystem
 - B. A species that eliminates a previous species that lived in an area
 - C. A species that lives in a limited area of space
 - D. A species whose presence prevents other species from becoming a domineering presence in the ecosystem
 - E. A species that is resistant to invasive species.

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50. A population of Gobi bear (*Ursus arctos gobiensis*) exhibited a size of 532 in 1980, 602 in 1990, 293 in 2000, and 340 in 2010. What is this population's effective population size?
- A. 404
 - B. 524
 - C. 343
 - D. 416
 - E. 532