

USABO SEMIFINAL EXAMINATION
March 23 to March 27, 2015

Read the directions included with the *Student Certification Form* provided by your teacher. Be certain to complete all requested information and to sign the Student Certification Form. Your exam cannot be graded without completion of this form. Use your scantron to answer all questions in Parts A and B.

PART A: Each question is valued at 1 point unless indicated otherwise.

1. Which of the following sequences is most likely to be cleaved by a restriction endonuclease?
 - A. 5'-CCCAAA-3'.
 - B. 5'-TAATTA-3'.
 - C. 5'-GAGAGA-3'.
 - D. 5'-GTGCTC-3'.
 - E. 5'-ACTTCA-3'.

2. Which of the following is TRUE about Anaphase of Mitosis?
 - A. The chromosomes condense.
 - B. The nuclear membrane disintegrates.
 - C. Chromosomes line up at the metaphase plate.
 - D. Spindle microtubules attach to chromatids.
 - E. Sister chromatids separate and move towards the opposite poles.

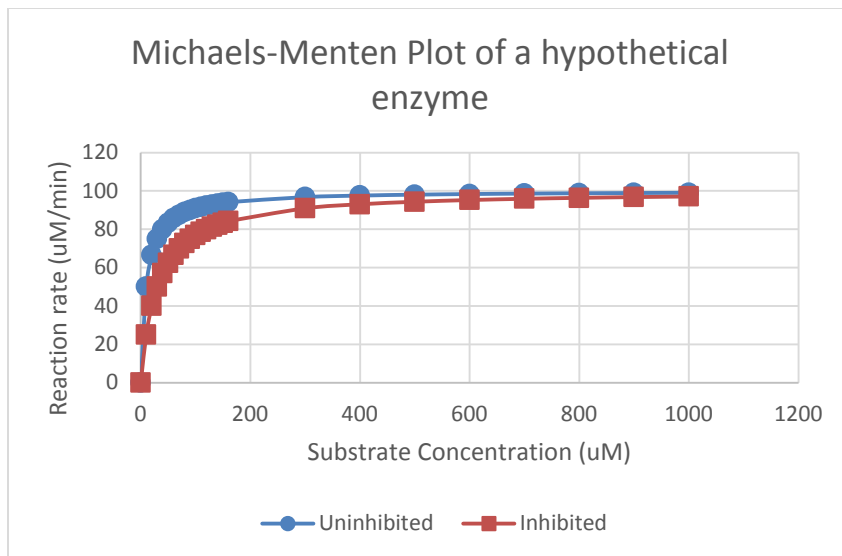
3. You are taking a biology exam. You are provided with several ultrastructure images of a process obtained from a neuron, imaged by electron microscopy. Looking at the electron micrographs you observe that there's a 'triskelion-like' structure around a circular body near the plasma membrane. You also see a similar structure further away from the membrane. What protein do you think this could be and what process is it?
 - A. Profilin, actin polymerization.
 - B. Clathrin, endocytosis.
 - C. Cofilin, actin depolymerization.
 - D. Neutrophils, inflammation.
 - E. AMPA receptor, vesicle release.

4. Which of the following is true about transcription in a bacterial cell?

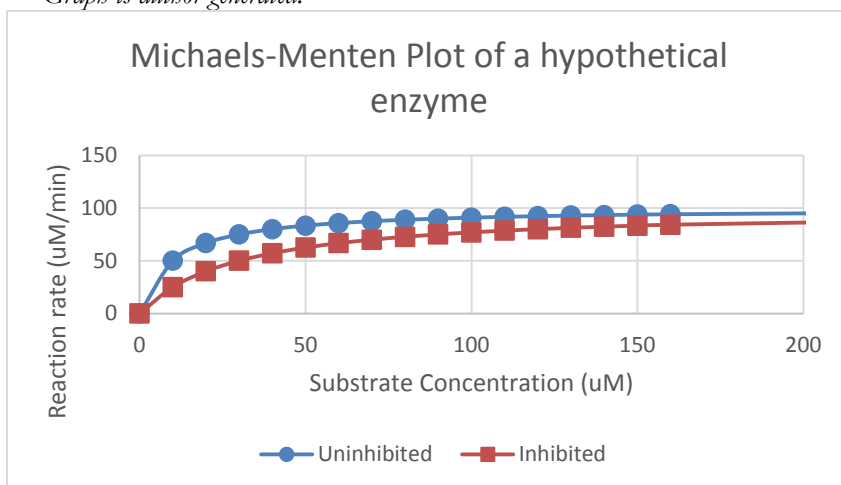
- I. A single mRNA transcript will often code for more than one protein
- II. Nascent mRNA transcripts undergo numerous post transcriptional modifications before translation initiation
- III. mRNA transcripts use a start codon that codes for glycine
- IV. Promoters for transcription usually feature a TATA rich region about 10bp upstream of the start codon
- V. The same RNA polymerase transcribes rRNA, tRNA, and mRNA.
- VI. The DNA template strand is read by the polymerase in the 3' to 5' direction
- VII. The transcript contains a purine rich sequence about 8bp before the start codon that is used in translation initiation

- A. I and V only.
- B. I, V, VI, and VII only.
- C. II, III, VI, and VII only.
- D. II, IV, VI, and VII only.
- E. I, III, IV, and V only.

5. Hypothetical data for an enzyme on its reaction kinetics were collected in the presence and absence of an inhibitor. Assuming that the enzyme is properly modeled using Michaelis-Menten kinetics, Use the two plots below to answer the following questions. *Note that the plots show the same data, however, the horizontal axes are scaled differently.*



Graph is author generated.



Graph is author generated.

What is the maximum reaction rate possible for the uninhibited enzyme under these conditions?

- A. 10 uM/min.
- B. 40 uM/min.
- C. 80 uM/min.
- D. 100 uM/min.
- E. 120 uM/min.

6. Which of the following statements is FALSE regarding mechanisms of enzyme inhibition?

- A. Reversible inhibitors form only noncovalent bonds with the inhibited enzyme
- B. Reversible inhibitors are often classified as poisons, whereas irreversible inhibitors are often used as medicines.
- C. Competitive inhibitors affect the K_m of the enzyme but not the V_{max} .
- D. Noncompetitive inhibitors can bind to the enzyme itself, as well as to the enzyme-substrate complex.

7. What are the observed Michaelis-Menten constants (K_m) for the uninhibited and inhibited enzyme conditions respectively?

- A. 80uM/min and 60uM/min.
- B. 60uM/min and 80uM/min.
- C. 10uM and 30uM.
- D. 30 uM and 10uM.
- E. 50uM and 50uM. The inhibitor does not affect the apparent K_m .

8. Which of the following statements is TRUE regarding the structure and functions of the Golgi apparatus?

- A. The Golgi apparatus is constantly “created” and “destroyed”.
- B. The trans side of the Golgi apparatus is facing the endoplasmic reticulum.
- C. SPR receptors are found embedded in the membranes of the Golgi apparatus medial membranes.
- D. Only intramolecular disulfide bonds are formed in the in the Golgi apparatus.

9. The genome of the Ebola virus consists of ssRNA with negative polarity. In order to express its genetic information the virus should:

- A. Translate its genome directly.
- B. Add Cap and polyA to the genome, so that the ribosome can recognize the RNA molecule as mRNA.
- C. Copy the genome into positive polarity RNA which can be translated.
- D. Convert the genome to dsDNA which can be transcribed and then translated.
- E. Force the ribosome to read the genome RNA in 3' to 5' direction.

10. Which way(s) can the addition of ubiquitin NOT affect proteins?

- A. Affect the activity of the protein.
- B. Change their location within a cell.
- C. Reduce in vitro stability of protein isolate.
- D. Promote protein interactions
- E. Reduce in vitro stability of protein isolate.

11. You are made a dilution plating with a soil sample by resuspending 0.1g of soil in 10 mL of nutrient medium and labelled it *Soil Suspension*. Next, you followed the dilution scheme below:

Dilution Scheme

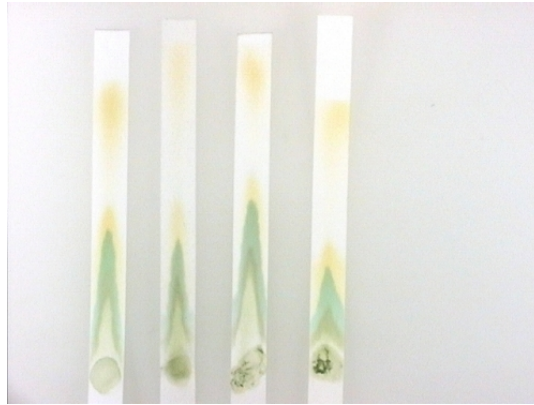
- Step 1. Transfer 0.1 mL from the *Soil Suspension* to 10mL of nutrient medium, mix well, and transfer 1 mL to another 10 mL of nutrient medium.
- Step 2. Carefully, pipette 1 mL from the suspension in Step 1 and plate on nutrient-poor agar.

The next day, you count 34 colonies growing on your plate. What is your final dilution factor and the most reasonable number of Colony Forming Units (CFUs) per mL in your starting sample?

- A. 10^{-4} ; 34 CFUs.
B. 10^{-4} ; 34×10^4 CFUs.
C. 10^{-4} ; 34×10^3 CFUs.
D. 10^{-3} ; 34×10^3 CFUs.
E. 10^{-3} ; 34×10^4 CFUs.
12. You would like to know if Proteins A and B interact. You immobilize Protein A (MW=30kD) to the resin, incubate it with Protein B (MW=30kD) for a while, wash it, and run a SDS-PAGE denaturing gel. What could be a possible result?
- A. If there is no interaction, then you will see no bands.
B. If there is an interaction, then you will see one band at 60 kD.
C. If there is an interaction, you will see two distinct bands.
D. If there is an interaction, then you will see one band at 30 kD.
E. It is not possible to predict the result of the experiment based on the given information.

13. A figure shown is below the result of paper chromatography for plant pigments from *Arabidopsis thaliana*. What is the main principle behind the observed separation of pigments?

?



Source: <http://www4.unsp.edu/biology/courses/botlab/Lab11a.html>.

- A. Differences in the polarity of the pigments.
- B. pH gradient.
- C. Differences in the molecular weight (mass) of the pigments.
- D. Amount of sugars produced by the plants used to generate the pigment sample.
- E. Amount of oxygen produced by the plants used to generate the pigment sample.

Questions 14 & 15. Indicate whether the following are TRUE (A) or FALSE (B).

14. Which of the following statements about different types of photosynthesis is TRUE?

- A. C3 plants tend to have better water use efficiency, and grow where water is less limiting relative to C4 and CAM plants.
- B. C4 and CAM photosynthesis are both adaptations to arid conditions that result in better water use efficiency.
- C. C4 plants do not use rubisco due to its affinity for oxygen, which leads to the much less efficient photorespiration.
- D. CAM plant leaves have Kranz anatomy, where photosynthesis takes place in the bundle sheath cells.
- E. Corn is an example of a CAM plant.

15. Which of the following structures are not found in the location designated?

- A. Pith – monocot root.
- B. Endodermis – dicot root.
- C. Vascular bundle – monocot stem.
- D. Epidermis – dicot stem.
- E. Spongy mesophyll – monocot leaf.

16. A dichotomous key would be described as ALL of the following EXCEPT:

- A. A taxonomic method of identification.
- B. A set of fixed sequence and structure of identification steps.
- C. An analytical key.
- D. Requiring a detailed background knowledge at each step.
- E. Requiring a decision process at each step.

17. In angiosperms, the embryo sac consists of

- A. 3 antipodal cells (n), 2 synergids (n), and one central cell (n).
- B. 2 antipodal cells (n), 2 synergids (n), and one central cell (n).
- C. 2 antipodal cells (n), 2 synergids (n), and one central cell (3n).
- D. 2 antipodal cells (n), 3 synergids (n), and one central cell (2n).
- E. 3 antipodal cells (n), 2 synergids (n), and one central cell (2n).

18. Which of the following is TRUE of plants, in general (Select all that apply)?

- A. Flow in xylem is always unidirectional and upwards.
- B. Flow in phloem is always unidirectional and downwards.
- C. Fertilization occurs near archegonia in both ferns and moss.
- D. Unlike roots, stems have ground tissue and can transport water.
- E. Evolution of seeds and fruits are most likely to be responsible for increasing genetic change or diversity between plants.

19. In general, what is the very first step in the germination of a seed?

- A. Imbibition of water.
- B. Emergence of the radicle.
- C. Breakdown of seed coats.
- D. The release of gas from the embryo.
- E. Hydrolysis of starch and other food reserves.

20. Moving from the edge of a flower toward its center, the order of floral structures is

- A. Calyx, corolla, anthers, stigma, and sepals.
- B. Ovules, carpels, stamens, and petals.
- C. Ovules, stigma, petals, stamens, and corolla.
- D. Sepals, petals, carpels, stamens, and ovules.
- E. Sepals, petals, stamens, carpels, and ovules.

21. The durability of pollen grains is best explained by

- A. A strong seed coat that prevents cracking.
- B. Endosperm reserves.
- C. Internal partner cell that supplies nutrients.
- D. Tendency of pollen grains to lodge in cool, dry areas.
- E. Thick outer wall that prevents the loss of moisture.

22. There are several muscles in the body that are part of antagonistic pairs. In short, when a particular location action is required, one set of muscles contracts while the antagonist simultaneously relaxes. Select the pair that is NOT an antagonistic pair.

- A. Gracilis/Sartorius.
- B. Biceps femoris/Quadriceps Femoris.
- C. Biceps femoris/Triceps brachii.
- D. Adductor magnus/Gluteus medius.
- E. Soleus/tibialis anterior.

Questions 23 to 26. True (A) or False (B), skeletal muscles contract when

23. Acetylcholine binds to postsynaptic receptors on the muscle cell.

24. ATP is released from the sarcoplasmic reticulum following depolarization.

25. Calcium ions bind to regulatory proteins to expose myosin binding sites on actin.

26. ATP is hydrolyzed by myosin heads prior to breaking cross-bridges.

Questions 27 to 30. Determine if the following statements comparing male and female gametogenesis in humans are TRUE (A) or FALSE (B):

27. Meiosis for male gametogenesis begins at puberty, but meiosis for female gametogenesis begins before birth.

28. Both male and female gametogenesis is completed after fertilization.

29. Meiosis in males produces multiple gametes per cycle but each complete meiotic cycle in females produces only one viable gamete.

30. Both male and female gametes contribute DNA and cytoplasmic organelles to the zygote during fertilization.

31. Plasma proteins are responsible for a number of physiological functions. Which of the following are examples of plasma protein functions?

- I. Protection against bacteria and viruses.
- II. Transportation of iron.
- III. Transportation of oxygen.
- IV. Transportation of fats.
- V. Transportation of water-soluble hormones.
- VI. Transportation of lipid-soluble hormones.
- VII. Protection against blood loss.
- VIII. Activation of nuclear receptors.

- A. I, II, IV, VI, VII only.
- B. I, IV, V, VIII only.
- C. II, III, IV, V, VII only.
- D. I, III, VI, VII only.
- E. III, V, VI, VII, VIII only.

32. Grave's disease occurs when there is

- A. Excess thyroid hormone due to the presence of antigens.
- B. Excess thyroid hormone due to the presence of antibodies.
- C. Not sufficient thyroid hormone due to the presence of antigens.
- D. Not sufficient thyroid hormone due to the presence of antibodies.

33. The final step in the synthesis of the biologically active form of vitamin D in humans occurs in the:

- A. Kidney.
- B. Liver.
- C. Parathyroid.
- D. Skin.
- E. Thyroid.

34. Which of the following statement (s) is (are) CORRECT regarding different hormones produced in human?

- A. Glucocorticoids typically activate signal transduction pathways.
- B. Thyroxines are peptide hormones, which have extracellular receptors.
- C. Leptin, a hormone produced from adipose tissue, suppresses appetite.
- D. Epinephrine can increase gastric motility and stimulate secretion of digestive enzymes.
- E. Vasopressin is stored in neurohypophysis; it regulates osmolarity by increasing reuptake of water from distal tubule.

35. Which of the following are TRUE regarding immune systems in human (Select all that apply)?

- A. Cytokines are secreted proteins that mediate both humoral and cell-mediated immunity.
- B. Immune cells moving through the body may use both blood vessels and lymphatic system.
- C. Potentially, cortisol may be used as treatment for a hyperactive immune system.
- D. T cell receptors cannot recognize foreign antigens unless they are in the context of major histocompatibility complex and cluster of differentiation.

36. Blood glucose levels are lowered by insulin by

- A. Inhibiting glucose absorption from the intestines.
- B. Promoting glucose excretion in the urine.
- C. Stimulating cellular uptake and utilization of glucose.
- D. Stimulating the conversion of glucose to amino acids.
- E. Stimulating the conversion of glucose to fatty acids.

37. Which of the following is an adaptive explanation?

- A. Tadpoles lose their tails in the process of becoming frogs because of programmed cell death, or apoptosis.
- B. Some finches in the Galapagos have longer, thinner beaks because their ancestors stopped mating with other finches on the islands and evolved independently after that point.
- C. The “Mad Hatterpillar” carries around a stack of shed head exoskeletons because its molting mechanism continues to push the stack higher as it grows.
- D. The darker form of the peppered moth increased in relative frequency after the industrial revolution because it was better equipped to camouflage itself against the darker background provided by soot-covered bark.
- E. The relative frequency of short pea plants increased drastically because blight destroyed 95% of Mendel’s crops.

38. All of the following are examples of operant conditioning EXCEPT:

- A. Every time you do not pick up your clothes, you have to put a quarter for each piece in the “Family Pickup After Yourself” jar.
- B. In an experiment, the subject received a slight electric shock when they got an answer wrong.
- C. You put on your earbuds to mask the noise on the bus ride home.
- D. Your biology teacher exempts you from the final exam to give you more time to prepare since you have been sick.
- E. Your biology teacher excuses students from dissecting a pig if they ace the anatomy chapter test.

39. Opossums have no highly developed or specialized mechanisms for attack or aggressive offense, but defensive behavior is highly developed. Which of the following is NOT a defensive behavior that might be displayed by an opossum?

- A. Defecating.
- B. Displaying intimidation.
- C. Feigning death.
- D. Hissing, growling or screeching.
- E. Jumping toward the aggressor.

Questions 40 to 43. Hemophilia is a condition characterized by inability to control bleeding in response to injury. The genes for most common forms of hemophilia are on the X chromosome. Determine if the following statements are true or false. Select "A" for TRUE and "B" for FALSE.

40. A woman can only have X-linked hemophilia if her father has hemophilia.

41. A boy with X-linked hemophilia must have a maternal grandfather with hemophilia.

42. A bone marrow transplant from a normal donor would completely cure hemophilia.

43. A liver transplant from a normal donor would completely cure hemophilia.

44. Which of the following about chromatin in eukaryotes is/are generally TRUE?

- I. The nucleosome is a complex of DNA and four histone subunits.
- II. Histone tail acetylation is most often associated with an increase of gene transcription.
- III. DNA methylation most often decreases regional gene transcription.
- IV. Compact regions of chromatin help facilitate transcription factor – DNA interactions, and are thus associated with genomic regions of high transcription.
- V. Chromatin structure of a parent cell affects the phenotype of the daughter cells.
- VI. Amino acid substitutions in histone proteins are often well tolerated.

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

Questions 45 to 47. Jack and Diane marry and have a son John. Four years later, they divorce amicably. Jack later marries Jill and they have a son, Fletch. Diane remarries a man named Charles and they have a daughter Beth. Twenty-five years pass, Beth is married to Bob and they have twins Kate and William. Fletch is married to Ellen and they have a son Michael. The entire blended family reunites for John's wedding.

45. Which of the following carry Diane's mitochondrial DNA, but not Jack's Y chromosome?

- A. Bob
- B. Charles.
- C. Fletch.
- D. Michael.
- E. William.

46. Which of the following carry Diane's mitochondrial DNA and John's Y Chromosome?

- A. Fletch
- B. John
- C. Michael
- D. William

47. What is the coefficient of relatedness between John and Michael?

- A. $1/16$.
- B. $1/8$.
- C. $1/4$.
- D. $3/8$.
- E. $1/2$.

48. You take a summer job on earthworm population genetics in the composting division of the Berkeley, California Department of Waste Management. Your composting field is full of 100,000 very happy, well-fed earthworms hard at work disposing of kitchen scraps. One day catastrophe strikes. A flood, caused by a faulty valve in the sprinkler system kills off 99% of your earthworms, and only 1000 random individuals have survived. Two months later your earthworm population recovers back to 100,000 individuals. Your boss says, "Thank goodness we are back to 100,000 earthworms. Now there is nothing to worry about." What do you tell your boss?

- I. The bottleneck has caused genetic diversity to be higher, making your earthworm population better at adaptation.
- II. More of the earthworms after the population bottleneck are related to one another compared to before the bottleneck, increasing the likelihood of inbreeding, a very bad thing for the earthworms.
- III. The bottleneck may have caused detrimental mutations to spread in the population, a problem for your earthworms.
- IV. The bottleneck and population recovery has not affected genetic diversity for your earthworm population, because only the total number of individuals in the population influences genetic diversity.

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

49. As part of your summer job as an intern in the composting division of the Berkeley, California Department of Waste Management, you sequence the genomes of all 100,000 earthworms in the city compost bin. You find a mutation that is found in 90% of all the earthworms that you survey. Your boss says, "Aha! This mutation must have spread through the population by selection! This is cool!" What do you tell your boss?

- I. It would be impossible for a mutation to spread to 90% of the population unless it was favored by natural selection.
- II. Non-random mating where every individual produces offspring but prefers to mate with an organism that has the same type of allele that it does at that locus, can also cause the allele to spread through the population.
- III. Genetic drift can cause alleles to spread through populations, so the mutation might be neutral.
- IV. You cannot determine if selection has acted on the allele without a selectively neutral control for comparison.

- A. I only.
- B. II & III only.
- C. II, III & IV only.
- D. III only.
- E. III & IV only.

50. For your Intel Science Talent Search project, you sequence the nuclear genome of Euglena and find the nearest match for each gene sequence in other organisms. You find that 85% of the genome matches with single-celled heterotrophs like amoeba, dictyostelium, and yeast. The other 15% of the genome matches with autotrophs like maize, Arabidopsis, and cyanobacteria. Which of the following could explain your results? There has been a transfer of genes from the euglena:

- A. Mitochondria to the nucleus, resulting in a match with autotrophs for those genes.
- B. Golgi apparatus to the nucleus, resulting in a better match with autotrophs for those genes.
- C. Chloroplast to the nucleus, resulting in a match with autotrophs for those genes.
- D. Lysosome to the nucleus, resulting in a match with autotrophs for those genes.
- E. Paramylon granules to the nucleus, resulting in a match with autotrophs for those genes.

51. Which of the following is NOT TRUE regarding translation in prokaryotes?

- A. tRNA synthetases couple amino acids to charged tRNAs.
- B. The peptidyl transferase reaction requires a charged tRNA bound at the P site.
- C. Polypeptide synthesis proceeds from the amino end to the carboxyl end; while mRNAs are translated in a 5'-to-3' direction.
- D. The positioning of the very first tRNA entering the P site is facilitated by the binding of mRNA to 16s RNA in the small subunit of the ribosome.

52. Why is it disadvantageous to grow deciduous trees in Oregon?

- A. There is not enough water available in winter to meet the tree's water requirements.
- B. There is insufficient light to support photosynthesis in the winter.
- C. There is insufficient moisture in summer to support photosynthesis.
- D. The soil is too shallow for their roots to support the weight of the tree.
- E. The absence of leaves the trees with no protection during the very bitter winters.

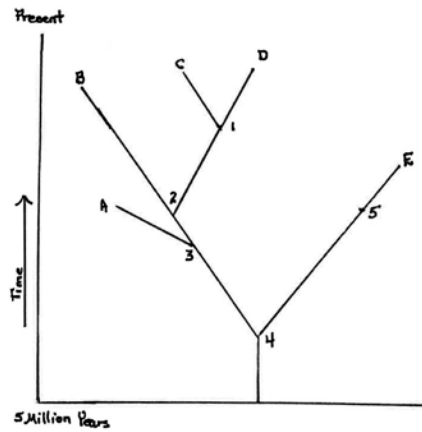
53. Desert nights in Yuma are cool due to:

- A. The lack of water vapor in the air to prevent heat loss.
- B. The cooling effect of the high winds found in the desert.
- C. Daytime warming is limited by the angle of the sun's rays.
- D. Daytime warming is prevented by the characteristic heavy cloud cover.
- E. Desert rocks have a low specific heat and thus quickly lose the day's heat.

Questions 54 to 56. Decide if the following questions are TRUE (A) or FALSE (B) regarding the tropical rainforest of South America that lies roughly within the latitudes 28 degrees south of the equator.

54. The soil fertility is high due to the immense vegetative growth and the rapid decomposition of plant material.
55. One finds numerous trees, but a limited diversity of tree species.
56. The actions of man are responsible for the mass extinctions that could take place due to large-scale destruction of the tropical rainforest.
57. Which statement is TRUE for flowering plants found in the tundra?
- A. All are biennials.
 - B. All are perennials.
 - C. There is a mixture of annuals and biennials.
 - D. There is a mixture of annuals, biennials, and perennials.
 - E. There is a mixture of perennials and annuals.

Refer to the phylogenetic tree for Questions 58 to 60. Notice that the tree is not a true cladogram based on shared, derived characters, but on the time of divergence from a common ancestor.



58. Which number indicates the common ancestor for Species C and E?

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

59. Which of the following statements about the above cladogram is the most accurate?

- A. It depicts an unrooted phylogenetic tree.
- B. This is an example of an ultrametric tree.
- C. A trait that formed at 5 is considered an autapomorphy.
- D. D is most likely extinct.
- E. B is as evolutionarily distant from C as A is from D.

60. If the tree was derived from common homologies, a clade within the tree would include (Select all that are TRUE):

- A. A, B, C, D, E.
- B. A, B, C, D.
- C. A, B, C, E.
- D. A, C, E.
- E. B, C, D.

PART B: Each question is valued at 2 points.

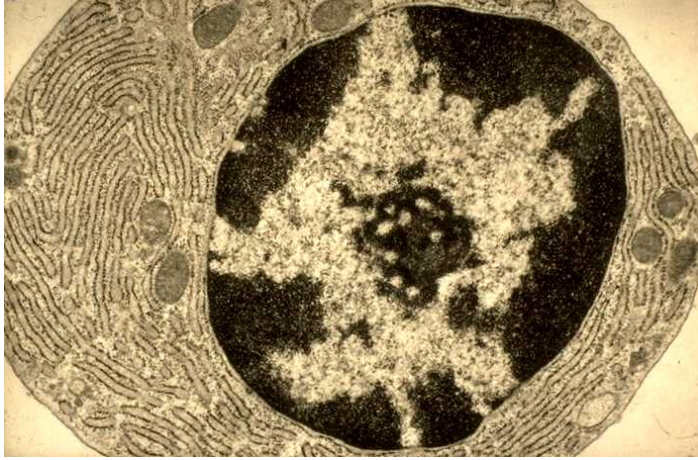
61. The ability of a cell to oxidize and reduce compounds is of the utmost importance for cell survival. Which of the following is true about NAD⁺, NADP⁺, and their reduced forms NADH and NADPH in the cell?

- I. NADH and NADPH can be used interchangeably by many biological processes as reducing agents.
- II. NAD⁺ is primarily used in catabolic cellular activities.
- III. NADPH is primarily used in catabolic cellular activities.
- IV. The cell aims to maintain a high NADH to NAD⁺ ratio.
- V. The cell aims to maintain a high NADPH to NADP⁺ ratio .
- VI. Most enzymes that use NADH are unable to use NADPH and vice versa.

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

62. Which of the following statements are TRUE regarding the similarities and differences between prokaryotic and eukaryotic translation (Select ALL that apply.)?

- A. In both prokaryotes and eukaryotes translation is coupled to transcription.
- B. Peptidyl transferase activity of the ribosomes in prokaryotes and eukaryotes is attributed to a ribozyme.
- C. Termination factors in prokaryotes resemble tRNA whereas termination factors in eukaryotes do not.
- D. The initiation codon is recognized by an initiation tRNA (tRNA_i) in all organisms.



63.

Source: <http://www.bmb.leeds.ac.uk/illingworth/food/immunol/plasma.jpg>.

The image above displays a cell of the immune system. Most likely this is:

- A. T helper cell.
- B. T cytotoxic cell.
- C. Plasma cell.
- D. Naïve B-cell.
- E. NK lymphocyte.

64. Transcription factors are often allosterically regulated by protein kinases. Select ALL the sequences that would MOST likely be responsible for protein kinase regulation in transcription factors.

- A. AGVSFN.
- B. KGITHRW.
- C. IVVIKRF.
- D. KIGVIKP.
- E. IGVYVSP.

65. Select ALL that are TRUE about the structure and function of nucleic acids.

- A. B form DNA is closest to the structure of DNA in living cells.
- B. A form DNA is closest to the structure of DNA in living cells.
- C. RNA is susceptible to hydrolysis in an alkaline environment.
- D. The major groove of B DNA reveals information about base sequences.
- E. Telomerase contains a DNA segment as its template for telomere elongation.

66. Select ALL that are FALSE regarding the ribosomes.

- A. The catalytic site is protein.
- B. Catalytic activity is still relatively functioning after removing protein portions of ribosomes using proteases.
- C. Ribosome catalyzed protein synthesis occurs in N to C direction.
- D. The catalytic site is RNA and thus a ribozyme.
- E. Catalytic activity is still relatively functional after removing RNA portions of ribosomes using RNAases.

67. Gel electrophoresis uses an electrical current to separate DNA fragments according to size. Which of the following statements are TRUE about gel electrophoresis?

- A. Larger DNA fragments are found toward the bottom of the gel.
- B. DNA molecules migrate toward the negative electrode because they are positively charged.
- C. DNA migrates more slowly in a 3% agarose gel than a 1% agarose gel.
- D. Plasmids migrate more quickly when circularized than when cut.
- E. DNA can be visualized using Coomassie Blue, a dye which binds to the DNA through ionic interactions.

68. You would like to sequence a gene that is inserted into the expression vector. You would like to know the sequence of this gene using Sanger sequencing. What are the most basic requirements for this reaction?

- A. Your template, one primer supporting unidirectional DNA synthesis, dNTPs, ddNTPs and polymerase.
- B. Your template, a pair of primers that can support bi-directional DNA synthesis, ddNTPs and polymerase.
- C. Your template, one primer supporting unidirectional DNA synthesis, dNTPs and polymerase.
- D. Your template with one primer that can support bi-directional DNA synthesis, ddNTPs and polymerase.
- E. Your template with a pair of primers that can move bi-directionally with dNTPs and polymerase

69. One of the techniques employed in this paper was immunoprecipitation. Here is the method part for immunoprecipitation and the data are shown here:

Immunoprecipitation, Western Blot, and Immunofluorescence Analyses—For immunoprecipitation (IP) experiments, 80% confluent cells from 15-cm dishes were washed in cold PBS and lysed in 800 μ l of lysis buffer (same as used for mass spectrometry protein preparation) (30) with an EDTA-free protease inhibitor mixture (Roche Applied Science) and PMSF. Cell lysates were then sonicated and centrifuged. For IP bead preparation, 10 μ l of protein A/G beads (Santa Cruz Biotechnology) were washed with PBS, incubated with 10 μ l of antibodies for 1 h at room temperature, washed again, and then cross-linked with 20 mM dimethyl pimelimidate dihydrochloride prior to addition to 800 μ l of cell lysate for IP. IPs were carried out for 4–12 h at 4 $^{\circ}$ C. Beads were subsequently boiled for 5 min in SDS protein loading buffer to elute bound protein.

For Western blot analysis, either IP or whole cell lysate samples were subjected to SDS-PAGE and subsequently transferred to nitrocellulose membranes (Bio-Rad). Membranes were blocked in milk prior to primary antibody incubation (all antibodies were diluted 1:1,000 in milk).

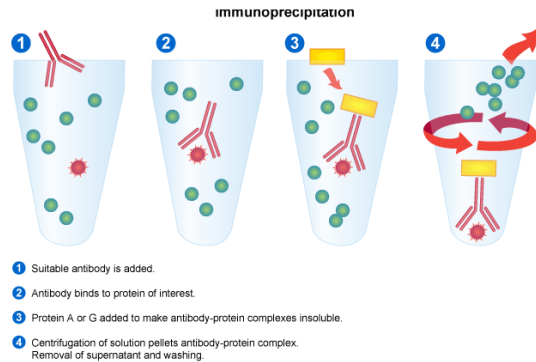
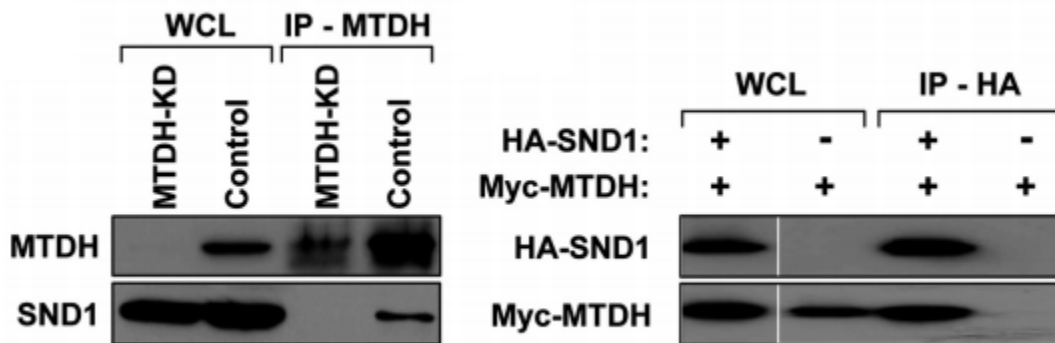


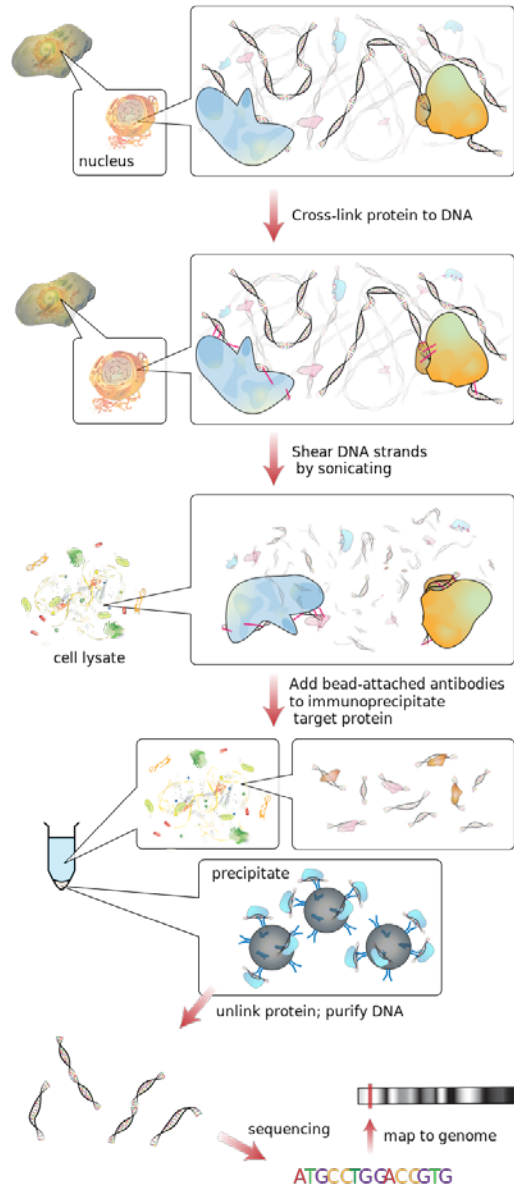
Diagram 1: Illustration of Immunoprecipitation process.



What can you conclude about the relationship between SND1/MTDH based on this data (Select ALL that apply)?

- A. MTDH and SND1 do not interact with each other.
- B. When the level of MTDH is decreased, SND1 does not form a complex with MTDH.
- C. When the level of MTDH is decreased, SND1 favors forming a complex with MTDH.
- D. The expression level of SND1 and MTDH is low in the cancer cell line used for this experiment.
- E. The expression level of SND1 and MTDH is high in the cancer cell line used for this experiment.

70. The technique shown below is called ChIP (Chromatin Immunoprecipitation.) When would it be most useful from the following examples (Select ALL that apply.)



- A. To sequence or build the genomic maps of the unknown organism.
- B. To identify the pattern of proteins that activate (or repress) the promoter of a certain gene, in controlling transcription.
- C. To measure the change in level of protein expression before/after knock-out of the specific gene.
- D. To identify all proteins associated with one certain gene (or protein) by using this technique as a proteomic approach.
- E. To determine the specific location in the genome that various histone modifications are associated with, indicating the target of the histone modifiers.

71. You are trying to discover the mechanism by which an inhibitor acts on an enzyme you are studying. To this end, you construct a Lineweaver-Burk double reciprocal plot comparing initial reaction velocity with substrate concentration. You find that as the concentration of inhibitor increases, the slope of the best fit line increases, but the y intercept remains constant. Based on its reaction kinetics, through what mode of inhibition does the inhibitor in the experiment act?

- A. Uncompetitive inhibition.
- B. Competitive inhibition.
- C. Noncompetitive inhibition.
- D. Allosteric inhibition.
- E. Weakly coupled inhibition.

Questions 72 to 75. Decide if the statement is TRUE (A) or FALSE (B).

72. The phelloderm is produced to the interior of the cork cambium, and is part of the periderm.

73. Cytokinin is one of the hormones most directly involved in flowering.

74. Turgor pressure in roots forcing water up the xylem is the primary cause of guttation.

75. Apomixis is a process by which plants can reproduce asexually, where the embryo develops from the egg without pollination.

76. Select ALL statements that are TRUE about flowering.

- A. The biologically active form of phytochrome (P_r) promotes flowering in short-day plants and inhibits flowering in long-day plants.
- B. In some plants, a difference in light exposure of even 5 to 10 minutes during the photoperiod can result in the plant not flowering.
- C. A flowering schedule of approximately 12 hours of light and 12 hours of dark is representative of a day-neutral plant.
- D. Trees may take years to flower and are unaffected by photoperiods until the “ripeness of flower” stage is reached.
- E. Long-day plants that have a critical photoperiod of 16 hours will flower with a day length of 8 hours if there is a brief exposure to light during the dark period.

77. When a plant is grown under environmental conditions that vary a great deal from their natural environment , it shows that most biological rhythms are

- A. Endogenous.
- B. Not influenced by environmental conditions.
- C. Temporary in nature.
- D. Unadaptive.
- E. Very variable.

78. Rapid movements in sensitive plants result from motor cells that:

- A. Contain myofibrils like those found in animal cells.
- B. Contract in response to opposing gradients of calcium and potassium ions.
- C. Have either flagella or cilia.
- D. Have sudden turgor pressure changes.
- E. Send an electrical signal which causes leaf cells to lose turgor.

79. When a Venus flytrap traps an insect, which of the following is most likely NOT involved in the response?

- A. ATP.
- B. Electrical impulse.
- C. Hydrogen ions.
- D. Potassium ions.
- E. Three-haired trigger.

Questions 80 to 83. Select TRUE "A" or FALSE "B". A person's blood test results may demonstrate higher than normal blood osmolality because:

80. Their kidneys do not respond to antidiuretic hormone.

81. They drink too much water.

82. They become dehydrated.

83. They have a tumor that produces excess aldosterone.

Questions 84 to 87. A person suffers head trauma that results in vision impairment. Which of the following statements would be True (A) or False (B) in helping to diagnose the nature of his injury?

84. Damage to the optic chiasm would result in complete blindness.

85. Damage to the optic chiasm would still allow visual input from each eye to reach the occipital lobe on the same side of the brain.

86. Damage to the left occipital lobe would impair vision in only the right eye.

87. Damage to the right occipital lobe would impair vision from the right half of the retina of each eye.

88. Which of the following physiological processes are examples of *positive* feedback systems?
- I. A neuron is stimulated allowing influx of sodium ions from the extracellular fluid. The resulting depolarization causes sodium channels to open further along the membrane.
 - II. Baroreceptors notify the brain that the blood pressure has dropped significantly. The pituitary gland releases antidiuretic hormone which causes constriction of blood vessels and greater water reabsorption in the kidneys.
 - III. Blood glucose falls below threshold levels causing the pancreas to release less insulin and more glucagon.
 - IV. Erosion of blood vessel endothelium promotes adhesion of platelets to exposed collagen fibers and stimulates thromboxane release to activate other nearby platelets.
 - V. Thermoreceptors in the hypothalamus sense elevated body temperature and induce flushing and sweating.
 - VI. Low blood Ca^{2+} concentration stimulates release of parathyroid hormone which increases osteoclast activity, decreases osteoblast activity and raises circulating Vitamin D levels.
 - VII. Decreasing blood pH during exercise stimulates deeper, faster breathing.
 - VIII. Initial contractions in labor stimulate oxytocin release to intensify and accelerate frequency of uterine contractions.

- A. I, VI, VII only.
- B. I, IV, VIII only.
- C. II, IV, VI only.
- D. II, V, VIII only.
- E. III, V, VII only.

Questions 89 and 90. Carol's resting heart rate is 70 beats/min and her stroke volume is 75ml/beat. She goes on a vigorous run. Her heart rate increases to 150 beats/min and her stroke volume increases to 110 ml/beat. Decide if the following statements are TRUE (A) or FALSE (B) as a reasonable explanation for the stroke volume increasing with increased heart rate.

89. More blood is returning to the heart to fill and stretch the left ventricle during diastole.
90. The increased stretch in the cardiac muscle fibers causes the fibrils to eject an increased volume of blood during systole.
91. Which of the following is NOT a method of gas exchange that may be facilitated in some fish?
- A. Blood flows through gill filaments in a direction opposite to the flow of water.
 - B. Oxygen diffuses through the integument to a rich supply of blood vessels lying just beneath the skin.
 - C. The fish may swim swiftly through the water with its mouth open.
 - D. The fish may swim to the surface and gulp air into its lungs.
 - E. Water is pumped into the mouth by movements of the gill cover.

92. If the P_{O_2} of a liquid is 100 mm Hg and the P_{O_2} the surrounding air is 160 mm Hg, oxygen will:

- A. Diffuse from the liquid into the air.
- B. Diffuse from the air into the liquid.
- C. Equilibrates at 130 mmHg.
- D. Move by bulk flow from the liquid to the air.
- E. Move by bulk flow from the air to the liquid.

Questions 93 to 96. Select TRUE "A" or FALSE "B"

93. The affinity of hemoglobin F for oxygen is greater than the affinity of hemoglobin A for oxygen.

94. Diving mammal are able to remain submerged at great depths for long periods of time due to their high lung capacity and circulator system volume relative to their body size.

95. Humans acclimate to higher altitudes (and thus lower P_{O_2}) by decreasing hemoglobin's affinity for oxygen.

96. A distinguishing factor between the spontaneous activity of breathing and that of the heart is that breathing may more easily be brought under control voluntarily.

Questions 97 & 98. Decide if the following questions are TRUE (A) or FALSE (B). An example of imitative learning is

97. A dog that opens a sliding glass door by accident when it hits the door handle at an angle with its paws.

98. A ground squirrel that stops responding to distress calls when they are made frequently in the absence of predators.

99. In spring, indigo buntings migrate from the southern states to the northern states. Which mechanism is involved?

- A. Earth's magnetic field.
- B. Moon.
- C. Odor of the northern temperate forest.
- D. Stars.
- E. Sun and an internal sense of time.

Questions 100 to 103. In frequency-dependent selection, the fitness of a trait is influenced by the trait's frequency in a population. In positive frequency-dependent selection, fitness increases as the trait becomes more common; in negative frequency-dependent selection, fitness is higher when the trait is rare. Determine if the following statements are TRUE (Select "A") or FALSE (Select "B").

100. A venomous snake that develops a new pattern of warning coloration experiences positive frequency-dependent selection.
 101. A modified protein on the outer membrane of the influenza virus experiences negative frequency-dependent selection.
 102. Bacterial "cheaters," which exploit metabolites produced by neighboring bacteria of the same species rather than producing their own, experience positive frequency-dependent selection.
 103. A trait under negative frequency-dependent selection must either fix in the population or go extinct.
 104. For your high school science fair project you decide to work on transposable elements that copy themselves and insert next to genes. You find one transposable element that lands next to the 5' end of the sense strand of a gene that is associated with a massive change in mRNA levels for that gene even though it does not change the protein sequence of the gene. Which of the following could explain the change in gene expression?
 - I. The transposable element caused the change in gene expression by putting a new promoter next to the gene.
 - II. The transposable element caused the change in gene expression by breaking a repressor for that gene.
 - III. The transposable element caused the change in expression by altering the chromatin folding for the region.
 - IV. The student mutagenized yeast cells and, in one mutant and isolated a transposon. The transposable element did not cause the change in gene expression. A second mutation in the nucleotide sequence unrelated to the transposable element caused the expression change
- A. I & II only.
B. I, II, III, & IV.
C. I & III only.
D. II, III, & IV only.
E. IV only.

Questions 105 to 108. A geneticist has sequenced the genomes of several flu strains isolated from patients in a recent outbreak and is examining patterns of variation at six single-nucleotide polymorphisms (SNPs). The genotypes are given at the table below. Determine whether the following statements are TRUE (Select “A”) or FALSE (Select “B”).

	Locus 1	Locus 2	Locus 3	Locus 4	Locus 5	Locus 6
Outgroup	A	A	G	C	T	C
Strain 1	A	A	G	C	A	T
Strain 2	A	C	A	C	T	T
Strain 3	A	A	G	C	C	C
Strain 4	G	A	G	A	A	T
Strain 5	A	A	G	A	A	T
Strain 6	G	A	G	C	C	T
Strain 7	G	C	A	C	C	T
Strain 8	A	A	G	C	G	T

105. Locus 5 is likely an example of purifying selection.
106. Loci 2 and 3, which are 10 base pairs apart, are likely experiencing linkage disequilibrium.
107. Based on these variable sites, Strain 3 is most closely related to the outgroup.
108. The allele frequencies at the six loci closely match those predicted by neutral models of evolution.
109. Which of the following amino acid substitutions would likely have the largest destabilizing effect on a typical wild-type globular, intracellular protein stable at pH 5?
- Substituting an A found on the surface of the protein for a K.
 - Substituting an I found in the core of the protein for a R.
 - Substituting an L found in the core of the protein for a V.
 - Substituting an H for an E on the surface of the protein.
 - A & B would likely have an equally destabilizing effect that is greater than the Option C and Option D.
110. Which of the following molecules would make good candidates for phylogenetic analysis (Select ALL that apply)?
- tRNA genes.
 - The gene for 23S rRNA.
 - The genes for ribosomal proteins.
 - The gene for a subunit of DNA polymerase.
 - The gene for a critical step in the synthesis of an amino acid.

Questions 111 to 113. Indicate TRUE (A) or FALSE (B) whether you would expect the following statements about genetic diversity to be true in general.

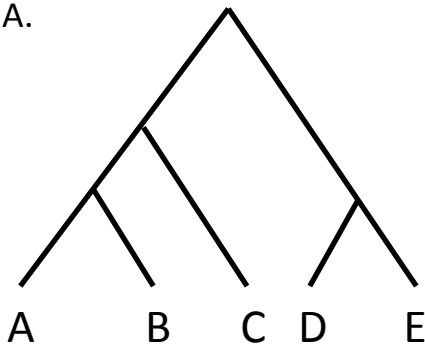
- 111. r-selected populations usually have higher autosomal diversity than K-selected populations.**
- 112. Monogamous populations usually have higher mitochondrial diversity than polyandrous populations.**
- 113. Polyandrous populations usually have higher Y chromosome diversity than polygynous populations.**
- 114. Plants usually have a lower mineral requirement than animals of the same mass. Why?**
- A. Plants do not need minerals to conduct all their important biochemical processes like animals.
 - B. Plants have more inert (nonmetabolic) biomass than animals do.
 - C. Plant metabolic processes are basically different than animals'.
 - D. Plants store minerals and animals do not.
 - E. Plants are more efficient in utilizing minerals than animals.
- 115. Which of the following is the correct pathway in the nitrogen cycle from ammonification to absorption by plants?**
- A. Nitrate, nitrite, ammonia/ammonium.
 - B. Ammonia/ammonium, nitrate, nitrite.
 - C. Ammonia/ammonium, nitrite, nitrate.
 - D. Nitrite, ammonia/ammonium, nitrate.
 - E. Nitrate, ammonia/ammonium, nitrite.
- 116. Which of the following statements are TRUE with respect to density-dependent and density-independent factors (Select ALL that apply)?**
- A. Density-dependent factors affect population growth rates to a greater degree as the density of the population increases.
 - B. Density-dependent factors affect population growth rates to a greater degree as the density of the population decreases.
 - C. Density-independent factors can affect population growth rates regardless of population size or density.
 - D. Some examples of density-dependent factors are disease and resource supply.
 - E. An example of a density-independent factor is resource supply.

117. Species I has many offspring at different times over the course of its lifespan. Species II has numerous offspring once and then dies shortly afterward. Decide which of the following statements is FALSE regarding these species.

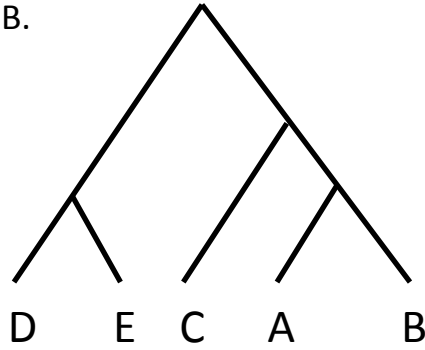
- A. Species I evolved in an environment where the risk of dying young was low.
- B. Species I evolved in an environment where or the risk of offspring mortality was low.
- C. Species I was the earliest in investing the most energy into reproduction.
- D. Species II passed the most genes onto the next generation.
- E. Species II was the earliest in investing the most energy into reproduction.

118. Which of the following phylogenetic trees does NOT display the same information as the others?

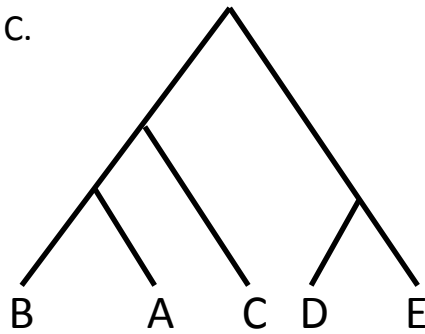
A.



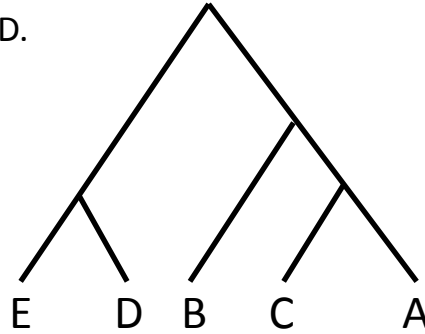
B.



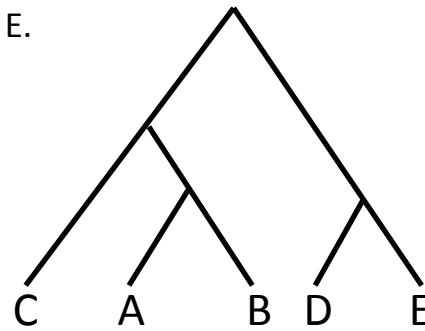
C.



D.



E.



119. In sponge, the water moves in through _____ and out through _____.

- A. Choanocyte; osculum.
- B. Osculum; choanocyte.
- C. Osculum; Archaeocytes (amoebocytes).
- D. Archaeocytes (amoebocytes); choanocyte
- E. Choanocyte; Archaeocytes (amoebocytes).

120.

Species	Dorsal Fin	Teeth	Fusiform	Hind Legs	Body Hair	Blubber	Fluke-like tail
Blue Whale	+	-	+	-	-	+	+
Sperm Whale	+	+	+	-	-	+	+
Sea Lion	-	+	+	+	+	+	-
Sea Otter	-	+	-	+	+	-	-
Manatee	-	+	-	-	+	+	+
Rat	-	+	-	+	+	-	-

Consider the table of marine mammal and rat synapomorphies. + indicates the presence and – indicates the absence of the traits. If you were to construct a phylogeny based off the table data, which of the following would be true?

- A. Blue whales, sperm whales and manatees display homoplasy with respect to tail shape.
- B. Hair is a synapomorphy in sea lions and sea otters.
- C. Having teeth is an apomorphy in everything except blue whales.
- D. Using parsimony, sea lions will be most closely grouped with sperm whales
- E. The rat and the blue whale are in a polyphyletic group.

2015 USABO Semifinal *PART C*

Student Name _____ Student ID# _____

Place all answers to Part C, Questions 1 and 2, on these two pages. Additional sheets of paper may be used, if necessary. Be sure that each page has the Your Name and Your Student ID#. Please staple all pages for Part C together.

1. The following question has three parts that are all related. Be sure to express all answers in the appropriate number of significant figures

- A. Two corn farmers by the names of Old MacDonald and his son Young MacDonald started competing corn farms in the heart of Illinois. Young Macdonald claimed to his father's biggest customer that an ear of corn on his farm, on average, was bigger than the corn from his father's fields. The customer being a shrewd business man, decided that he would test this himself.

He picked 15 ears of corn at random from each field and measured their mass. These are his results.

Old MacDonald	Young MacDonald
Ear Mass (g)	Ear mass (g)
130	138
107	136
125	115
117	120
118	112
129	121
104	144
112	110
105	125
108	126
123	123
109	113
112	132
104	123
98	115

Given the data above, what are the best estimates for the average mass of an ear of corn from Old MacDonald's field and the average mass of an ear of corn from young MacDonald's field? (5 points)

- B. Can the customer say with confidence that, on average, an ear of corn from Young MacDonald's field is bigger than an ear of corn from Old MacDonald's field? State the null hypothesis and the calculated p-value of the null hypothesis being true. Use a one-tailed t-test to estimate the p-value and assume that the population variances are equal. Assume a p-value < 0.05 is the confidence cut-off. (5 points)

t Table

cum. prob	$t_{.50}$	$t_{.25}$	$t_{.20}$	$t_{.15}$	$t_{.10}$	$t_{.05}$	$t_{.025}$	$t_{.01}$	$t_{.005}$	$t_{.001}$	$t_{.0005}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
Z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

Source: <http://www.sjsu.edu/faculty/gerstman/StatPrimer/t-table.pdf>

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{X_1 X_2} \cdot \sqrt{\frac{2}{n}}} \quad s_{X_1 X_2} = \sqrt{\frac{1}{2}(s_{X_1}^2 + s_{X_2}^2)}$$

- C. Given the data in B, what are the best estimates for the variance of the mass of an ear of corn from Old MacDonald's field and the variance of the mass of an ear of corn from Young MacDonald's field?

Genetics & Evolution

2. You would like to find a structure of TRPV4 (Transient Receptor Potential Cation Channel), which is known to sense mechanosensitivity. You would like to express the eukaryotic gene in *E. coli* in order to purify and then crystallize it. List three challenges of expressing eukaryotic membrane proteins in *E. coli* (2 points each). Then, list one other challenge after even successfully expressing this protein (2 points). *Total points possible: 8.*

We hope to see you as a Finalist!!