

USABO SEMIFINAL EXAMINATION

March 14 to March 18, 2016

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. Consider a cell bathed in a solution mimicking normal ECF. If $[K^+]$ was raised to 100 mM in the ECF, but everything else about the ECF and the cell stayed the same, we would expect that

- A. The membrane potential would fall.
- B. The membrane potential would stay the same.
- C. The membrane potential would rise.
- D. The membrane potential would oscillate slowly.
- E. The membrane potential would oscillate rapidly.

2. Action potentials propagate along an axon because

- A. Each AP alters nearby membrane shape, opening mechanically-gated Na^+ channels in adjacent regions of the axon.
- B. Each AP alters nearby membrane shape, opening mechanically-gated Ca^{2+} channels in adjacent regions of the axon.
- C. Each AP alters nearby membrane potential, opening voltage-gated Na^+ channels in adjacent regions of the axon.
- D. Each AP alters nearby membrane potential, opening voltage-gated Ca^{2+} channels in adjacent regions of the axon.
- E. Each AP alters nearby membrane potential, opening mechanically-gated K^+ channels in adjacent regions of the axon.

3. During the cross-bridge cycle involving myosin and actin, which if the following events most directly triggers the power stroke in myosin?

- A. ATP binding to myosin.
- B. Myosin releasing actin.
- C. ATP hydrolyzing to form ADP and P_i .
- D. Energized myosin binding to actin.
- E. Ca^{2+} binding to myosin.

4. Which of the following statements about capillaries is FALSE?

- A. They are the blood vessel type with the thinnest walls.
- B. They are the vessels with the narrowest diameter.
- C. Blood moves through the capillaries at a lower velocity than other vessels.
- D. More blood moves through the combined capillaries each minute than through the combined arteries.
- E. All of these are true.

5. Which of the following changes, by itself, would tend to make lymph form more slowly?

- A. An increase in capillary blood pressure.
- B. An increase in the osmotic concentration of the interstitial fluid.
- C. An increase in the osmotic concentration of the blood plasma.
- D. Two of the above could both make lymph form more slowly.
- E. All of the above could make lymph form more slowly.

6. Which of the following statements is TRUE?

- A. Oxygen moves from the atmosphere into the alveoli by diffusion and from the alveoli into the blood by bulk flow.
- B. Oxygen moves from the atmosphere into the alveoli by bulk flow and from the alveoli into the blood by diffusion.
- C. Oxygen moves from the atmosphere into the alveoli and from the alveoli into the blood by diffusion.
- D. Oxygen moves from the atmosphere into the alveoli and from the alveoli into the blood by bulk flow.
- E. Oxygen does not move from the atmosphere to the blood.

7. Which of the following experimental results would specifically show that myoD expression is sufficient for skeletal muscle differentiation?

- A. Staining for MyoD protein reveals it to be only expressed in skeletal muscle tissue.
- B. Deleting the MyoD gene in mice results in normal skeletal muscles, while deleting both the MyoD and Myf-5 genes results in immobile mice that do not survive birth.
- C. The Belgian Blue breed of cattle, which develops hyperplasia (increased cell number) of skeletal muscle fibers, was shown to carry a loss-of-function mutation in myostatin, a gene repressed by MyoD.
- D. Mutations which disrupt the myoD DNA binding site upstream of the myoD gene results in incomplete skeletal muscle differentiation.
- E. Introducing a plasmid expressing MyoD into fat cells or fibroblasts causes them to express skeletal muscle genes such as myosin, fuse into syncytia, and contract upon calcium ion injection.

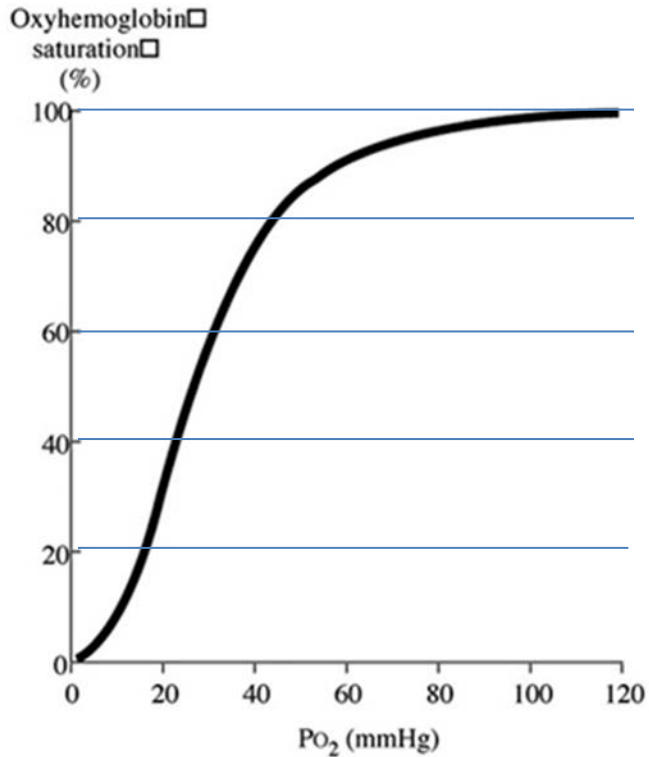
8. In a person suffering an acute respiratory acidosis (so ignore any renal responses), what blood chemistry would we expect relative to normal values?

- A. Elevated CO_2 and elevated H^+ .
- B. Elevated CO_2 and decreased H^+ .
- C. Decreased CO_2 and elevated H^+ .
- D. Decreased CO_2 and decreased H^+ .
- E. No change in either variable.

9. Goiters may occur due to iodine insufficiency, but other causes are possible. Which of the following would NOT tend to result in increased size of the thyroid gland?

- A. High levels of thyrotropin releasing hormone.
- B. High levels of thyroid stimulating hormone.
- C. High levels of thyroxin and triiodothyronine.
- D. All of the above would tend to increase the size of the thyroid gland.
- E. None of the above would tend to increase the size of the thyroid gland.

10. Using the oxygen affinity curve below, determine the amount of oxygen that would be delivered to cells at $P_{O_2} = 20$ mmHg if the P_{O_2} of the lungs were 60 mmHg. Assume maximum HbO_2 to be the level of oxygen delivery if all available oxygen in the RBC's was transferred to cells.



- A. 17% of the maximum HbO_2 would be delivered.
B. 22% of the maximum HbO_2 would be delivered.
C. 65% of the maximum HbO_2 would be delivered.
D. 70% of the maximum HbO_2 would be delivered.
E. 82% of the maximum HbO_2 would be delivered
11. Which of the following statements about kidney function is FALSE?
- A. The kidneys help to regulate overall extracellular fluid volume.
B. The kidneys help to regulate the overall osmotic concentration of the ECF, but not the concentration of specific solutes.
C. The kidneys help to eliminate waste products from the ECF.
D. The kidneys help to regulate the pH of the ECF.
E. Urine is formed in the kidneys through the process of ultrafiltration.

12. Consider a solute that enters the nephron at Bowman's capsule along with all the other solutes that are part of the primary urine. As the substance moves along the nephron to the collecting duct, it is not reabsorbed in any amount, nor is any additional amount secreted into the nephron. Assuming the kidney is functioning in a relatively normal way, what can we safely say about this substance?

- A. It will have a higher concentration in the final urine than it did in the primary urine.
- B. It will have the same concentration in the final urine as it did in the primary urine.
- C. It will have a lower concentration in the final urine than it did in the primary urine.
- D. It will have a concentration of zero in the final urine.
- E. It is not possible to know which of the above will be true.

13. Which of the following statements best describes the patterns seen for glomerular filtration rate and mean arterial pressure in a healthy mammalian kidney?

- A. GFR increases in direct proportion to MAP.
- B. GFR decreases in direct proportion to MAP.
- C. GFR is fairly constant over a range of MAP values, but decreases if MAP drops too far, and increases if it gets too high.
- D. GFR is fairly constant over a range of MAP values, but increases if MAP drops too far, and decreases if it gets too high.
- E. GFR is constant for all possible values of MAP.

14. An individual who was hypersecreting ADH would

- A. Produce large volumes of dilute urine due to the collecting ducts being too permeable to water.
- B. Produce large volumes of dilute urine due to the collecting ducts being too impermeable to water.
- C. Produce small volumes of concentrated urine due to the collecting ducts being too permeable to water.
- D. Produce small volumes of concentrated urine due to the collecting ducts being too impermeable to water.
- E. Obviously be an alcoholic.

15. Imagine a neuron with a relatively long axon covered in myelin but lacking any nodes of Ranvier. Which of the following best describes the action potential results?

- A. The axon would have better cable properties than if it lacked myelin, and an action potential would be able to propagate the length of the axon.
- B. The axon would have better cable properties than if it lacked myelin, but an action potential would not be able to propagate the length of the axon.
- C. The axon would have worse cable properties than if it lacked myelin, but an action potential would still be able to propagate the length of the axon.
- D. The axon would have worse cable properties than if it lacked myelin, and an action potential would not be able to propagate the length of the axon.

16. Place the steps of cellular respiration in the correct order assuming normal oxygen levels.

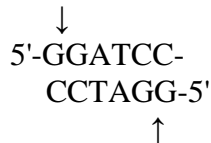
- I. The Krebs cycle produces energy carriers NADH, FADH₂ and ATP.
- II. Pyruvate is transported in mitochondria.
- III. Glucose is broken down to produce ATP and NADH.
- IV. An electron transport chain produces ATP from ADP.
- V. Fermentation takes place.

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

17. Solutions A and B, separated by a membrane that is permeable to urea but not to sucrose or water. Solution A is 1.0M sucrose and solution B is 1.0M urea. At equilibrium,

- A. Solution A is still 1.0M sucrose and Solution B is still 1.0M urea.
- B. Solution A is 1M sucrose and has between 0.0 and 0.5M urea, and Solution B is between 0.5 and 1.0M urea.
- C. Solution A is 1M sucrose and 0.5M urea, and Solution B is 0.5M urea.
- D. Solution A is 1M sucrose and has between 0.5 and 1.0M urea, and Solution B is between 0.0 and 0.5M urea.
- E. Solution A is 1.0M sucrose and 1.0M urea, and Solution B is just water.

18. The recognition sequence and cleavage pattern for the restriction enzyme BamH I (from *Bacillus amyloliquefaciens*) is shown below. Although the enzyme cleaves both strands of a double-stranded DNA, BamH I is said, by convention, to make *one cut* in the double-stranded recognition sequence.



Predict the number of cuts and the number of fragments produced if the DNA sequence shown below is presented as a substrate for BamH I digestion.

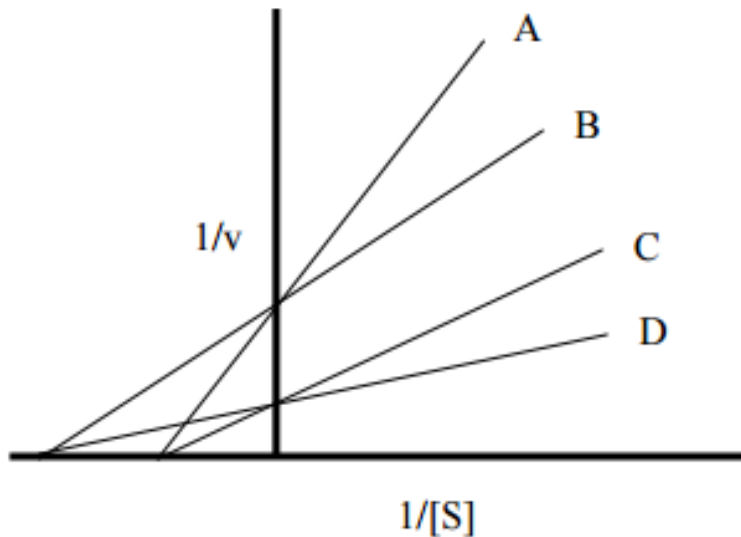
5' -GACGCGTCCTAGGTGACCGGATCCATGGAATTCGCGGCCACTGGTTAAC
3' -CTGCGCAGGATCCACTGGCCTAGGTACCTTAAGCACCGGTGACCAATTG

Number of cuts, Number of fragments produced

- A. 0, 1
- B. 1, 1
- C. 1, 2
- D. 2, 2
- E. 2, 3

19. Which form of DNA damage is least likely to be encountered on a day to day basis?
- A. Double strand breaks.
 - B. Hydroxylation.
 - C. Deamination.
 - D. Pyrimidine dimers.
 - E. Tautomerization.
20. Cells, when infected by a DNA virus, can transcribe both stands of the viral DNA and process it into ~21 nt single stranded fragments that can be loaded into protein complexes which target viral protein encoding transcripts for degradation. Which statement below correctly characterizes this process?
- A. This siRNA silencing results in a gene knock out.
 - B. This siRNA silencing results in a gene knock down.
 - C. This miRNA silencing results in a gene knock out.
 - D. This miRNA silencing results in a gene knock down.
 - E. This miRNA silencing results in reversible gene regulation.
21. Pepsin, a proteolytic enzyme found in the stomach, contains an active site aspartate residue. The β -carboxylic acid side chain group must be in its unprotonated (basic) form for the enzyme to be catalytically active. The pKa of the β -carboxylic acid group is 3.5. At pH 4.5, what is the approximate activity of the enzyme
- A. 1% of its maximum potential activity.
 - B. 10% of its maximum potential activity.
 - C. 50% of its maximum potential activity.
 - D. 90% of its maximum potential activity.
 - E. 99% of its maximum potential activity.
22. In a positive feedback loop, the signal and the response
- A. Must both be positive.
 - B. Must both be negative.
 - C. Must have the same sign (positive or negative).
 - D. Must have opposite signs.
 - E. There's no such thing as a positive feedback loop.
23. Enamored by G Protein-Coupled Receptors (GPCRs), a researcher is studying their mechanism of action and designs a non-hydrolysable GTP analog that a G protein can bind. Unbeknown to him/her, you already know the mechanism by which GPCRs work! How will the cycle of a GPCR be affected by a non-hydrolysable GTP analog?
- A. The GPCR's respective ligand will not bind it.
 - B. The G protein cannot associate with the GPCR.
 - C. The inactive G protein will never be reactivated.
 - D. The enzyme normally activated by the G protein will never inactivate.
 - E. The cycle of the GPCR will not be affected.

Questions 24 through 26 refer to the figure below, which shows the reaction of a single enzyme in the absence and presence of various inhibitors.



24. Which line best describes the activity of the enzyme in the absence of an inhibitor? **D**
25. Which line best describes the activity of the same enzyme in the presence of a competitive inhibitor? **C**
26. Which line best describes the activity of the same enzyme in the presence of a noncompetitive inhibitor? **B** (For the same enzyme, line A would result from the presence of a mixed inhibitor (one that decreases V_{max} and increases K_m))
27. For which of the following are all three changes in channel state excitatory?
- Closing of Na^+ channels, closing of K^+ channels, opening of Ca^{2+} channels.
 - Closing of Na^+ channels, opening of K^+ channels, closing of Ca^{2+} channels.
 - Opening of Na^+ channels, opening of K^+ channels, closing of Ca^{2+} channels.
 - Opening of Na^+ channels, closing of K^+ channels, opening of Ca^{2+} channels.**
 - Opening of Na^+ channels, opening of K^+ channels, opening of Ca^{2+} channels.
28. Sister chromatid is:
- The same thing as homologous chromosomes.
 - A pair of chromosomes of the same kind.
 - Identical copies of the same chromosome attached at the centromere.**
 - Always haploid.
 - Always diploid.

29. Place the following events of sexual reproduction in the correct order.

- I. Separation of homologous chromosomes.
- II. Separation of sister chromatids.
- III. Zygote mitosis.
- IV. Fusion of two gametes.
- V. Oocyte activation.

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

30. Convergent evolution can be seen across a wide range of taxa. Which of the following exhibit convergent evolution?

- I. Marsupial thylacine and placental canids.
- II. Dugong and Right Whale flukes.
- III. Leaf shape between *Plantanus orientalis* and *Plantanus occidentalis*.
- IV. Sesamoid thumb of the Giant Panda and Primate thumbs.
- V. Flying Fox and California Condor wings.
- VI. Hermit crabs, Porcelain crabs, and Spider crabs.
- VII. American and Old World Porcupine.

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

31. As a researcher in Nigeria, you are painfully aware of Sickle Cell Anemia. In an effort to address the issue, you study a population of 100 individuals in a rural area by sampling their blood for the normal hemoglobin gene (HbA) and the sickle cell hemoglobin (HbS). To analyze your samples, you perform a Western blot and protein electrophoresis with the following results:

Genotype	Number of individuals
HbA/HbA	88
HbA/HbS	10
HbS/HbS	2

What is the frequency of the HbS allele in this population?

- A. 0.02.
 - B. 0.04.
 - C. 0.07**
 - D. 0.10.
 - E. 0.93.
32. Sharon Osburn and Angelina Jolie underwent an elective double mastectomy due to an inherited familial mutation in the gene BRCA1. What DNA repair pathway would likely be defective due to a mutation in this gene?
- A. Direct oxidative repair.
 - B. Nucleotide excision repair.
 - C. Base excision repair.
 - D. Recombination repair.**
 - E. Nonhomologous end joining.
33. If a replicating cell encounters significant DNA damage during S phase, what is the most likely result?
- A. It will arrest in the S phase checkpoint and undergo repair.
 - B. It will immediately trigger apoptosis and die.
 - C. It will utilize bypass polymerases to complete S phase.**
 - D. It will utilize telomerase to extend past the damage.
 - E. It will undergo a reductive division.

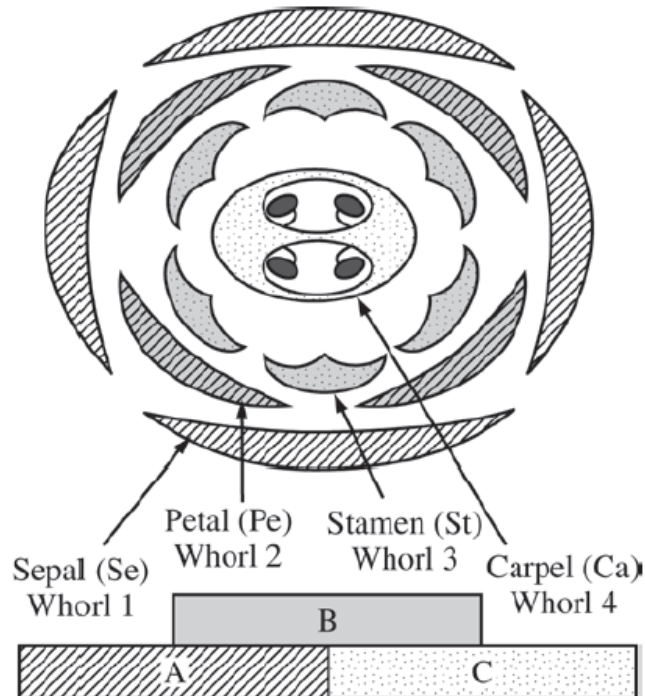
34. A young couple brings their 18-month-old son into their pediatrician for evaluation. Their son has decreased muscle strength, an increased startle response, and loss of muscle function with poor head control. The pediatrician is aware of the family's Ashkenazi heritage and suspects that their son may have Tay-Sachs disease. Testing confirms his suspicion, and he asks for tests done on the couple and their two children for Tay Sachs. The family's pedigree is shown below, along with Southern blots of a restriction fragment length polymorphism very closely linked to the gene for hexosaminidase A, which is defective in Tay-Sachs. Unfortunately, the pediatrician forgot to label which lane corresponded with which patient. Which of the following statements below is most accurate with respect to the couple's daughter?



- A. She has Tay-Sachs disease.
 B. She has a 25% chance of having Tay-Sachs disease.
 C. She is a carrier for Tay-Sachs disease.
 D. She has a 50% chance of having Tay-Sachs disease.
 E. She is homozygous normal.
35. Two patients with non-Hodgkin's lymphoma responded differently to therapy. This suggested different lymphoma subtypes. Since the existing procedures for classifying the lymphomas could not confirm this possibility, a comparison of each mRNA expression profile was conducted. Which of the following methods would most likely be used?
- A. Genomic library construction.
 B. Transcriptomics.
 C. Southern blot analysis.
 D. Fluorescence in situ hybridization (fish).
 E. Western blot analysis.
36. The Central Dogma of molecular biology states that one gene leads to one transcript and results in one protein product. Which of the following processes would refute this dogma?
- A. Ordered splicing.
 B. RNA editing.
 C. Telomerase activity.
 D. Translation start site recognition.
 E. Polyadenylation of new transcripts.

37. As you walk about Palmerston Island, you observe that many of the 60 islanders have extremely large feet and share the same last name. According to island history, a man with very large feet washed up on shore. You may be observing an example of:
- A. Selective advantage.
 - B. New mutation.
 - C. Variable expressivity.
 - D. Founder effect.
 - E. Random mating
38. Put the following relatives in the correct order in terms of degree of relationship from closest to most distant.
- I. Half-sister
 - II. First cousin once removed
 - III. Maternal great-uncle
 - IV. Brother
- A. I, IV, II, III.
 - B. II, III, I, IV.
 - C. III, II, IV, I.
 - D. IV, I, III, II.
39. Which of the following is a correct statement regarding a physical change in DNA and a possible resulting informational change?
- A. A deletion is most likely to result in a missense mutation.
 - B. Transversions are a common cause of frameshift mutations.
 - C. An insertion will always result in a frameshift mutation.
 - D. A transition mutation can lead to splicing errors.
 - E. Disruptions often result in silent mutations.
40. Louis is studying corn in Oaxaca, Mexico. He generates a novel technique which targets a Rubisco inhibitor to mesophyll cells and is puzzled by the results, when he sees that the corn plants still generate sugar. What best accounts for this result?
- A. Corn does not express Rubisco.
 - B. Rubisco is sequestered in the bundle sheath cells of corn.
 - C. Corn fixates carbon via CAM.
 - D. The sugar is being generated by photorespiration.
 - E. Rubisco inactivation upregulates PEP carboxylase activity.

41. Consider the below figure for ABC hypothesis:



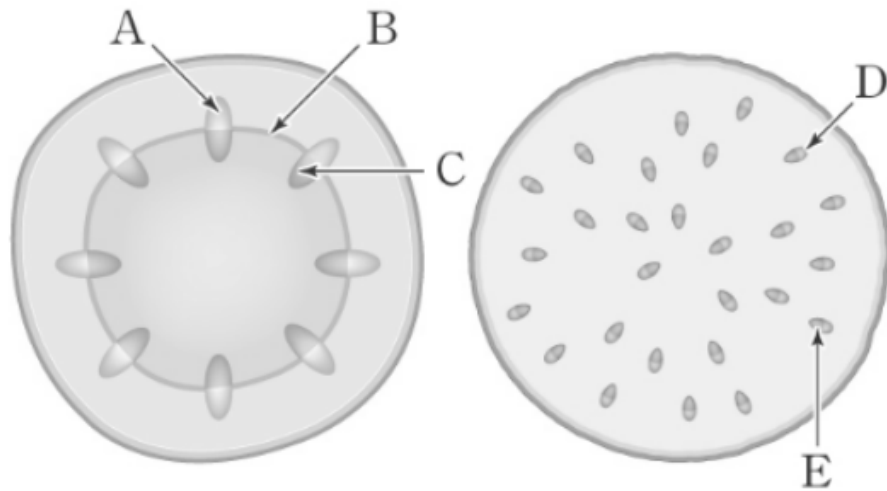
If wild type *Arabidopsis* were transformed with a chimeric gene consisting of an A class promoter fused to a B class coding sequence, which of the following arrangements (inner to outer) would be predicted?

- A. Ca, St, St, St.
- B. Ca, St, Se, Se.
- C. Ca, St, Se, Pe.
- D. Ca, St, Pe, Se.
- E. Ca, St, St, Ca.

42. The permeability of aquaporin in plants is

- A. Decreased by increases in both cytosolic calcium ions and cytosolic pH.
- B. Decreased by decreases in both cytosolic calcium ions and cytosolic pH.
- C. Decreased by increases in cytosolic calcium ions and decreases in cytosolic pH.
- D. Decreased by decreases in cytosolic calcium ions and increases in cytosolic pH.
- E. Not affected by cytosolic calcium ions and cytosolic pH.

43. Figures shown below are cross-sectional areas of stems.



You placed them into the blue-dye solution. Which of the following set will be dyed with blue color?

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

44. All of the following are examples of chemotropism EXCEPT:

- A. Growth of the pollen tube towards the ovules.
- B. Conversion of flowers into fruit.**
- C. Attraction of different rhizobia to legumes and non-legume root exudates.
- D. Growth of roots towards useful minerals.
- E. Addition of atmospheric nitrogen.

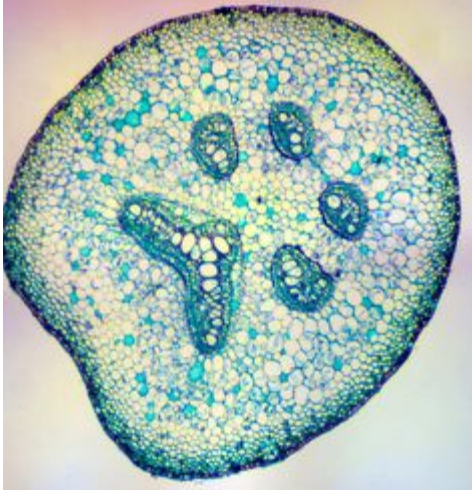
45. The mature nodule grows to many times the diameter of the root. Which cell type below forms a layer that reduces absorption of oxygen and thereby helps maintain the anaerobic environment needed for nitrogen fixation? These cells will most likely be which of the following?

- A. Collenchyma cells.
- B. Parenchyma cells.
- C. Phloem cells.
- D. Sclerenchyma cells.**
- E. Xylem cells.

46. Which of the following is not TRUE of life cycle in a moss and fern?

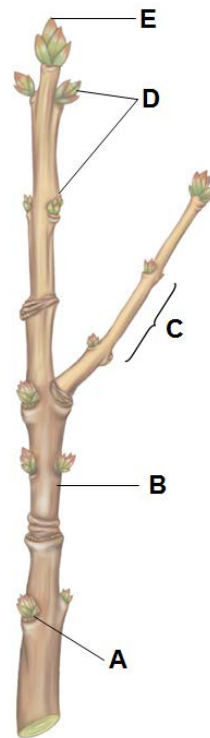
- A. The sporophyte remains nutritionally dependent on the gametophyte.
- B. For moss, spores develop into threadlike protonemata, which is haploid.
- C. The sporophyte grows a long stalk called seta that emerges from the archegonium.
- D. On the underside of the sporophyte's reproductive leaves are spots called sori in the fern.
- E. For moss, the function of peristome is to generate mature spores via meiosis by reducing the number of chromosomes from diploid to haploid.

47. 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

48. A figure shown below is a winter twig harvested in February, 2016. Which of the indicated structures would most likely be from 2014? **B**



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49. Which of the following would be a primary consumer in an Antarctic pelagic food web?

- A. Sperm whale.
- B. Copepod.**
- C. Penguin.
- D. Diatom.
- E. Squid.

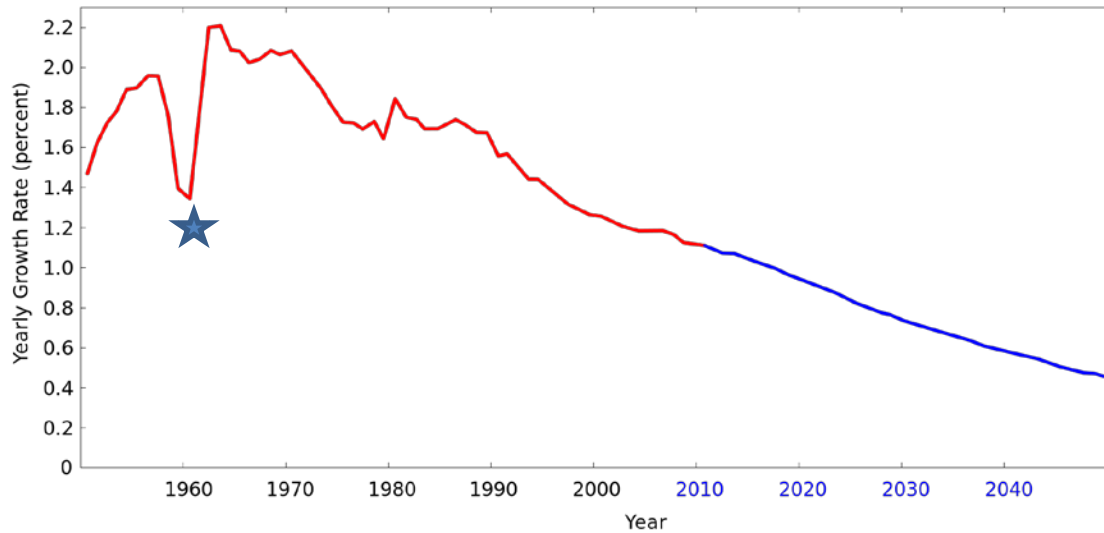
50. Which of the following is NOT true of aquatic biomes?

- A. An estuary is an example an ecotone.
- B. Oxygen levels are generally high in oceanic pelagic zone.
- C. Wetlands have a high capacity to filter dissolved nutrients and chemicals.
- D. A high diversity and biomass of attached marine algae inhabit rocky intertidal zone.
- E. While headwaters are generally depleted in oxygen, downstream waters are rich in oxygen for streams and rivers.**

51. Seasonal turnover of lakes occurs during

- A. Summer only.
- B. Spring and autumn.**
- C. Summer and winter.
- D. Spring, summer, and autumn.
- E. All four seasons.

52. Consider the below diagram, which shows the annual percent increase in the global human population.

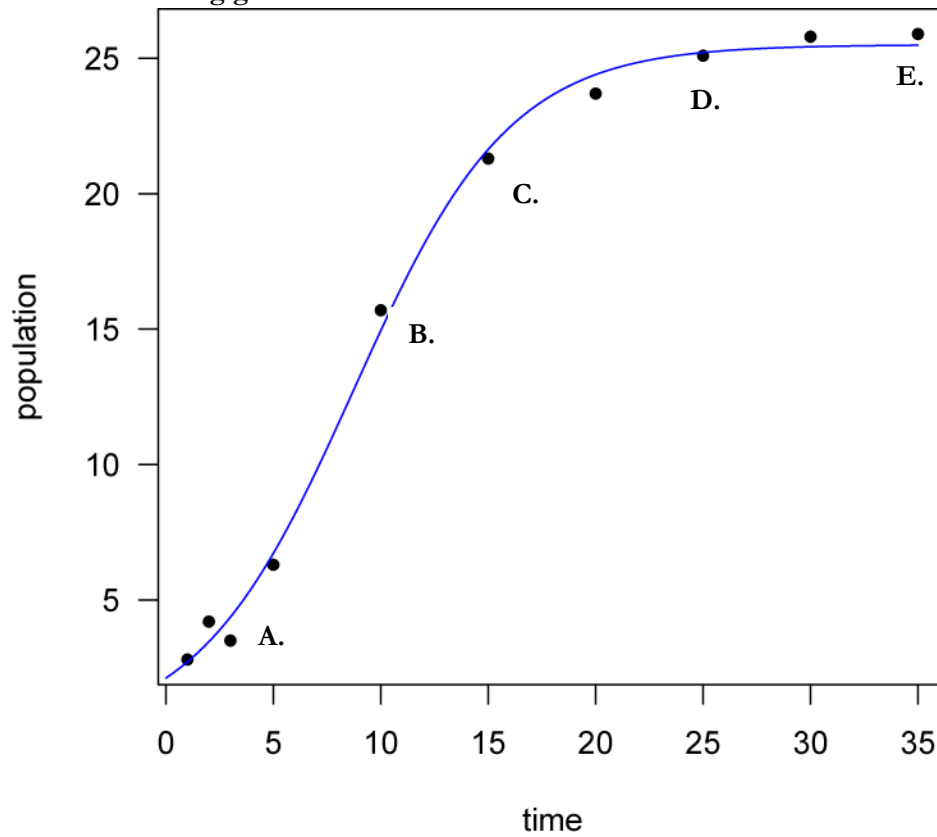


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Which of the below would be the most plausible reason for a sharp dip indicated by the star in the figure above?

- A. World War I.
- B. Vietnam War.
- C. A huge famine in China.
- D. AIDS and voluntary population control by Chinese government.
- E. Atomic bombings of Hiroshima and Nagasaki during World War II.

53. Consider the following growth curve.



Which one point has the highest per capita rate of increase?

54. Which of the following is incorrectly matched with its terms and calculations?

- A. Effective population size = $(4 \times N_f \times N_m) / (N_f + N_m)$.
- B. Turnover time – standing crop (g/m^2) / production ($\text{g}/\text{m}^2 \times \text{day}$).
- C. Leaf area index - one-sided green leaf area / unit ground surface area.
- D. Production efficiency - biomass that is ingested by consumers / available biomass.
- E. Net primary production = gross primary production - the energy used by the primary producers for their autotrophic respiration.

55. Which of the following is not a line of evidence whereby scientists try to determine genetic factors which influence the development of behavior?

- A. Isolation experiments.
- B. Comparison of relatives.
- C. Natural selection.
- D. Hybridization..
- E. Mutation (single gene/molecular genetic analysis).

56. Ants as well as other animals have the ability to run straight home after a circuitous outward path to find food. If we define “learning” as a change in behavior as a result of experience, this is a form of learning, since the homeward path depends upon the experience during the outward path. However, this behavior doesn’t fit the definition of “associative learning.” Which of the following statements does NOT accurately describe this phenomenon?

- A. It is not trial and error learning.
- B. The ant is not linking novel stimulus to one that is responded to reflexively.
- C. The “learned” action has been rewarded.
- D. The “learned” action (homeward path) was never performed before.
- E. It is not classical conditioning.

57. Which of the following is a key way in which classical conditioning differs from operant conditioning during two events E1 and E2?

- A. Change in behavior after experiencing association of E1 and E2.
- B. Short latency between E1 and E2.
- C. E1 must precede E2.
- D. E2 must precede E1.
- E. Many trials.

58. Which of the following is incorrectly paired with plant-derived medicines for human use?

- A. Caffeine – Rubiaceae.
- B. Morphine – Magnoliaceae.
- C. Cocaine – Arecaceae.
- D. Menthol – Myrtaceae.
- E. Atropine – Solanaceae.

59. Evidence for including us within the order primates is provided by:

- A. Anatomy.
- B. Biochemistry.
- C. Ethology.
- D. Fossils.
- E. All of the above.

60. Which of the following protist taxa have been CORRECTLY paired with one of its characteristic traits?

- A. Euglenozoa : mitochondria lack electron transport chains.
- B. Rhodophyta : flagellated gametes produced by diploid generation.
- C. Diplomonadida : possesses two equal-sized nuclei.
- D. Oomyceta : cell walls contain chitin.
- E. Foraminifera : secretes a test of silica (SiO₂).

PART B: Each question is valued at 2 points.

61. Typical heart cells have a $\text{Na}^+/\text{Ca}^{2+}$ antiporter on their plasma membranes, exporting one Ca^{2+} ion for every three Na^+ ions that are imported. If Digitoxin, an inhibitor of the Na^+/K^+ ATPase pump, is administered to a patient experiencing cardiac arrest, what will result?

- A. Cytosolic $[\text{Na}^+]$ lowered, muscle contraction is sustained.
- B. Cytosolic $[\text{Na}^+]$ raised, muscle contraction is sustained.**
- C. Cytosolic $[\text{Na}^+]$ lowered, muscles contraction ceases.
- D. Cytosolic $[\text{Na}^+]$ raised, muscle contraction ceases.
- E. Digitoxin will only affect the extracellular environment.

62. Neuron A and neuron B are the only two presynaptic neurons that affect a particular postsynaptic neuron. If a single Action Potential (AP) arrives at A, and none at B, the postsynaptic potential increases. If A and B see APs at the same time, the postsynaptic potential increases, but by less than when just A is active. Given this information,

- A. Neuron B must have effects that are excitatory, and the simultaneous effects of A and B are an example of spatial summation.
- B. Neuron B must have effects that are inhibitory, and the simultaneous effects of A and B are an example of spatial summation.**
- C. Neuron B must have effects that are excitatory, and the simultaneous effects of A and B are an example of temporal summation.
- D. Neuron B must have effects that are inhibitory, and the simultaneous effects of A and B are an example of temporal summation.
- E. It's impossible to tell from the information given.

63. Which of the following associations is INCORRECT?

- A. Proximal convoluted tubule – Simple cuboidal epithelium with microvilli.
- B. Loop of Henle – Helps create the osmolarity gradient in the renal medulla.
- C. Parietal layer of glomerular Capsule – Part of the filtration membrane.**
- D. Visceral layer of glomerular Capsule – Contains podocytes.
- E. Glomerulus – Receives blood from the afferent arteriole.

64. A low sodium concentration of the filtrate in the distal convoluted tubule could indicate that:

- A. Blood pressure is normal and blood volume is high.
- B. Blood pressure is high.
- C. Blood volume is high.
- D. Blood pressure is high and blood volume is low.
- E. Blood volume is low.**

65. Consider the following data and calculate the rate of excretion of molecule X.

Molecule X is filtered at a rate of 8ug per minute
Molecule X is reabsorbed at a rate of 7ug per minute
Molecule X is not secreted at all

- A. Molecule X is excreted at a rate of 8ug/minute.
- B. Molecule X is excreted at a rate of 7ug/minute.
- C. Molecule X is excreted at a rate of 7.5ug/minute.
- D. Molecule X is excreted at a rate of 15ug/minute.
- E. Molecule X is excreted at a rate of 1ug/minute.

66. You injected your patient with a chemical known as PZB and collected the following data. Based on this data, calculate the amount of PZB appearing in his urine per minute.

Rate of PZB filtration → 10mg/min
Rate of PZB reabsorption → 2mg/min
Rate of PZB secretion → 4mg/min

- A. 16mg/min.
- B. 4mg/min.
- C. 12mg/min.
- D. 8mg/min.
- E. 0mg/min.

67. Select the TRUE statement relating to the lymph system.

- A. Lymphatic capillaries are involved in the absorption of digested sugars.
- B. Lymphatic vessels typically have very few valves.
- C. Compared to blood, lymph has a higher density of red blood cells.
- D. The expansion and recoil of arteries assists in causing lymph flow.
- E. Macrophages are NOT examples of lymphoid cells.

68. The lymphatic system:

- I. Plays no role in nutrient transport.
- II. Returns interstitial fluid to the vascular system.
- III. Plays an active role in immune defense.

- A. I, II, and III are TRUE.
- B. Only I and II are TRUE.
- C. Only II and III are TRUE.
- D. Only I and III are TRUE.
- E. I, II, and III are all FALSE.

69. Put the following items in correct sequential order.

- I. B cell binds and endocytoses its specific antigen.
- II. B cells differentiate into plasma and memory B cells.
- III. Helper T cell releases cytokines that activate the B cell.
- IV. Plasma antibody levels rise.
- V. B cell presents the antigen/MHCII complex.

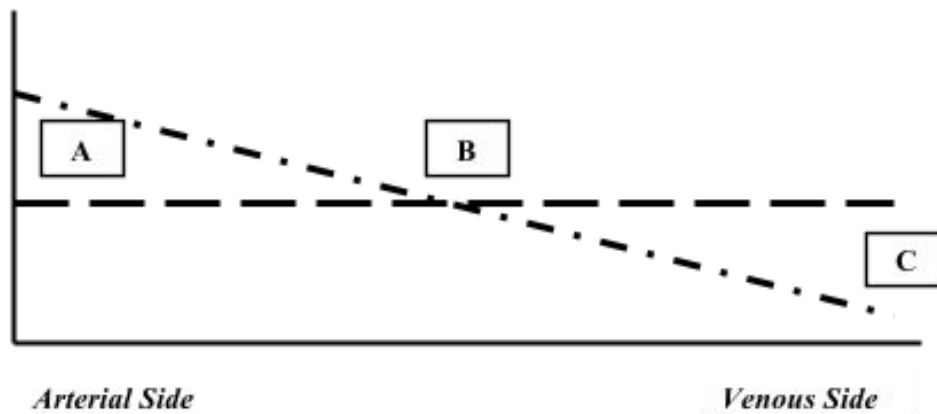
- A. I, IV, V, III, II.
- B. I, V, III, II, IV.
- C. I, III, II, V, IV.
- D. I, V, II, III, IV.
- E. I, III, V, II, IV.

70. Which of the following reactions is more likely to occur in pulmonary capillaries than in systemic capillaries?

- A. $\text{HHb} + \text{O}_2 \rightarrow \text{HbO}_2 + \text{H}^+$.
- B. $\text{H}^+ + \text{HbO}_2 \rightarrow \text{HHb} + \text{O}_2$.
- C. $\text{HHb} + \text{CO}_2 \rightarrow \text{HbCO}_2 + \text{H}^+$.
- D. $\text{HbCO}_2 + \text{H}^+ \rightarrow \text{HHb} + \text{CO}_2$
- E. $\text{HbCO}_2 \rightarrow \text{HCO}_3^- + \text{H}^+$.

71. If the alveolar Po_2 and Pco_2 were each 100mmHg and the plasma Po_2 and Pco_2 were each 10mmHg, oxygen would dissolve in the plasma in large amounts. Is the statement TRUE (A) or FALSE (B). **B**

Questions 72 to 74. Consider the following graph of pressure (y-axis) and distance along the capillary (x-axis).



72. Which of the following is TRUE?

- A. The dashed line (horizontal) represents capillary hydrostatic pressure while the dotted line (diagonal) represents capillary osmotic pressure.
- B. The dotted line (diagonal) represents capillary hydrostatic pressure while the dashed line (horizontal) represents capillary osmotic pressure.

73. At Point A,

- A. Capillary hydrostatic pressure is greater than capillary osmotic pressure and thus fluid is forced out of the capillary.
- B. Capillary hydrostatic pressure is greater than capillary osmotic pressure and thus fluid is forced into the capillary.
- C. Capillary osmotic pressure is greater than capillary hydrostatic pressure and thus fluid is forced into the capillary.
- D. There is no net movement of fluid at point A.

74. Starvation from inadequate protein intake would cause point B where the 2 lines intersect to shift to the LEFT (A) or to the RIGHT (B)? **B**

75. In gnathostomes, which of the following body parts arises from neural crest cells?

- A. Kidneys.
- B. The mandible.
- C. Notochord.
- D. Spinal cord.
- E. Thyroid gland.

76. Which of the following statements is/are FALSE regarding glycolysis? (Select all that apply)

- A. Glycolysis is the first stage of cellular respiration.
- B. Glycolysis can proceed under low oxygen conditions with assistance of fermentation.
- C. Glycolysis produces less ATP than the Krebs cycle or oxidative phosphorylation.
- D. Glycolysis produces most of the ATP required by aerobic organisms like us.
- E. Prokaryotes such as Salmonella do not execute Glycolysis.

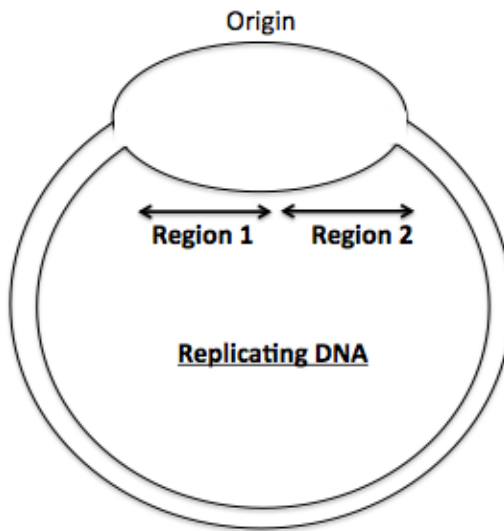
77. Which of the following statements is/are TRUE regarding secondary messengers? (Select all that apply)

- A. Phospholipase C cleavage of a membrane phospholipid produces diacylglycerol and inositol triphosphate.
- B. Diacylglycerol binds to calcium channels in order to open the channels.
- C. Inositol triphosphate diffuses throughout the cell after being cleaved from the membrane phospholipid.
- D. cAMP is formed by phosphodiesterase catalyzed cyclization of ATP.
- E. GTP is hydrolyzed to GDP by the G protein, which functions as a GTPase.

78. Which of the following statements is/are TRUE regarding glycogen buildup and breakdown? (Select all that apply)

- A. Glycogen phosphorylase builds up glycogen branches.
- B. Insulin release into the bloodstream and signaling leads to glycogen buildup.
- C. Glucagon release into the bloodstream and signaling leads to glycogen buildup.
- D. Phosphorylation of glycogen synthase inhibits its activity.
- E. Phosphorylation of glycogen phosphorylase inhibits its activity.

Questions 79 & 80. The following schematic represents a replicating circular DNA in a human somatic cell.



79. Which of the following organelles would show the sub-cellular localization of the above replicating DNA?

- A. Lysosomes
- B. Mitochondria
- C. Nucleus
- D. Endoplasmic reticulum (ER)
- E. Chloroplasts

80. The sequence of DNA in Region 1 is given below.

5'-TAAACCG-3' Top strand
3'-ATTTGGC-5' Bottom strand

Which of the following sequences represents the base sequence of the newly synthesized leading strand in Region 1:

- A. 5'-CGGTTTA-3'
- B. 5'-TAAACCG-3'
- C. 5'-GCCAAAT-3'
- D. 5'-ATTTGGC-3'

Questions 81 to 84. You isolate two mutant versions (m1& m2) of an enzyme. The m1 has a reduced enzymatic activity compared to the wild type version. In comparison, m2 has an increased enzymatic activity compared to the wild type version. Based on this information, select one of the options below.

Options

- A. Same as.
- B. More than/Faster than.
- C. Less than/Slower than.

81. The activation energy of m1 catalyzed reaction is the same as/ more than/ less than that of m2. **B**
82. The free energy change of m1 catalyzed reaction is the same as/ more than/ less than that of m2. **A**
83. The reaction equilibrium for m1 catalyzed reaction is the same as/ more than/ less than that of m2. **A**
84. The reaction rate for m1 catalyzed reaction is the same as/ faster than/ slower than that of m2. **C**
85. Bacteriophages are the viruses that infect bacteria. You infect a bacterial cell with an experimentally constructed virus that has the protein coat from Type I phage and DNA from Type 2 Phage. Select the correct option. The newly generated phages will have...
- A. Type 1 phage proteins and Type 2 phage DNA.
 - B. Type 2 phage proteins and Type 1 phage DNA.
 - C. A mixture of DNA and protein from both phages.
 - D. Type 2 phage proteins and DNA.**
 - E. Type 1 phage proteins and DNA.

86. The figures shown below are complementary DNA (cDNA) and translated amino acids from cDNA of metadherin (MTDH), a gene involved in metastasis and chemoresistance in various cancer types.

10	20	30	40	50	60	70	80	90	100	110	
<pre> ATGGCTGCACGGAGCTGGCAGSACGAGCTGGCCACGAGGCCGAGSAGGGCTCGGCCCGGCTGCGGGAATGCTCTCGGTGCGCTAGGCTTTCTGCGCACCGAGCTGGG CCTCGACCTGGGGCTGGAGCCGAAACGGTACCCCGGCTGGGTGATCCTGGTGGGCACTGGCGCGCTGGGCTGCTGCTGCTTTCTGCTGGGCTACGGCTGGGCCGCGGG CTTGGCCGGCCGCCGCAAAAAGCGGAGGAGGCCGCCGCCGCAAGCGGGAGGAGGCCGGCGGCGGTGCCGGCCGCGGCCCGCCGACGACCTGGCCCTTGCTGAAAGAACTCCGCG AGCGAGGAACAGAAAGAAAGAACCGGAGAAACTGTCCGAGAAGCCCAACCAATGGGCGGACTGTTGAAAGTGGCTGAGGGTGAAGCTGTTGGAACACCTCAAGAGTGT AACAGCAAAAGCAGCCACAGAGATTGACAAAGAAAATGAAAAGTCAAGAAAAAATAAGAAAGAAATCAAAGTCAAGATGCTAAAGCAGTGCAAAACAGTTCACGCCATGATG GAAAGGAAGTTGATGAAGGAGCCTGGGAAAATAAAATTAGTACAGAGAGAAACGACAGCAGCGTAAACGATGATAAGGTGCTGACTGATTCTGGTTTCATTGGATTCACACT ATCCCTGGGATAGAAAAATACCATCACAGATTACCACCGAGCAACTTACAACCGCATCATTTTCTGTTGGTTCCAAGAAGAAATAAGGGTGAATTCATCTAAATGTTCAAGT TAGCAACTTTAAATCTGGAAAAGGAGATTCTACACTTCAGGTTTCTCAGGATGAAATGAAAACCTCACTGTCAATAGGAGGAGGCTGGAATGAAAAGTCTGTAAAACCTCT CCTCACAGATCAGTGCAGGTGAGGAGAGGAACTCCGTTTCACTGCTTCTGCAAGGAAAGAGGAAACTGAGCCATCTGCTTGGAGTCAAGACACTGGAGATGCTAAAT ACAAAAGGAAAGACTGGGAAAGGAGTTGGAGTGACCGTTCATATTTCTGCGATGGGTCTACTGCTGAGCCAGTTTCTCAGTCTACCCTTCTGATTATCAGTGGGA TBTAGCCGTAATCAACCCTATATCBATGATGAATGGTCTGGGTAAATGGTCTGCTTCTGCTGATCCCACTCTGATTGGAATGCACCAGAAAGAGTGGGCAATT GGGTAGACGAAGAAAGAGCTTCACTTCAAAGTCCCAAGAACCAATTCCTGATGATCAAAAAGTCTCAGATGATGATAAGAAAAGGAGAGGGAGCTCTTCCAACTGGG AAATCCAAAAAGAAAAAAGAAAAAGAAAGAAAGCAAGGTGAAGATAACTCTACTGACAGGACACAGAAGAAATAGAAAAAGAGATTAGAGAAAGACCTTCCAGTGAATAC CTCTAAAAACCCGTCACAAACAGGAAAAAGCTTTTTCTTGAAGACCATAAGCACTAGTATCCAGCCGAAAGTACTCGTCAAAAAATAGCCAGCCTATCAAGACTCTCCAC CTGCTACTTCTACCGAGCCATCTGTAATCTTATCAAAAAGTGAATTCGACAGAGCTCTTCCCAAGTGCCGCCAATACTACAAAGAGACAGATAAATCCAAAGTCAAAATACC AAGCAAAATAGTGTGCTCCTTCCACAGACCAAGTCTGAAACTAGTGGGAATCTCCCAACAAATAAAAAAGAAAGAAAAAGCCAGACGAGAAACGTG</pre>											110 220 330 440 550 660 770 880 990 1100 1210 1320 1430 1540 1650 1749

10	20	30	40	50	60	
<pre> MAARSWODELAQQAEEGSARLREMLSVGLGFLRTELGLDLGLEPKRYPGWVILVGTGALG LLLLLFLLYGWAAACAGARKRRSPPRKREEAAAVPAAAPDDLALLKNLRSEEQKKKNRK KLSEKPKPNGRTVEVAEGEAVRTPQSVTAKOPPEIDKKNEKSKKNNKSKSDAKAVQNSS RHDGKEVDEGAWETKISHREKRQQRKRDKVLTDGSLDSTIPGIENITVTTEQLTTASF PYGSKKNKGDSHLNVQVSNFKSGKGDSTLQVSSGLNENLTVNGGGWNEKSVKLSQISAG EEKWNSVSPASAGKRKTEPSAWSQDTGDANTNGKDWGRSWSDRSIFSGIGSTAEVPSQST TSDYQWDVSRNQPYIDDEWVSLNGLSSADPNSDWNAPAEWGNWVDEERASLLKSDQEP DDQKVSDDDKEKGEALPTGKSKKKKKKKKQGEDNSTAQDTEELEKEIREDLPVNTSKT RPKQEKAFSLKTISTSDPAEVLVKNSQP IKTLPPATSTEPSVILSKSDSDKSSSQVPPIL QETDKSKSNTKQNSVPPSQTKSETSWESPQIKKKKKARRET</pre>						60 120 180 240 300 360 420 480 540 582

You would like to amplify MTDH amino acids from 20 to 500 and insert the amplified DNA fragment into bacterial expression vector using standard PCR-based cloning strategy (a.k.a molecular cloning or gene manipulation) and express them in *E. coli*. You made the following primer set. What is/are the problem(s) in using these primers? (Select all that apply)

Forward Primer: 5' CGGCTGCGGGAAATGCTC 3'
Reverse Primer: 3' TTATTCGGCTGGATCACTAGT 5'

- A. The direction of forward primer and reverse primers is incorrect; it needs to be reversed. (i.e. 3' to 5' for forward and 5' to 3' for reverse)
- B. You are amplifying the wrong MTDH fragments. The primers shown above would amplify from 40 to 1500, not 20 to 500.
- C. Stop codons are missing from reverse primers; thus translation will not occur properly.
- D. Designed primers for forward and/or reverse are not in frame, which will cause frameshift mutations.
- E. Amplified PCR product from these primers cannot be well ligated to the vector since they do not have sticky ends.

87. Which of the following concepts are components of Darwin's theory of natural selection?
Select all that apply

- A. Variation exists within a species for characteristics.
- B. Parents pass on some of their characteristics to offspring.
- C. Random mutations affect hereditary information.
- D. Because of distinct characteristics, some individuals within a particular population produce more offspring than others.
- E. Only the fit survive.

Questions 88 to 94. Indicate if each of the statements below describes a typical prokaryotic genome (A), a typical eukaryotic genome (B) or both (AB).

- 88. Contains several million base pairs of DNA. **B**
- 89. DNA is distributed among several chromosomes. **B**
- 90. DNA is shared between individuals via horizontal transfer. **A**
- 91. Most of DNA consists of genes coding for proteins. **A**
- 92. A large amount of DNA is noncoding. **B**
- 93. Within a gene, there is a little noncoding DNA. **A**
- 94. Genes with related functions are separated across the genome. **A, B**

Questions 95 & 96. The gene *noey2* is present on Chromosome 1, and in healthy individuals is only expressed from the chromosome of paternal origin while it is silenced on the chromosome of maternal origin.

95. What molecular mechanism most likely accounts for this phenomenon?

- A. This region is deleted from the maternal chromosome by transposons.
- B. This region has histones that are highly acetylated.
- C. This region is highly methylated on the maternal chromosome.
- D. Maternal Chromosome 1 is inactivated.
- E. This gene uses an alternative sigma factor.

96. In a healthy female of 30 weeks gestation, what would be the expected imprinting pattern of the *noey2* gene?

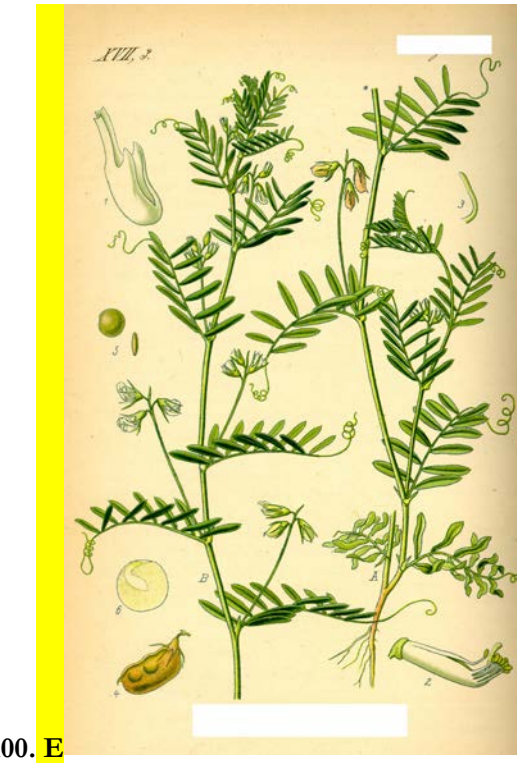
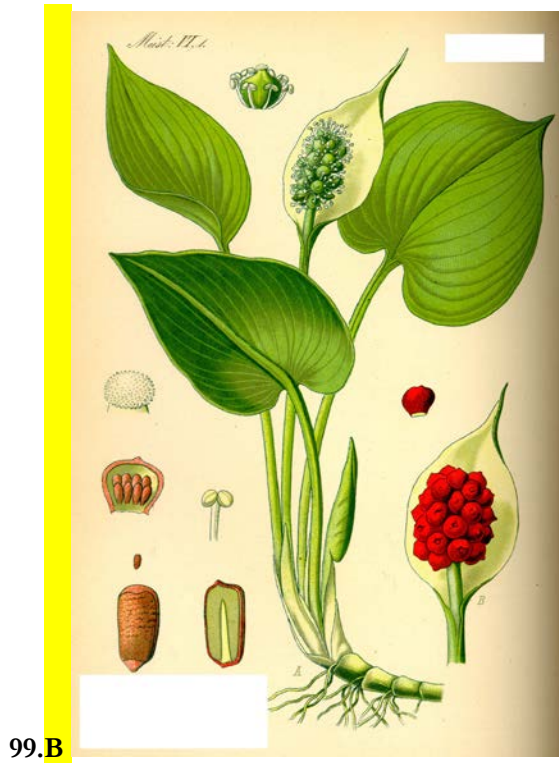
- A. All copies of the *noey2* gene will have a female (maternal) imprint.
- B. One copy of the *noey2* gene will have a female (maternal) imprint in her somatic cells.
- C. All copies of the *noey2* gene will reset after birth to have a female (maternal) imprint.
- D. One copy of the *noey2* gene will have a male (paternal) imprint in her germ cells.
- E. All copies of the *noey2* gene with a male (paternal) imprint will be silenced.

Match the 5 depicted angiosperm species with the family each one belongs to.

- A. Amaryllidaceae
- B. Araceae

- C. Brassicaceae
- D. Cyperaceae

- E. Fabacea





101. C

102. Which of the following is NOT true of life cycle for gymnosperms? Choose all that apply.

- A. An ovulate cone scale has two ovules, each containing a megasporangium.
- B. The megaspore develops into a female gametophyte that contains two or three archegonia, each of which will form an egg.
- C. Embryo is diploid while seed coat and gametophyte tissue (food reserves) are haploid after fertilization.
- D. While the pollen tube develops, the megasporocyte undergoes meiosis, which is divided into one or two megaspores. One survives as a megaspore.

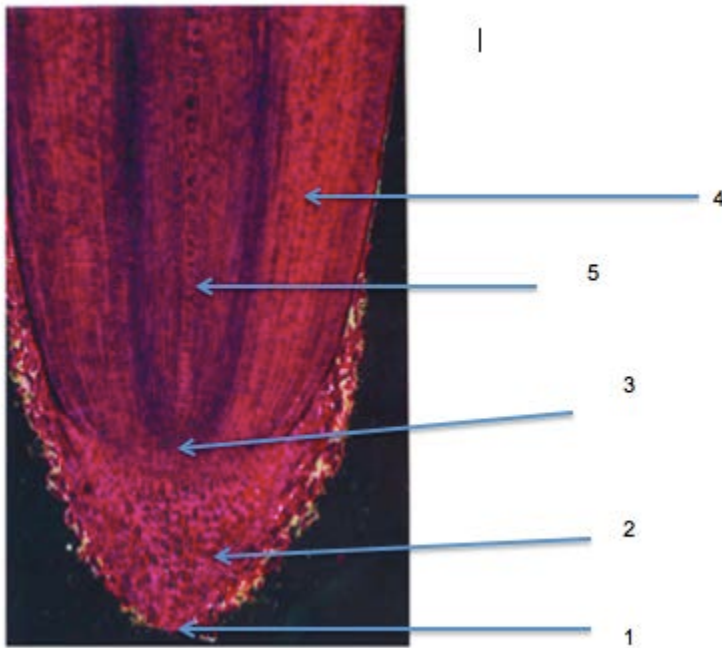
103. When compared to plants grown in normal soils, plants grown under soil that is partially waterlogged would have which of the following characteristics? (Select all that apply)

- 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.

104. Select all of the following that are similarities of both plants and charophytes? (Select all that apply)

- A. Alternation of generations.
- B. Rosette-shaped cellulose synthesizing enzymes.
- C. Peroxisome enzymes.
- D. Formation of phragmoplast.
- E. Presence of sporopollenin.

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



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

106. In contrast to animals which can move, plants must get all their minerals from the surrounding soil. As a result plants must alter their local environment including the pH of the surrounding soil. Which of the following statements about nutrition of plants from their surrounding soil are CORRECT? (Select all that apply)

- A. Mineral anions such as nitrates are much more available to plants than 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.

107. Auxin and cytokine 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. (Select all that apply)

- 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.

108. Select all of the following effects that are induced by increased ethylene levels. (Select all that apply)

- A. The triple response (simultaneous slowdown in elongation, thickening of stem and increased curvature).
- B. Leaf senescence.
- C. Apoptosis.
- D. Thickening of cell walls.
- E. Increased cellulose synthesis.

Questions 109 to 114. For each of the following taxa, mark “A” for TRUE if it includes more than 1000 known parasitic species, and “B” for FALSE if it does not. An example organism (which may not be parasitic) from each group is given in parentheses.

109. Arachnida (spider) **A**

110. Nematoda (*Caenorhabditis elegans*) **A**

111. Polyplacophora (chiton) **B**

112. Hymenoptera (bumblebee) **A**

113. Nemertea (ribbon worm) **B**

114. Acanthocephala (spiny-headed worm) **A**

115. Which of the following hypotheses are plausible explanations for the observation that most individuals within a species behave very similarly despite being exposed to many distinct environments and having different genomes? (Select all that apply)

- A. Neural development depends more on chemical concentration than on the kind of chemical signal between cells.
- B. Only a brief exposure to the environment during a critical period is required for ‘normal’ development.
- C. Developing embryos are sheltered from environmental differences in most animals
- D. An organism is capable of developmental compensation (playing catch-up).
- E. Animals learn the proper behavior by watching others of its species.

116. Tiger salamanders can develop into either a normal form, which eats insects, or a cannibalistic form. All else being equal, cannibals are less likely to develop when only their siblings are present in the pond. This is an example of... (Select all that apply)

A. Behavioral flexibility.

B. Latent learning.

C. Genetic differences.

D. Stimulus filtering.

E. Kin recognition.

117. Greylag geese retrieve eggs that roll away from the nest they are incubating. In experiments, the geese were found to continue the retrieval behavior even when the egg was taken away from them in the middle of retrieval. Moreover, geese will retrieve gigantic artificial eggs that are placed near their nests. This example illustrates... (Select all that apply)

A. Behavioral inflexibility.

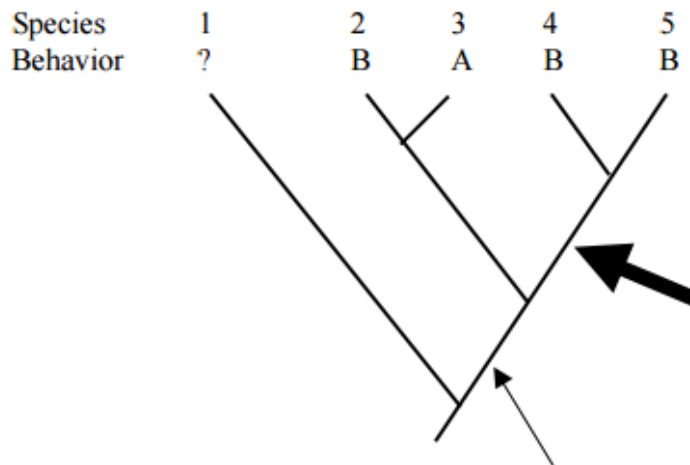
B. A fixed action pattern (FAP).

C. Developmental homeostasis.

D. Stimulus filtering.

E. Behavior toward a supernormal stimulus.

Questions 118 to 120. Here is a make-believe phylogeny. Species 2, 4, and 5 exhibit behavior B, while species 3 exhibits behavior A. Experts have reason to believe these behaviors have largely genetic explanations. Note that the behavior of Species 1 is currently unknown:



118. What is the most parsimonious inference about the behavior shown by the species at the thick arrow? **B**

119. What can be inferred by parsimony about the behavior of the species at the thin arrow? **B**

120. How does the answer to B change if Species 1 is found to have behavior A? Both A and B are acceptable

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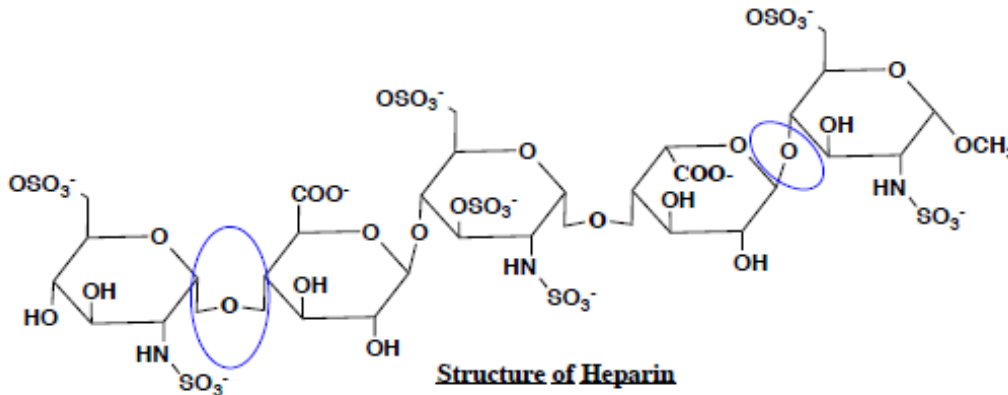
Student Name _____ Student ID# _____

Place all answers to Part C, Questions 1 to 4, 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.

Question 1. (10 points)

The following is the structure of heparin, which is naturally produced by basophils and mast cells in the body and is also manufactured and distributed as the most widely used anti-coagulant.



- a. Which class of macromolecules best describes heparin: choose from *lipids/ nucleic acids/carbohydrates/ proteins*? Explain why you selected this option.

Answer: carbohydrates (1 point)

Explanation: It is comprised of modified hexose monosaccharides linked to each other by glycosidic bonds. (3 points)

- b. Identify the circled covalent bonds as *glycosidic/ peptide/ phosphodiester/ ester bond* and list the byproduct of the reaction that results in the formation of this covalent bond.

Glycosidic 2 points

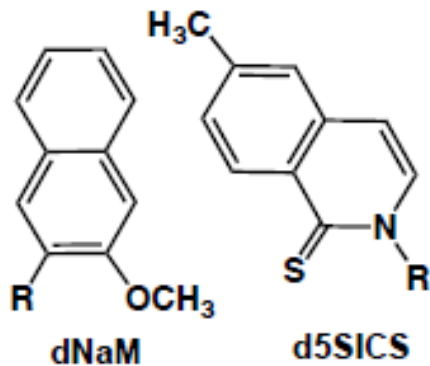
Water molecule 2 points

- c. Heparin is often used to purify nucleic acid (both DNA and RNA) binding proteins. Explain what the similarity between heparin and nucleic acids is that allows them to bind to these proteins.

Both heparin (due to SO₃⁻ groups) and nucleic acids (due to the PO₄²⁻ of the sugar phosphate backbone) are negatively charged and therefore form ionic bonds with the nucleic acids binding proteins that are rich in amino acids with positively charged side chains. (4 points)

Question 2 (15 points)

Organisms are defined by the information encoded in their genome, which can either be DNA or RNA. Essentially, there are four bases (A, T, G and C) that undergo specific complementary base pairing per Chargaff's rule to form the DNA genome. Recently, *Malishev et al.*, Nature, Vol 509, Page 385-388) have introduced two synthetic nucleotides into bacteria, which are designed to form a new complementary base pair of d5SICS–dNaM as shown below.



(R = sugar/phosphate backbone)

- a. In a bacterial cell, how many possible tri-nucleotides (codons) exist using the bases A, T, G, C, d5SIC and dNaM?

(6 X 6 x6) = 216 possible tri-nucleotides (3 points)

- b. Circle the most likely bonding (choose from *covalent bond/ hydrogen bond/ ionic bond/ hydrophobic interaction/ VDW forces*) that allows d5SICS–dNaM base pairing and specify how it differs from the typical purine–pyrimidine base pairing.

hydrophobic interaction (2 points)

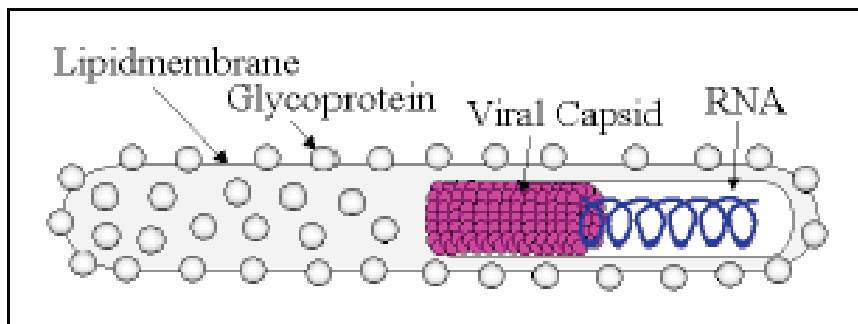
Typical purine–pyrimidine base pairing is through hydrogen bonding (2 points)

- c. The following schematic represents the process of adding the incoming nucleotides to a growing strand of Ribonucleic acid (RNA).

- i. On the schematic, label the 5' and 3' ends by filling in the shaded boxes. *(2 points)*
- ii. Show the direction of polymerization of RNA by drawing an arrow and give the sequence that serves as a template of the RNA sequence that is provided. *(1 point)*
 5' _____ 3' *5'-CATC-3'* *(4 points)*
- iii. Box the nitrogenous base that is uniquely a part of RNA and not DNA. *(1 point)*

Question 3 (15 points)

Ebola virus has a single-stranded RNA genome as shown in the schematic below.



- a. If the viral genome contains 35% adenine nucleotide, predict the percentages of remaining nucleotides that make its genome or if you can't, explain why not.

No. (1 point)

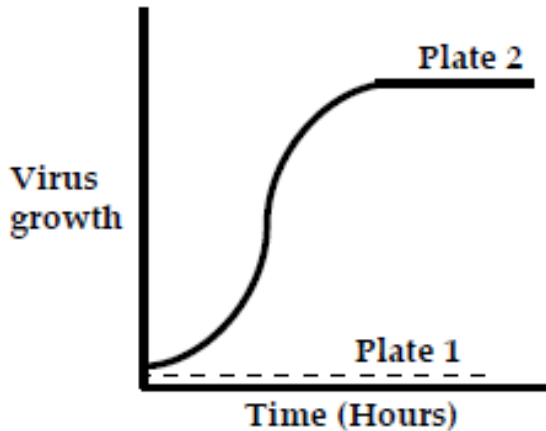
You can't since the virus has a single stranded RNA genome and does not show complementary base pairing. (2 points)

b. Would the genome of the Ebola virus be chemically less stable compared to the genome of a DNA virus? Why or why not?

The genome of Ebola virus would be less stable compared to the genome of a DNA virus. (2 points)

RNA is comprised of ribonucleotides as the building blocks, which have an extra hydroxyl group (-OH group) at the 2'C position of the ribose base. This makes RNA more reactive and less stable compared to DNA, which lacks the extra -OH group at the 2'C position. (3 points)

c. Niemann-Pick C1 (NPC1) is a lysosomal protein (*Nature*, Vol 477, Page 344-348). You isolate fibroblast cells from two Individuals. The fibroblasts from Individual 1 lack functional NPC1 protein, unlike those from Individual 2 that express normal levels of functional NPC1. You grow an equal number of fibroblasts from Individual 1 in Plate 1 and Individual 2 in Plate 2 and infect them with equal concentrations of Ebola virus. You measure the growth of Ebola virus within the cells of plates 1 and 2 at different time intervals and obtain the following profile. Based solely on the information provided...



a. Would you use an inhibitor or activator of functional NPC1 protein to combat Ebola infection? Explain why you selected this option.

You would use an inhibitor of NPC1 protein (1 point)

Since the NPC1 deficient fibroblast cells from Individual 1 prevents growth of Ebola virus. (2 points)

b. Would Ebola virus infect and grow within the target cells at *acidic/basic/neutral* pH? Select the correct option and explain why you selected this option.

Acidic (1 point)

This virus needs NPC1 protein for its growth. This is a lysosomal protein and therefore works in an acidic environment. (3 points)

Question 4 (5 points)

Unlike eukaryotes, there is only one origin of replication (ori site) in the bacterial genome. If DNA polymerase enzyme adds nucleotides at the rate of 10,000 base pairs/minute *in one direction* and the bacterial cells replicate every 20 minutes, what is the size (in terms of base pairs) of the bacterial genome?

Replication occurs at the rate of 10,000 bp/min in one direction. Number of bases replicating bidirectionally is 20,000 bp/min.

In 20 minutes, number of replicating bases is $20,000 \times 20 = 4 \times 10^5$ bp. So, the size of the genome is 4×10^5 bp. (5 points)

Question 5. (6 points)

If sexual reproduction enhances a species' fitness why are there asexual organisms? Provide two reasons and explain why. (Each reason: 1 point; Support for each reason: 2 points)

The answers to this question are quite complex and elaborate and would fill many papers. However, for this purpose, some major highlights of the answer to the question would include the following:

- 1. Asexual reproduction does not require time and energy to be spent on seeking a receptive mate. (2 points)*
- 2. It is an efficient method as it enables species to produce a large number of offspring very quickly and thus perhaps fill up niche's quickly, preventing or delaying other species competing to utilize a habitat or resource. (2 points)*
- 3. It enables organisms, such as plants, to spread and colonize an area in short period of time. (2 points)*
- 4. It enables an organism to quickly take advantage of, and utilize stable environments in with there is very little change. (2 points)*

We hope to see you as a Finalist!!