

USABO SEMIFINAL EXAMINATION

March 19 to March 28, 2014

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.*

*Cell Biology*

1. Which of the following statements is TRUE regarding protein self-assembly?

- A. ALL subunits must be completely identical.
- B. ATP is always required for self-assembly because entropy of the system is decreasing.
- C. Catalysts or nucleating agents are always required for self-assembly.
- D. Protein self-assembly occurs only in eukaryotes.
- E. Self-assembly can occur along a scaffold.

2. Which of the following proteins act as molecular motors that move along microtubules of the cytoskeleton?

- A. Myosin.
- B. Dynein.
- C. Flagellin.
- D. Kinesin.
- E. B and D.

3. Which of the following statements is FALSE concerning electrochemical gradients in a neuron at normal physiological conditions?

- A.  $[\text{Ca}^{2+}]$  is greater outside the cell than inside the cytosol.
- B.  $[\text{Ca}^{2+}]$  is greater in the ER than inside the cytosol.
- C.  $[\text{Na}^+]$  is greater in the cytosol than outside the cell.
- D.  $[\text{K}^+]$  is greater in the cytosol than outside the cell.
- E.  $[\text{Cl}^-]$  is lower inside the cell than inside the cytosol.

Questions 4 to 7. Characterize each question regarding hemoglobin switching as either TRUE (A) or FALSE (B):

4. It exhibits cooperative binding. **A**
5. It transforms from R state to T state to bind oxygen in the lungs. **B**
6. 1,3-bisphosphoglycerate increases affinity to oxygen. **B**
7. Mutations that stabilize the R state increase affinity to oxygen. **A**
8. Which of the following molecules would be expected to bind to membrane-bound receptors?
  - A. Thyroid hormones.
  - B. Vitamin D.
  - C. Cortisol.
  - D. Antidiuretic hormone.**
  - E. Nitric oxide.
9. A protein has a pH of 5.6. How would you purify it from a mixture of protein?
  - A. Anion exchange column with buffer pH 7, protein eluting later.**
  - B. Anion exchange column with buffer pH 4, protein eluting later.
  - C. Anion exchange column with buffer pH 5.6, protein eluting later.
  - D. Anion exchange column with buffer pH 7, protein eluting first.
  - E. Cation exchange column with buffer pH 6, protein eluting later.
10. Compare a *Escherichia coli* (*E. coli*) cell to a cell from the human intestinal tract. Which of the following is a TRUE difference between them?
  - A. The two cell types contain different proportions of the six major elements CHNOPS.
  - B. *E. coli* has no macromolecules while intestinal cells do.
  - C. *E. coli* cells have D-Alanine and L-Alanine, while intestinal cells only have L-Alanine.**
  - D. The ribosomes of intestinal cells have a lower sedimentation coefficient than ribosomes of *E. coli* cells.
  - E. Intestinal cells can use homologous recombination to repair DNA double strand breaks using the sister chromosome while *E. coli* cannot.
11. Organisms found in water have less temperature fluctuations due to water's high:
  - A. Ability to ionize.
  - B. Average kinetic energy.
  - C. Specific gravity.
  - D. Specific heat.**
  - E. Molecular weight.

12. What occurs to a cell from a human liver and a cell from the cortex of a plant root when placed in distilled water?

- A. The liver cell will swell; the plant cell will become very turgid.
- B. The liver cell will swell; the plant cell will become flaccid.
- C. The liver cell will shrivel; the plant cell will become very turgid.
- D. The liver cell will shrivel; the plant cell will become flaccid.
- E. Both cells will be in osmotic balance with the water, and hence will neither swell nor shrink.

13. Which of the following amino acids showing their R groups would you expect to find on the exterior of a globular protein in an aqueous solution?

- A. Alanine  $-\text{CH}_3$ .
- B. Glycine  $-\text{H}$ .
- C. Leucine  $-\text{CH}_2-\text{CH}-(\text{CH}_3)_2$ .
- D. Serine  $-\text{CH}_2-\text{OH}$ .
- E. Valine  $-\text{CH}-(\text{CH}_3)_2$ .

14. In your mentor's lab, you are responsible for growing and maintaining animal cells in culture. You come in on Monday morning and the cultures appear very unhealthy. You immediately run some tests and find there is a high concentration of lactic acid in your culture fluid. You determine that the cause is

- A. Glycolysis is not occurring.
- B. The medium has too high a concentration of sugar.
- C. There is excessive ethanol production.
- D. There is not sufficient  $\text{O}_2$ .
- E. There is too much  $\text{O}_2$ .

### *Plant Anatomy & Physiology*

15. During secondary growth, cork cambium is continually shed and replaced by cells in which of the following cell layers?

- A. Secondary phloem.
- B. Primary phloem.
- C. Phelloderm.
- D. Vascular cambium.
- E. Pith.

16. You have been assigned to measure  $\text{CO}_2$  exchange in a leaf. During the period that you measure,  $8.0 \times 10^6$  molecules of 3- phosphoglycerdehyde (PGAL) are made from  $\text{CO}_2$  in photosynthesis and  $2.0 \times 10^6$  molecules of glucose are used in cellular metabolism (glycolysis and respiration). How many net molecules of  $\text{CO}_2$  would you detect being taken up by the leaf in your measurement?

- A.  $2 \times 10^6$
- B.  $4 \times 10^6$
- C.  $18 \times 10^6$
- D.  $24 \times 10^6$
- E.  $32 \times 10^6$

17. Which of the following is **NOT** an effect of strongly acidic precipitation on plants grown in unbuffered soil?

- A. Decreased disease resistance.
- B. Decreased seedling survival.
- C. Increased nutrient availability.
- D. Reduced growth.
- E. Reduced seed germination.

18. Which of the following provides evidence for the statement:  
“Photophosphorylation is driven by a proton gradient and only indirectly by sunlight”?

- A. ADP phosphorylation can proceed in the dark after chloroplasts have been stimulated briefly by a flash of light.
- B. Free chlorophyll is capable of phosphorylating ADP if the pH is lowered to produce high levels of protons.
- C. Chloroplasts can phosphorylate ATP in the dark if a proton gradient has been established artificially.
- D. NADPH generated in cyclic electron flow can be used as a phosphate source for phosphorylating ADP.
- E. When light hits a chlorophyll molecule, its protons are excited to a higher energy level and transfer their energy to ADP.

19. In the  $C_4$  pathway, carbon fixation takes place in the \_\_\_\_\_ cells, and then is transferred as malic or aspartic acid to \_\_\_\_\_ cells where carbon dioxide is released for entry into the Calvin cycle.

- A. Bundle sheath, epidermal.
- B. Epidermal, mesophyll.
- C. Mesophyll, bundle sheath.
- D. Stomatal, epidermal.
- E. Stomatal, mesophyll.

20. You are growing legumes in your garden. You notice the following symptoms in your plants: reduced chlorophyll production in the leaves, poor root formation, and delayed maturity. This combination of symptoms is best linked to a deficiency in

- A. Calcium.
- B. Chlorine.

- C. Iron.
- D. Magnesium.
- E. Sulfur.

**21. One of the challenges of plants growing in the forest is receiving sufficient light. From the following, select the best evolutionary adaptation that increases exposure of a plant to light in this situation.**

- A. Absence of petioles.
- B. Apical dominance.
- C. Closing of the stomates.
- D. Intercalary meristems.
- E. Lateral buds.

**22. If you wanted to genetically engineer a plant to be more resistant to drought, increasing production of which of the following hormones might be a good first attempt:**

- A. Absciscic acid.
- B. Auxin.
- C. Brassinosteroid.
- D. Cytokinin.
- E. Gibberellin.

**23. Several characteristics that distinguish plants from green algae are evolutionary adaptations to life on land. Archegonia and antheridia are characteristics of land plants that:**

- A. Enclose their gametes and prevent them from drying out.
- B. Evade their being eaten from land animals.
- C. Prevent their leaves from drying out.
- D. Protect their leaves against mutagenic ultraviolet radiation.
- E. Move water from the soil to their leaves.

### ***Animal Anatomy and Physiology***

**24. Training exercises such as jogging, swimming and aerobics result in:**

- A. increased number of sarcomeres per unit.
- B. increased response time of muscle fibers.
- C. increased number of motor units.
- D. increased frequency of stimulated contractions.
- E. increased number of mitochondria per muscle fiber.

**25. The second line of defense for the body is the innate immune system. Which of the following is a receptor associated with the process of innate immunity?**

- A. Immunoglobulin receptor.

- B. Toll-like receptors.
- C. Major Histocompatibility complex-I.
- D. T-cell receptor.
- E. NMDA receptor.

Questions 26 to 28. Immunoglobulin class switching is a normal component of the human immune response. Characterize the following statements regarding class switching as either TRUE (A) or FALSE (B):

26. Any antibody isotype can undergo class switching to any other isotype. **B**
27. Once performed, class switching is irreversible. **A**
28. Class switching involves transcriptional silencing through methylation in certain parts of the immunoglobulin transcript. **B**
29. Only the constant Ig domain is affected during class switching, not the variable domain. **A**
30. Duchenne muscular dystrophy is a disease that leads to muscle wasting. Which of the following best describes what is occurring in the individual's muscles?
- A. GM<sub>2</sub> ganglioside accumulates in lysosomes of muscle cells.
  - B. Lactic acid accumulates in muscles until levels fatal to muscle cells are reached.
  - C. **Progressive muscle fibrosis restricts blood supply to muscle cells, which then die.**
  - D. Toxic levels of the protein dystrophin and its abnormal breakdown products accumulate, eventually killing muscle cells.
  - E. The walls of the blood vessels supplying muscles undergo fibrosis, occluding the blood flow to the muscles.
31. Which of the following is NOT a means whereby gas exchange may be facilitated in some fish?
- A. **Movements of the operculum pump water through the gills into the mouth.**
  - B. Oxygen diffuses through the skin to the blood vessels just below.
  - C. The direction of blood flow through the gill filaments is opposite the flow of water.
  - D. With its mouth open, a fish may swim swiftly through the water.
  - E. The fish may surface and take in air.
32. Which statement does NOT pertain to at least some hibernators?
- A. Warm up endothermically when aroused.
  - B. Awaken with an increase in CO<sub>2</sub> concentration in the atmosphere.
  - C. Continue to monitor the environment during hibernation.
  - D. **Hibernate during the winter to stay warm.**
  - E. Respire at a significantly lower rate.
33. Which of the following is the correct sequence involved in urine formation?

- I. Filtration
- II. Reabsorption
- III. Secretion

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

34. A large cube is formed from the material obtained by melting three smaller cubes: Cube 1 is 3cm per side; Cube 2 is 4cm per side; and Cube 3 is 5 cm per side. What is the ratio of the total surface areas of the smaller cubes and the large cube?

- A. 2:1
- B. 1:2
- C. 3:2
- D. 25:18
- E. 27:20

35. Some of the axons of spinal motor nerves may be up to a yard in length. Suppose you stimulated an axon about halfway along its length. What is NOT going to occur?

- A. Chloride ions will pass from inside the axon to the outside.
- B. Depolarization will be propagated toward and away from the cell body.
- C. The sodium-potassium pump will be activated.
- D. Sodium ions will pass from outside the axon to its interior.
- E. Potassium ions will pass from inside the axon to the outside.

36. During prokaryotic transcription:

- A. Nucleotides are polymerized by DNA polymerase.
- B. Initiation occurs at a site recognized by the sigma factor.
- C. Only single gene-sized mRNA molecules are synthesized.
- D. Both DNA strands of a single gene are used as templates simultaneously.
- E. Thymine in RNA pairs with adenine in DNA.

### *Ethology*

Questions 37 to 39 are descriptions of experiments or observations that can be classified as one of the following forms of learning:

- A. Classical conditioning.
- B. Cultural learning.
- C. Habituation.
- D. Imprinting.
- E. Operant conditioning.

37. A young elephant is captured. When you first enter its stockade, it sways from side to side and trumpets loudly. It continues this behavior each time you appear until finally it no longer sways or trumpets when you appear.

**D Habituation**

38. A zookeeper takes a chimp that was born at the zoo out to play each day. When it is older, the chimp has to be on leash before it can go outside. After a while, the chimp runs to the door whenever the zookeeper even leans down to pick up the leash.

**A Classical conditioning**

39. A worker bee is foraging for food in an open field where you have placed a dish of sugar water. The bee eventually finds your dish. You mark the bee as it feeds and note that the bee returns to the same location for sugar water repeatedly.

**E. Operant Conditioning**

### Genetics and Evolution

40. Which of the following mechanisms of microevolution is influenced specifically by population size?

A: Gene flow.

**B: Genetic drift.**

C: Mutation.

D: Natural selection.

E: Sexual selection.

Questions 41 to 44. The females of a certain species of dolphin have previously been reported to grow to an average body length of 1.72 meters from beak to tail. Marine biologists sample a subpopulation of these dolphins and find a sample mean body length of 1.78 meters for females, with a 95% confidence interval of (1.73, 1.83). The null hypothesis  $H_0$  is that the dolphins in this subpopulation have the same average body length as the previously reported value. Assuming a normal distribution and given the information above, which of the following statement(s) represent correct analyses in this study?

41. The researchers can reject the null hypothesis at the  $\alpha=0.05$  level. **A**

42. The researchers can reject the null hypothesis at the  $\alpha=0.1$  level. **A**

43. The researchers can conclude with 99% confidence that the population mean body length is in the given confidence interval. **B**

44. The researchers can conclude with 95% confidence that the population mean body length is less than 1.85 m. **A**



45. While researching a genetic disease, an aberrant molecule was found that leads to improper protein production. This molecule is found in the nucleus but rarely in the cytoplasm and binds to the middle of the freshly transcribed mRNA molecule. By what mechanism might this molecule impair protein production?

- A. Blocking of the intron splice site and misrecognition of the spliceosome leading to improper exon sequence.
- B. Early termination of translation due to blocked codon.
- C. Alternate anti-codon recognition at the site leading to wrong amino acid placement.
- D. Disruption of 5' cap or poly A tail leading to early degradation of the mRNA molecule.
- E. Retention of the mRNA molecule in the nucleus.

46. In the *lac* operon in *E. coli*, a mutation LacD causes constitutive beta-galactosidase expression. Constructing a heterozygote for LacD by introducing an F plasmid containing the wild-type *lac* operon does not restore the normal phenotype. Given this information, LacD could be which of the following?

- A. A mutation in the *lac* operon's promoter sequence.
- B. A mutation in the *lac* operon's operator sequence.
- C. A loss-of-function mutation in the *lac* repressor.
- D. A gain-of-function mutation in the *lac* repressor.
- E. A mutation in an extragenic upstream activating sequence.

Questions 47 to 50. Let population P1 be the F1 generation of a cross between inbred diploid lines with allelic states A and a. Let population P2 be the F2 generation. Let  $f_A(P)$  be the frequency of allele A in population P. Let  $HHWE(f_A)$  be the expected frequency of Aa heterozygotes in a population at Hardy-Weinberg equilibrium where  $f_A$  is the frequency of allele A. Finally, let  $H(P)$  be the expected frequency of Aa heterozygotes in population P given the mating structure of the cross. Which of the following should be TRUE (A) and which should be FALSE (B)?

47.  $HHWE(f_A(P1)) < H(P1)$ . **A**

48.  $HHWE(f_A(P1)) > H(P1)$ . **B**

49.  $HHWE(f_A(P2)) < H(P2)$ . **B**

50.  $HHWE(f_A(P2)) > H(P2)$ . **B**

51. The allosteric effectors allolactose and tryptophan exert their effects on target operons by:

- A. Binding to cyclic AMP.
- B. Binding to the catabolite activator protein (CAP).
- C. Causing a change in the configuration of the repressor molecule.

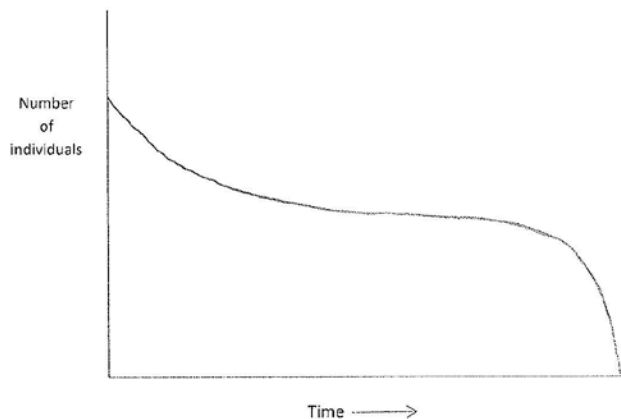
- D. Causing a change in the configuration of the operator.
- E. Interacting with the promoter region of the operon.

## Ecology

52. Factors whose influence on mortality or reproductive rates of a species increase as population size increases are known as

- A. Density-dependent limitations.
- B. Density-independent limitations.
- C. Intrinsic rate factors.
- D. S factors.
- E. Survivorship factors.

53. Which animal's life history best fits the survivorship curve below?



- A. Fruit fly.
- B. Hydra.
- C. Oyster.
- D. Human.
- E. Fish.

54. Which of the following statements is FALSE?

- A. Two different sympatric species will never have exactly the same niche.
- B. Intense competition occurs only between closely related species.
- C. Intense competition between two species sometimes leads to character displacement.
- D. Intense competition between two species may sometimes lead to extinction of one of the species.
- E. Intense competition between two species sometimes leads to range restriction, reduction or eliminating sympatry.

55. Which of the following would NOT have a significant effect on carrying capacity for a population of placental mammals?

- A. Competition.
- B. Infectious disease.
- C. Six-month drought after mating season
- D. Physiological changes induced by crowding.
- E. Predation.

**56. Which of the following is a growth limitation which most characteristically affects the increase in population of animals with short life spans, early reproduction, and high reproductive rates?**

- A. Predation.
- B. Competition for food.
- C. Weather.
- D. Emigration.
- E. Competition for shelter.

**57. The principal physical determinants of the nature of a biome are the**

- A. Amount of annual precipitation and the average temperature.
- B. Coriolis Force and its seasonal angle relative to the sun.
- C. History of continental drifting and the height of mountains.
- D. Temperature and the prevailing direction of the wind.
- E. Winds and ocean currents.

**58. Compare the circulatory system of an earthworm with that of a vertebrate and a mollusk.**

- A. An earthworm is like a vertebrate in that it has a closed circulatory system, but like a mollusk in that it has multiple hearts.
- B. An earthworm is like a vertebrate in that it has multiple hearts, but like a mollusk in that it has an open circulatory system.
- C. An earthworm is like a vertebrate in that it transports oxygen in a closed circulatory system, but like a mollusk in that it transports other nutrients in an open circulatory system.
- D. An earthworm is like a vertebrate in that it has a coelom, but like a mollusk in that the coelom contains only some of its vital organs
- E. An earthworm is like a vertebrate in that it has multiple heart chambers, but like a mollusk in that it has a closed circulatory system.

**59. If you traveled from northern Canada to the southernmost tip of Florida, what order I to IV would you cross?**

- I. Deciduous forest.
- II. Taiga.
- III. Tundra.
- IV. Tropical rain forest.

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

60. A food chain consists of four trophic levels, beginning with the primary producers. If the amount of energy fixed by the producers is  $x$ , approximately how much energy will probably be available to the fourth trophic level?

- A.  $1.0 x$
- B.  $0.1 x$
- C.  $0.01 x$
- D.  $0.001 x$
- E.  $0.0001 x$

*PART B: Each question is valued at 2 points.*

*Cell Biology*

61. A mixture of amino acids is spotted onto 10 cm long chromatography paper and run using ether. Chromatography separates molecules by polarity; polar molecules will interact more with paper and travel slowly. After finishing chromatography, you identify 4 spots which absorb UV light (a characteristic of conjugated pi systems), which we label A-D. Spot A traveled 6.2 cm, spot B traveled 6.1 cm, spot C traveled 5.5 cm, and spot D traveled 1.2 cm. What amino acid does spot C represent?

- A. Proline
- B. Tyrosine
- C. Phenylalanine
- D. Histidine
- E. Tryptophan

62. A yeast extract contains all the enzymes required for alcohol production. The extract is incubated under anaerobic conditions in 1 liter of media containing: 200 mM glucose, 20 mM ADP, 40 mM ATP, 2 mM NADH, 2 mM NAD<sup>+</sup> and 20 mM Pi. What is the maximum amount of ethanol that can be produced in these conditions?

- A. 2 mM
- B. 20 mM
- C. 40 mM
- D. 200 mM
- E. 400 mM

63. Which steps of the following general signal transduction pathway typically result in amplification?

Receptor ligand ➡ GPCR ➡ G protein ➡ Adenylyl cyclase ➡ Cyclic AMP ➡ Protein kinase cascade ➡ Target proteins

- A. GPCR ➡ G protein.
- B. Adenylyl cyclase ➡ cAMP.
- C. cAMP ➡ Protein kinase cascade.
- D. Protein kinase cascade.
- E. G protein ➡ Adenylyl cyclase.

Questions 64 to 68. A new cancer drug is being developed to target a certain point in the cell cycle. The drug stops the cell cycle from proceeding and halts growth in the rapidly dividing cells. The drug could work by (Use “A” for TRUE and “B” for FALSE):

64. Mimicking a growth factor. **B**

65. Causing premature degradation of cyclin proteins. **A**

66. Promoting mitosis. **B**

67. Enhancing the binding of cyclins to CDKs. **B**

M

68. Blocking the signal to enter the G2 phase. **A**

69. Because migrating hummingbirds store energy for flight as \_\_\_\_\_, they are still light enough to fly.

- A. Disaccharides
- B. Fat
- C. Glycogen
- D. Protein.
- E. Steroids

70. Which statement about buffers is FALSE?

- A. Large, sudden pH shifts are moderated by the presence of a buffer in a solution.
- B. Each buffer has a particular pH range at which it is most effective at buffering changes in pH.
- C. A buffering system is usually composed of a weak acid and its conjugate base.
- D. The equilibrium between the H<sup>+</sup> donor form and the H<sup>+</sup> acceptor form does not change with the addition of acid or base to the solution.
- E. A major buffering system in the human bloodstream is the carbonic acid-bicarbonate system.

**71. One way in which scientists can visualize proteins in cells is to label them with primary antibodies that bind specifically to the protein of interest. Secondary antibodies conjugated to fluorescent particles are then bound to the primary antibodies thus helping to visualize the staining. Suppose a researcher who is studying nuclear lamina uses this procedure to label lamin proteins (which are part of the nuclear envelope) in cells. Unfortunately, she does not see any staining when she looks at the cells through a microscope. What are some possible reasons for this problem?**

- I. The cells were prepared incorrectly and the protein structures were disrupted, preventing antibodies from recognizing them.
- II. The researcher added too much primary antibody, leading to nonspecific binding.
- III. The primary antibodies were unable to bind to the lamins because the binding sites were blocked by chromatin in the nucleus.
- IV. The secondary antibody was not correctly designed, so it did not recognize the primary antibody.
- V. The researcher added too much secondary antibody, leading to nonspecific binding.

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

**72. Considering Question 71, a researcher is studying progeria, a disease characterized by rapid aging in children. Progeria is often caused by various mutations in the lamin A gene that disrupt protein stability and function. After the researcher finishes troubleshooting her staining assay, she repeats the process to label lamin A in skin cells from control patients and patients with progeria. She is surprised to find that:**

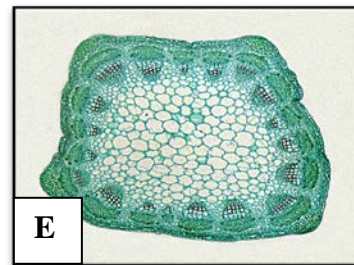
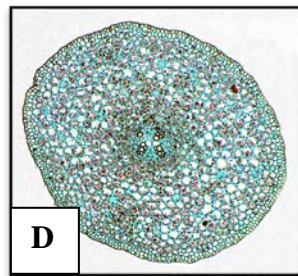
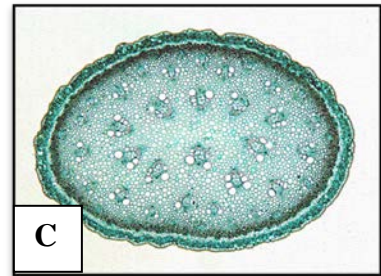
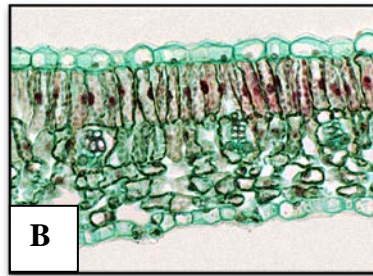
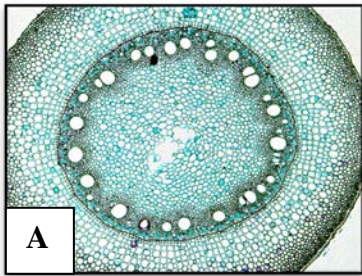
- **Case 1: Some of the progeria cells look exactly like the control cells, with even, bright staining in the nucleus.**
- **Case 2: Others show more clumped uneven staining.**
- **Case 3 Some have no staining at all.**

**Assuming the technical parts of the assay all worked perfectly, which of the following are possible explanations for the Case 2 results?**

- A. Different patients have different types of lamin A mutations.**
- B. Mutations could affect small (but crucial) parts of lamin A that are far away from the part that binds to the primary antibody.
- C. Mutations could disrupt lamin A structure in the same area as the primary antibody binding site, making it impossible for the primary antibody to recognize the protein.
- D. Mutations may cause lamin A to be distributed unevenly in the nuclear envelope**

*Plant Anatomy & Physiology*

For questions 73 and 75, use the diagrams below labeled A through E.



73. Which of the images above are monocot stem and a dicot root? **C & D**
74. Which of the images above are monocot root and a dicot leaf? **A & B**
75. Which of the images above are monocot root and a dicot stem? **A & E**
76. A certain type of organism is photosynthetic, uses starch as its principal carbohydrate storage product, possesses multicellular reproductive organs with a lining of sterile jacket cells, undergoes its early embryonic development while still contained within the female reproductive organ of the parent plant, has no xylem and produces no seeds. The organism is most likely a
- A. Bryophyte.**
  - B. Conifer.
  - C. Fern.
  - D. Magnolia.
  - E. Spirogyra.
77. The concentration of cytokinin in the axillary buds low on a stem is greater than that in the axillary buds higher on the stem because:
- A. Cytokinin is produced in greater amounts in the lower buds.
  - B. Cytokinin migrates upward from the roots.**
  - C. The presence of auxin in higher buds inactivated cytokinins.
  - D. Increased gibberellin levels in lower buds promote cytokinin synthesis.
  - E. Lower buds have more receptors for cytokine than do upper buds.

78. What occurs when kinetin is “spotted” on excised leaves?

- A. The spotted areas are bleached.
- B. Small shoots grow from the spotted areas.
- C. Amino acids migrate to the spotted areas.
- D. Photosynthetic products leave the spotted areas.
- E. Senescence occurs in the spotted areas.

79. The hydrolysis of nutrients contained in the aleurone layer of grass seeds is initiated by the action of \_\_\_\_ produced by the \_\_\_\_.

- A. Gibberellin; female gametophyte.
- B. Auxin; mother sporophyte.
- C. Cytokinin; endosperm.
- D. Gibberellin; embryo.
- E. Auxin; seed coat.

80. Strawberries, poinsettias, primrose, and ragweed are examples of \_\_\_\_ plants and will flower when exposed to a dark period that is \_\_\_\_.

- A. Day-neutral; variable in length.
- B. Long-day; shorter than 12 hours.
- C. Short-day; longer than a critical length.
- D. Long-day; shorter than a critical length.
- E. Short-day; greater than 12 hours.

### *Animal Anatomy & Physiology*

Questions 81 to 84. Patch clamping is used to record an IPSP in a post-synaptic neuron in a hippocampal slice after the pre-synaptic cell is stimulated. Which of the following MAY have occurred?

81. Inhibitory neurotransmitters were released by the pre-synaptic terminal prior to the recorded IPSP. **A**

82. The membrane of the post-synaptic cell became slightly depolarized but did not reach threshold voltage for an action potential. **B**

83.  $\text{Na}^+$  ions flowed into the post-synaptic cell following the stimulus. **B**

84.  $\text{Cl}^-$  ions flowed into the post-synaptic cell following the stimulus. **A**

85. Order the earthworm digestive structure in the sequentially for the path which food moves after entering the mouth.

- I. Crop
- II. Pharynx



- III. Intestine
- IV. Gizzard
- V. Esophagus

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

86. What is the route of large fatty acids and cholesterol as they enter the bloodstream?

- A. Active transport into mucosal cells, enzymatic degradation to simpler compounds, secretion into villi capillaries.
- B. Simple diffusion into mucosal cells, enzymatic degradation to simpler components, secretion into villi capillaries.
- C. Simple diffusion into mucosal cells, packaging into transport forms, secretion into lymph vessels, emptying of lymph into bloodstream.
- D. Active transport into mucosal cells, packaging into transport forms, secretion into villi capillaries.
- E. Facilitated diffusion into mucosal cells, secretion into lymph vessels. Emptying of lymph into bloodstream.

87. Trace a sperm cell from the structure where it is produced to fertilization of the egg.

- I. Seminiferous tubules
- II. Vas deferens
- III. Uterus
- IV. Oviduct
- V. Vagina
- VI. Epididymis
- VII. Urethra

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

88. All of the following are general trends in the evolution of the nervous system EXCEPT:

- A. Centralization of nerves into major nerve cords.
- B. Neurons evolved to carry impulses in two directions rather than one.
- C. Pathways within the central nervous system became more complex by the addition of interneurons.
- D. Increasing development of the rostral end of the nerve cords to form a brain.

E. The number and complexity of sense organs increased.

**89. Cilia could be found in (Select ALL that apply):**

- A. Bacteria.
- B. Fungi.
- C. Plant.
- D. Protist.
- E. Human.

**90. Which of the following conditions will cause an increase in blood pressure, an acceleration of the heartbeat, an increase in blood flow to peripheral muscles, and dilation of the pupils?**

- A. Stimulation of the somatic nervous system.
- B. Stimulation of the thyroid gland.
- C. Stimulation of the parasympathetic nervous system.
- D. Stimulation of the sympathetic nervous system.
- E. Stimulation of the somatic nervous system and the thyroid gland.

**91. All of the following are adaptations for osmoregulation in bony fishes living in freshwater or marine environments EXCEPT:**

- A. Seawater: active excretion of salt through the gills.
- B. Seawater: thick, waterproof skin.
- C. Freshwater: swallowing large quantities of water.
- D. Freshwater: thick, waterproof skin.
- E. Freshwater: production of large quantities of urine.

**Questions 92 to 94. A child inhaled a penny and was promptly brought to the hospital. The penny is stuck in her lung, blocking air flow to a significant portion of her lung tissue. She is breathing rapidly and reports feeling "hungry for air". She is otherwise in good health and has normal circulation. Decide whether the following statements are TRUE (A) or FALSE (B).**

**92. The oxygen levels in her blood are lower than normal. A**

**93. The CO<sub>2</sub> levels in her blood are lower than normal. A**

**94. The pH of her blood is lower than normal. A**

**95. Her heart rate is lower than normal. B**

### *Ethology*

**96. A major difference between insect and vertebrates societies is that**

- A. Communication is absent in insect societies.

- B. There is more individual recognition in vertebrate than in insect societies.
- C. Only member of insect societies display altruistic behavior on behalf of the society's well-being.
- D. The insect society is based on the family unit whereas the vertebrate society is not.
- E. Vertebrate societies do not use chemical forms of communication.

**97. Which statement is FALSE regarding eusocial insect societies?**

- A. Sterile individuals work for the benefit of reproductive members.
- B. There is a division of labor among members.
- C. Individuals cooperate in caring for the young.
- D. All females are fertile and the responsibility for reproduction rotates among them.
- E. Examples include ants, termites, and wasps.

**98. Which statement is FALSE regarding dominance hierarchies?**

- A. They are maintained by species-specific patterns of behavior.
- B. They determine the priority of access to resources.
- C. They influence the relative reproductive success of individuals.
- D. Subordinate individuals make no contribution to the reproductive success of the group.
- E. Depending upon the species, males and females may have separate hierarchies.

### *Genetics and Evolution*

**99. Scientists were able to successfully clone a calico cat. However, the clone, named "CC," for Copy Cat or Carbon Copy does not have identical fur compared to her mother. How did this occur? Choose ALL that apply.**

- A. CC was made from only one set of chromosomes, so she has less genetic variability.
- B. CC has different patterns of X inactivation, resulting in different fur patterns.
- C. Cloning only ensures that CC's germ cells are identical, not her somatic cells.
- D. The epigenetic state of CC's DNA is different from her mother's.
- E. Crossing over during meiosis resulted in changes to the genes encoding fur color.

**Questions 100 to 103. Suppose we have a large randomly mating diploid population that is initially fixed for allele  $A$ . At time  $t_0$ , a single mutant offspring is produced with genotype  $Aa$ . Allele  $a$  confers a recessive reproductive advantage, such that genotypes  $AA$ ;  $Aa$ ; and  $aa$  have relative fitnesses.**

$$1 = F(AA) = F(Aa) < F(aa) = 1 + s$$

**Assume that after many generations of random mating, the population eventually becomes fixed for allele  $a$ . Let  $t_f(a)$  be the time at which allele  $a$  first reaches frequency  $f$ .**

Suppose that a second randomly mating population is initially fixed for allele  $B$ . At time  $t_0$ , a single mutant  $Bb$  offspring appears. This time, allele  $b$  confers a dominant reproductive advantage, with

$$1 = F(BB) < F(Bb) = F(bb) = 1 + s$$

As before, assume that the population eventually becomes fixed for allele  $b$ . Let  $t_f(b)$  be the first time when  $b$  reaches frequency  $f$ . Which of the following do you expect to be TRUE (A) and which would you expect to be FALSE (B)?

100.  $t_{0.05}(a) > t_{0.05}(b)$  **A**

101.  $t_1(a) - t_{0.95}(a) > t_1(b) - t_{0.95}(b)$  **B**

102.  $t_{0.5}(a) > t_1(a) - t_{0.5}(a)$  **A**

103.  $t_1(a) > t_1(b)$  **B**

104. Consider the following tetrahybrid cross:  $A/a B/b C/C D/D \times A/a B/b C/c D/d$ . Assume that it is a dominant/recessive system. What proportion of the offspring will have the recessive phenotype for all four characteristics?

- A. 1/12
- B. 1/64
- C. 1/128
- D. 1/256
- E. None**

Questions 105 to 108. Your friend is interested in buying a genetic testing kit from *23andme* to assess his risk of a heritable disease. He asked his doctor, who dismissed the idea, saying "the tests are not sensitive, though they are fairly specific". Your friend was too embarrassed to ask the doctor what that meant. How would you explain it to him? Decide whether the following statements are TRUE (A) or FALSE (B).

105. The sensitivity of these tests, but not the specificity, is affected by the error rate of SNP detection technology. **B**

106. When a test is not sensitive enough, both positive and negative results must be viewed with suspicion. **B**

107. If a test is highly sensitive, and the test result is positive, you can be nearly certain you do have the disease. **B**

108. If a test is highly specific, and the test result is negative, you can be nearly certain you don't have the disease. **B**

## *Ecology*

Questions 109 to 112. Which of the following can occur during secondary ecological succession? Select TRUE (A) or FALSE (B).

109. Autotrophic and heterotrophic prokaryotes colonize an area where soil is not present. **B**
110. Early-arriving species inhibit the establishment of later species. **B**
111. A forest fire kills all old-growth trees in the area. **A**
112. The seeds of some Proteaceae plants only become active after the heat of a forest fire. **A**
113. Which action is NOT among those that a moth may take to avoid predation by a bat?
- A. Fly away from an oncoming bat.
  - B. Change directions frequently.
  - C. Collapse its wings and dive to the ground.
  - D. Fly with other moths.**
  - E. Produce a signal to jam the bat's echolocation ability.
114. One of the oldest and ecologically most successful cases of mutualism, which has altered the evolutionary course of the organisms involved, is
- A. Pinnixa crabs and Chaeopterus worms.
  - B. Littorina littorea snails and Enteromorpha algae.
  - C. Snowshoe hare and lynx.
  - D. English rabbit and wildflower.
  - E. Lichens.**
115. According to the equilibrium hypotheses of island biogeography, there is a balance between the rate at which species immigrate to the island and the rate at which species:
- A. Emigrate from the island.
  - B. Become locally extinct.**
  - C. Fill other ecological niches.
  - D. Undergo character displacement.
  - E. Become extinct on the mainland.
116. In a cornfield, forest, or marsh, where vegetation is abundant, as much as \_\_\_\_\_ percent of the solar energy reaching the surface of the earth is captured in the bonds of organic molecules during photosynthesis. Choose the HIGHEST correct range from the responses below.

- A. 0.1 to 0.3
- B. 0.5 to 0.7
- C. 1.0 to 1.3
- D. 1.0 to 3.0**
- E. 10 to 13

117. The most conspicuous autotrophs in the littoral zone of lakes and ponds are

- A. Liverworts adhered to the shoreline.
- B. Duckweed floating on the surface.
- C. Phytoplankton floating in the water.
- D. Angiosperms rooted to the bottom.**
- E. Water lilies floating on the surface.

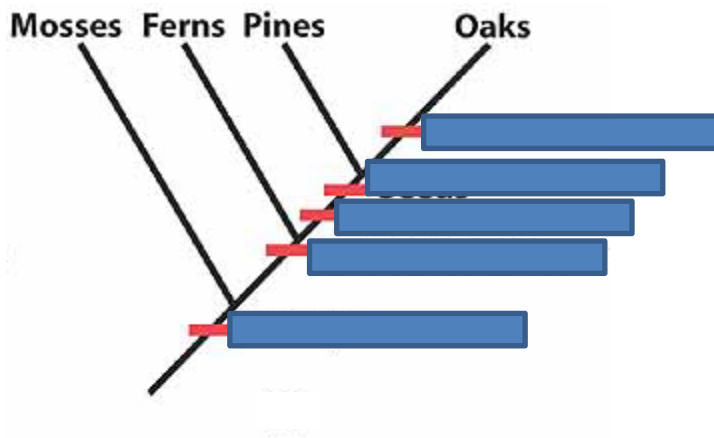
Phil: unclear "conspicuous autotrophs"

### *Biosystematics*

118. In species X a critical polypeptide has the following amino acid sequence:  
met-ala-cys-cys-phe-try-phe-pro.

The amino acid sequences of five other species is determined. Which of the following species is probably **LEAST** related to Species X?

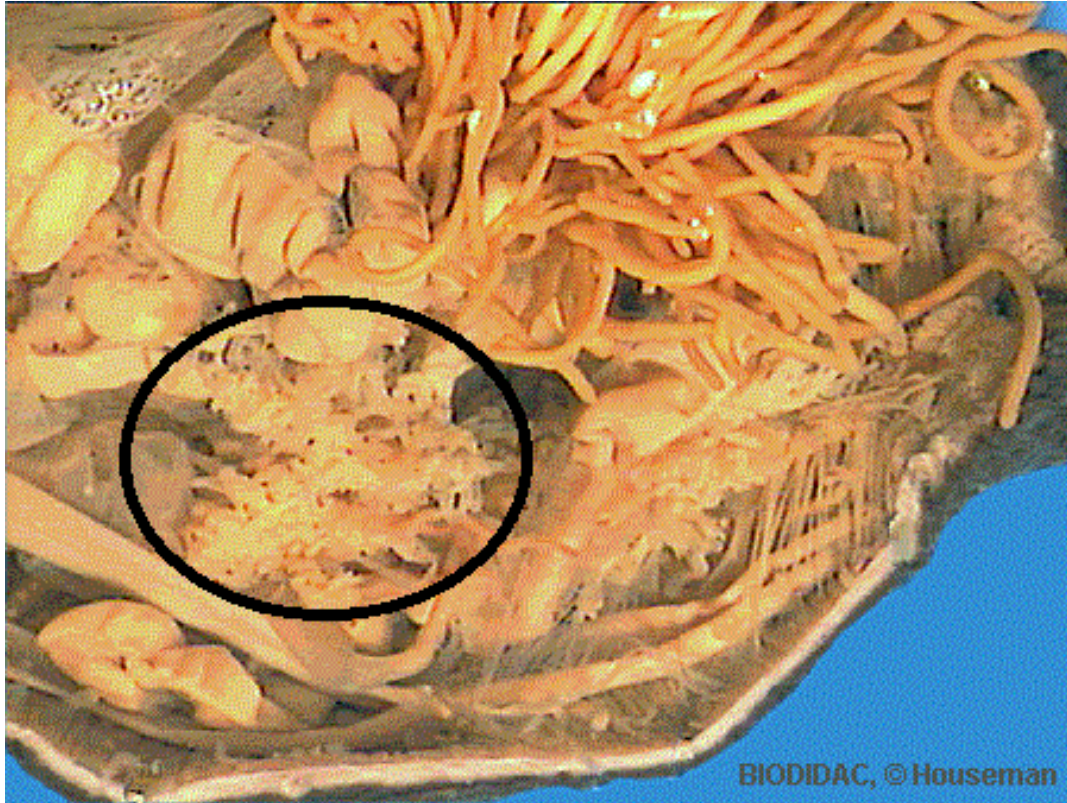
- A. met-ala-cys-cys-phe-try-phe-pro
- B. met-ala-ser-cys-phe-try-phe-pro
- C. met-ala-cys-cys-phe-arg-phe-pro
- D. met-ala- ser-cys-arg-try-phe-pro**
- E. met-ala-cys-cys-phe-try-phe- glu



119. Moving from the base of the cladogram above where mosses are located to oaks, the correct sequence of evolution of structures is

- A. Embryo, xylem and phloem, wood, seeds, flowers.**

- B. Embryo, flowers, seeds, wood, xylem and phloem.
- C. Seeds, flowers, embryo, xylem and phloem, wood.
- D. Flowers, seeds, embryo, wood, xylem and phloem.
- E. Embryo, seeds, flowers, xylem and phloem, wood.



120. Refer to the above diagram, which is a close-up of the internal anatomy of a sea cucumber. Which of the following is the function of the circled structure?

- A. Digestion
- B. Reproduction
- C. Gas exchange
- D. Oxygen circulation
- E. Locomotion

#### PART C

##### 1. Mercury Resistance

You are studying the genetics controlling the capacity to grow in the presence of mercury in the bacteria *Escherichia coli*. Beginning with a mutagenesis screen, you identify two mutants that display mercury sensitivity: M1 and M4. You also find two mutants that display hyper-resistance to mercury: M2 and M3. Following is a table summarizing your results:

Genotype	Mercury Resistance
WT	Wild Type



M1	Sensitive
M2	Hyper-resistant
M3	Hyper-resistant
M4	Sensitive
M5	Sensitive

- a) In order to interrogate this pathway you decide to identify these mutations, but you first have to find where they lie in the genome. You have created a library of genomic DNA from the wild-type bacterial strain. Describe how you could use this library to try and find the genomic regions corresponding to the mutations.
- b) This approach is successful in finding a genomic DNA fragment containing the loci mutated in M1, M2, M4, and M5. Give one reason this approach might fail to find M3.
- c) The results of your mapping show that M1, M2, M4, and M5 lie relatively close together in the genomic DNA. You decide to test whether these mutations are in different, or the same, gene. Using primers designed against this entire region, you use PCR to clone out the mutant regions from mutant strains M1, M2, M4, and M5. You insert these mutant DNA pieces into F plasmids and put them into your mutant strains. These data are summarized below. How many genes are represented in mutations M1, M2, M4, and M5? Explain your reasoning.

Genotype	Mercury Resistance
M2 / F' M1	Wild Type
M4 / F' M1	Wild Type
M1 / F' M2	Wild Type
M4 / F' M2	Wild Type
M1 / F' M5	Wild Type
M2 / F' M5	Wild Type
M4 / F' M5	Sensitive

- d) Having cloned these mutations, you now create double mutants. You see the following results from your double mutant strains:

Genotype	Mercury Resistance
WT	Wild Type
M1 M2	Hyper-resistant
M4 M2	Sensitive
M5 M4	Sensitive
M5 M2	Sensitive



From the data you have collected so far, and assuming a linear pathway, assemble the genes (not the mutations!) in a genetic pathway. Name the genes Mer[number] with the [number] corresponding to the number of the mutation in that gene. Remember to include the resulting resistance in your diagram. Use ---> to indicate a positive relationship and ---| to indicate a negative relationship. Partial credit will be awarded for incorrect final answers with partially correct explanations.

Solutions:

- a) Transform mutant strains with library and look for rescue to wild-type phenotype
- b) This would fail to find dominant mutations, mutations in genes larger than the fragments, genes with restriction sites in them (if that's how the library was made), if the mutation can't be rescued in trans (and the cis site it interacts with is far enough away it can't 'be rescued).
- c) 3 genes. M5 and M4 fail to complement, others do.
- d) Mer1 ---| Mer2 ---| Mer4/5 ---> resistance

## 2. Codon Analysis

The probability of a given codon being a stop codon in the genome of an organism with equal AT and GC content is 3/64. However, many organisms don't have an equal AT and GC content.

- a) There exists a thermophile *I. toohothereii* that has a genomic AT content of 36.8%. What is the probability of a given codon from random sequence of its genome being a stop codon?
- b) Find the probability of a given codon in random sequence from any bacterial genome being a stop codon as a function of the genome AT content.
- c) Find the probability of finding an ORF, starting with a start codon, of L codons or more in a random sequence from the genome of a bacterium as a function of its genome AT content.

Solutions:

a)

Probability of A or T = 36.8%

Probability of A = Probability of T = 18.4%

Probability of G or C = 63.2%

Probability of G = Probability of C = 31.6%

Probability of finding UAA =  $(0.184)^3 = 6.22 \times 10^{-3}$

Probability of finding UAG or UGA =  $(0.184)^2 (0.316) = 0.0107$

Therefore, probability of finding a stop codon =  $0.00622 + 2 \times 0.0107 = 0.0276 = 2.76\%$

b)

Let the AT content of the organism is x.

Probability of A or T =  $x/2$

Probability of G or C =  $(1-x)/2$

Probability of finding UAA =  $(x/2)^3$

Probability of finding UAG or UGA =  $(x/2)^2(1-x)/2$

Therefore, probability of a given codon being a stop codon =  $(x/2)^3 + 2 * (x/2)^2 (1-x)/2 = (2x^2 - x^3)/8$

c)

Probability of a given codon being a stop codon =  $(2x^2 - x^3)/8$

Probability of a given codon not being a stop codon =  $1 - [(2x^2 - x^3)/8]$

Probability of a given codon being a start codon =  $(x/2)^2(1-x)/2$

Probability of finding an ORF of L codons or more =  $[(x/2)^2(1-x)/2] \{1 - [(2x^2 - x^3)/8]\}^{L-1}$

2. A 45 year old woman comes to you complaining of constant, mild headache and loss of peripheral vision. Blood work reveals abnormally high levels of prolactin, confirming your suspected diagnosis.

A. What pathology could cause all three of these signs and symptoms?

B. Justify your diagnosis. How exactly does the pathology described above cause each of your patient's conditions? Answer in three sentences or less.

C. Upon physical examination, you notice that the patient has developed hypertension and has large fat deposits in the back and face. Looking over the blood work again you also find evidence of hyperglycemia. What hormone relates to this syndrome, and what organ does it act on?

D. Name three other hormones whose levels might be affected.

- E. Pick one of those three and describe the effects of increased levels of that hormone in the blood. Limit your answer to two or three sentences.

Answers:

- A. A tumor of the anterior pituitary. (Half-credit for any answer involving the anterior pituitary, full credit for the word "prolactinoma" even if the anterior pituitary is not mentioned.)
- B. The headache is caused by elevated CSF pressures present with any large mass in the brain. The loss of peripheral vision is caused by pressure on the optic chiasm by the enlarged pituitary, and the elevated blood prolactin levels are caused by the tumor secreting excess amounts of the hormone. (1/3 credit for each sign or symptom explained.)
- C. Adrenocorticotrophic hormone acts on the adrenal cortex to produce cortisol. (Answers receiving full credit should mention adrenocorticotrophic hormone (ACTH and corticotropin are also acceptable forms), the adrenal glands, and cortisol.)
- D. Any three of: growth hormone, luteinizing hormone, follicle-stimulating hormone, and thyroid-stimulating hormone (thyrotropin). Abbreviations (GH, LH, FSH, and TSH) are also acceptable. (1/3 credit for each hormone mentioned.)
- E. Increased growth hormone levels cause acromegaly, which is characterized by increased bone growth in the hands, feet, and face. (Bone growth in the extremities receives half credit, growth in the extremities and face receives full credit, the word "acromegaly" receives full credit.)  
Increased thyroid stimulating hormone levels cause hyperthyroidism, characterized by increased metabolism, weight loss, rapid heart rate, and hot, red skin. (The word "hyperthyroidism" alone does not receive any credit, any answer receiving credit must mention at least one symptom and full credit will be awarded only to any answer that includes abnormally fast metabolism.)
- High LH and high FSH can both cause infertility. (Any answer associating high LH or FSH with infertility merits full credit.)