

USABO SEMIFINAL EXAMINATION
April 9 to April 13, 2018

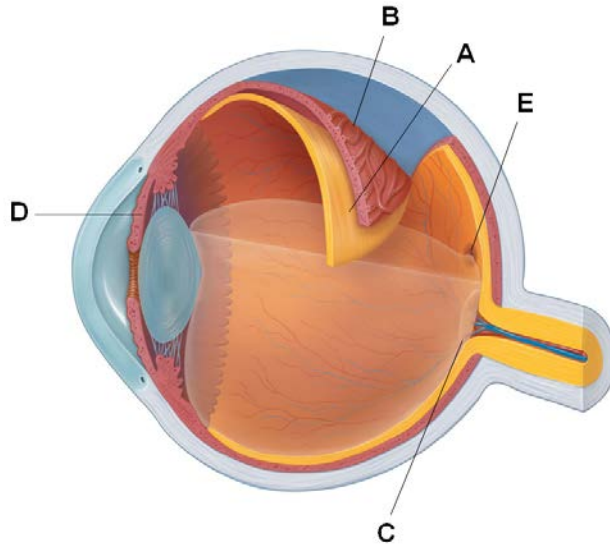
Read the directions included with the *Student Certification Form* provided by your teacher. Be certain to complete all requested information and to sign the Student Certification Form. Your exam cannot be graded without completion of this form. Use your Answer Sheet to answer all questions in Parts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

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

For your independent research, you transferred lymphocyte populations between syngeneic mice. You irradiated recipients first to ablate (get rid of) existing lymphocytes, then transferred defined cell populations from donors of same genetic background. The result is shown below.

1. Which hormone is directly responsible for triggering ovulation?
 - A. Estrogen
 - B. Luteinizing hormone
 - C. Human chorionic gonadotropin hormone
 - D. Bstrogen
 - E. Progesterone
2. *What is the sedimentation value for one eukaryotic ribosome?*
 - A. 40S
 - B. 50S
 - C. 60S
 - D. 70S
 - E. 80S
3. As a budding tumor immunologist you are interested in the mechanism of tumor rejection. You develop an injectable sarcoma cell line through use of a mutagen that disrupt different genes at random so you can probe their potential effect on tumor survival. Tumor cell line 1 is quickly killed in wild type mice, but grows well in RAG2 knock-out mice. Tumor cell line 2 is quickly killed in wild type mice and RAG2 knockout mice, but grows well in perforin knockout mice. You vaguely recall that RAG2 is a gene involved in recombination of heavy and light chain segments in the immune system. Which cell type is likely directly mediating this tumor rejection, for each of the two cell lines?
 - A. Eosinophils; B cells
 - B. CD4 T cells; CD8 T cells
 - C. CD8 T cells; Natural killer cells
 - D. CD8 T cells; Basophils
 - E. Natural killer cells; CD8 T cells

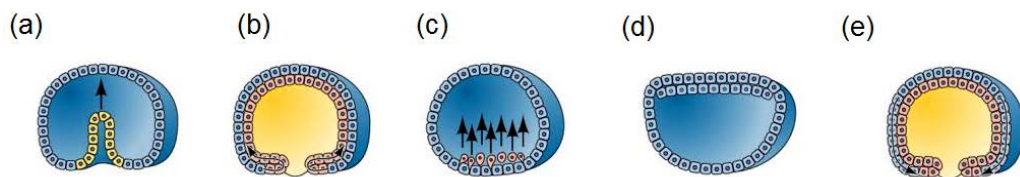
4. Consider the following figure, which describes the cross-sectional area of a mammalian eye.



Which of the following statement is incorrectly matched with its characteristics and structure?

- A. this structure is derived from neural ectoderm.
 - B. this structure provides blood
 - C. this structure does not have visual receptors
 - D. this structure controls the amount of the light
 - E. this structure has the lowest visual acuity
5. All of the following are similarities in the functions of cells in the reproductive systems of males and females EXCEPT:
- A. Granulosa and Sertoli cells can both secrete inhibin, which downregulates FSH secretion.
 - B. Theca and Leydig cells both increase their hormone production in response to FSH.
 - C. The Fallopian tubules and vas deferens both transport gametes from the gonad toward the site of fertilization.
 - D. Estrogen and testosterone levels contribute to negative feedback on gonadotropin releasing hormone.
 - E. All of the above are correct.
6. All of the following molecular events involve endocytosis EXCEPT for which of the following?
- A. B cell's receptor-bound antigen
 - B. Entry of granzymes to the infected cells
 - C. Selective retrieval of cell-surface proteins for recycling
 - D. Insertion of vesicles with aquaporins into lining lumen of collecting duct
 - E. Formation of the TLRs on the inner surface of vesicles formed from TLR precursors

7. A certain caterpillar has a net production efficiency of 28%, assimilation efficiency of 39%, exploitation efficiency of 50%, and a gross production efficiency of 10.92%. If there are 900 calories in the form of leaves (which this certain caterpillar loves to eat), how many calories will actually be used for production by this caterpillar?
- A. 5.405 calories
 B. 90 calories
 C. 49.14 calories
 D. 10.81 calories
 E. 19.305 calories
8. Which of the following markers (I to V) can be used to help determine the species diversity of an ecosystem?
- I. Species richness
 II. Relative abundance
 III. Shannon index
 IV. Wiener index
 V. Species evenness
- A. I, II, III, IV
 B. I, II, III, V
 C. I, III, IV
 D. II, III, IV, V
 E. II, III
9. Which of the following statement is NOT true regarding human chorionic gonadotropin (hCG)?
- A. Its main source is from endometrium.
 B. Its mode of action is similar to that of pituitary LH.
 C. It stimulates the corpus luteum to make progesterone.
 D. It is possible to use monoclonal antibodies against hCG to make home pregnancy test kits.
 E. It is possible that some hCG can pass from the maternal blood to the urine during first trimester.
10. As the blastopore is forming in a frog embryo, a sheet of cells begins to spread out of the animal hemisphere. After this process, which of the following morphogenetic movement will occur?



- 11. Gastrulation in chicks similar to that in humans because**
- It does not generate ectoderms via gastrulation
 - It does not generate mesoderms via gastrulation
 - most of the cells that will form the embryo come from the epiblast.
 - most of the cells that will form the embryo come from the hypoblast.
 - it produces a fertilization cone in response to sperm penetration of the plasma membrane.
- 12. In the chicken embryo, which of the following is the counterpart of the blastopore lip for the frog embryo?**
- Yolk sac
 - Epiblasts
 - Hypoblasts
 - Primitive streak
 - Migrating cells (mesoderms)
- 13. Which of the following correctly lists the steps required for the formation of neural tubes in vertebrates?**
- Cuboidal ectodermal cells form a continuous sheet.
 - Microtubules help elongate the cells of the neural plate.
 - Actin filaments at the dorsal end of the cells may contract, deforming the cells into wedge cells.
 - Cells wedging in the opposite direction causes the ectoderm to form a hinge. It pinches off of the neural plate and forms the neural tube.
- I → II → III → IV
 - I → III → II → IV
 - II → I → III → IV
 - I → II → IV → III
 - III → II → I → IV
- 14. During light responses in rod cells, which of the following event sequence will occur?**
- Rhodopsin active → sodium channels open → rod deperpolarized → glutamate released
 - Rhodopsin active → sodium channels open → rod hyperpolarized → glutamate released
 - Rhodopsin inactive → sodium channels closed → rod depolarized → glutamate released
 - Rhodopsin active → sodium channels closed → rod hyperpolarized → no glutamate released
 - Rhodopsin inactive → sodium channels closed → rod hyperpolarized → no glutamate released
- 15. These cells have cilia in their cellular structures.**
- Microglia
 - Astrocytes
 - Schwann cells
 - Ependymal cells
 - Oligodendrocytes

16. Which of the following statement is NOT true regarding beta-pleated strands?
- A. Strands can be parallel or antiparallel.
 - B. Hydrogen bonds form between strands.
 - C. Strands contain relatively few (3-10) amino acid residues.
 - D. Side chains are on alternate sides of the sheet to form a pleated sheet.
 - E. Beta sheets are not flat, which makes it more rigid, and do not have a characteristic twist.
17. Which of the following statements are TRUE regarding the process of meiosis?
- I. Segregation of unlinked alleles occurs during meiosis.
 - II. Kinetochores are responsible for aligning chromatids during meiosis I.
 - III. At the end of meiosis, the amount of DNA in each daughter cell is half of the parental cell.
 - IV. At the end of meiosis, the amount of chromosome in each daughter cell is half of the parental cell.
- A. I, IV
 - B. II, III
 - C. I, II, III
 - D. II, III, IV
 - E. I, II, III, IV
18. The famous mathematician Dr. M decided to implement his math prowess in studying population genetics. Currently, he is studying a population of *Ariolimax californicus* on the island Iniquit, which is plagued by a recessive disease that results in a completely brown body and death before reproductive age. Currently, there is only one population of *A. californicus* on Iniquit (all of the same age), and Dr. M finds 124 brown *A. californicus* out of 567 total *A. californicus*. How many generations will it take to take for the recessive allele to drop below a 10% proportion of the total gene pool?
- A. 6 generations
 - B. 7 generations
 - C. 8 generations
 - D. 9 generations
 - E. 10 generations
19. Dr. O, who is also known for being an expert on Japanese culture, stumbles upon a population of *Mustela putorius* that is incredibly prone to inbreeding. Nevertheless, this population is quite large, isolated from other populations, immune to DNA mutations, and has no natural selection currently acting upon it. A certain recessive allele that causes extra furriness constitutes 18% of the gene pool. Which of the following could be the proportion of *M. putorius* that are heterozygous for this allele?
- A. 0.159
 - B. 0.296
 - C. 0.297
 - D. 0.324
 - E. 0.999

20. Your somatic cells die after about 40 cell divisions because your chromosomes shorten with each cell division. Your chromosomes shorten because:
- A. Your somatic cells do not express telomerase
 - B. Your somatic cells' DNA polymerase has a catalytic activity of telomerase.
 - C. Your somatic cells do not have a telomerase gene through silencing mechanism.
 - D. Your somatic cells' DNA polymerase does not have a catalytic activity of telomerase.
 - E. DNA polymerase is very inefficient and usually copies about half of each chromosome.
21. Though it has been recently contested, the cisternal maturation model for movement through the Golgi has been reasonably well upheld by various experiments. Based on this model, consider the following enzymes: enzyme A adds mannose to serine, enzyme B adds mannose to N-acetylglucosamine, and enzyme C adds N-acetylglucosamine to mannose. Which of these enzymes will move from the trans to the medial Golgi?
- A. Enzyme A
 - B. Enzyme B
 - C. Enzyme C
 - D. Enzyme A and B
 - E. None; they all stay in their predetermined compartment.
22. The fungus *Neurospora crassa* is a popular model organism for geneticists. During sexual reproduction, haploid cells from two compatible strains of *N. crassa* fuse together, forming a diploid zygote. The zygote undergoes meiosis to produce four haploid spores, which are conveniently bound together in a sac.
- You have identified two genes, A and B, which control pigmentation in *N. crassa*. Spores with genotype AB are dark, while spores with genotype a_ or _b are light. Genes A and B are located on different chromosomes. You mate a strain with genotype AB with a strain of genotype ab. What is the expected result?
- A. 100% of sacs contain 1 dark spore and 3 light spores.
 - B. 100% of sacs contain 2 dark spores and 2 light spores.
 - C. 25% of sacs contain 4 dark spores; the others contain 4 light spores.
 - D. 50% of sacs contain 4 dark spores; the others contain 4 light spores.
 - E. 50% of sacs contain 2 dark and 2 light spores; the others contain 4 light spores.
23. Which of the following statement is NOT a function of extracellular matrices?
- A. They provide elasticity in tissues.
 - B. They keep cell layers separated from each other.
 - C. They promote the diffusion of oxygen and carbon dioxide within tissues.
 - D. They enable tissues to resist compression and tension by providing strength and flexibility.
 - E. They can influence the activity of genes in the nucleus by the combination of mechanical and chemical signaling pathways (intracellular signals)

24. Schwann cells surround which type of cell found in most mammals?

- A. Erythrocytes
- B. Microglial cells
- C. Helper T cells
- D. Neurons
- E. Pericytes

25. The brain is made up of different cell types including:

- I. neurons**
- II. pericyte**
- III. astrocyte**
- IV. microglia**
- V. osteoblast**

- A. I
- B. I, II, III
- C. I, II, III, IV
- D. I, III, IV
- E. all of the above

26. A neuron consists of different sub cellular structures which can include:

- I. nucleus**
- II. Dendrites**
- III. axon**
- IV. cilia**
- V. node of ranvier**
- VI. schwann cell**

- A. I, II, III
- B. I, II, III, IV
- C. I, III, V
- D. I, II, III, V, VI
- E. all of the above

27. If someone has a lesion in the hippocampus, what behavioral deficits will the patient have?

- A. Lack of balance
- B. Inability to think ahead
- C. Memory loss
- D. Insomnia
- E. Speech deficits

28. The following chemicals are found in the brain as molecular signaling molecules known as neurotransmitters:

- I. Glutamine
- II. Dopamine
- III. Serotonin
- IV. Norepinephrine
- V. Raphine
- VI. Lysine

- A. I, II, V, VI
- B. I, II, III, IV
- C. I, II, V
- D. II, III, IV
- E. all of the above

29. The five lobes of the brain include these regions.

- A. Frontal lobe, temporal lobe, occipital lobe, parietal lobe, and cerebellum
- B. Frontal lobe, temporal lobe, occipital lobe, motor lobe, and cerebellum
- C. Frontal lobe, spatiotemporal lobe, occipital lobe, parietal lobe, and cerebellum
- D. Cerebral lobe, temporal lobe, occipital lobe, parietal lobe, and cerebellum
- E. Prefrontal lobe, spatiotemporal lobe, visual lobe, sensory lobe, motor lobe.

30. For summer project, you would like to explore different experimental techniques to address different physiological questions in *E. coli*. Which of the followings statements are true?

- I. If you want to visualize the microbe with staining, you can use light microscope.
- II. If you want to visualize the microbe with staining, you can use phase microscope
- III. If you want to visualize the microbe with staining, you can use confocal microscope.
- IV. If you want to demonstrate the existence of the pili on the outside of the cell, you can use light microscope.
- V. If you want to demonstrate the existence of the pili on the outside of the cell, you can use confocal microscope.
- VI. If you want to demonstrate the existence of the pili on the outside of the cell, you can use scanning electron microscope.

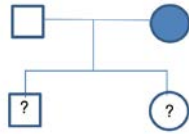
- A. I, II
- B. V, VI
- C. I, II, V, VI
- D. I, II, III V, VI
- E. I, II, IV, V, VI

31. What fraction of the offspring of AaBbCc x AABbcc will have the dominant A, dominant B, and recessive c phenotype, assume independence between all genes?

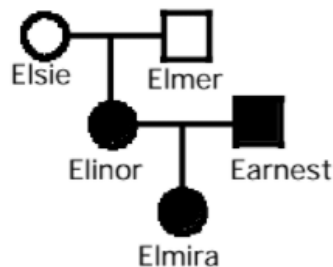
- A. 1/8
- B. 1/2
- C. 1/4
- D. 3/8
- E. 5/8

32. A good friend of yours, Dr. A, is breeding his favorite species of cats. For this specific experiment, he has a true breeding strand of red cats, and a true breeding strand of silver cats. When he crosses these two strands, he only gets golden cats. When he breeds these golden cats together, he gets 100 offspring: 56 golden cats, 19 silver cats, and 25 red cats. Which of the following statements must be true?
- A. This is an example of dominant epistasis
 - B. This is not an example of recessive epistasis.
 - C. The enzyme creating golden pigment comes before the enzyme creating silver pigment.
 - D. The enzyme creating red pigment is mutated in the true breeding strand of silver cats.
 - E. The enzyme creating red pigment is not mutated in the true breeding strand of gold cats.
33. A well-established geneticist, Dr. L is famous for experiments on the common plant *Camellia sinensis*. In particular, Dr. L has a few mutant, true-breeding lines of *Camellia sinensis*. Line A gives off a sweet odor, line B gives off a musty odor, and line C gives off no odor at all. When he crosses lines A and B, he gets only sweet odor *C. sinensis*. When he crosses lines B and C, he gets only musty odor *C. sinensis*. Moreover, when he self-crosses the offspring of lines of lines A and B, he gets mostly sweet odor *C. sinensis*, some musty odor *C. sinensis*, and few no odor *C. sinensis*. Which of the following statements must be not true?
- A. This is an example of dominant epistasis.
 - B. This is not an example of pleiotropy.
 - C. If he self-crossed the no odor *C. sinensis* from the last cross, Dr. L would get some sweet odor *C. sinensis* offspring.
 - D. If he self-crossed the musty odor *C. sinensis* from the last cross, Dr. L would get some no odor *C. sinensis* offspring.
 - E. The enzyme responsible for creating the intermediate that gives off the sweet odor is not in the same pathway as the enzyme responsible for creating the intermediate that gives off the musty odor.
34. Your best friend Dr. O is studying a population of *Ursus arcotus*, a common mammal. She is interested in two phenotypes: black-haired *Ursus arcotus* and blue-haired *Ursus arcotus*. It is thought that the blue hair phenotype is the recessive phenotype. Interestingly enough, however, in a sample of 5000 male *Ursus arcotus* and 5000 female *Ursus arcotus*, Dr. O finds that there are 1600 male blue-haired *Ursus arcotus* but only 512 female blue-haired *Ursus arcotus*. Which of the following is the best explanation of this phenomenon?
- A. There are two genes that control hair color.
 - B. Dr. O used too small of sample size to get a reliable result.
 - C. The species *Ursus arcotus* exhibits the temperature-dependent sex determination system.
 - D. The allele responsible for blue hair is not autosomal.
 - E. The blue hair phenotype is not actually the recessive phenotype.

35. Consider the pedigree below, which shows a dominant, X-linked disease. The two children have not yet been evaluated for whether they have the disease. Doctor's are not yet sure of the mother's genotype, but based on previous family history, there is a $\frac{1}{4}$ chance she is homozygous for the disease gene, and $\frac{3}{4}$ chance she is heterozygous. What is the probability that her son will have the disease?



- A. $\frac{1}{8}$
 B. $\frac{1}{2}$
 C. $\frac{1}{4}$
 D. $\frac{3}{8}$
 E. $\frac{5}{8}$
36. In Ayrshire cattle, the mahogany/red locus is an autosomal gene. In both sexes, mahogany homozygotes are mahogany colored, and red homozygotes are red. However, the mahogany/red heterozygote is mahogany if male and red if female. Here is a pedigree for an Ayrshire family that is of great interest to Farmer MacDonald. (In the pedigree, open circles and squares indicate the mahogany phenotype; filled indicate red.) Although Elmer has long ago become a huge pile of Big Macs, Farmer MacDonald has frozen a good supply of Elmer's semen and has used it to artificially inseminate Elmira. What is the probability that Elmira will produce a mahogany female calf?



- A. $\frac{1}{2}$
 B. $\frac{1}{4}$
 C. $\frac{3}{4}$
 D. $\frac{1}{8}$
 E. $\frac{1}{16}$

37. The coloration of tortoiseshell and calico cats is a visible manifestation of X-inactivation. The black and orange alleles of a fur coloration gene reside on the X chromosome. For any given patch of fur, the inactivation of an X chromosome that carries one gene results in the fur color of the other, active gene. Inactivation of one X chromosome in female mammals is an example of
- A. Epigenetics
 - B. Sex-linked inheritance
 - C. Autosomal dominance
 - D. Autosomal dominance
 - E. Autosomal recessiveness
38. Which of these answer choices matches the organism with the correct chromosomal system of sex determination?
- A. Koala; Y-W
 - B. Grasshopper; Haplo-diploid
 - C. Chicken; Z-W
 - D. Salmon; X-W
 - E. Ant; X-0

Use the following information to answer Questions 39 and 40.

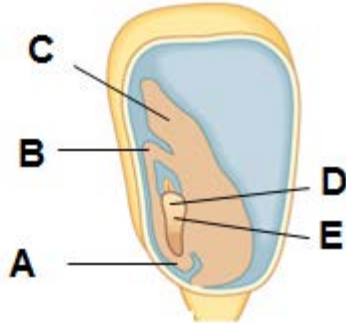
Lesch-Nyhan is a severe, recessive X-linked disorder resulting from deficiency in an enzyme involved in purine nucleotide recycling. The disorder results in buildup of uric acid, and significant mental and physical incapacities that present in the first few years of life. A woman is heterozygous for Lesch-Nyhan. Determine whether the following statements are true (A) or false (B):

39. The woman most likely inherited the Lesch-Nyhan allele from her father.
40. The woman has a fifty percent chance of having a child with Lesch-Nyhan.
41. You are discussing the various facets of ecology with your good friend. Which of the following is a true statement?
- A. Standing crop is measured over a period of time.
 - B. Effective population size is not always smaller than the actual population size.
 - C. Net primary productivity is about $\frac{3}{4}$ of gross primary productivity.
 - D. The oceans contribute about as much production as all terrestrial biomes combined.
 - E. An inverted biomass pyramid has a high standing crop.
42. During angiosperm reproduction, all of the following transitions occur EXCEPT that the:
- A. Ovulary becomes a fruit
 - B. Megasporangium generates the central cell
 - C. Generative cell becomes sperm
 - D. Megaspore becomes the endosperm
 - E. Ovules become seeds

43. Which of the following is NOT a site of meiosis?

- A. Sporangium
- B. Antheridia in bryophytes
- C. Sori in pteridophytes
- D. Ovules in angiosperms
- E. All of the above are sites of meiosis

Questions 44 and 45. Consider the representative figure, which shows the maize seed, to answer the following two questions.



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44. Which of the structure covers the young root of the embryo?

- A. B. C. D. E.

45. Which of the structure covers the young shoot of the embryo?

- A. B. C. D. E.

46. In plants, ion channels are also involved in producing electrical signals analogous to the action potentials of animals. How are the ion channels in plants different from the ones in animals?

- A. They are 1,000 times faster than the channels used by animals.
- B. They utilize facilitated diffusion to generate electrical gradients.
- C. Most channels are not gated, opening, or closing in response to stimuli.
- D. The plant channels can respond to all the senses, except for mechanosensitivity.
- E. They employ calcium-activated anion channels, rather than the sodium ion channels.

47. When the megaspore divides, it produces a large cell with _____ nuclei.

- A. 2
- B. 4
- C. 6
- D. 8
- E. 16

48. Which of the following mechanism is responsible for transporting sugar between symplasts?
- Passive diffusion via gap junctions
 - Passive diffusion via plasmodesmata
 - Facilitated diffusion using sucrose transport pump proteins
 - Active transporter using sucrose transport pump proteins
 - Active transport using co-transporter coupled with proton pump
49. _____ are the most primitive vascular plant cells that conduct water and provide and support while _____ are cells that primarily provide rapid transport of water in angiosperms.
- Tracheids; vessel members
 - Vessel members; tracheids
 - Sieve-tube members; tracheids
 - Tracheids; sieve-tube members
 - Sieve-tube members; vessel members
50. Following are the relative abundance of 5 species in four hypothetical communities (A-D). Which community has the **SECOND LOWEST** diversity measured by Shannon's index?
- | | sp-1 | sp-2 | sp-3 | sp-4 | sp-5 |
|----|------|------|------|------|------|
| A. | 0.22 | 0.20 | 0.22 | 0.20 | 0.16 |
| B. | 0.50 | 0.30 | 0.15 | 0.05 | 0.00 |
| C. | 0.25 | 0.23 | 0.25 | 0.23 | 0.04 |
| D. | 0.26 | 0.24 | 0.26 | 0.24 | 0.00 |
51. A wildlife biologist has adopted a number of techniques to protect the Willow Flycatcher, a bird that often nests and feeds in willows. Some techniques reflect top-down while some reflect bottom-up control. Which of the following approaches demonstrates her understanding of how **BOTTOM-UP** forces affect community dynamics?
- Willow Flycatchers can lose eggs to squirrels, weasels, and other predators. The biologist attempts to protect nests by putting metal collars around the base of the willows that keep ground predators from climbing up to reach the nests.
 - The biologist attempts to increase food availability by reintroducing beaver. She hypothesizes that beaver will raise the water table, stimulating the growth of willow, which will result in an increase in insect abundance, giving flycatchers more food.
 - Both approaches rely on bottom-up forces.
 - Both approaches rely on top-down forces.

52. Which of the following is true?

- A. An ecosystem will always achieve its maximum NPP after it has reached its maturity.
- B. Natural ecosystems always change and never show any trends.
- C. Replacement of one biological community by another in a given area is called population dynamics.
- D. The process of one ecosystem being replaced by another in a given area is called succession.

53. What are the three principal levels of biodiversity?

- A. genetic, species and ecosystem
- B. individual, population and community
- C. population, community and ecosystem
- D. community, ecosystem and landscape

54. Optimal foraging theory predicts that the shorter the travel time between patches, the ___ time the forager should stay in each patch.

- A. more
- B. less
- C. more feeding
- D. more resting

55. The log-normal distribution of species indicates that ___?

- A. most species in a community have intermediate abundance
- B. most species in a community have very low abundance.
- C. most species in a community have very high abundance.
- D. most species in a community have the same abundance.

56. Dr. T is a famous lecturer on ethology, and his favorite topic happens to be agnostic behavior. Which of the following are examples of agnostic behavior?

- I. A female guppy picking a mate based on the males' external features
- II. Two grey kangaroos boxing with each other to decide who gets the mate
- III. Two male stalk-eyed flies squaring off for rights to a mate
- IV. Male grey catbirds fluffing their feathers when their territory is threatened by another male

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

57. Another famous ethologist, Dr. L, focuses on the classification of Niko Tinbergen's four main ethologic questions. Which of the following ask questions of ultimate causation?

- I. How does the action of aldosterone on the distal convoluted tubule make a human more fit?
- II. What is the most recent common ancestor that used the enzyme Phosphofructokinase-1?
- III. What neurological pathway do geese implement when imprinting?
- IV. Does lifestyle impact epigenetic modifications in humans?

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

58. You have found three new species, call them A, B, C. A has no coelom, a simple gut, and a simple nervous system; B also has no coelom and interestingly has protonephridia, and C is a pseudocoelomate with a cuticle and no circulatory system. Which of the following classifications is the most specific classification that still contains these three groups?

- A. Bilateria
- B. Deuterostomia
- C. Metazoa
- D. Eukarya
- E. Chordata

59. Which of the following are characteristic of deuterostomes?

- I. Determinate cleavage
- II. Schizocoelous
- III. Radial cleavage
- IV. An example is the Cephalopoda

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

60. You are discussing with your amazing biology teacher various biosystematics concepts. Which of the following are true statements?

- I. Porifera are basal metazoans
- II. The Ediacara marked the appearance of the first eukaryotic organisms
- III. The first organisms that existed and left a distinct record are the stromatolites
- IV. Tunicates lack a notochord
- V. Nematodes lack a circulatory system

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

PART B: Each question is valued at 1 point.

61. Which of the following examples of symbiosis are correctly defined?
- I. Synnecrosis -/-
 - II. Ammensalism -/0
 - III. Commensalism +/-0
 - IV. Mutualism +/+
 - V. Parasitism -/+
- A. I, II
B. I, II, III, IV, V
C. II, III, IV, V
D. III, IV
E. III, IV, V
62. You are discussing the various facets of biology with your good friend. Which of the following is a true statement?
- A. Standing crop is measured over a period of time.
B. Effective population size is not always smaller than the actual population size.
C. Net primary productivity is about $\frac{3}{4}$ of gross primary productivity.
D. The oceans contribute about as much production as all terrestrial biomes combined.
E. An inverted biomass pyramid has a high standing crop.
63. John, 45 years old, ran his first marathon in Denver, Colorado, with a time of 3 hours and 43 minutes. Running hard at Mile 23 -- Oh God, John has collapsed! Paramedics rush him to the hospital, but he unfortunately passes away before anything can be done. Initial examination by trauma experts find no bodily injury and normal blood work but the coroner immediately gives a diagnosis after looking at his family history. What did he conclude?
- A. Cardiac Arrest due to hardening of the aorta from plaque buildup
B. Starvation due to depletion of personal glucose reserves
C. Heat Stroke and dehydration due to strenuous exercise
D. Myocardial Infarction due to thrombocytosis
E. Cardiac Arrest due to hypertrophic cardiomyopathy
64. You injected large quantities of BAPTA (calcium chelator) into a sea urchin egg. After fertilization, which of the following molecular event will NOT occur?
- A. Cortical granule exocytosis
B. An increase in intracellular pH
C. Elevation of protein kinase C activity
D. Elevation of phospholipase C activity
E. Depolarization of the plasma membrane.

65. You injected large quantities of an inhibitory peptide that disrupts the function of phospholipase C γ (gamma) into a sea urchin egg. After it is fertilized, certain events of egg activation are inhibited. You would also like to perform some additional biochemical experiments for your independent project. Which of the following statement is NOT true regarding your independent project?
- A. Cortical granule exocytosis will be affected by the inhibitory peptide treatment.
 - B. DAG is likely a downstream signaling molecule affected by the inhibitory peptide treatment.
 - C. If a sea urchin egg is fertilized in seawater that is made mildly acidic with vinegar (acetic acid), this would decrease the normal pH increase.
 - D. If you want to access whether a calcium wave occurs properly, you can inject the egg with a calcium indicator dye to visualize the changes in calcium.
 - E. Appearance of the fertilization envelope would be another read-out to access whether egg activation is affected, even though it does not necessarily correlate with calcium spread across the egg in a wave.
66. In a developmental biology lab at UCSD, your task as a research assistant was to remove the zone of polarizing activity (ZPA) from a normal wing bud and place a ZPA at its anterior margin. As a result of your manipulation, what would be the expected outcome?
- A. You will still get a normal wing, since the AER provides a non-specific growth signal.
 - B. You will not get any wing due to missing crucial genes for proper development of wings.
 - C. You will get a wing with inverted anterior-posterior polarity (thumb at anterior, digit IV at posterior).
 - D. A third (extra) wing will grow out at the site of the implant, with characteristics of a wing (anterior) and leg (posterior).
 - E. A third (extra) wing will grow out at the site of the implant, with characteristics of a wing (posterior) and leg (anterior).
67. As a dietician, you carefully examined the patient's diets. You found that niacin and iron are severely lacking in your patient's diets. Compared to a healthy individual, you would expect to find low level of
- A. Pepsin
 - B. Collagen
 - C. Hemoglobin
 - D. Co-enzyme A
 - E. Fatty acid desaturase

68. As a research assistant, you examined the effect of vitamin supplementation on the risk of neural tube defects. Women who had had one or more babies with such a defect were put into two study groups. The experimental group consisted of those who were planning a pregnancy and began taking a multivitamin at least four weeks before attempting conception. The control group, who were not given vitamins, included women who declined them and women who were already pregnant. The numbers of neural tube defects resulting from the pregnancies were recorded for each group.

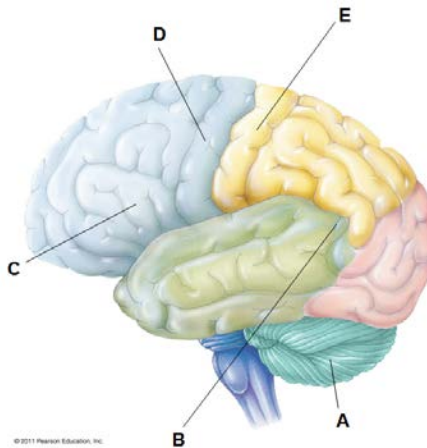
Results

Group	Number of infants/fetuses Studied	Infants/fetuses with a neural tube defect
Vitamin supplements (experimental group)	141	1
No vitamin supplements (control group)		

This controlled study provided evidence that vitamin supplementation protects against neural tube defects, at least after the first pregnancy. Which vitamin would you further test as follow-up trials?

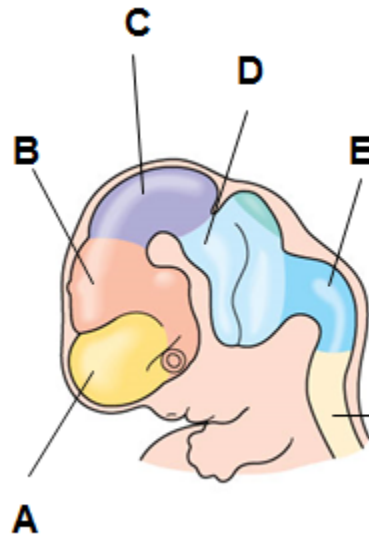
- A. Folic acid
- B. Pyridoxine
- C. Cobalamin
- D. Cobalamin
- E. Ascorbic acid

69. A figure shown below is the human cerebral cortex. Which of the following is incorrectly paired with its function and indicated structure?



- A. coordination of balance and movement
- B. comprehending language
- C. forming speech
- D. decision making and planning
- E. sense of touch

70. The figure shown below is the organization of the human brain of the embryo at 5 weeks. Which of the following is INCORRECTLY paired with its embryonic brain regions and brain structures in child and adult?



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- A. thalamus
- B. hypothalamus
- C. midbrain
- D. cerebellum
- E. medulla oblongata

71. During evolution, differences arose in the relative size of the major structures common to vertebrate brains. Which of the following is incorrectly matched with its figure and examples?



- A. I – Shark
- B. II – Lamprey
- C. III – Ray-finned fish
- D. IV – Frog
- E. V – Chicken

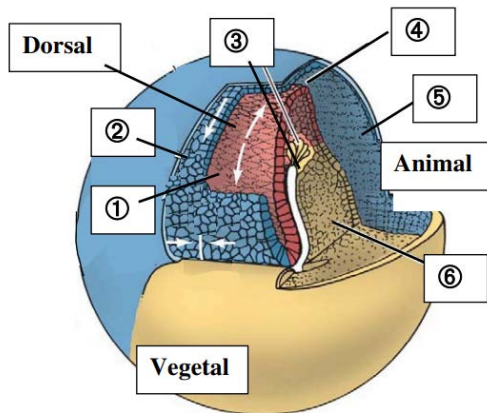
72. You have a cage of mice that has the same genetic background. Specifically, the mice background (strain) you have is OT-I mice, which can recognize MHCI-SIINFEKYL peptide (a specific peptide sequence that is loaded on MHC-I molecule, which is derived from ovalbumin (OVA) protein). You decided to purify CD8 T cells from the spleen of the mouse and chemically labeled with CFSE, a functional dye that will increase the signal as the cell divides. The CFSE will be incorporated into the nucleus of the next daughter cells. You then injected purified OT-1 CD8 splenocytes labeled with CFSE. Next day, you injected OVA (1mg/mice) with or without LPS (lipopolysaccharide, 10ug/mice). After 7, 14, 21, and 28 days, you purified CD8 T cells from draining lymph nodes and measured the intensity of CFSE for each cell; the data are shown below.

	OVA	LPS+OVA
7 days	20	200
14 days	40	400
21 days	60	600
28 days	80	800

What can you conclude based on this experiment?

- A. LPS triggers proliferation of CD8 T cells in the draining lymph nodes.
- B. LPS triggers apoptotic events in CD8 T cells in the draining lymph nodes, which causes increase in CFSE signal.
- C. The efficiency of conventional dendritic cells to present ovalbumin to CD8 lymphocytes is significantly increased by LPS.
- D. LPS triggers TLR pathway in CD8 T cells, which induces the pro-inflammatory cytokines, which in turn results in proliferation of CD8 T cells.
- E. OVA is likely retained in early endosomes of dendritic cells, rather than lysosomes, which is more favorable for efficient antigen-presentation due to alkaline pH.

73. A figure shown below is a graphic representation of amphibian gastrulation.



Which of the following statement is NOT true?

- A. Cells from 2 form central nervous system (CNS).
- B. Cells from 3 and 6 form a part of the archenteron.
- C. Cells from 1 contribute to the formation of somites.
- D. Cells from 1, 2, and 4 undergo convergent extension.
- E. Cells from 3, 5, and 6 do not undergo convergent extension.

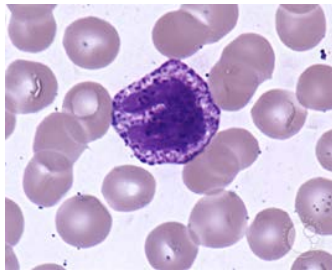
74. You would like to co-culture GM-CSF induced dendritic cells (DCs) from bone marrow and CD8 T cells purified from the spleen in the presence of vaccine adjuvant called MPLA. Adjuvant is a substance that is added to a vaccine to increase the body's immune response to the vaccine. After treating DCs with MPLA, you would like to access if purified CD8 T cells can be activated in the presence of MPLA. All of the following parameters can be used to access CD8 T cell activation EXCEPT FOR which of the following?

- A. CD8 T cell CD activation markers
- B. Type II interferons, including interferon- γ
- C. Specific transcription factors for CD8 T cell activation
- D. Cytopathic molecules, including granzymes and perforins
- E. Type I interferons, such as interferon- α and interferon- β

75. As a medical doctor, you vaccinated a 12-month-old baby with attenuated rubella vaccines via subcutaneous injection. Next day, the baby came to the emergency room and developed a progressive necrotic lesion of the skin, muscles, and subcutaneous tissue at the site of inoculation. The vaccination reaction probably resulted from:

- A. B cell deficiency
- B. T cell deficiency
- C. B and T cell deficiency
- D. Complement proteins deficiency
- E. B and complement proteins deficiency

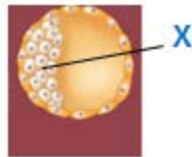
76. You worked as a research assistant at the vet clinics and found that the immune cell can be characterized histologically by its ability to be stained by wright staining (a mixture of eosin (red) and methylene blue dyes.) After staining with wright staining of the unknown sample, the color of the staining was extremely dark purple as shown below.



They are the least common of the granulocytes (<0.1%), representing about 0.5 to 1% of circulating white blood cells. The size of this cell type is about 14-16 μm . Most likely, these are

- A. Basophils
- B. Mast cells
- C. Eosinophils
- D. Neutrophils
- E. Erythrocytes

77. Some cancers escape the immune system by suppressing the expression of MHC class I molecules. However, the lack of MHC I molecule targets cells for destruction by natural killer cells. These cancer cells will likely escape natural killer cells by
- resisting breakdown within lysosomes of NK cells
 - interfering with molecular recognition and phagocytosis by NK cells
 - suppressing the expression of both MHC class I and MHC II molecules simultaneously.
 - repressing the expression of stress proteins or antibodies that can induce apoptosis by NK cells.
 - producing chemicals that will block the secretion of cytokines from the golgi apparatus of the NK cells.
78. As a medical clinician, you decided to collect some cells from the human embryo for regenerating neurons. The cells you decided to collect from the donated human embryo are indicated by "X" as shown below.



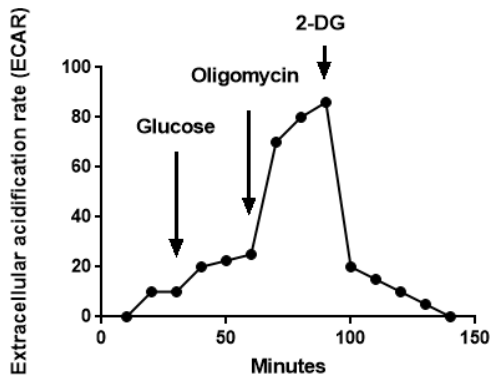
Before you use it for clinical purpose to regenerate some tissues, you would first need to confirm the potency of the collected cells. What is the potency of the cell subset X?

- They are totipotent under normal circumstances, because they can form all tissues.
 - They are pluripotent under normal circumstances, because they cannot form trophoblasts.
 - They are multipotent under normal circumstances, because they can form epiblasts, not extraembryonic tissues
 - They are pluripotent under normal circumstances, because they cannot form extraembryonic tissues.
 - They are multipotent under normal circumstances, because can form extraembryonic tissues, not trophoblasts.
79. Using a lentiviral transduction system, you made a stable cell line of fibroblasts in which it stably expresses thyroid hormone receptors tagged with mCherry fluorescent protein (mCherry-thyroid hormone receptors (THR)) *In vitro*, you treated the transgenic fibroblasts with triiodothyronine (T3). After 3 hours, you fixed your samples with 4% paraformaldehyde to fix your samples, counter-stained the nucleus using Hoechst dye, mounted your coverslips, and examined your samples under confocal microscope. What would happen to the intracellular location of mCherry-THR upon T3 treatment (0 hours vs. 3 hours) *In vitro*? mCherry-THR will
- escape from nucleus to cytoplasm upon T3 treatment.
 - translocate from cytoplasm to nucleus upon T3 treatment.
 - be always located in the nucleus before and after T3 treatment.
 - be always located in the cytoplasm before and after T3 treatment.
 - will be always embedded in the cellular membrane before and after T3 treatment.

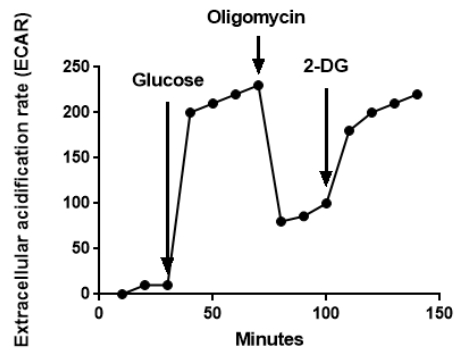
80. Using a CRISPR/Cas9 method, you made a transgenic mice that does not globally express insulin receptor (insulin receptor (IR KO). 2-NBDG is a fluorescent glucose analog that has been used to monitor glucose uptake. For 2-NBDG-labeling experiments, mice received 2-DG (4 g per kg body weight) or vehicle control intravenously 30 mins in control and IR KO mice. 15 min later mice were euthanized and the brain cells were processed and brain cells were analyzed by flow cytometry (in the fluorescein isothiocyanate channel) for the uptake of 2-NBDG. What would be the expected results?
- A. The uptake of 2-NBDG in brain cells from IR KO mice will not be affected.
 - B. The uptake of 2-NBDG will be significantly lower in brain cells from IR KO mice.
 - C. The uptake of 2-NBDG will be significantly higher in brain cells from IR KO mice.
 - D. We cannot predict the uptake of 2-NBDG based on the experiment described above.
81. You generated two plasmids that code GFP-protein HYL and RFP-protein WJL. Protein HYL is found in the thylakoid of the plasmids while protein B is found in the mitochondrial matrix. mRNAs of protein HYL and protein WJL are transcribed in the nucleus and translated by the cytoplasmic ribosomes in the cytosol. You co-transfected cardiomyocytes with two plasmids by electroporation, incubated them in the petri dish, and recorded the time-lapse imaging over 24 hours using fluorescence microscope. To reach the final destination of GFP-HYL and RFP-protein WJL, how many membrane bilayers must proteins A and protein B cross, respectively?
- A. 2, 2
 - B. 2, 3
 - C. 3, 1
 - D. 3, 2
 - E. 3, 3
82. During your summer internship, you decided to remove (knockout) GLUT1, a gene responsible for encoding glucose transporters, in liver cells using a CRISPR/cas9 method. For this transgenic cell line (GLUT1 $-/-$, KO), you incubated 200 μ M of fructose (a structural isomer of glucose) conjugated with FITC (fluorescent probe, FITC-fructose) for 3 hours and read the fluorescence intensity using a plate reader. Compared to your normal liver cells, what would happen to the fluorescence intensity of FITC-fructose in GLUT1 $-/-$ liver cells?
- A. It is likely that the fluorescence intensity of FITC-fructose will not be affected much.
 - B. It is likely that the fluorescence intensity of FITC-fructose will be lower than normal cells.
 - C. It is likely that the fluorescence intensity of FITC-fructose will be higher than normal cells.
 - D. It is likely that the fluorescence intensity of FITC-fructose will be higher, and then lower than normal cells.
 - E. It is likely that the fluorescence intensity of FITC-fructose will be lower, and then higher than normal cells.

83. In macrophages purified from murine spleen, you want to measure extracellular acidification rate (ECAR) in a non-buffered media by adding different chemical treatments in the following order: Glucose, oligomycin (an irreversible inhibitor of ATP synthase), and 2-DG (an irreversible inhibitor of hexokinase). How would ECAR change over different time points in purified macrophages?

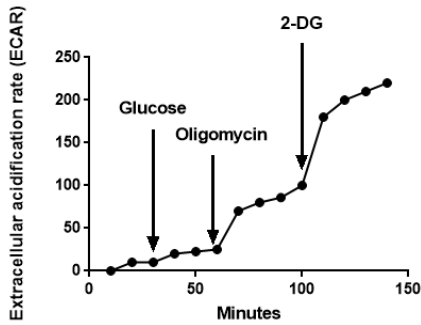
(A)



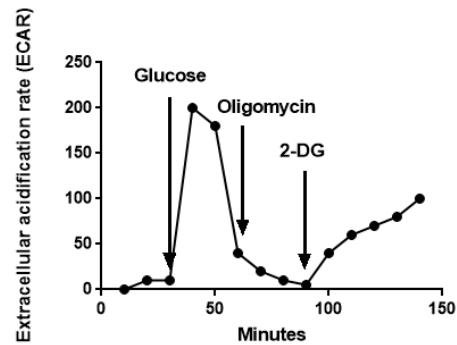
(C)



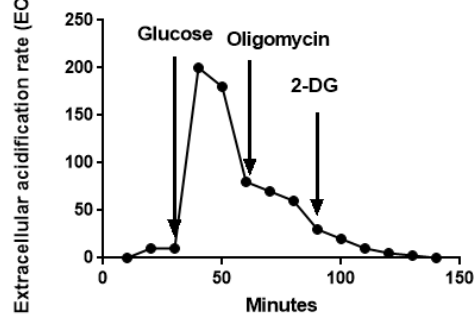
(B)



(D)



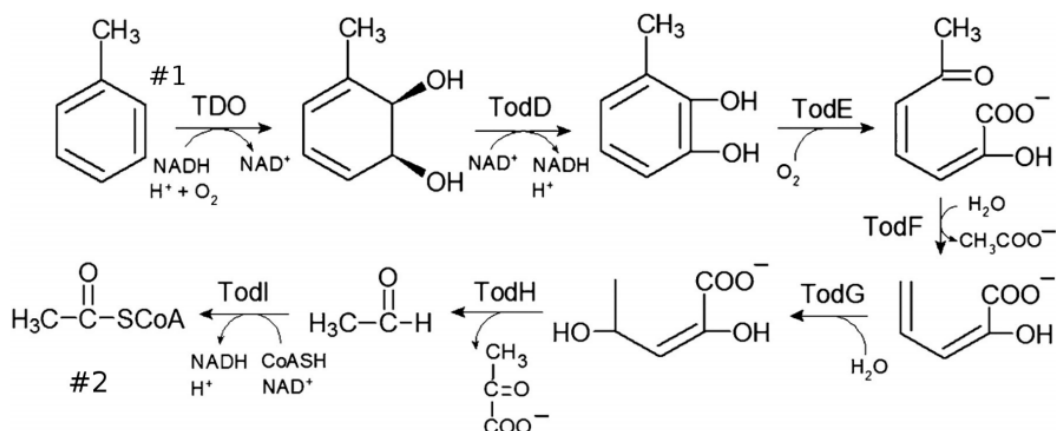
(E)



84. Glycolytic capacity refers to a measure of the maximum rate of conversion of glucose to pyruvate or lactate that can be achieved acutely by a cell. If you want to know the glycolytic capacity of purified splenic macrophages from previous experiment, how can you calculate this?

- A. ECAR after 2-DG treatment
- B. ECAR before addition of glucose
- C. ECAR after addition of glucose - ECAR after 2-DG treatment
- D. ECAR after oligomycin treatment – ECAR after 2-DG treatment
- E. ECAR after oligomycin treatment - ECAR after addition of glucose

85. Consider the following pathway, which describes the degradation for toluene, a colorless, water-insoluble liquid with the smell associated with paint thinners. The main effect of toluene is on the brain and nervous system, but animals exposed to moderate or high levels of toluene also show harmful effects in their liver, kidneys, and lungs and impaired immune function.



Most likely, you have never seen this pathway, but apply the general principles of energy metabolism to this pathway. Which of the following statement (s) is (are) true regarding the pathway shown above?

- A. The first step in the pathway (#1) is an ATP generating step.
- B. The first step in the pathway (#1) is a redox reaction with toluene that oxidizes the toluene.
- C. The product of the toluene degradation pathway (#2) is probably further degraded using the TCA cycle and beta-oxidation.
- D. The microorganism capable of utilizing this pathway cannot be used for bioremediation due to anabolism of toxic chemicals using toluenes as monomers.
- E. None of the above.

86. You treated murine macrophages with cytochrome C purified from horse heart *in vitro*. The cytochrome C (an enzyme that donates electrons to mitochondrial cytochrome oxidase) is localized in the internalized vesicles (phagosomes) of murine macrophages. What would happen if cytochrome C is released from the vesicles to the cytosol?
- A. There will be likely an apoptotic cell death.
 - B. There will be a higher rate of cellular respiration, thus yielding more ATPs
 - C. Less electrons will be shuttled from electron carriers, including NADH and FADH₂.
 - D. The rate of glycolysis will be increased because cytochrome C can promote glycolysis.
 - E. Relay proteins capable of transducing the apoptotic signal, including Ced-3, Ced-4, and Ced-9, will be inactivated.
87. Meselson and Stahl first grew bacteria for several generations in a medium containing only ¹⁵N ("heavy" nitrogen). When examined in an analytical centrifuge, DNA isolated from these bacteria produced a single "heavy" band. Meselson and Stahl then transferred a portion of the culture to a new medium that contained only ¹⁴N ("light" nitrogen). When DNA was isolated from the culture after three generations from the same culture, what would you expect to observe in ¹⁵N-¹⁵N DNA (heavy), ¹⁵N-¹⁴N DNA (intermediate), ¹⁴N-¹⁴N DNA ratio (light)?
- A. 1:2:1 (light:intermediate:heavy)
 - B. 1:2 (light:intermediate), no heavy nitrogen incorporated DNA
 - C. 3:1 (light:intermediate), no heavy nitrogen incorporated DNA
 - D. 1:3 (light:intermediate), no heavy nitrogen incorporated DNA
 - E. 100% intermediate, no heavy or light nitrogen incorporated DNA
88. The endangered golden toad has eye color determined by a single gene. If at least one copy of B is present, the toad will have blue eyes; otherwise it will have green eyes. In jungle a population of golden toads, 84% have blue eyes. Assume the population is in Hardy Weinberg equilibrium. As part of an effort to preserve genetic diversity in the species, you collect all the green-eyed toads and ship them off to a zoo in San Diego. When you return to the jungle population a few generations later, what percent of the population do you expect to see having green eyes?
- A. 15.23%
 - B. 5.71%
 - C. 21.11%
 - D. 8.16%
 - E. 10.21%
89. A class of small, endogenous RNAs of 18–25 nucleotides (nts) in length. They play an important regulatory role in animals and plants by targeting specific mRNAs for degradation or translation repression. This group of RNA are named
- A. mRNA
 - B. tRNA
 - C. rRNA
 - D. microRNA (miRNA)
 - E. Microsatellite

90. A class of mutations in *Caenorhabditis elegans* is known as “HIM” for high incidence of males in the progeny of hermaphrodites. Most HIM loci have been found to affect chromosome segregation in meiosis. Which of the following is the most plausible underlying cause of this phenotype?

- A. increased survival of males owing to dosage compensation.
- B. elevated nondisjunction resulting in more nullo-X eggs and sperm.
- C. increased survival of males because of less frequent nondisjunction.
- D. decreased survival of females resulting from the lack of dosage compensation, thus increasing the relative proportion of males.
- E. decreased survival of females resulting lower viability of the nondisjunctional ZZ versus ZW sex chromosomal constitution.

91. This question refers to a corn plant known to be heterozygous for C and c (colored and colorless seeds), Wx and wx (nonwaxy and waxy endosperm) and Sh and sh (plump and shrunken endosperm). A testcross to a triple recessive plant (colorless, waxy, shrunken) produced the following 2000 seeds:

colorless, nonwaxy, shrunken	25
colorless, nonwaxy, plump	290
colorless, waxy, shrunken	6
colorless, waxy, plump	700
colored, waxy, shrunken	284
colored, waxy, plump	30
colored, nonwaxy, shrunken	661
colored, nonwaxy, plump	4

What is the recombination frequency between shrunken and waxy?

- A. 10.5%
- B. 29.2%
- C. 17.7%
- D. 35.2%
- E. 8.94%

92. In contrast to chemical induced mutagenesis, transposon mutagenesis are more likely to

- A. be dominant.
- B. be recessive.
- C. be codominant.
- D. revert to wild type.
- E. be incomplete-dominant.

93. The following is a pedigree for a specific trait in humans that is associated with the mutations in Gene A. Assume that the disease is rare and individuals marrying into the family only have the alleles(s) of Gene A that is associated with the wild-type phenotype. What is the genotype(s) of Individual 4?

- A. AA
- B. Aa
- C. XAXA
- D. XaXA
- E. XAO

94. Which of the following statement is NOT true regarding retrotransposons?

- A. Reverse transcriptase is encoded by the retrotransposon.
- B. They always leave a copy at the original site during transposition.
- C. They are DNA sequences that replicate via an RNA intermediate.
- D. They represent most of transposable elements in eukaryotic genomes.
- E. They are DNA sequences that can move from one site in the genome to another without replicating.

95. You found the following karyotype structure shown below:



This could be due to which of the following?

- A. Portions of non-homologous chromosomes have been translocated.
- B. The homologous chromosomes have each suffered a gene duplication
- C. One of the two homologous chromosomes has undergone an inversion.
- D. Both of the two homologous chromosomes have undergone an inversion.
- E. One of a pair of homologous chromosomes has been lost via nondisjunction

- 96. Which of the following best explains why histone acetylation increases transcription of DNA bound to that histone?**
- A. At cellular pH, DNA is negatively charged and is repelled by the negatively charged acetyl groups.
 - B. At cellular pH, DNA is negatively charged and is attracted to the positively charged acetyl groups.
 - C. At cellular pH, DNA is positively charged and is repelled by the positively charged acetyl groups.
 - D. At cellular pH, DNA is positively charged and is attracted to the negatively charged acetyl groups.
 - E. At cellular pH, DNA is negatively charged and is attracted to the negatively charged acetyl groups.
- 97. You are trying to determine how large a certain population of trout is. You capture 50 trout, mark them, then return them to the stream. Then, the next time you capture trout (some time later), you find that, out of the 100 you captured, only 7 are marked. About how many trout are in the stream?**
- A. 500 trout
 - B. 600 trout
 - C. 700 trout
 - D. 800 trout
 - E. None of the above
- 98. You want to inhibit the autophagic flux in endothelial cells in vitro and measure the expression marker of p62, which is an important indicator of autophagic flux. To do so, which of the following can act as a general chemical inhibitor of autophagy in most cell types?**
- A. MG-132, 26s proteasome inhibitor
 - B. Thioridazine, a reversible inhibitor of peroxisomes
 - C. Bafilomycin, a fusion inhibitor of lysosomes and phagosomes
 - D. Rapamycin, a chemical that triggers the fusion of phagosomes and lysosomes
 - E. Sodium azide, a chemical inhibitor of cytochrome complexes in the mitochondria

99. You've discovered a mysterious new caniform species, *Doggo corgus*. In *D. corgus*, floofiness is dominant to non-floofiness and short-leggedness is dominant to long-leggedness. You believe that, in *D. corgus*, the genes for floofiness and tail length are linked. In order to study the linkage, you start with two true-breeding lineages, one floofy with short legs and one not floofy with long legs. Then, you cross a floofy short legged individual with a non-floofy long-legged individual, and obtain an F1 population of floofy, short-legged individuals. Assume that the recombination frequency is 0.3. If you cross two F1 individuals, what fraction of the F2 population would you expect to be floofy and long-legged? Select the answer closest to the actual number.
- 0.10
 - 0.125
 - 0.15
 - 0.25
 - 0.35
100. Which of the following statement is NOT true regarding programmed cell death in plants?
- Roots treated with high concentration of ethylene will likely undergo senescence.
 - Xylem vessel members need to undergo programmed cell death to become functional.
 - During apoptosis, newly formed enzymes break down chlorophylls and membrane lipids.
 - To provide functional barriers, root cap cells need to undergo programmed cell death to become functional
 - Non-productive leaves or branches can undergo programmed cell death and are eventually shed by self-pruning.
101. The famous physicist C. W. Jason has discovered a miraculously novel organism! It has an open circulatory system, a mesothorax, and Malphigian tubules. Which of the following clades would this organism most likely belong to?
- Crustacea
 - Mollusca
 - Insecta
 - Echinodermata
 - Chordata
102. Imagine you are a molecule of water moving from the outside of a monocot root towards the center; in what order would you encounter these structures?
- Casparian Strip
 - Pith
 - Phloem
 - Xylem
 - Cortex
- V, I, II, III, IV
 - V, I, II, IV, III
 - I, V, III, II, IV
 - I, II, V, IV, III
 - V, I, III, IV, II

103. All of the followings can be transported by the phloem EXCEPT for
- A. Jasmonates
 - B. Abscisic acid
 - C. Methylsalicylic acid
 - D. Nitrogen export from the root, such as NO_3^-
 - E. Macromolecules, including RNA and proteins
104. Mycorrhizal fungi are important to many plants because they can
- A. recruit nitrogen-fixing bacteria to plants
 - B. improve the rate of photosynthesis in plants
 - C. improve delivery of phosphate ions in plants
 - D. provide organic nutrients, such as carbohydrates, to the plants
 - E. produce toxins that can kill other parasitic microbes or infectious fungi
105. After knocking out the gene PP2A in *Arabidopsis thaliana* using TALEN, you found that there are no mycorrhizal fungi attracted to the plant. Most likely, PP2A has an important role in synthesizing
- A. auxin
 - B. ethylenes
 - C. jasmonates
 - D. strigolactones
 - E. brassinosteroids
106. Which of the following correctly lists the vascular tissues from pith to the cork, starting from the pith?
- A. Primary xylem → secondary xylem → vascular cambium → secondary phloem → primary phloem
 - B. Secondary phloem → primary phloem → vascular cambium → secondary phloem → primary phloem
 - C. Primary xylem → secondary xylem → vascular cambium → primary phloem → secondary phloem
 - D. Secondary xylem → primary xylem → vascular cambium → primary phloem → secondary phloem
 - E. Secondary phloem → primary phloem → vascular cambium → primary phloem → secondary phloem
107. Which of the following is the final product of protoplast fusion of two plant cells?
- A. Plant cells with lysosomes removed
 - B. Plant cells with their nucleus removed
 - C. Plant cells with their cell walls removed
 - D. Plant cells with their cytoplasm removed
 - E. Plant cells with their cell membrane was removed

108. Which of the following statement is NOT true regarding the role of auxins in plant development?
- A. Auxin transport plays a role in phyllotaxy.
 - B. Polar transport of auxin from leaf margins directs leaf venation pattern
 - C. The activity of the vascular cambium is under control of auxin transport
 - D. Polar transport of auxin plays a role in pattern formation of the developing plant
 - E. Increased auxin flow from the shoot of a branch stimulates growth in lower branches
109. The primary research that Karl von Frisch conducted that contributed to his winning the Nobel Prize was related to:
- A. negative feedback
 - B. sexual imprinting
 - C. the waggle dance of bees
 - D. the Psychohydraulic Model of Motivation
 - E. operant conditioning
110. Tungara frogs make a one-note “whine” call and a more complex “whine+chuck” call. The more complex call is more attractive to females than the one-note call. Why don’t the frogs always make just the more attractive call?
- A. The complex call takes more energy so the frogs only use it when they have not been able to attract a female for some weeks.
 - B. Even though the females prefer the more complex call, it is harder to localize. So the males mix up the more attractive call with the one that makes them easier to find by the females.
 - C. The frogs are switching their behavior according to the need to attract females and to deal with predation pressure.
 - D. The “chuck” component is added as a territorial aggressive call directed toward males, so a resident male will only use the more complex call if he is both trying to attract females and defend his territory against intruder males.
111. Industrial melanism refers to moth populations where the historical morph was white, but due to coal soot coating trees the moths are now mostly dark in color. Thus they remain cryptic despite the change in tree bark color. What is the behavior here?
- A. The moths are able to rapidly change their skin melanin to match whatever sort of tree they are on.
 - B. The moths seek out environmental dust which they ingest and which then accumulates in their tissues making them darker.
 - C. Moths that are born as a white morph know to choose light trees on which to hide, and dark moths know to choose dark trees.
 - D. The moths that find themselves on an inappropriate surface (light on dark or dark on light) have evolved a behavior of positioning themselves immediately next to other moths to make a mosaic pattern which a predator cannot resolve as a food item.

112. Catherine is breeding crickets. Crickets have four chirping phenotypes: deafening, loud, quiet, or silent. When Catherine crosses a pure-breeding deafening female cricket to a silent male, she observes only deafening offspring. When she crosses the offspring together, she observes a 13:3 ratio of deafening to silent offspring. Assuming that chirping is controlled by two unlinked genes, which of the following choices best explains this ratio?
- A. One dominant allele of each gene is necessary to produce the deafening phenotype
 - B. The homozygous recessive condition of one gene masks both alleles of the other gene
 - C. The dominant allele of one gene masks the effect of both alleles of the other gene
 - D. The dominant allele of one gene masks the dominant allele of the other gene
 - E. There is no interaction between the two genes
113. W. Jason is back at it again, and he's discovered yet another new organism! You discover that it is a coelomate and it has an open circulatory system. What's more, this organism exhibits a soft outer covering with a visceral mass inside. What clade does this organism most likely belong to?
- A. Onychophora
 - B. Nematoda
 - C. Hemichordata
 - D. Mollusca
 - E. Cephalopoda
114. For the bread mold (*Neurospora*), the products of how many meioses are found in one ascus?
- A. 1
 - B. 2
 - C. 3
 - D. 4
 - E. 5
115. Convection rolls are responsible for which of the following?
- A. Plate tectonics.
 - B. Heavy rains at low latitudes.
 - C. Polygons forming in oil heated in a skillet.
 - D. All of the above.
 - E. None of the above.
116. Which of the following is the best definition of "fitness"?
- A. The health of offspring produced by parents relative to the health of those in the population.
 - B. The slope of the relationship between mean phenotype of the parent and the offspring's phenotype.
 - C. The number of offspring produced by an individual relative to the average number produced by members of the population.
 - D. All of the above.
 - E. None of the above.

117. What's "p" given the following frequencies of genotypes?
A1A1 = 20, A1A2 = 50, A2A2 = 80.
- A. 0.133
 - B. 0.233
 - C. 0.300
 - D. 0.700
 - E. 0.950
118. You capture and mark 73 mice in the field. You release them and one week later capture 100 mice, of which 23 are marked. Assuming no violations of the Lincoln-Peterson technique occur what is our estimate of the population (note these values may be rounded down)?
- A. 31.
 - B. 103.
 - C. 196.
 - D. 317.
 - E. 996.
119. The population of wolves in Yellowstone went from 137 to 121 in one year. What was r if the population grew according to the exponential growth during this time? Which of the following is the closest estimate for "r" during this time period?
- A. -0.12
 - B. -0.08
 - C. 0.12
 - D. 0.88
 - E. None of the above.
120. What's the Shannon diversity index (H') for a community that has 5 species with the following number of individuals in each of the five species: 15, 40, 25, 75, 10?
- A. -1.2
 - B. 1.0
 - C. 1.28
 - D. 1.38
 - E. 5

Student Name _____ Student ID# _____

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

1. Protein gels in action (15 points)

You immunopurified a sample of Lic protein from the recently discovered species *V. manga* using polyclonal anti-Lic antibodies and decided to examine the purity of Lic protein using a native agarose gel electrophoresis. The surface of Lic proteins is highly enriched with cysteine residues. You ran the purified proteins on a horizontal gel under three different conditions. The results of gel I, II, and III are shown as below. Assume that the oligomerization status of Lic proteins is negligible in the scenario.

- (I) The sample is run natively (without denaturing) on the gel.
- (II) The sample is treated with SDS (ionic detergent) prior to running on the gel.
- (III) The sample is treated with \square -mercaptoethanol (reducing agent) prior to running on the gel.



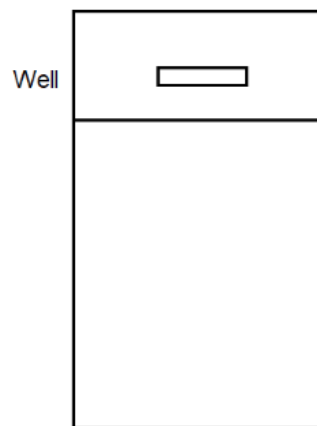
Please answer the following four questions. (15 points)

- a) Label cathode and anode in the gel pictures shown above. (2 point)
- b) Unfortunately, you forget which gel is which/ label each gel with its experiment. In each diagram, the thin black line is where the protein was initially loaded, and blue lines correspond to protein bands (stained with coomassie blue, 2 points)

Student Name _____ Student ID# _____

c) For each gel (b), briefly explain the rationale for your answers. (8 points)

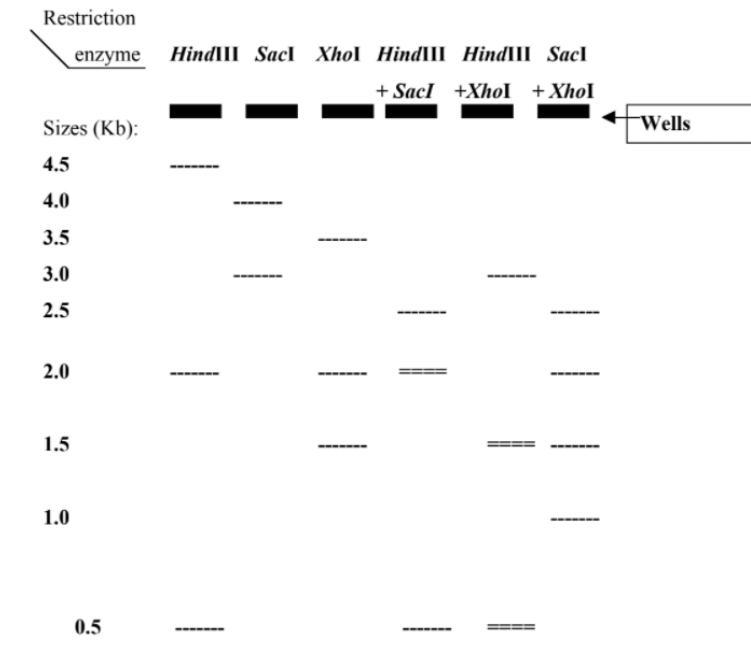
d) In the space below, draw what you would expect if you run your protein samples treated with β -mercaptoethanol and SDS prior to running the gel. (3 point)



Student Name _____ Student ID# _____

2. Restriction Digest (10 points)

YAC DNA (with its telomeres) is cleaved with HindIII, SacI, XhoI, or a combination of HindIII and SacI, HindIII and XhoI, or SacI and XhoI. After restriction digestion, the products of each reaction are loaded in separate wells of an agarose gel and separated by agarose-gel electrophoresis. The following fluorescence patterns are observed on the gel (Double line indicates that 2 fragments of similar size are generated by the digestion).



- a) If the YAC DNA is highly methylated, in general, what would happen to the efficiency of restriction enzymes? Explain your answer. (2 points)

- b) Describe how restriction enzymes got their names. What is the biological relevance of restriction enzymes? (1 point)

- c) Provide a restriction map for this YAC clone, and indicate on this map the distance between successive restriction sites. (7 points)

Student Name _____ Student ID# _____

3. Animal Physiology (15 points)

- 1) Early mammalian embryos are well known for their developmental plasticity. (4 points)
 - a) Two different sources from which embryonic stem cells can be derived in human are _____ cells and _____ cells from the fetus.
 - b) _____ involve the introduction of four genes, which are types of _____. They raise fewer ethical issues than human embryonic stem (ES) cells.
- 2) Complete the following table referring to cleavage patterns in embryos of various animals. (6 points)

Animal	Completeness of cleavage	Orientation of cleavages
Monkey		Rotational
Starfish		
Chicken		Discoidal
Snail		

- 3) The following statements describe cell types from various gastrula-stage embryos for the type of morphogenetic movement. Identify which morphogenetic movement is involved for each cell type. (2 points)
 - (a) Endodermal cells in the sea urchin at vegetal plate _____
 - (b) Sea urchin archenteron cells as the archenteron elongates _____
- 4) Identify the source of the embryonic germ layer for the following tissues in dogs. (3 points)
 - (a) Adrenal cortex _____
 - (b) Adrenal medulla _____
 - (c) Pituitary gland _____

We hope to see you as a Finalist!!