USABO Open Exam
April 6, 2024

20% Cell Biology (10 questions)

1. Which of the following organelles is not directly bound by a phospholipid bilayer membrane?

A. Mitochondria.
B. Nucleolus
C. Nucleus.
D. Peroxisome.
E. Vacuole.

2. You want to isolate a protein with a known MW of 60 kDa from cellular lysate. You begin by running a Western Blot on a ladder (Lane 1) and with your sample (Lane 2). Which of the following statements could explain your results?

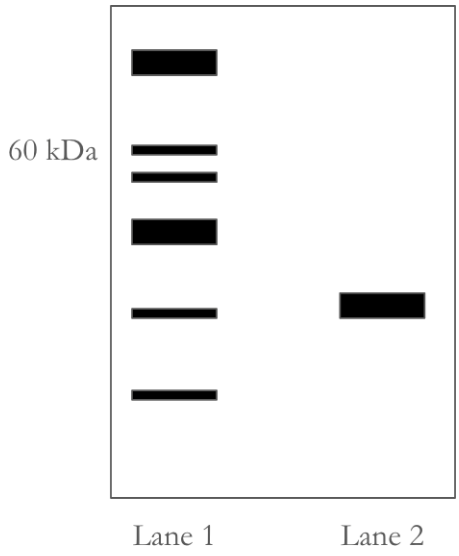

Image Credit: G. Ren

A. You did not transfer onto nitrocellulose for a long enough time.
B. You forgot to block.
C. Your protein is composed of multiple subunits.
D. You used a nonspecific primary antibody that resulted in the blotting of the wrong protein.
E. You used a nonspecific secondary antibody that resulted in blotting of the wrong protein.

3 At physiologic pH, a molecule of serum albumin can expect what percent of its histidine (pKa 6.4) residues to be uncharged?

A. 9%.
B. 10%.
C. 19%.
D. 91%.
E. 99%.

4. Streptomycin is an antibiotic that works by binding to the 16S rRNA, preventing protein synthesis from occurring. Which of the following structures does streptomycin most likely directly bind to?

A. Golgi Apparatus.
B. Nucleolus.
C. Nucleus.
D. Ribosome.
E. Vacuole.

5. In mRNA delivery, in-vitro transcription mRNA may be entrapped within a lipid nanoparticle; some mechanisms for entrapment are shown below. Which of the following proposed mRNA-loading vehicles (to which mRNA is attached) is unlikely to succeed?

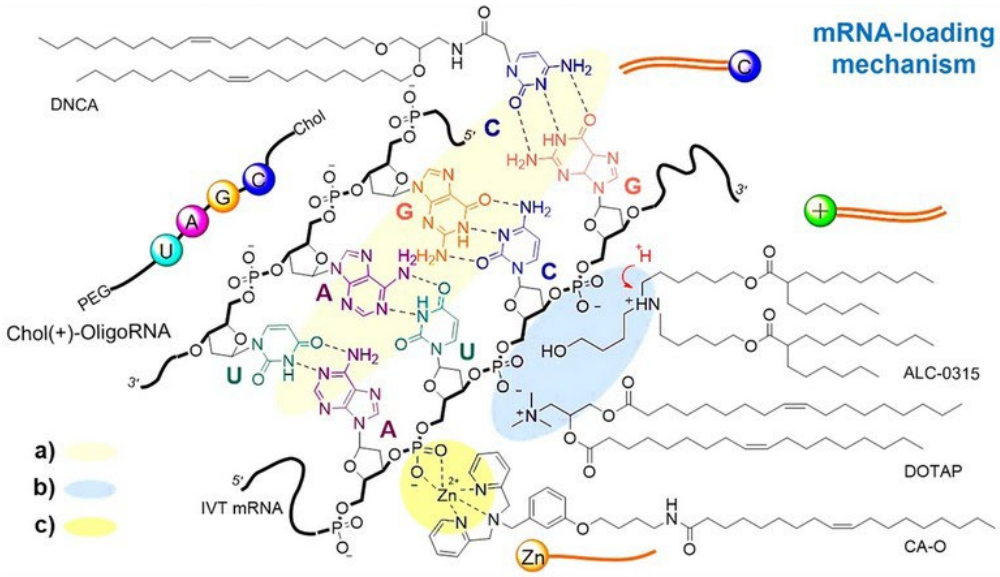

Image Credit: S. Qin et al.

A. Anionic polymers.
B. Ionizable lipids.
C. Metal-based compounds.
D. Nucleoside-based lipids.
E. Nucleoside-based polymers.

6 Which of the following proteins most likely contains a nuclear localization sequence?

A. Collagen.
B. Estrogen receptor.
C. Kinesin.
D. Phosphofructokinase.
E. Ubiquitin ligase.

7. You discover a new drug that prevents Ubiquinone (Q) from accepting electrons from complex I and II. Which of the following results would you first witness in cells treated with this drug?

A. Buildup of NAD^+ and FAD^+.
B. Buildup of acetyl-CoA.
C. Retention of Q in the oxidized state.
D. Reductive cell stress.
E. Dissipation of the proton gradient.

8. A gram stain is performed to determine whether a bacterial species is gram-positive or gram-negative. Which of the following steps is part of the procedure?

I. Immunoprecipitation
II. Staining with safranin
III. Visualization with UV light
IV. Staining with crystal violet

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

9. A sequence of DNA or RNA can be divided into a series of three-nucleotide long codons by the reading frame. During the initiation of translation, which of the following establishes the reading frame?

A. Ribosome binding site (RBS).
B. Start Codon.
C. 5′ 7-methylguanosine cap of mRNA.
D. mRNA poly-A tail.
E. Shine-Dalgarno Sequence.

10 Charlie wants to insert a fluorescent marker into a plant cell that will eventually end up in the plant cell wall after cell division. Which organelle should he inject the fluorescent marker into?

A. Chloroplast.
B. Golgi Body.
C. Nucleus.
D. Peroxisome.
E. Smooth Endoplasmic Reticulum.

15% Plant Anatomy and Physiology (7 questions)

11. The stem of two plants, *diver* and *floater* have been treated with gibberellin. A permeable block supplying a solution of 0.01 M IAA is then placed in between the ends of the cut stem as in the image below (11.1), and a red permanent marker is used to label points on the stems. After some time, you observe in the image below (11.2) that *diver* has experienced growth. Which image and hormone pair correctly demonstrates *floater*'s growth and identifies the hormone directly responsible for a change in *floater*'s growth compared to *diver*'s, if applicable?

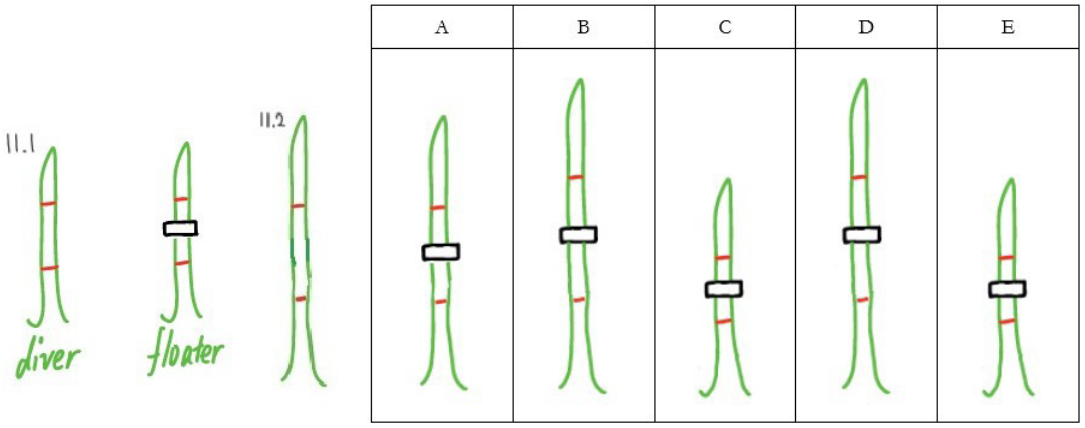

Image Credit: R. Zhu and J. Xu

A. Image A, none.
B. Image B, abscisic acid.
C. Image C, abscisic acid.
D. Image D, ethylene.
E. Image E, ethylene.

12. The Baobab tree stands proud in the dry deciduous forests of Madagascar. Which of these following inaccurately describes an adaptation the Baobab has to the dry climate

A. Closing of stomata to limit transpiration.
B. Growth underneath the shade of larger trees.
C. Shallow roots relative to a very wide root system.
D. Shedding leaves during the dry season.
E. Water storage in the trunk of the tree.

13 James is writing his thesis on tree fern indusia, structures known to grow from the abaxial leaf surface. Based on the graph below, which of the following plant processes does indusium most likely support?



Image Credit: VPLanet

A. Calvin cycle.
B. Light-dependent reactions.
C. Respiration.
D. Reproduction.
E. Vascular Transport.

14 Jessie is a farmer-scientist who cultivates a plant that produces aggregate fruit and is known to follow the ABC hypothesis. He wants to produce various mutants of this plant in an attempt to increase fruit yield. Which of the following mutant plant forms would improve fruit yield the most?

A. Constitutive expression of a cytokinin-producing gene.
B. Deletion of the B gene.
C. Expression of genes that increase phloem plasmodesmata.
D. Overexpression of the A gene.
E. Overexpression of the C gene in areas where the B gene is expressed.

15 Identify all the following events that can occur during effector-triggered immunity in plants in response to a bacterium:

I. Expression of R genes.
II. Phytoalexin production in response to flagellin.
III. Export of methylsalicylic acid to other parts of the plant.
IV. Lesion formation around infected cells.

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

16. Three plants display different mutations related to the plant hormone ethylene:

- ***ein*: ethylene-insensitive**
- ***eto*: ethylene overproducing**
- ***ctr*: constitutive triple response**

Farmer John crosses these plants with each other and with WT plants in an attempt to produce short offspring. Which of the following crosses is least likely to produce short offspring, and should thus be avoided by Farmer John?

A. WT with *ctr.*
B. WT with *eto.*
C. *ein* with *ctr.*
D. *ein* with *eto.*
E. *eto* with *ctr.*

17. A tree stump is examined as depicted below. What are the most durable layers and the youngest layer(s), respectively?

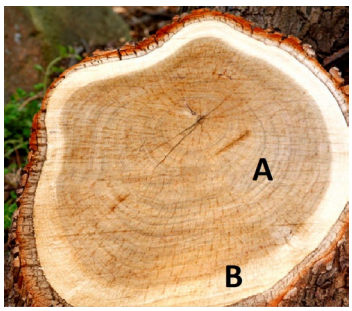

Figure 17.1



Figure 17.2

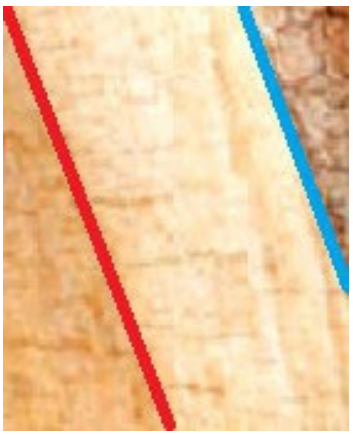

Figure 17.3

Image Credit: A Eliades

17.2: Taken from region A. layer 1 = light band(s), layer 2 = dark band(s), color differentiation is largely in part due to cell density

17.3: Taken from region B; figure left is closer to the center of the trunk. layer 3 = cells directly to the right of the red line, layer 4 = cells directly to the left of the blue line, layer 5 = cells directly to the right of the blue line

A. Layer 1 is the most durable; layer 3 is the youngest.
B. Layer 1 is the most durable; layers 4 and 5 are the youngest.
C. Layer 2 is the most durable: layers 3 and 5 are the youngest.
D. Layer 2 is the most durable; layers 4 and 5 are the youngest.
E. Layer 5 is the most durable; layer 3 is the youngest

25% Animal Anatomy and Physiology (13 questions)

18. As a new intern at the Department of Developmental Biology, you are tasked with studying pattern formation in chicks. Which of the following conditions would most likely result in the production of extra limb segments in the chick embryo?

I. Addition of a chemical that strongly stimulates ZPA activity and inhibits AER activity.
II. Addition of a chemical that promotes Sonic hedgehog expression in the posterior mesenchyme.
III. Addition of a chemical that strongly stimulates fibroblast growth factor (FGF) expression.

A. II only.
B. I and II only.
C. III only.
D. II and III only.
E. I, II, and III only.

19. Which of the following statements about the sliding-filament model is TRUE?

A. Binding of Ca^{2+} to tropomyosin frees the myosin-binding sites on actin.
B. Binding of ATP to myosin releases myosin heads from actin.
C. Myosin bound to ATP is in its high energy state.
D. Hydrolysis of ATP drives the myosin power stroke.
E. Release of Pi from myosin puts myosin in its high energy state.

20. Oh no! An antigen has directly entered the bloodstream! Where would you expect the adaptive immune response to the circulating antigen to begin?

A. Appendix.
B. Lymph Nodes.
C. Mucosa-associated lymphoid tissue (MALT).
D. Spleen.
E. Thymus.

21 A red blood cell traveling between which pair of locations (in the direction of first location to second location) would have the least distance to travel?

A. Left Atrium Cardiac Muscle to Left Atrium.
B. Left Lung to Right Lung.
C. Liver to Adrenal Gland.
D. Small Intestine to Liver.
E. Stomach to Spleen.

22. Ruffles has a condition where he retains too much water, causing him to feel bloated. His doctor prescribes a diuretic with the unfortunate side effect of shuttling protons through the inner mitochondrial membrane, which significantly reduces the yield of cellular respiration. Which of the following portions of the kidney would be most affected by this?

A. Proximal Convoluted Tubule.
B. Descending Loop of Henle.
C. Collecting Duct.
D. Ascending Loop of Henle.
E. Distal Convoluted Tubule.

23. You extract a sample of your own blood and spin it in a centrifuge to fractionate the parts. You notice that the bottom layer takes up a greater proportion of the tube than normal. Which of the following could be reasons for this?

I. Blood Doping.
II. Dehydration.
III. Sickle Cell Anemia.

A. I only.
B. II only.
C. I and II.
D. I and III.
E. I, II, and III.

24. You notice that a patient is having trouble sleeping regularly. After performing lab tests, you notice that he has a shortage of a certain amino acid. Which of the following amino acids is likely depleted?

A. Alanine.
B. Glutamate.
C. Glycine.
D. Tryptophan.
E. Tyrosine.

25 Which of the following statements is true about CD8?

A. It is most commonly found as an intracellular glycoprotein.
B. The D1 domain can bind to MHC II from antigen-presenting cells.
C. It is a marker for cytotoxic T cells.
D. It is a highly polymorphic protein.
E. CD8 markers are an effective screening tool for the diagnosis of Human Immunodeficiency Virus.

26. For an individual with trouble hearing, which of the following parts of the brain is most likely damaged?

A. Frontal Lobe.
B. Hypothalamus.
C. Parietal Lobe.
D. Occipital Lobe.
E. Thalamus.

27. Which of the following conditions would result in a right shift of the hemoglobin oxygen dissociation curve?

A. Increased concentration of blood CO_2.
B. Increased pH.
C. Decreased concentration of 2,3 bisphosphoglycerate.
D. Decreased body temperature.
E. Presence of fetal hemoglobin.

28. Abiraterone is an inhibitor of CYP17A1, an enzyme involved in androgen synthesis. Which of the following hormone level changes would you expect for a patient taking Abiraterone?

A. Decreased levels of epinephrine.
B. Decreased levels of ACTH.
C. Increased levels of cortisone.
D. Increased levels of TSH.
E. Increased levels of GnRH.

29. Inhibition of which of the following neuron ion transporters would most severely impact the formation of the resting membrane potential?

A. Voltage-gated Na^+ channels.
B. Na^+/K^+ ATPase.
C. cAMP-activated Na^+ channels.
D. Leaky K^+ channels.
E. Leaky Na^+ channels.

30 Orlistat is a weight loss drug that decreases lipid absorption through inhibiting lipase, occasionally resulting in steatorrhea, or the increased excretion of fat in feces. Damage to which organ most closely resembles the steatorrhea-like symptoms of Orlistat?

A. Large intestine.
B. Liver.
C. Pancreas.
D. Stomach.
E. Small intestine.

5% Ethology (2 questions)

31. Environmental *zeitgebers* induce activity patterns. In African stonechats, *zeitgebers* allow for synchronization and further determine molting based on the specific photonic stimuli. Which of the following describes this African stonechat behavior?

A. Fixed action pattern.
B. Cicannual rhythm.
C. Pheromone signaling.
D. Kin selection.
E. Courtship-stimulus response chain.

32. Aphids, herbivores with a short generation time, have been observed to run on *S. niknud* sap as a new food source. *S. niknud* sap initially had a lower cost of acquisition but greater foraging time relative to *T. do* sap. Which of the following would best explain the given change in aphid herbivory patterns?

A. Imprinting.
B. Optimal foraging model.
C. Game theory.
D. Problem-solving.
E. Spatial learning.

20% Genetics and Evolution (10 questions)

33. Reinforcement would NOT occur in which of these scenarios?

A. A peripatric species following reintroduction of the parent species.
B. During the course of sexual selection with different male ideals.
C. In two recently geographically isolated populations of one species.
D. In a newly formed, sympatric hybrid.
E. Following an adaptive radiation.

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34 You stumble across a stock of heterozygous flies carrying a recessive lethal mutation, *lentilsoup*. You wish to check if the *lentilsoup* mutant is an allele of an already known gene with recessive lethal mutant *bean stew*. To do so, you set up a complementation test. You decide to cross *lentilsoup*/CyO and *bean stew*/CyO flies, where CyO is a balancer chromosome that causes recessive embryonic lethality and a dominant curly wing phenotype. What pattern of offspring phenotypes indicates the mutations are of the same gene?

A. All flies are wild-type.
B. All flies have curly wings.
C. No flies have curly wings.
D. There are no surviving offspring.
E. The offspring display a novel phenotype.

35. Parents Judith and Sonny go to a genetic counselor because they are planning to grow their family. They are concerned, however, because Judith has a family history of X-linked color blindness. Her father was colorblind, and so was her mother's father. Sonny is colorblind, but their daughter, Dotty, has completely normal vision just like her mother. Judith is already pregnant with their son, Harold, and wants to know if she should ask for the top signs in her neighborhood to be changed to blue to better accommodate their son. What is the probability that Judson will NOT be colorblind?

A. ¼.
B. 1/3.
C. ½.
D. 2/3.
E. 1.

36. Assume that the recessive gene *wnt* in humans gives people rainbow irises and has a gene frequency of 0.01, and that the population is in Hardy-Weinberg equilibrium for the *wnt* gene. Two parents heterozygous for the *wnt* gene have a child that does not have rainbow irises. If this person has a child with a random person from the population, which of the following is closest to the probability that their child has rainbow eyes?

A. 0.1%.
B. 0.2%.
C. 0.5%.
D. 1%.
E. 2%.

37 Auntie Anne has a child, but she is unsure of the father's identity. She has narrowed it down to three potential fathers, each with blood type as described below. Which of the following men are for certain NOT that father, given that Auntie Anne is blood type A and her child is blood type B.

I. Mac Donalds: Blood Type O.
II. Jack Box: Blood Type B.
III. Chip Oatlay: Blood Type AB.

A. I only.
B. II only.
C. III only.
D. I and II only.
E. I and III only

38. SABOU is an autosomal, sex-influenced trait that acts recessively in females and dominantly in males. Given that individual II-4 has no family history of SABOU, what is the probability that individuals II-3 and II-4 have a child who does not express SABOU?

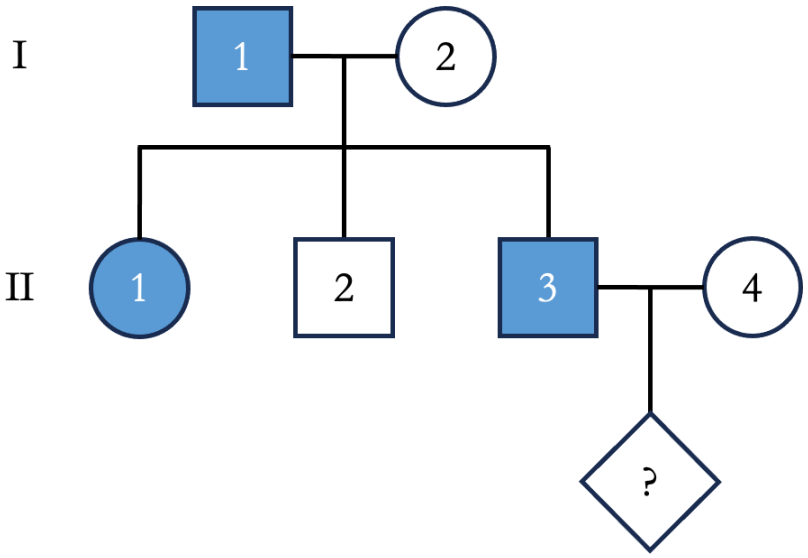

Image Credit: J. Xu

A. Less than 0.2.
B. Between 0.2 and 0.3.
C. Between 0.3 and 0.4.
D. Between 0.4 and 0.5.
E. Greater than 0.5.

39 You are designing an alternative to rational protein design within the protein engineering space. Using phage display, a technique popular in the 1980s, you wish to make use of the principles of evolution to design a protein-of-interest. Specifically, by using a fusion of a protein-of-interest in a bacteriophage viral coat protein, you can express the protein-of-interest on the viral coat surface and screen for certain chemical properties. A diagram of the steps of phage display is shown below. Based on the above, which of the following best describes the mechanism of phage display?

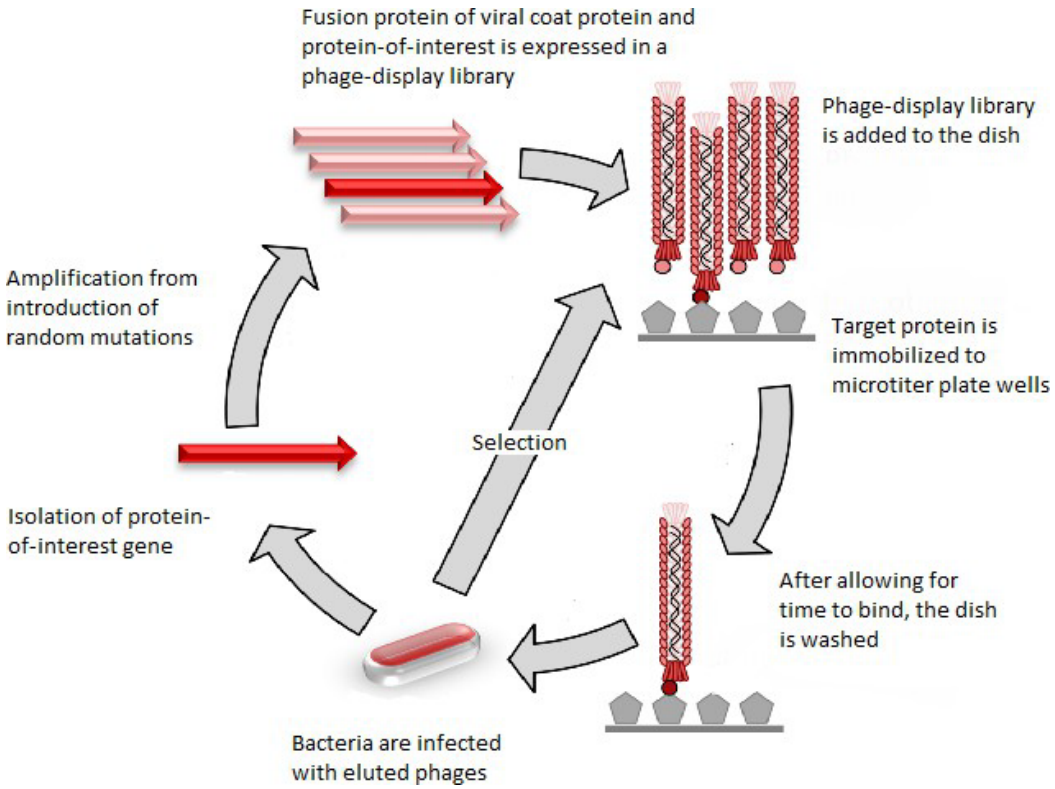

Image Credit: T. Shafee

A. Artificial selection.
B. Balancing selection.
C. Directional selection.
D. Disruptive selection.
E. Stabilizing selection.

40 Which of the following disease inheritance patterns is NOT consistent with the given pedigree?

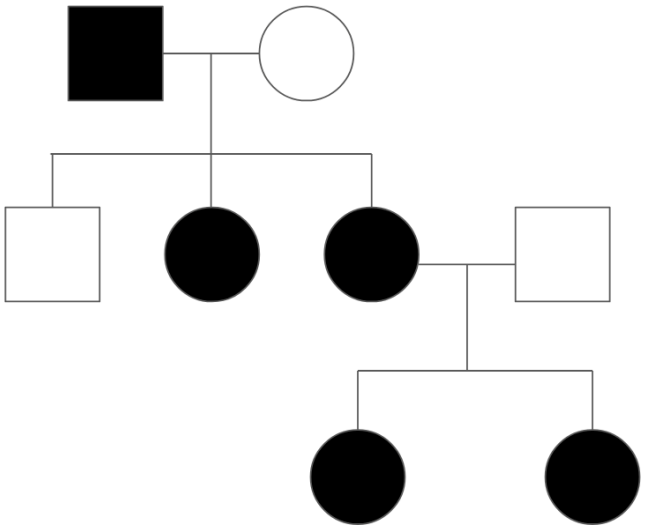

Image Credit: G. Ren

A. Huntington's.
B. Tay-Sachs.
C. Achondroplasia.
D. Duchenne Muscular Dystrophy.
E. Fragile X Syndrome.

41. Assume that a gene in *E. coli* has a high observed mutation rate without any corresponding changes in phenotype or fitness. Which of the following best explains this observation?

A. The gene exhibits strong positive selection.
B. The gene exhibits weak positive selection.
C. The gene exhibits neutral selection.
D. The gene exhibits weak negative selection.
E. The gene exhibits strong negative selection.

42. R_0 is a measure of how infectious a disease is, where the value of R_0 is the average number of people that someone who has the disease infects. The case fatality rate (CFR) of a disease is the fraction of people who have a disease that die from it. Assume that THEOFFSEASON-2021 (TOS-2021) is a new zoonotic virus that has just spread to the human population. Which of the following best describes the evolutionary changes in R_0 and CFR as TOS-2021 spreads?

A. Decreased R_0 and Increased CFR.
B. Decreased R_0 and Decreased CFR.
C. Increased R_0 and Increased CFR.
D. Increased R_0 and Decreased CFR.
E. There will be no changes in R_0 and CFR

10% Ecology (5 questions)

43 An algaecide spill causes the death of 90% of algae in an ocean, but there are no significant population changes in higher trophic levels. This is an example of:

A. Bottom-up Regulation.
B. Biological Magnification.
C. Inverted Trophic Pyramid.
D. Secondary Succession.
E. Symbiosis.

44. You observe species diversity in a garden. Using quadrat observations over time, describe how the species distribution changes over time.

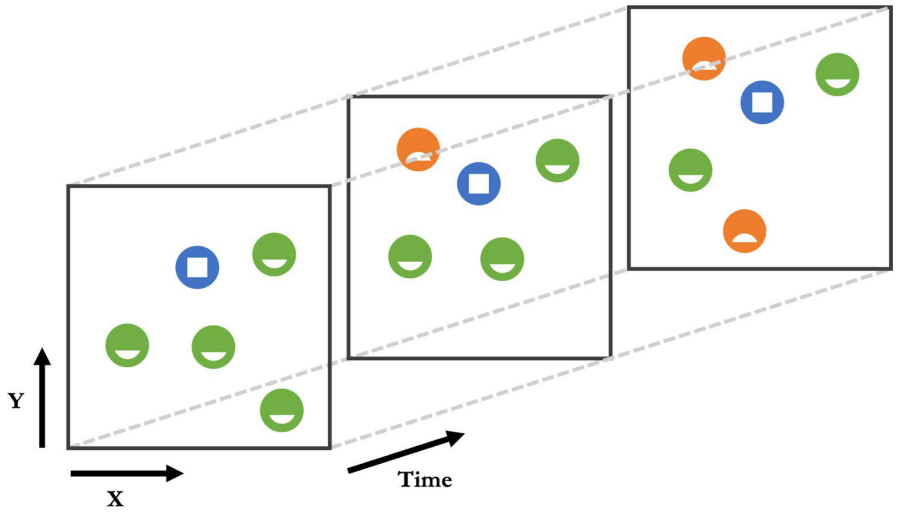

Image Credit: J. Dong

A. Species richness increases, species evenness decreases.
B. Species richness decreases, species evenness decreases.
C. Species richness decreases, species evenness increases.
D. Species richness increases, species evenness increases.
E. Species richness increases, species evenness stays the same.

45 Justin, a student at the Department of Ecological Sciences, is studying a species of stuffed animal *S. noah*. He analyzes the population of *S. noah* over time, as shown in the graph. Based on this data, categorize *S. noah* as r-selected or K-selected and identify a change in birth or death rate at the time indicated by the arrow.

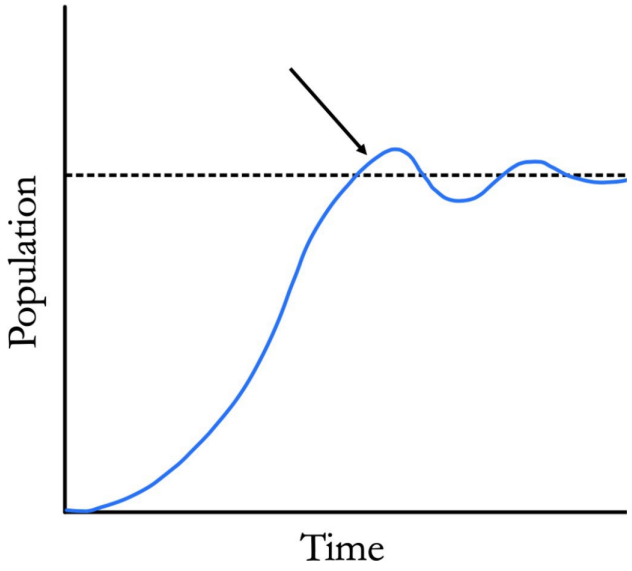

Image Credit: J. Xu

A. K-selected, density-dependent birth rate is decreasing.
B. K-selected, density-dependent death rate is decreasing.
C. r-selected, density-dependent birth rate is decreasing.
D. r-selected, density-dependent death rate is decreasing.
E. r-selected, density-independent death rate is decreasing.

46. An epiphytic plant is observed to grow on the branches of a fig tree. You notice that the epiphyte performs photosynthesis, its roots wrap around the host plant, and that it emits volatile organic compounds which interact with its environment. The epiphyte's interaction with the fig tree is best described as:

A. Amensalism.
B. Commensalism.
C. Competition.
D. Parasitism.
E. Predation.

47. Why does the phosphorus cycle tend to be a more local phenomenon compared to other nutrient cycles?

A. Phosphate anions bind tightly to soil particles.
B. Phosphorus is a limiting nutrient so there is not much to cycle around.
C. Phosphorus is inert when not in the orthophosphate form.
D. There are no soluble or gaseous forms of phosphorus.
E. The premise is false: phosphorus cycling is not any more localized than other nutrient cycles.

5% Biosystematics (3 questions)

48 Truffles is a fun guy studying fungi. He notices the specific fungus that he is studying has no flagella in any life cycle stage, a long-lived dikaryotic stage, and four spores produced per karyogamy event. Which fungal phylum is he studying?

A. Ascomycota.
B. Basidiomycota.
C. Chytridiomycota.
D. Mucuromycota.
E. Zoopagomycota.

49. You are at a tide pool when you stumble across an organism with a water vascular system. Which of the following neighbors in the seashore ecosystem is most closely related to this organism?

A. Acorn Barnacle.
B. Fiddler Crab.
C. Mussel.
D. Sea Anemone.
E. Sea Gull.

50. In a BLAST sequence similarity search on the NCBI website, which of the following proteins will likely have the highest sequence similarity to Porpoise cytochrome c?

A. Human Cytochrome c.
B. Horse Cytochrome c.
C. Manatee Cytochrome c.
D. Sheep Cytochrome c.
E. Zebra Cytochrome c.