USABO Open Exam 2023

1. The physical separation of a eukaryotic cell during cell division is:

A. Mitosis.
B. Meiosis.
C. Binary fission.
D. Cytokinesis.
E. Asynthetic fission.

2. Which of the following is TRUE about osmosis?

A. A solution of $CaCl_2$ will have a lower water potential than a solution of NaCl with the same concentration.
B. Isosmotic solutions can be hypotonic if the solute cannot pass through the cell membrane freely.
C. Raising the temperature of a solution increases its water potential.
D. Smaller cells are more vulnerable to plasmolysis because they have a higher surface area to volume ratio which lets more water leak out.
E. Water moves from higher to lower pressure and higher to lower solute concentration.

3. Which of the following cell mechanisms are NOT considered as part of innate immunity:

A. Phagocytes.
B. Mucous.
C. Interferons.
D. Lymphocytes.
E. Natural killer cells.

4. Polymerase Chain Reaction (PCR) is an extremely common process that is used for medical testing as well as biological research. This technology seeks to replicate and amplify DNA. The thermostable polymerase most used in this process is:

A. Polynucleotide adenylyltransferase (Poly-A-polymerase).
B. Taq polymerase I.
C. coli DNA polymerase I.
D. Terminal deoxynucleotidyl transferase.
E. Mouse DNA polymerase II.

5. Which of the following chemical species does NOT function as a final electron acceptor in either aerobic respiration, anaerobic respiration, or fermentation?

A. Pyruvate. B. Oxygen. C. Acetaldehyde. D. Lactate. E. Sulfate.

6. Which of the following molecules is NOT directly formed by any of the steps of the Citric Acid Cycle?

A. ATP. B. CO_2. C. NADH. D. $FADH_2$. E. Coenzyme A.

7. Which of the following statements is TRUE?

A. Amino acids found in regions of regular secondary structure always have phi (ϕ) bond angles that are equal to their psi (ψ) bond angles.
B. Disulfide bridges decrease the effective local concentration of amino acid residues.
C. The amine group of a right-handed alpha-helix residue forms a hydrogen bond with the carbonyl of the amino acid four residues earlier.
D. Each amino acid in a right-handed α -helix is hydrogen bonded to an amino acid above and below it in the helix.
E. Every third amino acid residue in an α -helix is either proline or hydroxyproline.

8. According to Levinthal's paradox, polypeptide chains can fold in almost an infinite number of ways after they are translated. When polypeptide chains are translated, they are almost uniquely folded into a single conformation. This is due to the presence of which of the following:

A. Chaperonins.
B. Proteasomes.
C. Ribosomal interactions with polypeptide.
D. Ubiquitination.
E. Untranslated regions on the RNA.

9. Which of these atoms has a preferred oxidation number of -3?

A. Carbon. B. Hydrogen. C. Phosphorus. D. Calcium. E. All the above.

10.

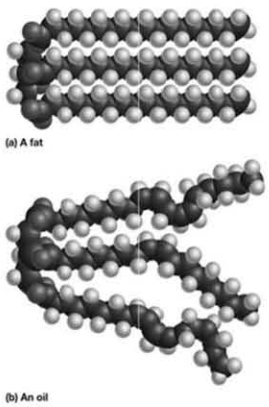


Figure 1a. Hydrocarbon chain in fat. Figure 1b. Hydrocarbon chain in oil.
Credit: Molecular Biology of the Cell, p. 52.

The hydrocarbon chain in the top triglyceride above has _____; the hydrocarbon chain in the bottom triglyceride has _____.

A. Double bonds and saturated; no double bonds and is unsaturated.
B. No double bonds and is saturated; double bonds and is unsaturated.
C. No double bonds and is unsaturated; double bonds and is saturated.
D. Double bonds and is unsaturated; double bonds and is unsaturated.
E. Double bonds and is unsaturated; no double bonds and is saturated.

11. Which of the following angiosperm species does NOT rely on animals to aid pollination?

A. Trifolium repens (white clover).
B. Ficus carica (common fig).
C. Saccharum officinarum (sugar cane).
D. Rafflesia arnoldii (corpse flower).
E. Agave tequilana (blue agave).

12. One important difference between the anatomy of roots and the anatomy of leaves is:

A. Only leaves have phloem and only roots have xylem.
B. The cells of roots have cell walls that are lacking in leaf cells.
C. A waxy cuticle covers leaves but is absent in roots.
D. Vascular tissue is found in roots, but it is absent from leaves.
E. Leaves have epidermis, while such tissue is absent from roots.

13. Of the following cell types, which is not correctly matched with its functions?

A. Mesophyll/photosynthesis.
B. Guard cell/regulation of transpiration.
C. Sieve tube member/translocation of sugars.
D. Vessel element/water transport.
E. Companion cell/formation of secondary xylem and phloem.

14. Following pollination, indicate the sequence of tissues the pollen tube would pass through as it grows toward the egg.

A. Micropyle → Ovary → Style → Stigma → Ovule → Egg.
B. Ovule → Ovary → Micropyle → Stigma → Style → Egg.
C. Stigma → Style → Ovary → Ovule → Micropyle → Egg.
D. Style → Ovary → Ovule → Stigma → Micropyle → Egg.
E. Style → Stigma → Ovary → Ovule → Micropyle → Egg.

15. According to the pressure-flow hypothesis of phloem transport,

A. The high concentration of solute in the "source" osmotically creates the turgor pressure needed.

B. Active transport of water into the "source" creates the turgor pressure needed.
C. Transpiration water loss from the "sink" moves solutes through phloem conduits.
D. The formation of starch from sugar in the "sink" increases the solute concentration and osmotically creates the turgor pressure needed.
E. The turgor pressure in the phloem of a root is normally greater than the pressure in the phloem of a leaf.

16. The green sea slug Elysia chlorotica can photosynthesize due to:
A. Photosynthetic microbiome.
B. Inherited chloroplasts.
C. Kleptoplasty.
D. Mitochondria.
E. Endogenous chlorophyll.

17. In plant roots, the Casparian strip is correctly described by which of the following? It …
A. Is in the walls between endodermal cells and cortex cells.
B. Provides energy for the active transport of minerals into the vascular bundle from the cortex.
C. Ensures that all minerals are absorbed from the soil in equal amounts.
D. Ensures that all water and dissolved substances must pass through a cell before entering the vascular bundle.
E. Provides increased surface area for the absorption of mineral nutrients.

18. Which of the following changes to a plant would increase water transport efficiency through the xylem?
A. Decreasing stomatal density in leaves.
B. Replacing tracheids with nucleated sieve-tube elements.
C. Increasing mineral transport into the xylem in the roots.
D. Decreasing the radius of tracheids and vessel elements.
E. Increasing humidity of the external environment.

19. The active shortening in muscle is due to:
A. Elastic contraction.
B. Filament sliding.
C. Hypotonicity.
D. Hypertonicity.
E. Fiber shortening.

Questions 20 to 24. Pressure differences between cardiac chambers determine the velocity of blood flow (including both speed and direction of flow). Ultrasound can be used to examine the velocity

of blood flow by aligning an ultrasound beam with the region of interest. Ultrasound beams are reflected by moving red blood cells and return to the ultrasound transducer – these returning beams undergo Doppler shifts. The resultant change in the frequency is converted to velocity. The following questions relate to the examination of blood flow between various cardiac chambers. Based on the laws of confirmation of mass and energy, blood flow through a narrower orifice will move at a higher velocity. Aortic stenosis – or an abnormally narrow aortic valve orifice – can be diagnosed based on faster than normal blood flow through the valve. Blood flow through a normal aortic valve occurs when the left ventricle contracts (systole) and has a maximum velocity under 2.6m/s. Mild, moderate and severe aortic stenosis are defined respectively by maximum systolic blood flow velocities within the ranges 2.6-2.9m/s (mild), 3-3.9m/s (moderate) and >4m/s (severe). The accompanying images are a schematic representation of the Doppler spectral profiles obtained when an ultrasound beam is directed at blood flow through the aortic valves of two different Patients (A and B), both in normal sinus rhythm as demonstrated by the electrocardiogram tracing at the bottom of each image. Velocity is on the y-axis, with flow towards the ultrasound probe plotted above the y axis, and flow away from the probe plotted below. The x-axis represents time (the x-axes representing time for the electrocardiogram and the Doppler spectral profile are synchronized).

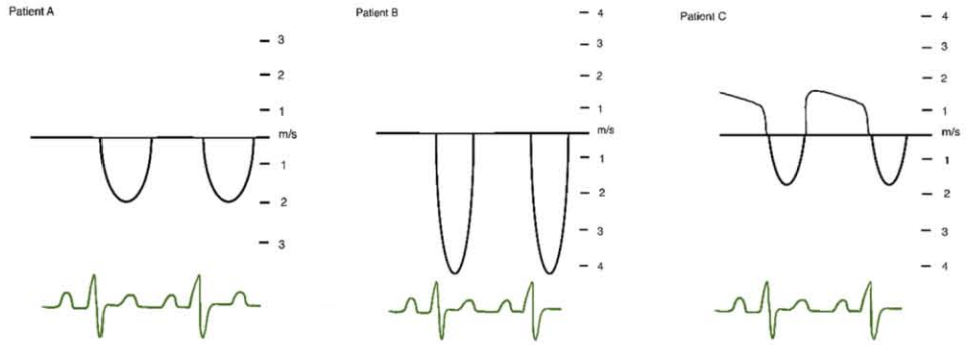


Figure 2a. Patient A. 2b. Patient B. 2c. Patient C.
Credit: Dr. Lisann-Goldman.

20. During what portion of the cardiac cycle, for both Patients A & B, is the blood flow through the aortic valve occurring?

A. Systole.
B. Diastole.
C. Relaxation.
D. Continuously.
E. No flow is occurring.

21. How should Patient A's aortic valve be categorized?

A. Normal.
B. Mildly stenotic.
C. Moderately stenotic.

D. Severely stenotic.
E. Extremely stenotic.

22. How should Patient B's aortic valve be categorized?
A. Normal.
B. Mildly stenotic.
C. Moderately stenotic.
D. Severely stenotic.
E. Minimally stenotic.

23. What is represented by the velocities plotted above the baseline in Patient C?
A. Flow away from the ultrasound probe.
B. Flow perpendicular to the ultrasound probe.
C. Flow towards the ultrasound probe.
D. Absence of flow.
E. Flow adjacent to the ultrasound probe.

24. When is the flow above the baseline in Patient C occurring during the cardiac cycle?
A. During systole.
B. During diastole (ventricular relaxation).
C. During ventricular contraction.
D. Continuously.
E. No flow is occurring.

25. Oh no! You have recently come down with COVID. While isolating in your room, you decide to isolate the most common class of antibodies from your mucus. Which of the following is most likely true about these antibodies?
A. They activate the complement system strongly.
B. They are the first antibody to appear in the immune response.
C. They bind to mast cells and basophils.
D. They can cross the placental barrier.
E. They have two antigen binding locations.

26. Which of the following processes do NOT rely on countercurrent exchange?
I. Gas exchange in alveoli.
II. Gas exchange in fish gills.
III. Gas exchange in parabronchi.
IV. Heat conservation in penguin feet.
A. I only. B. I and II. C. I and III. D. I, II, and III. E. I, II, III, and IV.

27. In 2018, a dramatic rescue plan for 13 lives trapped in an underground cave system in Thailand required extreme measures. Ultimately, those who had the responsibility of making the rescue developed a plan to bring the thirteen out through the system of caves in a state of suspended animation. One crucial factor was to develop an anesthesia plan to render the individual unconscious during the entire time of the underwater rescue. The drugs benzodiazepines, clonidine, chloral hydrate and ketamine hydrochloride were considered. The final choice was ketamine hydrochloride due to all the following facts except:

A. High performance in austere environments.
B. Ease of use by unskilled hands.
C. Ability to determine the end point of successful anesthesia.
D. Maintenance of spontaneous respiration in appropriate dosages.
E. Potential protection from hypothermia.

28. Nixtamalization is a process developed by ancient Mesoamericans involving cooking of maize (corn) with an alkaline solution. One effect of this process is to increase the amount of bioavailable niacin. Which of the following nutrient deficiency diseases does nixtamalization help prevent?

A. Beriberi. B. Pellagra. C. Rickets. D. Pernicious Anemia. E. Scurvy.

29. Which of the following structures is most directly responsible for the blind spot in human vision?

A. Fovea. B. Macula lutea. C. Optic disk. D. Iris. E. Lens.

30. To test the effect of vitamin D on growth, two groups of rats were raised under identical conditions and fed the same diet. One of the groups received daily injections of vitamin D. The other group received injections of saline without vitamin D. All the rats were weighed weekly for 2 months. What is the control in this study?

A. Average weight gain of the rats.
B. Group receiving vitamin D.
C. Group receiving saline.
D. The 2-month period.
E. The diet consumed by the rats.

31. Dr. Judy notices large numbers of mating mayflies being attracted to dry asphalt roads, where they lay eggs that inevitably perish. She seeks to find an explanation for this unexpected behavior. She remembers that mayflies can find water sources to lay eggs through polarotaxis, or the attraction to horizontally polarized reflected light. She hypothesizes that dry asphalt gives off a similar degree of light polarization as water surfaces, thereby attracting the mayflies to breed and lay eggs on these roads. If Dr. Judy's hypothesis is correct, then this behavior is an:

A. Habituation.
B. Classical conditioning.
C. Operant conditioning.

D. Learning from social cues.
E. Fixed action pattern.

32. You want to purchase the two 3-acre Crowley Farm in Waterville on Kerry's Iveragh Peninsula and you need directions. What would be the difference between using a map and asking a local gentleman to provide you with directions?
A. The difference between navigation and orientation, respectively.
B. The difference between learning and migration, respectively.
C. The difference between orientation and navigation, respectively.
D. The difference between orientation and learning, respectively.
E. The difference between migration and orientation, respectively.

33. According to optimal foraging theory,
A. Individuals minimize energy intake per unit of time.
B. Energy content of a food item is the only determinant of a forager's food choice.
C. Time taken to capture a food item is the only determinant of a forager's food choice.
D. A higher energy item might be less valuable than a lower energy item if it takes too much time to capture the higher energy item.
E. Individuals are sometimes incentivized to share food with closely related individuals.

34. Which chromosomal abnormality is most likely to require FISH for its diagnosis?
A. A Robertsonian translocation.
B. A monosomy.
C. A trisomy.
D. A pericentric inversion.
E. A microdeletion.

35. A female is an unbalanced carrier of a duplication of part of the q arm (long arm) of one X chromosome. What X inactivation pattern would you expect in this patient?
A. Random X inactivation.
B. Nonrandom X inactivation where the normal X is preferentially inactivated.
C. Nonrandom X inactivation where the abnormal X is preferentially inactivated.
D. Inactivation of just the duplicated region on the abnormal X-chromosome.
E. X-inactivation pattern depends upon the tissue you are analyzing.

36. Malignant hyperthermia (MH) is a rare autosomal dominant condition affecting 1 in 100,000 individuals in the population. Affected individuals are susceptible to a severe reaction to certain anesthetic medications. A man has an MH reaction to one of these medications. His son has received the same medication without any complications. If he also has a daughter, what is the probability

that she is susceptible to MH?

A. 0%. B. 25%. C. 50%. D. 75%. E. 100%.

37. Hemophilia is an X-linked recessive genetic disorder with XH denoting the hemophilia allele and X denoting the non-hemophilia allele. If a man and a woman have a son with Klinefelter's syndrome and hemophilia as well as a son with neither Klinefelter's nor hemophilia, which of the following options could NOT have been the genotype of the parents?

I. XX and X_HY.

II. X_HX and X_HY.

III. X_HX and XY.

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

38. Judy is studying a population of deer in Hardy-Weinberg Equilibrium. The deer have a gene that completely controls the length of ears in this population, with long ears being the dominant phenotypic trait and short ears being the recessive phenotypic trait. Judy counted 1,000 deer, with 840 deer having long ears and 160 with short ears. Assuming the deer population stays in HardyWeinberg Equilibrium, what percent of deer in this population will be heterozygous for the ear length gene in 10 years?

A. 10%. B. 24%. C. 48%. D. 72%. E. 96%.

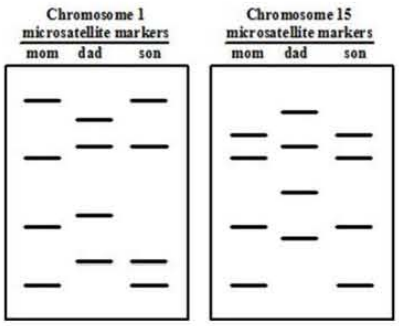
39. Flanking the region of E. coli with two repeats of the sequence GTGGTGTAA would make it prone to a:

A. Deletion.
B. Duplication.
C. Frameshift mutation.
D. Inversion.
E. Missense mutation.

40. Attenuated Familial Adenomatous Polyposis (AFAP) is an autosomal dominant disease characterized by increased prevalence of polyps in the colon, and a 70% chance of developing colorectal cancer in life. For the average person, the chance of developing colorectal cancer in their lifetime is 4%. Two heterozygous individuals with AFAP have a child. What is the probability that their child will develop colon cancer in their lifetime?

A. 4%. B. 37%. C. 52.5%. D. 53.5%. E. 70%.

41.



A young man with small hands, feet and genitals is grossly overweight. His parents indicate that he is continually hungry, always eating, and hoarding and stealing food. He and his parents underwent genetic testing. The linked image above shows the results of a PCR analysis of two microsatellite markers (highly polymorphic short tandem repeat) on Chromosome 1 and Chromosome 15 from all three. What disorder is the son likely to have and what is its likely cause?

A. Prader-Willi syndrome/microdeletion.

B. Prader-Willi syndrome/uniparental disomy.

C. Angelman syndrome/microdeletion.

D. Angelman syndrome/uniparental disomy.

E. The results show no evidence of a genetic disorder.

42. Tay-Sachs is an autosomal recessive disease that causes cherry-red spots in the eye, "startle" responses in infancy, neurodegeneration, and death. What is the risk that the maternal grandmother of an affected child is a carrier of the abnormal allele?

A. 100%. B. 67%. C. 50%. D. 25%. E. Virtually 0.

43. Inbreeding depression due to a small population is an example of:

A. Allee Effect.

B. Carrying Capacity Overshoot.

C. Competitive Exclusion Principle.

D. Dollo's Law of Irreversibility.

E. Intermediate Disturbance Hypothesis.

44. Dr. Long is studying species that can go through anhydrobiosis ("life without water"), where these organisms dry up and become dormant until living conditions are favorable again. Which of the following is NOT a characteristic of an organism undergoing anhydrobiosis?

A. Acceleration of the cell cycle.

B. Oxidative stress response.

C. Reduced metabolic activity.

D. Synthesis of trehalose.

E. Expression of heat shock proteins.

45. A Non-Dispersive Infrared (NDIR) Sensor at a research station in Washington state measures global CO_2 levels. Why do global CO_2 levels rise in the winter but drop in the summer?

A. The northern hemisphere contains most of the world's photosynthesizing vegetation.

B. There is increased human consumption of energy that relies on burning fossil fuels.

C. Colder ocean waters absorb less CO_2 from the atmosphere.

D. Volcanoes are more active in the winter.

E. Global animal biomass peaks in the winter.

46. Thomas Park's work on competitive interactions between two species of flour beetles is summarized Table 1 below. Which of the following statements best identifies the significance of this work?

A. Ecological systems are simply too complex to understand.
B. Competitive exclusion between two closely related species is inevitable.
C. Competitive coexistence is possible if the competitors are different species.
D. Competitive coexistence would be possible if environmental conditions fluctuated.
E. Competition is a stochastic process; winning is much like gambling.

Table 1

Percent Wins by *Tribolium castaneum* and *T. confusum* in Competition under Different Laboratory Conditions.

Temperature (°C)	*Relative Humidity* (%)	*Climate*	*Single Species Numbers*	*Mixed Species (% Wins)*	
				T. confusum	*T. castaneum*
34	70	Hot-moist	*confusum = castaneum*	0	100
34	30	Hot-dry	*confusum > castaneum*	90	10
29	70	Temperate-moist	*confusum < castaneum*	14	86
29	30	Temperate-dry	*confusum > castaneum*	87	13
24	70	Cold-moist	*confusum < castaneum*	71	29
24	30	Cold-dry	*confusum > castaneum*	100	0

Values (percent wins) are the proportions of cultures in which one or the other species won in competition.

From Park 1954.

47. In the interaction between two species of Streptococcus bacteria in our mouths, it was found that one species creates biofilms on our teeth, and the other does not. Which of the following BEST describes the interaction between these bacteria in our mouths?

A. Competition.
B. Predator-prey parasites.
C. Pathogens.
D. Commensalism.
E. Amensalism.

48. Which of the following is your best estimate for a population of animals if you first capture 25 animals, mark them, and then release them and a week later you capture 33 animals and find 5 are marked?

A. 7. B. 38. C. 63. D. 12 E. 165.

49. Which of the following is the most compelling evidence supporting the claim that the whale is the closest living relative of the hippopotamus?

A. Morphological informant from fossils.
B. Morphological information from hippopotamuses.
C. Morphological evidence from carnivores.
D. DNA sequence data.

E. RNA sequence data.

50. Determine which feature of the choanoflagellates was the most significant for animal evolution?

A. Flagellum with a funnel-shaped, contractile collar also found in sponges.
B. A tyrosine kinase receptor on the surface of choanoflagellates that has strong homology to fungi.
C. A colonial form that resembles some fungi.
D. Eyespots that are like ribbon worms.