

1. Embryonic question layers can often be solved by envisioning the body as a hollow tube; the outside of the tube is ectoderm while its inner surface is endoderm. Thus, we see that option E (bronchiole lining) is derived from endoderm. Then, we notice that most internal organs are derived from endoderm, except the spleen and kidneys, which are derived from mesoderm. Therefore, our answer is option **B**.
2. First, let's identify each of the numbered substances. By looking at the graph, we see that substance 1 is LH, substance 2 is FSH, substance 3 is estrogen, and substance 4 is progesterone. Now, we go through each of the options.
 - A. *In the first week of the menstrual cycle, LH directly stimulates cells to secrete estrogen.* This statement is **false**. In the first week of the menstrual cycle, LH stimulates the theca cells to secrete androgens while FSH stimulates the granulosa cells to synthesize estrogens. It is only by the second week of the cycle that granulosa cells become sensitive to LH.
 - B. *At high concentrations, estrogen inhibits the release of LH and FSH.* This statement is **false**. High concentrations of estrogen are actually responsible for the midcycle spike in LH and FSH; low concentrations of estrogen earlier in the cycle, however, do inhibit LH and FSH secretion.
 - C. *Progesterone is synthesized from testosterone by the action of aromatase.* This statement is **false**. This is true of estrogens, specifically estradiol. Progesterone is earlier in the steroid biosynthetic pathway than testosterone.
 - D. *LH is secreted from the hypothalamus and FSH is secreted from the anterior pituitary.* This statement is **false**. LH and FSH are both secreted from the anterior pituitary.
 - E. *Estrogen increases the expression of receptors for progesterone in some of its target cells.* This statement is **true**; this effect is called "estrogen priming."

Therefore, the correct answer is **E**.

3. Let's go through each of the choices.
 - A. *Müller cells are glial cells that help photoreceptor cells maximize light absorption.* This statement is **true**; in addition to metabolic support, Müller cells funnel light to photoreceptors, analogous to fiber-optic cables.
 - B. *Nearsightedness can be corrected by convex lenses.* This statement is **false**. Nearsightedness is correct using concave lenses.
 - C. *The fovea contains a high concentration of rods.* This statement is **false**. The fovea is the region of the retina with the highest concentration of cones.
 - D. *A rod with inactive rhodopsin molecules would not allow Na^+ to enter it.* This statement is **false**. Inactive rods are depolarized and permeable to sodium.
 - E. *Retinal is a derivative of Vitamin C.* This statement is **false**. Retinal is a derivative of vitamin A.

Therefore, the correct answer is **A**.

4. Wernicke's area is responsible for language comprehension, while Broca's area is responsible for speech production. Since Wernicke's area is located in temporal lobe, the correct answer is **B**.
5. Again, let's go through each option.
 - A. *Skeletal muscle: Dense bodies, which are mostly made of anchoring proteins, are important here.* This statement is **false**. Dense bodies are found in smooth muscle, not skeletal muscle.
 - B. *Cardiac muscle: Desmosomes in intercalated disks are responsible for the synchronized contraction of the heart.* This statement is **false**. Gap junctions in cardiac muscles are responsible for the synchronized contraction of the heart.
 - C. *Skeletal muscle: Creatine phosphate is the primary source of energy for longer aerobic exercises here.* This statement is **false**. Creatine phosphate is a short-term source of energy that allows for extremely rapid production of ATP at the beginning of a muscle contraction.
 - D. *Skeletal muscle: Binding of ATP to myosin causes its disassociation from actin.* This statement is **true**.

- E. *Smooth muscle: The DHP receptor is connected to the ryanodine receptor through foot proteins, thus releasing Ca^{2+} from the sarcoplasmic reticulum.* This statement is **false**. DHP receptors are characteristic of skeletal muscle; smooth muscles have L-type calcium channels.

Therefore, the correct answer is **D**.

6. Again, we analyze each option.

- A. *Usage of triamterene, a diuretic that decreases sodium reabsorption in the cortical collecting duct.* This statement is **false**. Sodium absorption in the cortical collecting duct occurs through Na^+ channels, which has no effect on potassium reabsorption.
- B. *Increased activity of H^+/K^+ ATPases throughout the renal tubule in response to moderate ketoacidosis.* This statement is **false**. H^+/K^+ ATPases in the renal tubule are involved in the import of potassium and export of hydrogen; increased activity of these ATPases would lead to higher potassium levels in the body.
- C. *Administration of enalapril, an ACE inhibitor, due to hypertension.* This statement is **false**. ACE is a part of the RAAS which leads to aldosterone release; since aldosterone increases potassium secretion, inhibiting it would lead to decreased potassium secretion and higher potassium levels in the body.
- D. *Usage of furosemide, a diuretic that decreases sodium reabsorption in the loop of Henle.* This statement is **true**. Sodium absorption in the loop of Henle occurs through NKCC cotransporters; inhibiting these leads to higher potassium in the urine and thus lower potassium in the body.
- E. *Partial death of juxtaglomerular cells due to the ingestion of a toxin.* This statement is **false**. Like with option C, inhibiting the RAAS leads to higher potassium levels in the body.

Therefore, the correct answer is **D**.

7. Beetles are insects, which primarily undergo meroblastic cleavage, not holoblastic cleavage. Beetles do actually have a fast block to polyspermy (unlike most insects). The main indicator, however, should be holoblastic cleavage. The answer should be **E**.

8. The primary effector cells against viral infections are T cells, corresponding to option **C**.

9. The vitamin primarily implicated in clotting is vitamin K, or phyloquinone (option **B**).

10. This question is just memorization of embryonic limb regions. The answer is **C**.

11. Notice that pancreatic lipases are the primary enzymes involved in fat digestion (salivary lipases only have a limited amount of time and the stomach does not produce lipases). Thus, we can immediately eliminate options A, B, and E. Finally, since fats are absorbed through lacteals (not the circulatory system), the correct answer is **C**.

12. Again, we go through each option.

- A. *If a loss-of-function genetic mutation is induced at the 11p15.5 locus, which codes for tyrosine hydroxylase, I. ntelligent will have trouble sleeping at night.* This statement is **false**. Tyrosine hydroxylase is involved in the production of dopamine, norepinephrine, and epinephrine from tyrosine, while the main hormone involved in sleep is melatonin (which is derived from tryptophan).
- B. *In I. ntelligent, Na^+ influx through the NMDA receptor causes the closing of AMPA channels in presynaptic neurons, allowing for LTP to occur.* This statement is **false**. In LTP, calcium influx through the NMDA receptor causes the insertion of AMPA receptors.
- C. *Atropine, a chemical that dilates pupils by inhibiting metabotropic ACh channels, has the opposite effect of muscarine on the I. ntelligent nervous system.* This statement is **true**. Metabolic ACh receptors are muscarinic, and atropine is a muscarinic antagonist; thus, atropine and muscarine have opposite effects.
- D. *If a genetic mutation is induced that causes loss of function in 5-HT_{2a} receptors, LSD's hallucinogenic effects on members of I. ntelligent will be amplified.* This statement is **false**. LSD is partially due to hyperstimulation of serotonin pathways.

- E. *Sarin, a potent inhibitor of acetylcholinesterase, can cause fatal muscle relaxation if administered to members of* I. ntelligent. This statement is **false**. Sarin leads to pathological muscle contraction leading to spastic paralysis.

Therefore, the correct answer is **C**.

13. FRET is commonly used to observe protein-protein interactions. Thus, the answer is **B**.
14. Notice that β -cells and plasma cells likely have the lowest smooth ER:rough ER ratio, because they are specialized in protein secretion. Hepatocytes have the highest ratio since one of their main functions is detoxification, which is done by smooth ER. Thus, we narrow down the possible options to III, IV, I, II and III, IV, II, I. Only one of these options is an answer choice, option **A**.
15. Remember that the replication fork proceeds in both directions, so the total copying speed of the genome is 2000 nt/s. We compute

$$\frac{4.6 \cdot 10^6 \text{ nt}}{2000 \text{ nt/s}} \cdot \frac{1 \text{ min}}{60 \text{ s}} = 38.\bar{3}.$$

This is closest to option **B**.

16. Hfr cells are named for their **high** frequency of recombination, due to their integrated F factor; they definitely do not lack conjugation. The answer is **E**.
17. The interior of plasma membrane is hydrophobic, so a significant portion of residues in a transmembrane portion should be hydrophobic. However, option **C** has almost all hydrophilic side chains.
18. Intracellular receptors bind to hydrophobic molecules. Option **E** has two hydrophilic amine groups, so it is the most hydrophilic.
19. Cortisol is a steroid and thus binds to an intracellular receptor, without need for second messengers like cAMP. Therefore, **E** is the false statement.
20. p53 (the “guardian angel of the genome”) and *BRC1* (another protein involved in DNA repair) are both tumor-suppressor genes, while Ras (part of a signaling pathway that activates mitosis) and EGF (epidermal growth factor) are both proto-oncogenes. The option containing both of the proto-oncogenes is **C**.
21. snRNAs (**E**) are the RNAs in the spliceosome and crucial to its catalytic activity; they are not “scaffolds.”
22. We want to find the person whose STR bands are those found in the crime scene. Note that P1P2 and P1P3 both share bands with CS. The common denominator is P1, or Euna (option **A**).
23. The fact that the disease is not present equally in males and females suggests that it is X-linked. Since the affected I-1 and I-2 have an unaffected child, the disease must be dominant (not recessive). For the same reason, I-2 must have a wild-type allele, so her genotype must be $X^A X^a$, or option **D**. Checking the pedigree more rigorously confirms this.
24. In HWE, the allele frequencies are fixed at p and q and the genotype frequencies are also fixed (at p^2 , $2pq$, and q^2). Thus, option **E** is the incorrect statement.
25. The scenario describes selection for an intermediate phenotype, which is stabilizing selection (option **C**).
26. Consider the parental genotype bEC and the DCO genotype bEc (these can be identified by their frequencies). Notice that the allele for gene C is the difference between the two, so gene C is in between genes B and E. The only option that has this is option **B**.
27. This question is just memorization of inheritance patterns. Through process of elimination, we can narrow down our options to choice **D**. Rett Syndrome is, in fact, often inherited through an X-linked dominant pattern.

28. Based on the descriptions of the groups, we're looking for a SNP with low occurrence in group 1, high occurrence in group 2, and roughly 50% occurrence in group 3. The SNP that matches this is Ch9 B922744 T, which denotes a thymine SNP on chromosome 9 (option **C**).
29. *TUBA1A* and *XPB* are most likely pleiotropic given that they affect "basic" cellular functions. *PAH* causes phenylketouria, a complex disease with symptoms in many different organ systems. *LCT* mutations cause a lactase deficiency, which only leads to lactose intolerance. Thus, the answer is **B**.
30. In option **D**, both parents have the same allele for all genes on each chromosome, so no recombination could have occurred.
31. The lowest level of pigmentation occurs when there are 0 dominant alleles, and the highest level of pigmentation occurs when there are $2 \cdot 5 = 10$ dominant alleles. Thus, the number of possible phenotypes is $10 - 0 + 1 = 11$, or option **B**.
32. Observe that gg females have all golden children, while Gg or GG females have all black children. Thus, dragon color appears to be a maternal-effect gene. The F2 offspring of the F1 Gg $\times$ Gg cross will be in the ratio 1 GG : 2 Gg : 1 gg. The only relevant factor in dragon color phenotype is the maternal genotype; dragons will only be golden if the mother has a gg genotype. Thus, the ratio between black F3 dragons to golden dragons is 3 (if the F2 mother is GG or Gg) to 1 (if the F2 mother is gg). This is option **C**.
33. Only options A and C are related to plant defense. Salicylic acid is more involved in pathogen defense, leaving jasmonic acid (option **C**) as the correct choice.
34. Vessel elements are not found in conifers; their xylem consists solely of tracheids. **B** is thus the answer.
35. The continuous ring of vascular tissue seen in the section is most characteristic of monocot roots (option **A**). Additionally, the multi-layer epidermis called the velamen is characteristic of epiphytic orchids, which are monocots.
36. We examine each answer option.
- A. *Double fertilization is an ancestral trait to all angiosperms.* This statement is **false**. Double fertilization is a derived trait of angiosperms, according to the diagram.
 - B. *Seeds are a derived trait to all plants.* This statement is **false**. Seeds are only found in gymnosperms and angiosperms, not all plants.
 - C. *Mosses and hornworts are direct descendants of liverworts.* This statement is **false**. Although mosses, hornworts, and liverworts descended from a common ancestor, mosses and liverworts did not directly descend from liverworts.
 - D. *The length of the line segment is an exact measurement of time since divergence.* This statement is **false**. There is no time scale given, and the points of divergence are too evenly spaced and linear to accurately represent divergence time.
 - E. *Embryonic protection is a derived trait to land plants.* This statement is **true**.

Therefore, the correct answer is **E**.

37. According to the ABCDE hypothesis, gene A by itself produces sepals, genes A and B together produce petals, genes B and C together produce stamens, and gene C by itself produces carpels. Gene D is involved in the production of ovules and gene E is expressed in the whole flower. Therefore, a plant with genes B, C, D, and E (option **D**) would be able to produce carpels and thus megaspores (it would only lack sepals).
38. Vascular rays are usually composed of parenchyma cells, not sclerenchyma cells. (Option **E** is thus the false statement.)
39. Ethylene, not brassinosteroids, is the hormone involved in fruit ripening. Thus, we can immediately eliminate options C and E. Furthermore, fruits are not photosynthetic, so we can eliminate option B. This leaves us with option A. By remembering that climacteric fruits are characterized by a rise/peak in ethylene and respiration rate after detachment from the parent plant (or by using word roots; note the similarity between "climax" and "climacteric"), we identify the solid lines as representing climacteric fruit and the dotted lines as representing non-climacteric fruit. Thus, the answer is **D**.

40. This is another memorization question; this time, one on the types of fruits. As a logical hint, notice that pomegranates (option **E**) have one pericarp that does not appear to be derived from fusion in any way, making them unlikely to be multiple fruits.
41. A fixed action pattern is defined as a behavior that is triggered by a sign stimulus and always runs to completion. Option **D** best describes this.
42. Flashy male displays are hypothesized to be a product of sexual selection; they indicate the high fitness of the male implied by the extra energy that could have gone to survival instead spent on the display. This corresponds to option **B**.
43. How often do you notice a bird's teeth (especially when compared to other animals)? **E**.
44. The description of highly territorial behavior among the animals suggests that they have an uniform distribution. We then perform the mark-and-recapture calculation: $5/x = 3/17$ to approximate the population's size as 28. Combining these, we arrive at option **B**.
45. All of the options except choice **B** are inconsistent with the graph. Option A is incorrect because the small fry population actually increased, option C is incorrect because the slurp fish population actually decreased, option D is incorrect because the small fry population actually increased, and option E is incorrect because the phytoplankton population actually increased.
46. First, we compute the Shannon's diversity index:

$$H = -\frac{5}{43} \ln\left(\frac{5}{43}\right) - \frac{3}{43} \ln\left(\frac{3}{43}\right) - \frac{10}{43} \ln\left(\frac{10}{43}\right) - \frac{25}{43} \ln\left(\frac{25}{43}\right) = 1.09.$$

- Thus, statement II is false. Statement I is true because the procedure would increase species evenness, while statement III is false because the procedure would decrease species evenness. Therefore, the answer is **A**.
47. **C**. This is a basic assessment of the definitions of primary/secondary succession and pioneer species. (Refer to Campbell's chapter 54).
48. The introduced species would decrease predator populations and thus increase herbivore populations, which would decrease algal populations. This corresponds to option **B**.
49. **B**. Chytrids also have flagella.
50. **C**. Invertebrates, despite being chordates, do not have a backbone.