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QUESTION 1

Alleles are created when a single gene undergoes several distinct mutations. These alleles may have different dominance relationships with one another; for example, there are three alleles coding for the human blood groups, the IA, IB, and i alleles. Both the IA and IB alleles are dominant to the i allele, but IA and IB are codominant to each other.

A multiple-allele system has recently been discovered in the determination of hair coloring in a species of wild rat. The rats are found to have one of three colors: brown, red, or white. Let B = the gene for brown hair; b = the gene for red hair; and w = the gene for white hair. The results from nine experimental crosses are shown below. The males and females in Crosses 1, 2, and 3 are all homozygous for hair color.

Cross	Male	Female	Offspring
1	brown	red	all brown
2	brown	white	all brown
3	red	white	all red
4	brown	brown	3 brown : 1 red
5	brown	brown	all brown
6	red	red	all red
7	red	red	3 red : 1 white
8	brown	red	2 brown : 1 red : 1 white
9	brown	red	1 brown : 1 red

Based on the experimental results, what is the genotype of the female in Cross 5?

A. Bb

B. BB or Bb

C. BB or Bw

D. BB, Bb, or Bw

Correct Answer: D

In Cross 5, a brown male is mated with a brown female, and we\\'re told that 100% of their offspring are brown. Since we know that the big B allele is dominant to the little b and w alleles, there are three types of genotypically distinct crosses between two brown parents that result in all brown progeny; again, you might want to write these down to avoid confusion: (1) big B, big B ?big B, big B; (2) big B, big B ?big B, w; and (3) big B, big B ?big B, little b. From this we see that at least one of the parents must be big B, big B. If the female is big B, big B, then the male can be big B, big B; big B, little b; or big B, w. Likewise, if the male is b B, big B, then the female can be big B, big B; big B, little b; or big B, w.

QUESTION 2

If an atom undergoes alpha decay, by how many units will its mass number decrease?

A. 2

B. 3

C. 4

D. 1

Correct Answer: C

When an atom undergoes alpha decay, it emits an alpha particle which is just like a helium-4 atom composed of 2 protons and 2 neutrons.

QUESTION 3

If a wire carrying a current flowing into the screen is placed in a magnetic field pointing left, in which direction will the Lorentz force act on the charge carriers?

A. to the left

B. to the right

C. upward

D. out of the screen

Correct Answer: C

The right hand rule can be used to find the direction of the Lorentz force.

QUESTION 4

A researcher in a molecular biology lab planned to carry out an extraction procedure known as an alkaline plasmid prep, which is designed to purify plasmids, small pieces of the hereditary material DNA, from bacterial cells. The bacteria are first placed into a test tube containing liquid nutrient medium and allowed to grow until they reach a high population density. The culture, which consists of solid cells suspended in the medium, is then centrifuged; a solid pellet is formed. The supernatant is poured out, leaving the pellet behind, and the cells are resuspended in a mL of lysis buffer solution (50 mM glucose, 25 mM Tris buffer and 10 mM ethylenediaminetetraacetic acid (EDTA), with 5 mg of the enzyme lysozyme added). They are then incubated for 30 minutes at 0°C, during which time the bacterial cell walls break down and the cell contents are released into the solution. After incubation, 1 mL of 0.4 N sodium hydroxide and 1 mL of 2% sodium dodecyl sulfate (SDS) are added, and the solution is again incubated on ice for 10 minutes. 2 mL of 3 M sodium acetate are added and the mixture is incubated for 30 minutes at 0°C. The test tube is centrifuged once more and the supernatant is decanted into a clean tube, leaving behind the protein and most other cell components in the pellet. Finally, 10 mL of pure ethanol are added to the supernatant from the previous step to precipitate out the DNA, and the test tube is incubated at –20°C for 60 minutes, during which the mixture remains liquid. The mixture is centrifuged a final time and the supernatant removed. The translucent precipitate that results is washed with 70% ethanol (70% ethanol and 30% water by volume), allowed to dry, and resuspended in 1 mL of TE buffer (10 mM Tris, 1 mM EDTA). In preparation for this experiment, the researcher prepared stock solutions of the various chemicals that she will need in the experiment. Stock solutions are highly concentrated solutions of commonly used chemicals in water from which dilute solutions are prepared for daily use. Table 1 shows the chemicals, their molecular formulas and weights, and the composition of commonly used stock solutions.

Table 1

Compound	Formula	MW	Stock
Tris	$(CH_2OH)_3CNH_2$	121	1*M* (pH 8)
EDTA	$(HOOCCH_2)_4(CNH_2)_2$	292	0.5 *M* (pH 8)
Sodium hydroxide	NaOH	40	5 *N*
SDS	$C_{11}H_{23}CH_2OSO_3^-Na^+$	288	10%
Sodium acetate	$CH_3COO^-Na^+$	82	3 *M* (pH 5.2)
Ethanol	CH_3CH_2OH	46	95%

Which of the following conclusions can be reached based on the fact that DNA precipitates in the last step of the plasmid prep procedure?

A. DNA dissolves better in water at lower temperatures.

B. DNA is polar and therefore dissolves better in water than in a mixture of water and ethanol.

C. DNA is nonpolar and therefore dissolves better in ethanol than in water.

D. DNA dissolves well in ethanol and precipitates only because the solution is centrifuged.

Correct Answer: B

In the last step of the plasmid prep procedure, ethanol is added to the mixture, which is an aqueous solution, or a solution whose solvent is water. Then the test tube is incubated at low temperature for an hour, and finally the solution is centrifuged and a DNA precipitate forms. This happens because DNA, or deoxyribonucleic acid, is a highly polar substance, and is therefore more soluble in an aqueous solution than in a solvent composed mostly of ethanol. Thus, choice B is correct. Remember the rule that like dissolves like: thus a highly polar substance will dissolve better in a more polar solvent -- water -- than in a less polar solvent -- ethanol. Choice c is wrong because there\\'s no evidence in the passage that DNA dissolves better in ethanol than in water; in fact, there\\'s evidence against this conclusion, since the DNA is fully dissolved in the water solution but precipitates out of the water-ethanol solution. Choice D is wrong because centrifugation can\\'t make a substance precipitate out of a solution; it can only make a precipitate that is suspended in the solution settle to the bottom. Finally, choice A is wrong because there\\'s no evidence that DNA dissolves better at lower temperatures; on the contrary, the incubation at ?0?apparently contributes to its precipitation.

QUESTION 5

Hemoglobin (Hb) and myoglobin (Mb) are the O2-carrying proteins in vertebrates. Hb, which is contained within red blood cells, serves as the O2 carrier in blood and also plays a vital role in the transport of CO2 and H+. Vertebrate Hb consists of four polypeptides (subunits) each with a heme group. The four chains are held together by noncovalent attractions. The affinity of Hb for O2 varies between species and within species depending on such factors as blood pH, stage of development, and body size. For example, small mammals give up O2 more readily than large mammals because small mammals have a higher metabolic rate and require more O2 per gram of tissue.

The binding of O2 to Hb is also dependent on the cooperativity of the Hb subunits. That is, binding at one heme facilitates the binding of O2 at the other hemes within the Hb molecule by altering the conformation of the entire molecule. This conformational change makes subsequent binding of O2 more energetically favorable. Conversely, the unloading of O2 at one heme facilitates the unloading of O2 at the others by a similar mechanism.

Figure 1 depicts the O2-dissociation curves of Hb (Curves A, B, and C) and myoglobin (Curve D), where saturation, Y, is the fractional occupancy of the O2-binding sites. The fraction of O2 that is transferred from Hb as the blood passes through the tissue capillaries is called the utilization coefficient. A normal value is approximately 0.25.

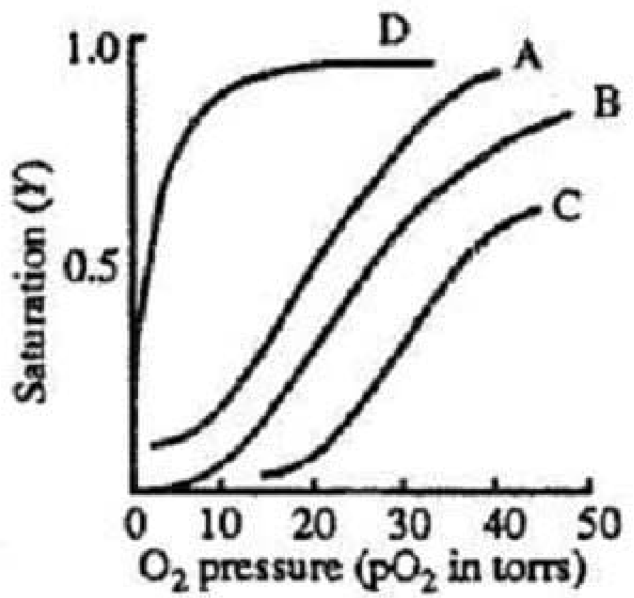

Figure 1

Myoglobin facilitates transport in muscle and serves as a reserve store of O2. Mb is a single polypeptide chain containing a heme group, with a molecular weight of 18 kd. As can be seen in Figure 1, Mb (Curve D) has a greater affinity for than Hb.

If Curve B represents the O2-dissociation curve for human adult Hb, which of the following best explains why Curve A most closely resembles the curve for fetal Hb?

A. Fetal tissue has a higher metabolic rate than adult tissue.

B. Fetal tissue has a lower metabolic rate than adult tissue.

C. Fetal Hb has a higher affinity for than adult Hb.

D. Fetal Hb has a lower affinity for than adult Hb.

Correct Answer: C

Fetuses are 100% dependent on their mothers for all of their nutritional needs, oxygen being one of them. Oxygen is delivered to the fetus by way of diffusion across the placenta. According to the question stem, Curve A most closely resembles the oxygen-dissociation curve for fetal hemoglobin assuming that Curve B is the curve for adult hemoglobin. This means that a given oxygen pressure, fetal hemoglobin is more saturated with oxygen than adult hemoglobin is. This implies that fetal hemoglobin has a greater affinity for oxygen than adult hemoglobin. In fact, at low partial pressures of oxygen, fetal hemoglobin has a 20-30% greater affinity for oxygen than adult hemoglobin. That is why oxygen binds preferentially to fetal hemoglobin in the capillaries of the placenta. Thus, choice C is correct and choices A, B, and D are wrong. In addition, fetal blood has a 50% higher concentration of hemoglobin than maternal blood, which increases the amount of oxygen that enters fetal circulation.