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Topic Break Down

Topic	No. of Questions
Topic 1, Verbal Reasoning	219
Topic 2, Biological Sciences	251
Topic 3, Physical Sciences	358
Topic 4, Mix Questions	2
Total	830

QUESTION NO: 1

The equation for Ampere law is:

A. μoI = Bπr

B. μoI = Bπr2

C. μoI = B2πr

D. μoI = Bπ2r2

ANSWER: C

Explanation:

The correct expression is **μoI = B2πr**, more conventionally written as $\mu_0 I = B(2\pi r)$. Ampère's circuital law states that the line integral of the magnetic field around any closed path equals μ_0 times the current enclosed by that path: $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{enc}$. For a long, straight current-carrying wire, symmetry makes the magnetic-field magnitude constant at every point on a circular Amperian loop centered on the wire. The field is tangent to that loop, so the integral becomes the field magnitude, B, multiplied by the loop circumference, 2πr. Therefore, $B(2\pi r) = \mu_0 I$, or equivalently $B = \mu_0 I/(2\pi r)$. Here, μ_0 is the permeability of free space, I is the enclosed current, and r is the radial distance from the wire. This is the standard MCAT-level application of Ampère's law to an infinitely long straight wire. See OpenStax University Physics: Ampère's Law and The Physics Classroom: Ampère's Law.

QUESTION NO: 2

Which metal have least tendency to form a positive ion?

A. Aluminum

B. Calcium

C. Iron

D. Sodium

ANSWER: C

Explanation:

Iron is correct because, among the listed metals, it has the lowest tendency to lose electrons and become a positive ion under standard electrochemical conditions. Formation of a positive metal ion is an oxidation process: a neutral metal atom gives up one or more electrons. This tendency can be compared using standard reduction potentials, since a more negative reduction potential corresponds to a metal that is more readily oxidized. The standard reduction potential for the iron(II)/iron half-reaction is approximately −0.44 V. In contrast, aluminum, calcium, and sodium have substantially more negative standard reduction potentials, indicating that they lose electrons more readily than iron does. Therefore, iron is comparatively less reactive in this respect and has the least tendency of the listed metals to form positive ions. This conclusion is based on the electrochemical series and assumes standard-state comparisons; actual reaction behavior can also depend on factors such as surface oxide layers, solution conditions, and the ions present. Standard electrode-potential tables and their interpretation are discussed by Chemistry LibreTexts and the IUPAC Gold Book.

QUESTION NO: 3

The breathing system of birds is efficient due to:

A. gills.

B. trachea.

C. air sacs.

D. book lungs.

ANSWER: C

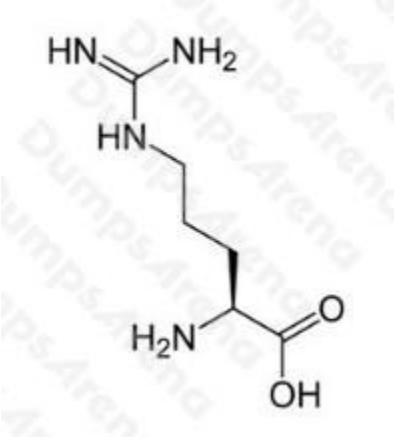
Explanation:

Air sacs are correct because they make the avian respiratory system function as a largely one-way, continuous-flow system. Unlike lungs that simply expand and contract as the primary site of ventilation, birds' air sacs act as bellows that move air through the relatively rigid lungs. Fresh air can therefore pass across the gas-exchange surfaces during both inhalation and exhalation. This sustained movement maintains a favorable oxygen concentration gradient across the parabronchi, the small tubes in bird lungs where gas exchange occurs.

The arrangement also supports highly effective exchange between air and blood through crosscurrent flow: blood in the pulmonary capillaries encounters air with progressively different oxygen concentrations as it travels through the lung. Together, continuous airflow, extensive exchange surfaces, and crosscurrent exchange allow birds to extract oxygen efficiently. This is especially important for meeting the high metabolic demands of flight and for obtaining sufficient oxygen at high altitudes. The air sacs themselves are not the principal location of gas exchange; their essential contribution is ventilating the lungs in this efficient, unidirectional pattern. See OpenStax Biology 2e: The Breathing System and Encyclopaedia Britannica: Bird respiration.

QUESTION NO: 4

Arginine is one of the 20 most common natural amino acids. Most healthy people do not need to supplement with arginine because the body usually produces sufficient quantities. The pathway for arginine synthesis was studied using cells from a red bread mold. This natural form of arginine is illustrated below.



The red bread mold Neurospora crassa grows well on a cultural plate with "minimal" medium which is a fluid containing only a few simple sugars, inorganic salts, and vitamin. Neurospora that grows normally in nature (wild type) has enzymes that convert these simple substances into the amino acids necessary for growth. Mutating any one of the genes that makes an enzyme can produce a Neurospora strain that cannot grow on minimal medium. The mutant would only grow if the enzyme product were to be added as a supplement. On the other hand, if a "complete" medium is provided, containing all required amino acids, then Neurospora would grow, with or without mutation.

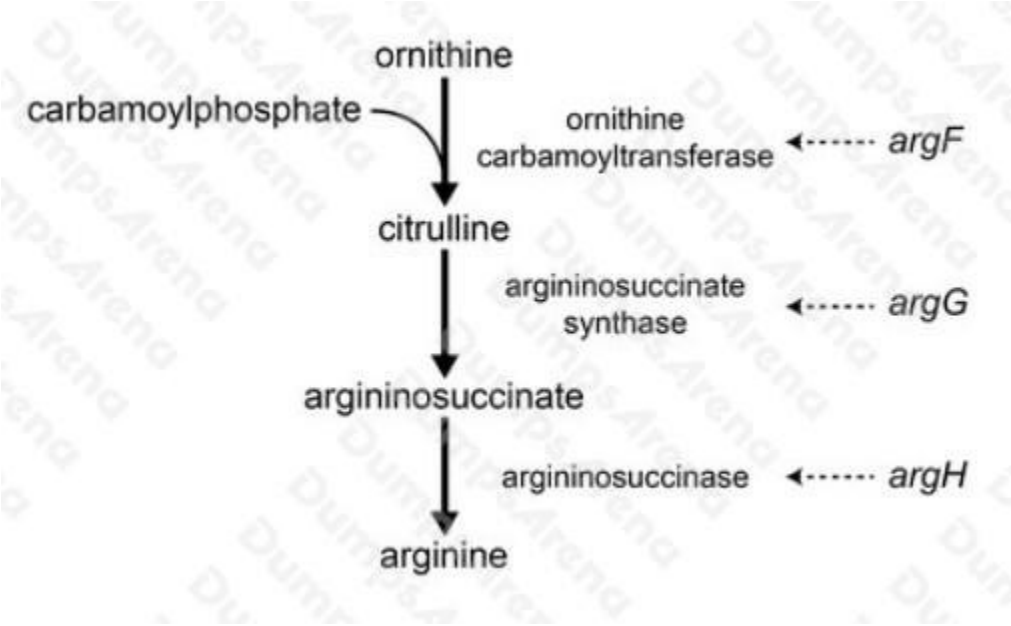


Figure 1 A synthesis pathway for the amino acid arginine. Each gene in italics in the diagram produces one enzyme necessary for the synthesis of this essential amino acid required for growth.

mutant strain	nothing	ornithine	citrulline	argininosuccinate	arginine
P	-	-	-	+	+
Q	-	-	-	+	+

Table 1 Growth response of mutant strains in “minimal” media with supplements (ornithine, citrulline, argininosuccinate, and arginine) as indicated. Strain growth is indicated by (+) and no strain growth is indicated by (−).

Which of the following is NOT an accurate description of naturally-occurring arginine?

A. Acidic amino acid

B. L-Configuration

C. α-Amino acid

D. S-Configuration

ANSWER: A

Explanation:

“Acidic amino acid” is the description that is not accurate for naturally occurring arginine. Amino-acid acid/base classification is determined by the ionizable functional group in the side chain. Arginine has a guanidino group at the end of its side chain, not an additional carboxylic-acid group. This guanidino group is strongly basic: its conjugate acid has a high pKa (commonly reported near 12.5). Consequently, at physiological pH, arginine’s side chain is predominantly protonated and carries a positive charge. Arginine is therefore classified as a basic, polar, hydrophilic amino acid. Its positive side chain is particularly important in protein interactions with negatively charged groups, including phosphate groups in nucleic acids and acidic residues in proteins. The structure and chemical properties of L-arginine, including its guanidino side chain, are listed by PubChem. Standard amino-acid side-chain classifications likewise identify arginine as a basic amino acid, as summarized in LibreTexts.

QUESTION NO: 5

At a recent meeting of the American Public Transit Association, the Environmental Protection Agency unveiled stringent new standards for pollution control. The transit authorities were particularly concerned about the implementation of a proposed “Clean Air Act.” They believed the provisions of the Clean Air Act could severely affect basic services to their local

communities. Many transit agencies were concerned that it would be difficult to comply with the pollution and emissions control standards while continuing to operate within realistic budgets.

The aim of the Clean Air Act is to assure that by the year 2000, there will be a reduction of at least 10 million tons of sulfur dioxide from 1980 levels. The bill also calls for a reduction in pollutants that contribute to the depletion of ozone. Strict regulations of toxic air emissions would have to be established and enforced. Additionally, the Clean Air Act would establish specific acid-rain reduction quotas and enforce severe penalties for transgressors of any of the new clean air regulations.

There is little doubt that mass-transit suppliers will be considerably affected by this new legislation, just as the chemical and petroleum industries have already been affected by similar legislation. Transit authorities are challenged to strike a difficult balance between complying with the government's new standards and developing an official concern for the environment, while continuing to fulfill the transportation needs of the general population.

Among the areas addressed by the Clean Air Act, the topic of mobile resources is of particular interest to mass transit authorities. Provisions contained in the Act under this title are aimed at encouraging the development and practical use of alternative fuel sources, like solar energy and methane fuel. The goal of this section of the Act is to eradicate toxic fuel emissions in order to provide cleaner air and a more favorable environment. The Act even goes so far as to declare that in cities like New York, Los Angeles and Houston – where air quality is particularly noxious and toxins exceed the limits of federal regulations – forms of mass transit should run on so-called "clean-burning fuels" by the year 2000. Such fuels include reformulated gasoline, propane, electricity, natural gas, ethanol, methanol, or any similar type of low-emission fuel. In addition, the Act proposes that, by 1994, all new urban buses in cities with populations exceeding one million must operate solely on clean-burning fuels.

The topics of alternative fuels and alternative fuel vehicles represent, by far, the most controversial issue in the Clean Air Act. President Bush has called alternative fuels "bold and innovative" means to control pollution, but according to many transportation experts, the Act's proposals on alternative fuel usage are unrealistic. The transit authorities recognize that concern for the environment and health hazards like pollution are global issues. However, most transit officials concur that inventing and developing new ways to fuel mass transit will take at least 50 years to realize. They point out that the Act does not mention the political and social ramifications of usurping the role of the petroleum industries. The Act does not mention if or how the thousands of people employed by the oil industry will get retrained to produce and implement the use of "clean" fuel.

No one disputes the fact that people need some form of transportation to get from place to place. Preserving the environment should be a priority, yet we need to remember that even if toxic emissions are completely eliminated sometime in the future, the challenge of moving mass numbers of people where they want to go will still exist and must remain a priority. Transit authorities contend that unless the Clean Air Act also acknowledges this, and develops a way to encourage mass transit over personal transportation, the problems of pollution might not be significantly altered. They suggest that there are many areas in this country that have little or no mass transit and that, if the Clean Air Act's goal is to reduce pollution, perhaps the most practical and realistic means to achieve that goal is to encourage the development and maintenance of mass transit systems.

The majority of transit officials seem to agree that developing new ways to power mass transit:

A. is an unrealistic goal, at least for the short term.

B. must be preceded by governmental restrictions on petroleum products.

C. should be subsidized at the state and federal levels.

D. will increase the cost of transportation to consumers.

ANSWER: A

Explanation:

The correct completion is *"is an unrealistic goal, at least for the short term."* The passage directly attributes this view to most transit officials, who agree that inventing and developing new methods of fueling mass transit would require at least 50 years. That estimate places practical implementation far beyond the legislation's near-term deadlines, including requirements tied to the years 1994 and 2000. Thus, the officials' concern is not a rejection of cleaner transportation as an environmental objective; rather, it is a judgment that the proposed timetable does not match the technological and operational reality described in the passage.

This conclusion also fits the broader tension developed throughout the discussion: transit agencies must attempt to meet emissions standards while maintaining essential public transportation within realistic budgets. The officials regard alternative-fuel development as controversial because it would entail long-term innovation and substantial changes to established

fueling systems and industries. The passage's central evidence is therefore the explicit fifty-year estimate, making the short-term-unrealistic conclusion the most accurately supported inference. For general background on Clean Air Act programs addressing air pollution, see the U.S. Environmental Protection Agency's Clean Air Act overview and its transportation, air pollution, and climate-change information.

QUESTION NO: 6

Noncompetitive inhibition differs from uncompetitive inhibition in that a noncompetitive inhibitor binds to an allosteric site on the enzyme and prevents it from catalyzing a reaction, whereas uncompetitive inhibitors bind to the enzyme-substrate complex and prevent catalysis. Increasing the substrate concentration would have which of the following effects?

A. Increasing impact of uncompetitive inhibitor and decreasing concentration of noncompetitive inhibitor

B. Decreasing impact of uncompetitive inhibitor and increasing impact of noncompetitive inhibitor.

C. Increasing impact of uncompetitive inhibitor

D. No effect

ANSWER: C

Explanation:

Increasing impact of uncompetitive inhibitor is correct because an uncompetitive inhibitor can bind only after substrate has already bound to the enzyme, creating an enzyme-substrate complex. Raising substrate concentration increases the formation of enzyme-substrate complexes. Consequently, it creates more of the specific molecular target to which the uncompetitive inhibitor binds. More enzyme-substrate-inhibitor complex is then formed, reducing the amount of enzyme-substrate complex that can proceed to product.

In Michaelis-Menten terms, uncompetitive inhibition decreases both the apparent maximum reaction velocity and the apparent Michaelis constant by the same factor. Unlike competitive inhibition, the inhibitory effect cannot be eliminated merely by adding excess substrate, because additional substrate promotes formation of the enzyme-substrate complex required for inhibitor binding. Thus, under the mechanism specified in the question, increasing substrate concentration increases the opportunity for uncompetitive inhibitor binding and makes its effect more evident. This enzyme-kinetics behavior is described in OpenStax Biology 2e: Enzymes and in Chemistry LibreTexts: Enzyme Inhibition.

QUESTION NO: 7

Flytraps in two pitcher plants – Sundew and Venus – are similar in that they both:

A. are saprophyte.

B. trap insects.

C. are symbiotic.

D. lack chlorophyll.

ANSWER: B

Explanation:

"trap insects" is correct because both sundews and Venus flytraps are carnivorous plants that capture small animals, particularly insects, as a source of mineral nutrients. These plants commonly grow in nutrient-poor soils, where nitrogen and phosphorus may be scarce. Capturing prey supplements the nutrients obtained through their roots and supports growth and reproduction.

Sundews use leaves covered in sticky, glandular tentacles. An insect that lands on the leaf becomes stuck in the adhesive secretion, and the tentacles can bend inward around the prey. Venus flytraps use paired leaves that close rapidly when trigger hairs are stimulated appropriately. Although their trapping mechanisms differ, both types of plants digest captured prey with enzymes and absorb released nutrients. They still photosynthesize and use light energy to make sugars, while

insect capture primarily provides nutrients rather than their main energy supply. The botanical gardens at Kew Gardens describe how carnivorous plants capture prey for nutrients, and the Encyclopaedia Britannica overview of the Venus flytrap details its insect-trapping adaptation.

QUESTION NO: 8

Due to ever-increasing paranoia about the transmission of hepatitis and AIDS via blood transfusions and the frequent difficulty of procuring matching blood donors for patients, researchers have been working at a feverish pace to produce disease-free and easy-to-use blood substitutes. The difficulty most synthetic blood researches have had is in formulating a substance that combines qualities of sterility, high capacity for carrying oxygen to body tissues, and versatility within the human body. Three major substitute technologies have been developed to date; each has certain advantages and shortcomings.

“Red blood,” the first of the blood substitute technologies, is derived from hemoglobin which has been recycled from old, dead, or worn-out red blood cells and modified so that it can carry oxygen outside the red blood cell. Hemoglobin, a complex protein, is the blood’s natural oxygen carrier and is attractive to scientists for use in synthetic blood because of its oxygen-carrying capacity. However, hemoglobin can sometimes constitute a two-fold threat to humans when it is extracted from the red blood cell and introduced to the body in its naked form. First, hemoglobin molecules are rarely sterile and often remain contaminated by viruses to which they were exposed in the cell. Second, naked hemoglobin is extremely dangerous to the kidneys, causing blood flow at these organs to shut down and leading, ultimately, to renal failure. Additional problems arise from the fact that hemoglobin is adapted to operate optimally within the intricate environment of the red blood cell. Stripped of the protection of the cell, the hemoglobin molecule tends to suffer breakdown within several hours. Although modification has produced more durable hemoglobin molecules which do not cause renal failure, undesired side effects continue to plague patients and hinder the development of hemoglobin-based blood substitutes.

Another synthetic blood alternative, “white blood”, is dependent on laboratory synthesized chemicals called perfluorocarbons (PFCs). Unlike blood, PFCs are clear oil like liquids, yet they are capable of absorbing quantities of oxygen up to 50% of their volume, enough of an oxygen carrying potential for oxygen-dependent organisms to survive submerged in the liquid for hours by “breathing” it. Although PFCs imitate real blood by effectively absorbing oxygen, scientists are primarily interested in them as constituents of blood substitutes because they are inherently safer to use than hemoglobin-based substitutes. PFCs do not interact with any chemicals in the body and can be manufactured in near-perfect sterility. The primary pitfall of PFCs is in their tendency to form globules in plasma that can block circulation. Dissolving PFCs in solution can mitigate globulation; however, this procedure also seriously curtails the PFCs’ oxygen capacity.

The final and perhaps most ambitious attempt to form a blood substitute involves the synthesis of a modified version of human hemoglobin by genetically-altered bacteria. Fortunately, this synthetic hemoglobin seems to closely mimic the qualities of sterility, and durability outside the cellular environment, and the oxygen-carrying efficiency of blood. Furthermore, researchers have found that if modified hemoglobin genes are added to bacterial DNA, the bacteria will produce the desired product in copious quantities. This procedure is extremely challenging, however, because it requires the isolation of the human gene for the production of hemoglobin, and the modification of the gene to express a molecule that works without support from a living cell.

While all the above technologies have serious drawbacks and difficulties, work to perfect an ideal blood substitute continues. Scientists hope that in the near future safe synthetic blood transfusions may ease blood shortages and resolve the unavailability of various blood types.

According to the passage, PFCs are helpful in the synthesis of blood substitutes because they:

I. mimic the oxygen-carrying capacity of blood. II. do not react with other body chemicals.

III. break down in the blood within several hours.

A. I only

B. II only

C. I and II only

D. II and III only

E. I, II, and III

ANSWER: C

Explanation:

“I and II only” is correct because the passage explicitly identifies two beneficial properties of perfluorocarbons (PFCs) for a blood-substitute application. First, PFCs can absorb substantial amounts of oxygen—up to 50% of their volume according to the passage—and thus imitate blood’s essential oxygen-delivery role. This oxygen solubility is the functional feature that makes PFCs candidates for temporary oxygen-carrying fluids. Second, the passage states that PFCs do not interact with chemicals in the body. That chemical inertness is presented as a safety advantage over hemoglobin-based substitutes, along with their potential for manufacture in near-perfect sterility. In biomedical terms, PFC emulsions have been investigated as oxygen therapeutics precisely because perfluorocarbons can physically dissolve large quantities of respiratory gases rather than relying on hemoglobin binding. See the review indexed by the U.S. National Library of Medicine and the background on oxygen transport in blood from NCBI Bookshelf. The passage attributes breakdown within several hours to hemoglobin after it has been stripped from the protective red-cell environment, not to PFCs. Therefore, only the first two stated properties support the usefulness of PFCs.

QUESTION NO: 9

Fluoroscopy is an imaging technique that uses X-rays to obtain real-time moving images of the interior of the body. A patient was asked to perform cycles of deep inspiration and deep expiration. Fluoroscopy was used to measure the linear velocity of the movement of the diaphragm and the data was plotted against time. The origin in Figure 1 is the reference time 0 when the diaphragm was essentially in its equilibrium position.

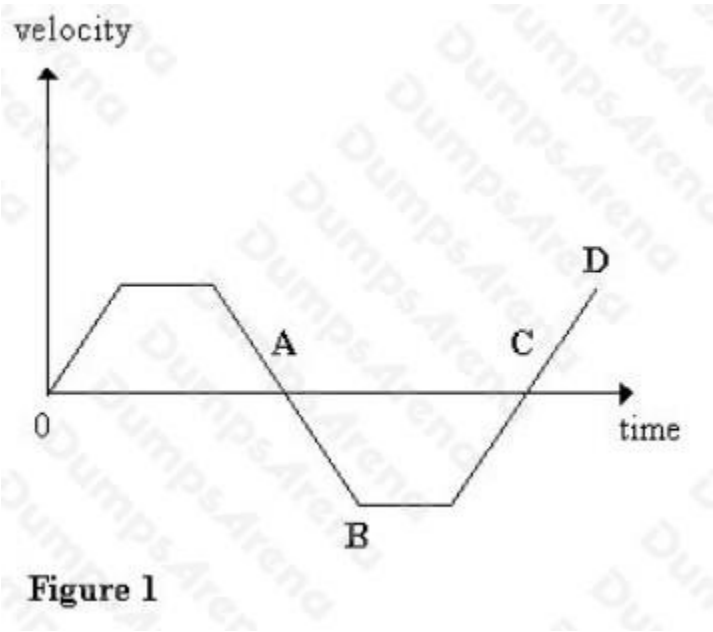


Figure 1

At what time after t = 0 is the displacement of the diaphragm at a minimum?

A. A

B. B

C. C

D. D

ANSWER: C

Explanation:

The time labeled C is correct. Displacement is determined from a velocity-versus-time graph by calculating the signed area between the velocity curve and the time axis. Area above the axis represents motion in one direction, whereas area below the axis represents motion in the opposite direction. It is therefore essential to use algebraic area rather than simply adding all geometric areas, which would instead describe total distance traveled.

By time C, the positive trapezoidal area accumulated during one part of the diaphragm’s motion is balanced by an approximately equal negative trapezoidal area during the subsequent opposite motion. The net signed area from the

reference time to C is consequently zero, meaning the diaphragm has returned to its equilibrium, or starting, position. Its displacement has the minimum magnitude at that instant. This is consistent with the fundamental kinematics relationship that displacement equals the time integral of velocity. See OpenStax Physics: Position vs. Time Graphs and OpenStax College Physics: Velocity vs. Time Graphs.

QUESTION NO: 10

…Squeaking sand produces sounds with very high frequencies – between 500 and 2,500 hertz, lasting less than a quarter of a second. The peals are musically pure, often containing four or five harmonic overtones. Booming sand makes louder, low-frequency sounds of 50 to 300 hertz, which may last as long as 15 minutes in larger dunes (although typically they last for seconds or less). In addition, they are rather noisy, containing a multitude of nearby frequencies. Booms have never been observed to contain more than one harmonic of the fundamental tone.

These dramatic differences once led to a consensus that although both types of sand produce acoustic emissions, the ways in which they do so must be substantially different… In the late 1970s, however, Peter K. Haff, then at the California Institute of Technology, produced squeaks in booming sand, suggesting a closer connection between the two.

Both kinds of sand must be displaced to make sounds. Walking on some sand, for example, forces the sand underfoot to move down and out, producing squeaks. In the case of booming sand, displacement occurs during avalanches. It is within the avalanche that sound begins and where the answers must be hiding.

Before an avalanche can occur, winds must build a dune up to a certain angle, usually about 35 degrees for dry desert sand. Once an angle is achieved, the sand on the leeward side of the dune begins to slump. Intact layers of sand slip over the layers below, like a sheared deck of cards. At the same time, the individual grains in the upper layers tumble over the grains underneath, momentarily falling into the spaces between them and bouncing out again to continue their downward journey. Their concerted up-and-down motion is believed to be the secret source of sound. Fully developed avalanches, in which sliding plates of sand remain intact for most of their motion, have the greatest acoustic output. In some places, where large amounts of sand are involved, booming can be heard up to 10 kilometers away.

Because it is caused by large volumes of shearing sand, the roaring is also loud. In fact, sounds made by booming sand can be nearly deafening, and the vibrations causing them can be so intense that standing in their midst is nearly impossible.

A good place to start in exploring the vibrational properties of sand is with the grains themselves. The mean diameter of most sand grains, whether acoustically active or not, is about 300 microns. Usually the grains in a booming dune are very similar in size, especially near the leeward crest, where the sound most often originates; such uniformity allows for more efficient shearing. Otherwise, the smaller grains impede the smooth motion of the larger ones.

Similar sizes do not alone allow sand to boom. On the contrary, the booming sands of Korizo and Gelf Kebib, also in Libya, feature an uncharacteristically broad range of particle sizes. Moreover, silent dune sand often contains grains somewhat similar to nearby booming sand.

Grains of booming sand also tend to have uncommonly smooth surfaces, with protrusions on the scale of mere microns. Booming dunes are often found at the downwind end of large sand sources; having bounced and rolled across the desert for long distances, the sand grains in these dunes are usually highly polished. Over time a grain can also be polished by repeated shifts within a moving dune. And squeaking sand as well tends to be exceptionally smooth…

…Another important factor is humidity, because moisture can modify the friction between grains or cause sand to clump together, thus precluding shearing. Sounds occur in those parts of the dune that dry the fastest. Precipitation may be rare in the desert, but dunes retain water with remarkable efficiency. Sand near the surface dries quickly, however, and sand around a dune's crest tends to dry the fastest.

Which of the following characteristics is most helpful in differentiating booming sand from squeaking sand?

A. duration of the sound

B. frequency of the sound

C. size of the sand grains

D. smoothness of the sand grains

ANSWER: B

Explanation:

frequency of the sound is the most helpful differentiating characteristic because the passage gives distinct, nonoverlapping frequency ranges for the two phenomena. Squeaking sand is described as producing high-frequency sounds from 500 to 2,500 hertz, whereas booming sand produces low-frequency sounds from 50 to 300 hertz. Thus, measuring a sound's frequency provides a direct basis for classifying it as squeaking or booming within the descriptions supplied by the passage. This conclusion follows from comparing the explicitly stated numerical evidence rather than inferring a distinction from related physical features of dunes or grains. The passage also characterizes the sounds in acoustical terms—high versus low frequency—making frequency the central quantitative feature for identification. In MCAT critical-analysis questions, the best-supported response is the one that answers the question using the passage's clearest and most definitive stated comparison. The AAMC describes the Critical Analysis and Reasoning Skills section as assessing reasoning from information presented in passages; see the AAMC MCAT exam overview and the AAMC CARS section overview.

QUESTION NO: 11

A ski jump is an inclined track from which a ski jumper takes off through the air. After traveling down the track, the skier takes off from a ramp at the bottom of the track. The skier lands farther down on the slope.

Figure 1 shows a ski jump, in which the ramp at the lower end of the track makes an angle of 30° to the horizontal. The track is inclined at an angle of to the horizontal and the slope is inclined at an angle of 45° to the horizontal. A ski jumper is stationary at the top of the track. Once the skier pushes off, she accelerates down the track, and then takes off from the ramp. The vertical height difference between the top of the track and its lowest point is 50 m, and the vertical height difference between the top of the ramp and its lowest point is 10 m.

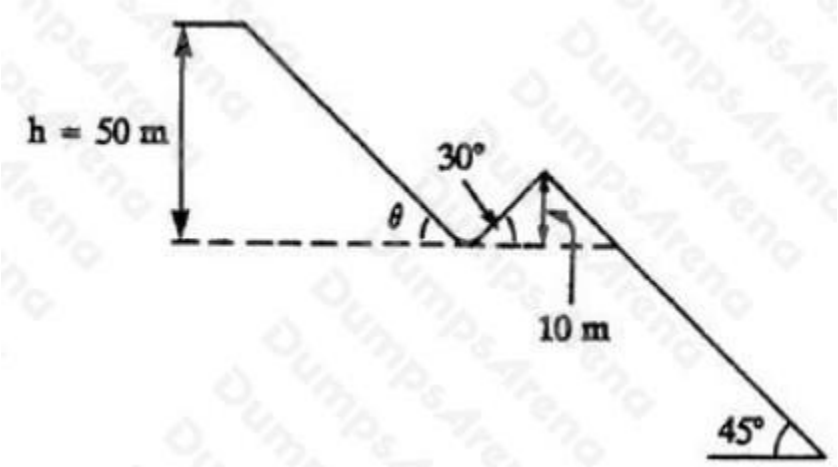


Figure 1

The distance traveled by the skier between leaving the ski jump ramp and making contact with the slope is called the jump distance. In some cases, in order to increase the jump distance a skier will jump slightly upon leaving the ramp, thereby increasing the vertical velocity. Unless otherwise stated, assume that friction between the skis and the slope is negligible, and ignore the effects of air resistance.

Which of the following would increase the jump distance?

I) Increasing the vertical height h of the jump track

II) Increasing the angle of incline of the jump track

III) Carrying extra weight to increase the total mass of the ski jumper

A. I only

B. I and II only

C. II and III only

D. I and III only

ANSWER: A

Explanation:

I only is correct because increasing the vertical height of the jump track increases the skier's gravitational potential energy before descent. With negligible friction and air resistance, this added potential energy is converted into kinetic energy as the skier travels downward. The energy relationship is $mgh = \frac{1}{2}mv^2$, so a larger vertical drop produces a greater speed at the ramp. The ramp's orientation fixes the direction of the skier's launch velocity; consequently, increasing the magnitude of that velocity increases both its horizontal and upward vertical components. A faster launch allows the skier to remain airborne longer and travel farther along the downhill landing slope, increasing the jump distance. This conclusion follows directly from conservation of mechanical energy: only the change in vertical position determines the available gravitational energy for the descent under the stated ideal assumptions. The skier's motion after leaving the ramp is then projectile motion governed by the launch velocity and gravity. For background on gravitational potential energy and conservation of mechanical energy, see OpenStax Physics: Conservation of Energy. The connection between initial velocity components and projectile travel is summarized in OpenStax Physics: Projectile Motion.

QUESTION NO: 12

Which of the following addictive drug is sometimes injected for relief from a severe pain?

A. Heroin

B. Alcohol

C. Aspirin

D. Nicotine

ANSWER: A

Explanation:

Heroin is correct. Heroin, also called diamorphine in medical contexts, is a potent opioid analgesic. Opioids act primarily at opioid receptors in the brain and spinal cord, reducing the perception of pain and altering the emotional response to it. Because diamorphine is highly potent and can act rapidly when administered by injection, it has been used in some clinical settings for severe acute pain, including pain associated with major trauma, surgery, myocardial infarction, or terminal illness. Its injectable route can be especially useful when rapid analgesia is required or when a patient cannot take medication orally.

Medical use is tightly controlled because heroin has a high potential for dependence, tolerance, and misuse. The fact that a substance can be prescribed for carefully supervised pain relief does not eliminate its addictive potential; rather, it illustrates why dosing, monitoring, and legal controls are important. The National Institute on Drug Abuse describes heroin as an opioid drug with serious addiction risks, while the UK National Health Service identifies diamorphine as a strong painkiller used for severe pain. See NIDA: Heroin and NHS: Diamorphine.

QUESTION NO: 13

The equation of state of an ideal gas is given by the ideal gas law: $PV = nRT$

where P is the pressure, V is the volume, n is the number of moles of gas, R is the ideal gas constant, and T is the temperature of the gas. The gas particles in a container are constantly moving at various speeds. These speeds are characterized by the Maxwell shown in the figure below.

If two particles collide, their velocities change. However, if the gas is in thermal equilibrium, the velocity distribution of the gas as a whole will remain unchanged by the collision.

The average kinetic energy (E) of a gas particle is given by:

Equation 1 where m is the mass of one particle and u is the root mean square speed (rms speed) of the gas particles:



where N is the number of gas particles; this is different from the average speed. For an ideal gas, the kinetic energy of all the particles is:



Equation 2 where n is the number of moles of gas. Combining these equations gives:



Equation 3 where M is the molar mass of the gas particles.

The average distance a particle travels between collisions is known as the mean free path l. Intuitively, the mean free path (mfp) could be expected to be larger for gases at low pressure, since there is a lot of space between particles. Similarly, the mfp should be larger when the gas particles are small. The following expression for the mfp shows this to be correct.



Equation 4

In this equation, s is the atomic diameter (typically on the order of 10-8), k is the Boltzmann constant, and P is the pressure.

In addition to colliding with one another, gas particles also collide with the walls of their container. If the container wall has a pinhole that is small compared to the mfp of the gas, and a pressure differential exists across the wall, the particles will effuse (or escape) through this pinhole without disturbing the Maxwellian distribution of the particles. The rate of effusion can be described by:



Equation 5

Where neff is the number of moles of effusing particles, A is the area of the pinhole, P and P1 are the pressures on the inside and outside of the container wall respectively, and P > P1.

The average kinetic energy of an ideal gas can be directly related to the:

A. rms speed.

B. temperature.

C. Boltzmann constant.

D. universal gas constant.

ANSWER: B

Explanation:

Temperature is correct because the mean translational kinetic energy of an ideal-gas particle is directly proportional to its absolute temperature: $\langle E_k \rangle = (3/2)k_B T$. Thus, raising the temperature in kelvin increases the average kinetic energy by the same factor. For example, doubling a gas's absolute temperature doubles its average translational kinetic energy. This relationship is fundamental to kinetic-molecular theory: temperature is the macroscopic measure associated with the random translational motion of gas particles. It also follows from the molar form, in which the total translational kinetic energy of an ideal monatomic gas is (3/2)nRT. Dividing by the number of particles and using $R = N_A k_B$ gives the per-particle expression above. The relevant temperature must be measured on an absolute scale, ordinarily kelvin, because proportionality to kinetic energy requires a zero point at absolute zero. This principle is summarized in OpenStax's discussion of the molecular model

of an ideal gas: Kinetic Theory of Gases. The relation between molecular kinetic energy and temperature is also stated by the Encyclopaedia Britannica kinetic theory overview.

QUESTION NO: 14

Saul Hoffman's scientific journal paper published in 2015 in Societies explores the relationship between two topics that at the surface are very distant from each other. As he goes on to state, "It is relatively easy, at least for an economist, to see why economists would be attracted to issues like teen pregnancy and teen childbearing, despite their apparent distance from the core topics of economics. First, economics – especially microeconomics – is fundamentally the study of choices that individuals make, traditionally and most often in formal markets with monetary prices, but now more and more frequently outside that sphere. Viewed from that perspective, choices involving sexual and fertility behavior among teens are an incredibly challenging, but inviting, target. Is it possible to identify the role of economic incentives, including government policy, on these behaviors? Is it sensible to apply traditional models of rational choice decision-making to teens?

Second, the traditional concern about teen fertility was predicated on the notion that it was an economically catastrophic act. In a famous and oft-quoted 1968 article, Arthur Campbell wrote that 'The girl who has an illegitimate child at the age of 16 suddenly has 90 percent of her life's script written for her,' including reduced opportunities for schooling, the labor market, and marriage. But it doesn't take too much reflection to appreciate that more may be going on in leading to these poor outcomes than just a teen birth. Disentangling the causal effect of teen childbearing on subsequent socio-economic outcomes from its correlational effect is another deliciously inviting and challenging target, this time well-suited for the applied economist or econometrician.

Just to make all this yet more inviting, the two research strands are closely related. Suppose it could be demonstrated that for some teens the socio-economic impact of a teen birth was negligible. For example, maybe future prospects for some teens were equally poor with or without a birth or perhaps government programs provided substantial benefits, so that the net impact on socio-economic well-being was consequently small or even positive. Then, it might well be 'rational' in an economic sense to have a teen birth in the first place, thereby linking the research on the causal impact of a teen birth with the research on the choice determinants of a teen birth. So what came to be known as the teen birth 'causes' literature and the teen birth 'consequences' literature were clearly interrelated.

And then, to add yet another layer of challenge, the teen fertility rate in the U.S. has fallen at a rate that is totally unprecedented. Teen fertility was once widespread, with most of it occurring within early and sometimes not entirely voluntary marriage. In 1960, the teen fertility rate was approximately 90 births per 1000, which implied that more than 40% of women ever had a teen birth. When I published my first article on teen births 25 years ago, the teen fertility rate was 60 births per 1000, down one-third from 1960, but it had increased six years in a row in what turned out to be a deviation from the downward trend. Since then the rate has declined every single year, except for a short but puzzling uptick between 2005 and 2007. In 2014, the teen fertility rate was 24.2 births per 1000, the lowest teen fertility rate ever recorded in the U.S., though still shockingly high by European standards. Thus, the rate fell by more than 50% during my professional association with the topic and by 70% since 1960. Of course, at the same time teen marital births largely disappeared, falling from 85% of teen births to 12%.

This adds yet another focus for economic research. Why did the rate fall? Did it have anything to do with changes in the costs of teen childbearing or changes in policy? Is it a good thing or not?

In this article I try to make sense out of these various research strands by providing a personal narrative through the economics literature on teen childbearing, with a special emphasis on the three issues discussed above. My goal is to make the literature, including some reasonably technical content, accessible and valuable to a non-economist." Hoffman, S. (2015). Teen Childbearing and Economics: A Short History of a 25-Year Research Love Affair. Societies, 5(3), 646-663. doi:10.3390/soc5030646

According to passage information, a scholar interested in microeconomics might study all of the following EXCEPT:

A. which environmental factors make a city dweller more likely to litter.

B. the reasons behind college students' choices to spend their time studying vs. socializing.

C. how divorce influences real estate prices and choices.

D. how recent college graduates prioritize cost versus convenient location in choosing an apartment.

ANSWER: C

Explanation:

“how divorce influences real estate prices and choices” is the best answer because its central emphasis is on the effect of divorce on real-estate prices, an outcome measured at the level of a market rather than a particular individual’s decision-making process. In the passage, microeconomics is characterized as the study of choices made by individuals, whether those choices occur in formal markets with monetary prices or in nonmarket settings. Hoffman applies that framework to choices and incentives surrounding teen sexual and fertility behavior, as well as the causal consequences associated with those decisions. A study framed around movements in real-estate prices due to divorce instead foregrounds a broad market-level relationship. Although the wording also mentions “choices,” it does not specify whose choices are being analyzed, their constraints, or the incentives and tradeoffs shaping an individual decision. Thus, it is less directly aligned with the passage’s stated conception of microeconomics than research focused on explaining how people make choices under incentives and limited resources. Hoffman's article is available from MDPI’s Societies journal. For a general discussion of microeconomics as the study of individual choices and markets, see OpenStax Principles of Economics.

QUESTION NO: 15

The center that controls breathing, constriction and dilation of blood vessels, and heart beating is located in:

A. Cerebellum.

B. Pons.

C. Medulla oblongata.

D. Hypothalamus.

ANSWER: C

Explanation:

The correct answer is **Medulla oblongata.** This structure, located in the inferior portion of the brainstem and continuous with the spinal cord, contains vital autonomic control centers. Its cardiovascular centers regulate heart rate, force of cardiac contraction, and blood-vessel diameter through autonomic output; altering vessel diameter directly affects peripheral resistance and blood pressure. The medulla also contains respiratory control networks that generate and adjust the basic rhythm of breathing in response to signals such as changing carbon dioxide, oxygen, and pH levels. These functions occur automatically and are essential for immediate survival, which is why significant injury to the medulla can rapidly compromise breathing and circulation. Although breathing is regulated through coordinated brainstem activity, the medulla is the principal location classically associated with the respiratory, cardiac, and vasomotor centers described in the question. The pons can modify respiratory rhythm, but the combined control of heartbeat, vascular constriction and dilation, and essential respiratory drive identifies the medulla oblongata. See the NCBI Bookshelf overview of medulla oblongata anatomy and function and the NCBI Bookshelf discussion of cardiovascular physiology.

QUESTION NO: 16

Aerobic respiration is the major process used by oxygen- requiring organisms to generate energy. During respiration, glucose is metabolized to generate chemical energy in the form of ATP:

$C6H12O6 + 6O2 \rightarrow 6CO2 + 6H2O + 36ATP$

The biochemical machinery necessary for cellular respiration is found in the mitochondria, small organelles scattered throughout the cytoplasm of most eukaryotic cells. The number of mitochondria per cell varies by tissue type and cell function.

Mitochondria are unusual in that they have their own genetic systems that are entirely separate from the cell’s genetic material. However, mitochondrial replication is still dependent upon the cell’s nuclear DNA to encode essential proteins required for replication. Despite this fact, mitochondria seem to replicate randomly, out of phase with both the cell cycle and other mitochondria.

The nature of the mitochondrial genome and protein synthesizing machinery has led many researchers to postulate that mitochondria may have arisen as the result of the ingestion of a bacterium by a primitive cell millions of years ago. It is postulated that the two may have entered into a symbiotic relationship and eventually became dependent on each another; the cell sustained the bacterium, while the bacterium provided energy for the cell. Gradually, the two evolved into the present-day eukaryotic cell, with the mitochondrion retaining some of its own DNA. This is known as the endosymbiotic

hypothesis. Because mitochondrial DNA is inherited in a non-Mendelian fashion (mitochondria are inherited from the maternal parent, who supplies most of the cytoplasm to the fertilized egg), it has been used to look at evolutionary relationships among different organisms.

Four different human cell cultures – erythrocytes, epidermal cells, skeletal muscle cells, and intestinal cells – were grown in a medium containing radioactive adenine. After 10 days, the mitochondria were isolated via centrifugation, and their level of radioactivity was measured using a liquid scintillation counter. Which of the following cells would be expected to have the greatest number of counts per minute of radioactive decay?

A. Erythrocytes

B. Epidermal cells

C. Skeletal muscle cells

D. Intestinal cells

ANSWER: C

Explanation:

Skeletal muscle cells are correct because radioactive adenine supplied in the culture medium can be incorporated into newly synthesized mitochondrial nucleic acids. After mitochondria are isolated, the measured counts per minute therefore reflect, in broad terms, the amount of labeled mitochondrial material present in each preparation. Cells with especially high ATP requirements generally contain abundant mitochondria, providing a larger mitochondrial DNA pool and more opportunity for radioactive adenine incorporation during the ten-day culture period.

Skeletal muscle has a particularly large and continuous energy demand. ATP is required for repeated cross-bridge cycling during contraction and for ion pumping processes that restore the membrane and calcium gradients needed for subsequent contractions. Consequently, muscle fibers are rich in mitochondria, especially fibers adapted for sustained oxidative activity. Their high mitochondrial content makes the isolated mitochondrial fraction from skeletal muscle expected to yield the greatest radioactive signal under the stated experimental design. Mitochondria generate much of a cell's ATP through oxidative phosphorylation, and their abundance is closely matched to cellular energy needs. See NCBI Bookshelf: Mitochondria and OpenStax Biology: Oxidative Phosphorylation.

QUESTION NO: 17

Gauguin's attitude toward art marked a break from the past and a beginning to modern art. Like all Post-Impressionist artists, he passed through an Impressionist phase but became quickly dissatisfied with the limitations of the style, and went on to discover a new style that had the directness and universality of a symbol and that concentrated on impressions, ideas and experiences. The beginning of his modern tradition lay in his rejection of Impressionism. He considered naturalism an error to be avoided. He was preoccupied with suggestion rather than description, seeking to portray not the exterior, but the essence of things in their purest, simplest, and most primitive form, which could only be achieved through simplification of the form. He firmly believed throughout his life that "art is an abstraction" and that "this abstraction [must be derived] from nature while dreaming before it." One must think of the creation that will result rather than the model, and not try to render the model exactly as one sees it. This was the birth of "Synthetism" or rather Synthetist-Symbolic, as Gauguin referred to it, using the term "symbolic" to indicate that the forms and patterns in his pictures were meant to suggest mental images or ideas and not simply to record visual experience.

Symbolism flourished around the period of 1885 to 1910 and can be defined as the rejection of direct, literal representation in favor of evocation and suggestion. Painters tried to give a visual expression to emotional experiences, and therefore the movement was a reaction against the naturalistic aims of Impressionism. Satisfying the need for a more spiritual or emotional approach in art, Symbolism is characterized by the desire to seek refuge in a dreamworld of beauty and the belief that color and line in themselves could express ideas. Stylistically, the tendency was towards flattened forms and broad areas of color, and features of the movement were an intense religious feeling and an interest in subjects of death, disease, and sin.

Similarly, "Synthetism" involved the simplification of forms into large-scale patterns and the expressive purification of colors. Form and color had to be simplified for the sake of expression. This style reacted against the "formlessness" of Impressionism and favored painting subjectively and expressing one's ideas rather than relying on external objects as subject matters. It was characterized by areas of pure colors, very defined contours, an emphasis on pattern and decorative qualities, and a relative absence of shadows.

Gauguin's new art form merged these two movements and succeeded in freeing color, form, and line, bringing it to express the artists' emotions, sensibilities, and personal experiences of the world around them. His style created a break with the old tradition of descriptive naturalism and favored the synthesis of observation and imagination. Gauguin sustained that forms are not discovered in nature but in one's wild imagination, and it was in himself that he searched rather than in his surroundings. For this reason, he scorned the Impressionists for their lack of imagination and their mere scientific reasoning. Furthermore, Gauguin used color unnaturalistically for its decorative or emotional effect and reintroduced emphatic outlines. “Synthetism” signified for him that the forms of his pictures were constructed from symbolic patterns of color and linear rhythms and were not mere scientific reproductions of what is seen by the eye.

Dempsey, A., & Dempsey,

A. "Treat nature in terms of the cylinder, the sphere, and the cone." (Paul Cezanne)

B. "There is only one true thing: instantly paint what you see. When you've got it, you've got it. When you haven't, you begin again." (Édouard Manet)

C. "Paintings have a life of their own that derives from the painter's soul." (Vincent van Gogh)

D. "Painting is a blind man's profession. He paints not what he sees, but what he feels, what he tells himself about what he has seen." (Pablo Picasso)

ANSWER: B

Explanation:

"There is only one true thing: instantly paint what you see. When you've got it, you've got it. When you haven't, you begin again." is the quote Gauguin would be least likely to endorse. Its central instruction is to record the visible world immediately and faithfully. That approach makes direct perception the decisive source of a painting and treats successful representation of what is seen as the artistic goal. In the passage, however, Gauguin explicitly rejects naturalism and rejects rendering a model exactly as it appears to the eye. He values abstraction, imagination, symbolic suggestion, and the artist’s internal response over descriptive observation. His Synthetist approach simplifies forms and uses color, contour, and pattern to evoke ideas and emotions rather than to make a scientific or instantaneous visual record. The emphasis on painting “what you see” therefore conflicts directly with the passage’s account of Gauguin’s break from Impressionism and his preference for a constructed, expressive image. Tate’s overview of Synthetism likewise describes the movement as synthesizing observed form with the artist’s feelings and aesthetic concerns. The Metropolitan Museum of Art’s discussion of Gauguin also notes his use of nonnaturalistic color and expressive design.

QUESTION NO: 18

If a person having Rh-negative blood is given Rh-positive blood by mistake, it will stimulate formation of:

A. Rh-antigens.

B. blood clots.

C. Rh-antibodies.

D. None of them.

ANSWER: C

Explanation:

Rh-antibodies is correct. Rh status depends principally on whether red blood cells express the Rh(D) antigen. A person with Rh-negative blood lacks this antigen. When Rh-positive donor red blood cells enter that person’s circulation, the recipient’s immune system can recognize the unfamiliar D antigen as foreign and become sensitized. This exposure stimulates an adaptive immune response, leading to production of antibodies directed against the Rh(D) antigen, commonly called anti-D or Rh antibodies. The first incompatible exposure may not cause an immediate severe reaction because antibody production takes time; however, sensitization is clinically important. On later exposure to Rh-positive red blood cells, preformed anti-D antibodies can bind the donor cells and contribute to hemolytic transfusion reactions. The same immune mechanism underlies Rh incompatibility in pregnancy, for which Rh-negative pregnant patients may receive Rh immune globulin to prevent sensitization. The Rh factor is an antigen carried on the transfused Rh-positive cells, whereas the recipient is

stimulated to form the corresponding antibodies. See the NCBI Bookshelf overview of the Rh blood group and the Merck Manual discussion of blood compatibility testing.

QUESTION NO: 19

Which part of the brain controls speech?

A. hypothalamus

B. cerebellum

C. occipital lobe

D. Broca's Area

ANSWER: D

Explanation:

Broca's Area is correct because it is a specialized cortical region that plays a central role in speech production. It is usually located in the inferior frontal gyrus of the dominant cerebral hemisphere, which is the left hemisphere for most people. This area coordinates the motor planning needed to transform intended language into articulated words, including the organized movements of the lips, tongue, larynx, and other structures used in speaking. Damage to Broca's Area can cause Broca aphasia, a language disorder characterized by slow, effortful, and nonfluent speech. People with this condition may generally understand spoken language relatively well but have substantial difficulty producing grammatically complete verbal responses. In introductory neuroscience and MCAT-style questions, "controls speech" commonly refers specifically to the production of spoken language, making Broca's Area the appropriate answer. Language function involves a network of brain regions rather than a single isolated structure, but Broca's Area is the classic and most directly associated location for speech expression. The National Institute on Deafness and Other Communication Disorders discusses aphasia and its effects on language production at https://www.nidcd.nih.gov/health/aphasia. A clinical overview of Broca aphasia is also available from StatPearls via NCBI Bookshelf.

QUESTION NO: 20

For much of the twentieth century, investigators treated fever chiefly as a troublesome accompaniment of infection. Because elevated temperature increases discomfort and can impose metabolic demands on a sick patient, the clinical impulse to lower it is understandable. Yet fever is not simply excess heat generated by an ailing body. It is a regulated change in the temperature at which the body attempts to maintain itself.

When immune cells encounter certain microbial products, they release signaling molecules that act, directly or indirectly, on the hypothalamus. The hypothalamus then raises the body's temperature set point. A person whose actual temperature lies below this newly established set point feels cold, constricts blood vessels in the skin, and may shiver. These responses produce and conserve heat until body temperature approaches the higher set point. When the set point later returns to normal, the same person may sweat and feel uncomfortably warm while the body dissipates heat.

This distinction helps explain why fever cannot be understood merely by measuring body temperature. Heat stroke, for example, may also produce a dangerously high temperature, but it results from excessive heat production or inadequate heat loss while the hypothalamic set point remains normal. The patient with heat stroke is not being directed to increase body temperature; the body's temperature has instead exceeded the level its regulatory mechanisms can control.

Whether fever benefits an infected organism remains a more difficult question. Moderate elevations in temperature can inhibit replication of some pathogens and can alter immune activity. But fever also increases oxygen consumption and may be harmful in patients with limited cardiopulmonary reserve. The appropriate clinical response therefore depends not on an assumption that all fever is either protective or destructive, but on the patient's condition and the cause of the elevated temperature.

Which of the following findings would most strongly support the passage's claim that fever can be beneficial during infection?

A. A pathogen reproduces more slowly at febrile temperatures than at normal body temperature.

B. A patient with heart failure consumes more oxygen during fever.

C. A patient's skin temperature rises during heat stroke.

D. Peripheral vasoconstriction occurs when ambient temperature falls.

ANSWER: A

Explanation:

A pathogen reproduces more slowly at febrile temperatures than at normal body temperature. The passage identifies inhibition of pathogen replication as one possible benefit of moderate fever. The other choices either describe a cost of fever or are unrelated to its possible protective role.

QUESTION NO: 21

Aerobic respiration is the major process used by oxygen- requiring organisms to generate energy. During respiration, glucose is metabolized to generate chemical energy in the form of ATP:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 36ATP$

The biochemical machinery necessary for cellular respiration is found in the mitochondria, small organelles scattered throughout the cytoplasm of most eukaryotic cells. The number of mitochondria per cell varies by tissue type and cell function.

Mitochondria are unusual in that they have their own genetic systems that are entirely separate from the cell's genetic material. However, mitochondrial replication is still dependent upon the cell's nuclear DNA to encode essential proteins required for replication. Despite this fact, mitochondria seem to replicate randomly, out of phase with both the cell cycle and other mitochondria.

The nature of the mitochondrial genome and protein synthesizing machinery has led many researchers to postulate that mitochondria may have arisen as the result of the ingestion of a bacterium by a primitive cell millions of years ago. It is postulated that the two may have entered into a symbiotic relationship and eventually became dependent on each another; the cell sustained the bacterium, while the bacterium provided energy for the cell. Gradually, the two evolved into the present-day eukaryotic cell, with the mitochondrion retaining some of its own DNA. This is known as the endosymbiotic hypothesis. Because mitochondrial DNA is inherited in a non-Mendelian fashion (mitochondria are inherited from the maternal parent, who supplies most of the cytoplasm to the fertilized egg), it has been used to look at evolutionary relationships among different organisms.

Which of the following mitochondrial genome characteristics differs most from the characteristics of the nuclear genome?

A. Mitochondrial DNA is a double-helix.

B. Some mitochondrial genes code for tRNA.

C. Specific mutations to mitochondrial DNA can be lethal to the organism.

D. Almost every base in mitochondrial DNA codes for a product.

ANSWER: D

Explanation:

Almost every base in mitochondrial DNA codes for a product is the best distinction because mitochondrial genomes are exceptionally compact relative to nuclear genomes. In humans, mitochondrial DNA is a small circular molecule of about 16.6 kilobases that contains genes for essential oxidative-phosphorylation components, transfer RNAs, and ribosomal RNAs. Its genes are tightly packed, with very little intergenic sequence and, in several places, overlapping or immediately adjacent coding regions. Although mitochondrial DNA does contain a noncoding control region needed for replication and transcription regulation, the great majority of its sequence is devoted directly to genes or gene-expression functions. This compact organization reflects the streamlined, bacterial-like history of mitochondria described by the endosymbiotic hypothesis.

In contrast, the nuclear genome is vastly larger and includes extensive noncoding DNA, such as introns, regulatory elements, repetitive sequences, and intergenic regions. Therefore, the predominance of functional, coding or gene-associated sequence in mitochondrial DNA represents the most substantial genomic contrast being tested. The

mitochondrial genome's size, gene content, and dense arrangement are summarized by the NCBI Bookshelf overview of mitochondrial DNA and the National Human Genome Research Institute's mitochondrial fact sheet.

QUESTION NO: 22

How many electrons can fit into the third shell of an atom?

A. 16

B. 4

C. 2

D. 18

ANSWER: D

Explanation:

The correct answer is 18. The maximum number of electrons that can occupy a principal electron shell is determined by the formula $2n^2$, where *n* is the principal quantum number of that shell. For the third shell, n = 3, so its maximum capacity is $2 \times 3^2 = 2 \times 9 = 18$ electrons. This shell contains the 3s, 3p, and 3d subshells, which respectively accommodate 2, 6, and 10 electrons. Together, these subshell capacities total 18 electrons. This is the theoretical maximum capacity of the third principal energy level; electron configurations of particular atoms may not fill all of these orbitals because electrons occupy lower-energy orbitals first. For an overview of electron configurations and shell/subshell structure, see Chemistry LibreTexts: Electron Configurations and OpenStax Chemistry 2e: Electron Configurations.

QUESTION NO: 23

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.

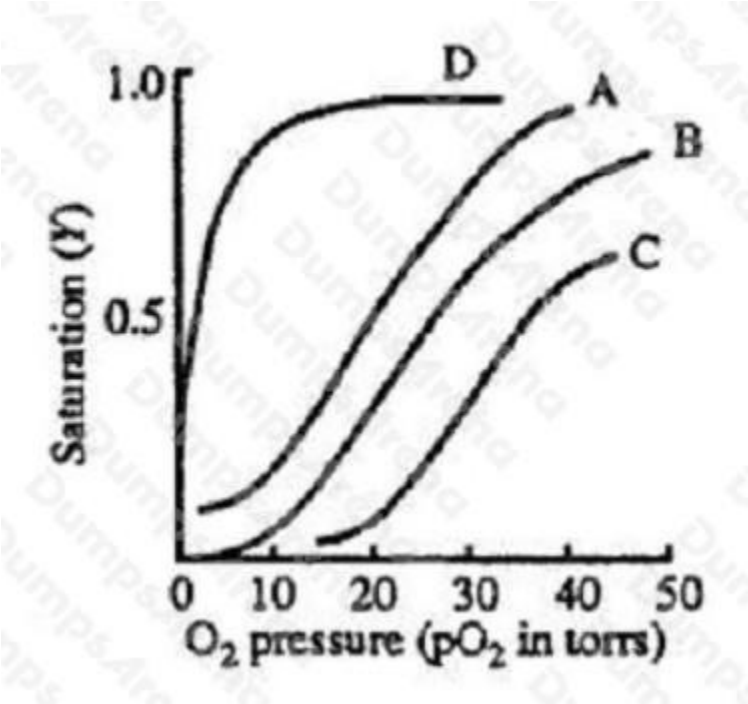


Figure 1

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.

The sigmoidal shape of the O2-dissociation curve of Hb is due to:

A. the effects of oxidation and reduction on the heme groups within the Hb molecule.

B. the concentration of carbon dioxide in the blood.

C. the fact that Hb has a lower affinity for than Mb.

D. the cooperativity in binding among the subunits of the Hb molecule.

ANSWER: D

Explanation:

The cooperativity in binding among the subunits of the Hb molecule is correct because hemoglobin is a tetramer with four oxygen-binding heme sites whose affinities are functionally linked. In the low-affinity, tense conformational state, initial oxygen binding is relatively less favorable. Binding of oxygen to one subunit promotes a conformational transition in the hemoglobin complex that increases the oxygen affinity of the remaining subunits. As oxygen partial pressure rises, this makes additional oxygen binding progressively easier, producing the steep middle portion of the saturation curve. At high oxygen partial pressure, most binding sites are occupied and the curve approaches a plateau. The combination of these low-, rapidly rising-, and plateau-regions gives hemoglobin its characteristic S-shaped, or sigmoidal, oxygen-dissociation curve. The same linked conformational behavior also promotes efficient oxygen unloading as oxygen pressure falls in peripheral tissues. This allosteric mechanism is physiologically valuable because it supports substantial oxygen loading in the lungs while allowing appreciable delivery to tissues over a relatively narrow range of oxygen pressures. A concise biochemical discussion of cooperative oxygen binding and hemoglobin conformational states is available in NCBI Bookshelf: Hemoglobin and Myoglobin. The relationship between cooperative binding and sigmoidal saturation behavior is also summarized by OpenStax Biology 2e: Proteins.

QUESTION NO: 24

The information coded on the mRNA is decoded into:

A. fats.

B. proteins.

C. amino acids.

D. carbohydrates.

ANSWER: B

Explanation:

mRNA is decoded into proteins. During translation, a ribosome reads the mRNA sequence in consecutive three-nucleotide codons. Each codon specifies an amino acid, or in particular cases signals termination of translation. Transfer RNAs carrying the corresponding amino acids recognize the codons through complementary anticodon pairing, and the ribosome links the delivered amino acids by peptide bonds. This creates a growing polypeptide chain, which folds and may undergo further processing to become a functional protein. Thus, although individual codons correspond to amino acids, the overall informational product produced by decoding an mRNA molecule is a protein (polypeptide). This flow of genetic information—from an RNA transcript to a protein—is the central process of translation. The National Human Genome Research Institute describes translation as the process in which cellular machinery reads mRNA to build proteins, and OpenStax explains that ribosomes use mRNA codons to assemble a polypeptide chain. See NHGRI: Translation and OpenStax Biology 2e: Protein Synthesis.

QUESTION NO: 25

A biochemist grows two cultures of yeast – one aerobically and the other anaerobically – and measures the amount of ATP produced by each culture. He finds that the aerobically-grown yeast produce about 18 times as much ATP as the anaerobically-grown yeast. These observations are consistent with the fact that in the aerobically grown yeast:

A. oxygen is converted into ATP.

B. oxygen is necessary to convert glucose into pyruvate.

C. oxygen is the final electron acceptor of the respiratory chain.

D. oxygen is necessary for the reduction of pyruvate into lactate.

ANSWER: C

Explanation:

oxygen is the final electron acceptor of the respiratory chain. This role explains why aerobic yeast can obtain much more ATP from each glucose molecule than anaerobic yeast. During aerobic metabolism, electrons captured in NADH and $FADH_2$ are transferred through the electron-transport chain in the inner mitochondrial membrane. The energy released during these transfers pumps protons across the membrane, establishing a proton-motive force. ATP synthase then uses that gradient to phosphorylate ADP, producing the large majority of ATP associated with aerobic respiration.

Oxygen accepts the low-energy electrons at the end of this chain and, together with protons, is reduced to water. By serving as the terminal electron acceptor, oxygen permits continual electron flow and permits NAD^+ and FAD to be regenerated for glycolysis, pyruvate oxidation, and the citric acid cycle. Consequently, glucose can be oxidized far more completely than under anaerobic conditions, accounting for the substantially greater ATP yield described. The precise ATP total can vary with organism and shuttle mechanisms, but the central principle remains that oxidative phosphorylation depends on oxygen as the terminal electron acceptor. See OpenStax Biology 2e: Oxidative Phosphorylation and NCBI Bookshelf: Oxidative Phosphorylation.

QUESTION NO: 26

A student conducts a chemical analysis of the components of a popular soft drink. The beverage label shows that the drink contains carbonated water, phosphoric acid, caffeine, and caramel color, but does not indicate the concentrations of these chemicals.

	Carbonic Acid	Phosphoric Acid
MW	62.03	98.00
mp (°C)	n/a	42.35
K_a	(1) 4.3×10^{-7} (2) 5.61×10^{-11}	(1) 7.52×10^{-4} (2) 6.23×10^{-8} (3) 2.2×10^{-13}
Formula	H_2CO_3	H_3PO_4

Table 1

Dissolved carbon dioxide will react reversibly with water to form carbonic acid. In an attempt to analyze the beverage composition, the student conducts the following experiments on a one liter sample of the beverage.

Experiment 1

The sample is placed in a sealed beaker cooled to 10° C and a vacuum is created in the space above the beverage. The gas pumped from this space is passed through a solution of BaCl2, producing a white precipitate. The process continues until no more precipitate forms. The precipitate is dried and found to have a mass of 9.5 grams.

Experiment 2

The remaining solution left in the sealed beaker is then titrated with 0.01 M NaOH to give the titration curve shown in Figure 1.

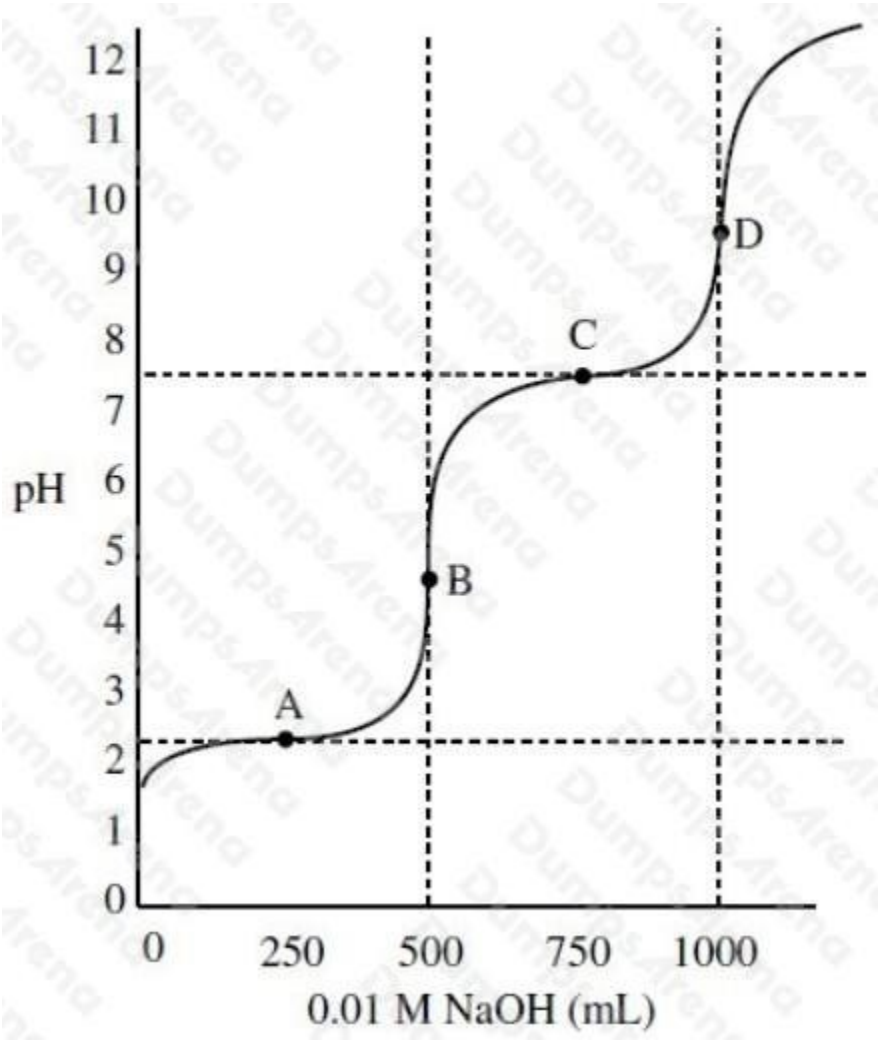


Figure 1

Which region of the graph in Figure 1 provides the best buffering around neutral pH?

A. A

B. B

C. C

D. D

ANSWER: C

Explanation:

The indicated region nearest neutral pH is correct because a buffer is most effective when appreciable amounts of a weak acid and its conjugate base are present together. During a titration, this condition occurs in a relatively shallow portion of the curve, centered near the acid's half-equivalence point. At that point, the Henderson–Hasselbalch relationship gives pH = pK_a, because the concentrations of conjugate base and weak acid are equal. Addition of a small amount of strong acid or base then changes their ratio only modestly, so the pH changes little.

The beverage residue contains phosphoric acid and its successive conjugate-base forms. Its relevant acid–base equilibrium produces a buffering region near pH 7, so the curve section identified in the answer is the one that best resists pH change around neutrality. The steep, near-vertical portions of a titration curve instead represent conditions in which a small addition of titrant causes a large pH change, not effective buffering. The relationship between buffer capacity, the half-equivalence point, and pK_a is described in OpenStax Chemistry 2e: Buffers. For phosphoric acid's stepwise dissociation behavior and pK_a values, see Chemistry LibreTexts: Polyprotic Acids.

QUESTION NO: 27

In the United States, breast cancer is the second leading cause of death for women, and as a result, the American Cancer Society, has recommended annual mammography screening for women age 40 years and older. It is estimated that the risk of mortality can be reduced through this procedure by approximately 20-25% during a ten-year period for women age 40 years and older.

In general, cancer screening behaviors have increased in the United States. According to the National Health Interview Survey, in 1987, approximately 29% of women age 40 years and older reported having had a mammogram in the last 2 years. By 2000, this increased to 70%. However, there are racial disparities, as fewer African American and Hispanic women have mammograms compared to their Caucasian female counterparts. Some studies have looked into these differences. Cultural factors seem to play a role in minority women obtaining fewer mammograms. Asian women, for example, do not like to discuss sensitive topics with strangers.

Prevention promotions have been designed to increase awareness for the need of breast cancer screening, particularly for women in racial and ethnic minority groups. An innovative breast cancer education program, called the Educational Intervention Asian Grocery Store-Based Education Program, was designed to target Asian women. Located in 20 different Asian grocery stores in communities, the cancer screening exhibits were placed at the entrances of the stores. As Asian women came into the grocery store, health information was passed out to Asian women. Even though only a small amount of women who were considered non-adherents to breast cancer screening ended up scheduling a screening, the study demonstrated an innovative culturally competent approach to health promotion.

Source: Adapted from G.R. Sadler, P.R. Beerman, K. Lee et al. “Promoting Breast Cancer Screening Among Asian American Women: The Asian Grocery Store Based Cancer Education Program.” Copyright 2012 Journal of Cancer Education.

After learning about the foot-in-the-door technique, what might a health promoter do so to promote Asian women to sign up for a mammogram appointment?

A. Give them a 15-minute lecture on the importance of early prevention.

B. Promote the cultural concept of “loss of face” by informing them that the sponsors of the Educational Intervention Asian Grocery Store-Based Education Program put in a lot of money into the program and will lose face if progress is not made.

C. Encourage them to take a free shopping bag that includes a box of tea bags and a brochure about mammograms.

D. Tell them that many other Asian women have signed up right on the spot.

ANSWER: C

Explanation:

“Encourage them to take a free shopping bag that includes a box of tea bags and a brochure about mammograms.” correctly applies the foot-in-the-door technique. This persuasion approach begins with a small, easy, low-pressure request that a person is likely to accept. Agreeing to that initial request can increase willingness to comply later with a larger, related request. Here, accepting a complimentary bag, tea, and educational brochure is a modest action that does not require the woman to disclose personal information, discuss a sensitive subject with a stranger, or commit immediately to screening. The brochure also creates an appropriate connection between the initial request and the eventual health behavior: arranging a mammogram. A health promoter could subsequently make the larger request—such as offering assistance scheduling an appointment—after this initial, nonthreatening interaction. This gradual approach is especially suitable for an outreach setting such as an Asian grocery store, where trust and comfort can be developed without confronting customers directly about an intimate health decision. Foot-in-the-door is a recognized compliance strategy in social psychology; research describes how compliance with an initial small request can promote compliance with a subsequent larger request. See the American Psychological Association Dictionary of Psychology and the original study by Freedman and Fraser.

QUESTION NO: 28

In the late nineteenth and early twentieth centuries, the public library became one of the most visible institutions in American civic life. Industrial fortunes supplied much of the money for library construction, but the resulting buildings were rarely simple gifts. Andrew Carnegie, the best-known library benefactor, typically required a town to provide a suitable site and to commit public funds annually for the library's maintenance. His grants thus depended upon a bargain: private capital would furnish the building, while local taxpayers would assume responsibility for the institution's continuing life.

This arrangement reflected Carnegie's general philosophy of philanthropy. He distrusted indiscriminate charity, which, he believed, could encourage dependency. A library, by contrast, gave citizens the means to improve themselves without prescribing the use they should make of it. The reader might consult a technical manual, a novel, a newspaper, or nothing at all. Yet the library's very openness made it an attractive civic symbol. It promised access to knowledge while requiring neither the discipline of a school nor the moral scrutiny associated with many charitable agencies.

The library was not, however, politically neutral. Decisions about which books to purchase, which languages to accommodate, and which groups could use reading rooms often exposed tensions within a community. Reformers praised libraries for educating immigrants and workers; critics sometimes feared that the same readers would encounter radical political ideas. In some towns, library trustees restricted controversial materials, thereby demonstrating that a public institution devoted to free inquiry could also serve prevailing local values.

Nevertheless, the rapid spread of libraries altered the meaning of civic responsibility. A town that accepted a grant was not merely acquiring a handsome building. It was accepting an obligation to support a shared resource year after year, even when enthusiasm for the original donation had faded. The durability of the library movement therefore rested less on the generosity of its benefactors than on the willingness of communities to convert a private gift into a public commitment.

Which of the following best states the main idea of the passage?

A. Public libraries endured because private philanthropy was joined to local civic obligation.

B. Public libraries were designed chiefly to protect workers from radical political influences.

C. Industrial philanthropists built libraries because schools failed to educate immigrants.

D. Public libraries became popular because they avoided all local political disputes.

ANSWER: A

Explanation:

Public libraries endured because private philanthropy was joined to local civic obligation. The passage discusses the terms of philanthropic grants, the social meaning of library access, and political controversies within libraries, but its concluding claim is that the movement depended on communities assuming ongoing responsibility for donated institutions.

QUESTION NO: 29

The mind, just like the body, has its needs. The needs of the body are the foundations of society; those of the mind are its amenities. While government and laws provide for the safety and wellbeing of men when they gather together, the sciences and the arts, which are less despotic but perhaps more powerful, spread garlands of flowers over the iron chains that bind them, stifle in them the sense for that original liberty for which they seem to have been born, cause them to love their own enslavement, and turn them into so-called “civilized people.” Necessity raised thrones; the sciences and the arts have strengthened them. O earthly powers: cherish talents and protect those who cultivate them. O civilized people, cultivate them: you happy slaves owe to them that delicate and refined taste of which you are so proud, that gentleness of character and urbanity of manner which make relations among you so amiable and easy – in other words, that semblance of all the virtues, none of which you actually possess…

…How pleasant it would be to live among us, if our external appearance were always a reflection of what is in our hearts, if decency were virtue, if our maxims served as our rules, and if true philosophy were inseparable from the title of philosopher! But so many qualities are seldom found together, and virtue hardly ever walks in such great pomp. Richness of adornment may be the mark of a man of taste, but a healthy, robust man is known by other signs: it is beneath the rustic clothes of a farmer, and not the gilt of a courtier, that strength and vigor of the body will be found. Ornamentation is just as foreign to virtue, which is the strength and vigor of the soul. The good man is an athlete who prefers to compete in the nude: he disdains all those vile ornaments which would hinder the use of his strength, ornaments which were for the most part invented only to hide some deformity.

Before art had molded our manners and taught our passions to speak an affected language, our customs were rustic but natural, and differences in conduct revealed clearly differences in character. Human nature, basically, was no better, but men found security in being able to see through each other easily, and this advantage, which we no longer appreciate, spared them many vices.

Now that more subtle refinements and more delicate taste have reduced the art of pleasing to set rules, a base and deceptive uniformity prevails in our behavior, and all minds seem to have been cast in the same mold. Incessantly politeness

and propriety make demands on us, and incessantly we follow usage but never our own inclinations. We no longer dare to appear as we are, and under this perpetual constraint, the men who form this herd called society, when placed in the same circumstances, will all act similarly unless stronger motives direct them to do otherwise. Therefore we will never know well those with whom we deal, for to know our friends we will have to wait for some crises to arise – which is to say that we will have to wait until it is too late, as it is for these very crises that it is essential to know one's friends well.

What vice would not accompany this uncertainty? No more sincere friendships, no more genuine esteem, no more well-based confidence. Suspicion, offenses, fears, coldness, reserve, hatred and betrayal will constantly hide under the same false veil of politeness, under that much touted urbanity which we owe to the enlightenment of our times. The name of the Master of the Universe will no longer be profaned by swearing, but insulted by blasphemies that will not offend our scrupulous ears. Men will not boast of their own merits, but belittle those of others. An enemy will not be crudely insulted, but adroitly slandered. National hatreds will die, but so will patriotism. A dangerous skepticism will take the place of the scorning of ignorance. Some excesses will be forbidden, some vices dishonored, but others will be dignified with the name of virtues, and one must either have them or feign them. Let those who want to praise the sobriety of the sages of our time do so; as for me, I see in it only a refinement of intemperance that is as unworthy of my praise as their hypocritical simplicity.

According to the tone and content of the passage, which statement best reflects the author's opinion of the purpose of the sciences and the arts?

A. They are necessary for the safety and well-being of mankind.

B. They interfere with responsive action and honest communication.

C. They reinforce the sense of "original liberty" that is present in all men.

D. They have molded our reactions into predictable but essential forms.

ANSWER: B

Explanation:

"They interfere with responsive action and honest communication" best captures the author's strongly critical view of the sciences and arts. He portrays them not as forces that improve human character, but as refinements that teach people to conceal their genuine thoughts, passions, and motives beneath polished manners. The passage contrasts an earlier, "rustic but natural" condition—in which differences in behavior made character readily visible—with a civilized condition governed by artificial rules of pleasing, politeness, and propriety. Because people follow social usage rather than their own inclinations, their conduct becomes uniform and deceptive; consequently, others cannot know them well enough to establish sincere friendship or well-founded trust. In this sense, the arts and sciences obstruct candid expression and prevent people from responding naturally and directly to one another. The author's imagery of ornamental coverings reinforces this point: embellishment hides deformity rather than revealing strength or virtue. This argument reflects Jean-Jacques Rousseau's critique in *Discourse on the Sciences and Arts*, which associates cultural refinement with moral corruption and loss of authenticity. See the text at Project Gutenberg and background on the work at Stanford Encyclopedia of Philosophy.

QUESTION NO: 30

Which of these is NOT true about ultrasound waves?

A. The medium (type of tissue) affects the propagation speed.

B. If frequency increases, wavelength increases as well.

C. The resolution of images depends on the wavelength.

D. Propagation speed is higher through solids than through liquids.

ANSWER: B

Explanation:

"If frequency increases, wavelength increases as well." is the statement that is not true. For any wave, propagation speed equals frequency multiplied by wavelength: $v = f\lambda$. In a given medium, ultrasound speed is determined principally by the medium's mechanical properties and is treated as approximately constant for this relationship. Therefore, wavelength must

vary inversely with frequency: when frequency rises, wavelength becomes shorter; when frequency falls, wavelength becomes longer. For example, using the commonly assumed soft-tissue sound speed of about 1,540 m/s, a 2 MHz ultrasound wave has a wavelength of approximately 0.77 mm, whereas a 4 MHz wave has a wavelength of approximately 0.39 mm. This inverse relationship is fundamental to diagnostic ultrasound and helps explain why higher-frequency probes can provide finer spatial detail, although their useful imaging depth is often reduced by greater attenuation. The relationship between wave speed, frequency, and wavelength is described in OpenStax College Physics: Wave Speed. Ultrasound physics and the role of frequency in image resolution are also summarized by StatPearls: Ultrasound Imaging.

QUESTION NO: 31

In the United States, breast cancer is the second leading cause of death for women, and as a result, the American Cancer Society, has recommended annual mammography screening for women age 40 years and older. It is estimated that the risk of mortality can be reduced through this procedure by approximately 20-25% during a ten-year period for women age 40 years and older.

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Source: Adapted from G.R. Sadler, P.R. Beerman, K. Lee et al. “Promoting Breast Cancer Screening Among Asian American Women: The Asian Grocery Store Based Cancer Education Program.” Copyright 2012 Journal of Cancer Education.

How must promoters of health behaviors communicate with a high-context culture like the Asian?

A. Communicate directly with participants, using informal language mostly, and with little emphasis on nonverbal cues

B. Assume what is being said is what is actually meant

C. Get to the point of the discussion as quickly as possible

D. Employ formal language, rely on nonverbal cues, and be comfortable with silences

ANSWER: D

Explanation:

“Employ formal language, rely on nonverbal cues, and be comfortable with silences” is the best answer because high-context communication conveys substantial meaning through the relationship, social setting, tone, timing, status, and nonverbal behavior rather than through fully explicit verbal statements alone. In this framework, pauses can communicate respect, consideration, or an opportunity to reflect; they need not be filled immediately. A health promoter should therefore establish trust, attend carefully to verbal and nonverbal feedback, and present sensitive information in a respectful manner that does not force an immediate personal disclosure or decision.

For a breast-screening intervention, this approach supports culturally responsive communication: using familiar community settings, allowing time for questions and reflection, and recognizing that interpersonal rapport can be as important as the literal wording of a health message. The grocery-store program described in the passage reflects this principle by bringing education into a trusted, accessible community environment. Although no communication style applies identically to every individual within a broad population, adapting communication to participants’ preferences and context is a core component of culturally and linguistically appropriate care. See the HHS National CLAS Standards and the National Academies discussion of effective health communication.

QUESTION NO: 32

The lead-acid battery, also called a lead storage battery, is the battery of choice for starting automobiles. It contains 6 cells connected in series, each composed of a lead oxide cathode “sandwiched” between 2 lead anodes. Insulating separators are placed between the electrodes to prevent internal short-circuits. Aqueous sulfuric acid is the electrolyte.

When the battery is being discharged, the following reaction takes place:

Pb(s) + PbO2(s) + 2H2SO4 (aq) → 2PbSO4 (s) + 2H2O Reaction 1

The electrode reactions, both written as reductions, are shown in Table 1.

Table 1

Half-reaction	E°(V)
$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O$	1.69
$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$	−0.36

As a car operates, the battery is recharged by electricity produced by the car’s alternator, an AC generator whose ultimate power source is the car’s internal combustion engine. In spite of this, batteries eventually lose their power. The battery is said to be “dead” when Reaction 1 has proceeded completely to the right.

How many cells would be required to produce a 20-volt lead-acid battery of the type described in the passage?

A. 5

B. 10

C. 15

D. 20

ANSWER: B

Explanation:

The correct answer is **10**. The two tabulated electrode potentials are standard reduction potentials, so the voltage of one discharging lead-acid cell is found by subtracting the anode’s reduction potential from the cathode’s reduction potential: 1.69 V − (−0.36 V) = 2.05 V. This positive result is the electromotive force for the spontaneous discharge reaction. Standard cell-potential calculations use reduction potentials in exactly this way: E°cell = E°cathode − E°anode. See OpenStax Chemistry: The Cell Potential.

Cells connected in series have additive voltages because the same charge passes through each cell while each cell contributes its own potential rise. Dividing the target voltage by the approximate voltage supplied by one cell gives 20 V ÷ 2.05 V ≈ 9.76. A whole number of cells is required, and ten cells produce approximately 20.5 V, conventionally described as a 20-volt battery. The familiar automotive six-cell arrangement similarly produces about 12 V from cells with a nominal voltage near 2 V each. This series-voltage principle is also summarized by Encyclopaedia Britannica’s lead-acid battery overview.

QUESTION NO: 33

Muzak, the intentionally unobtrusive music that most people associate with elevators and dentists’ waiting rooms, represents the paradoxical success story of a product designed to be ignored. Although few people admit to enjoying its blandly melodic sounds, Muzak reaches over 100 million listeners in 14 countries and has played in the White House, the Apollo lunar spacecraft, and countless supermarkets, offices, and factories. This odd combination of criticism and widespread acceptance is not surprising, however, when one considers that Muzak is not created for the enjoyment of its listeners: rather, its purpose is to modify physiological and psychological aspects of an environment.

In the workplace, Muzak is credited with increasing both productivity and profitability. Research into the relationship between music and productivity can be traced to the earliest days of the Muzak Corporation. Developed by a military officer in 1922 as a way of transmitting music through electrical wires, Muzak blossomed in the 1930's following a study which reported that people work harder when they listen to certain kinds of music. Impressed by these findings, the BBC began to broadcast music in English munitions factories during World War II in an effort to combat fatigue. When workers assembling weapons increased their output by 6 percent, the U.S. War Production Board contracted the Muzak Corporation to provide uplifting music to American factories. Today, the corporation broadcasts its "Environmental Music" to countless businesses and institutions throughout the world. And while most people claim to dislike Muzak's discreet cadences, it seems to positively influence both productivity and job satisfaction.

Researchers speculate that listening to Muzak and other soft music improves morale and reduces stress by modifying our physiology. Physiological changes such as lowered heart rate and decreased blood pressure have been documented in hospital studies testing the effect of calming music on cardiac patients. In addition, certain kinds of music seem to effect one's sense of emotional, as well as physical, well being. It is just this sort of satisfaction which is thought to result in increased performance in the workplace. In a study of people performing repetitive clerical tasks, those who listened to music performed more accurately and quickly than those who worked in silence; those who listened to Muzak did better still. Moreover, while Muzak was conceived as a tool for productivity, it also seems to influence a business' profitability. In an experiment in which supermarket shoppers shopped to the mellow sounds of Muzak, sales were increased by as much as 12 percent.

What makes Muzak unique is a formula by which familiar tunes are modified and programmed. Careful instrumentation adds to an overall sound that is neither monotonous nor rousing. But it is the precisely timed programming that separates Muzak from other "easy listening" formats. At the core of the programming is the concept of the "Stimulus Progression". Muzak programs are divided into quarter-hour groupings of songs, and are specifically planned for the time of day at which they will be heard. Each composition is assigned a mood rating between 1 and 6 called a stimulus value; a song with a rating of 2, for example, is slower and less invigorating than one with a value of 5. Approximately six compositions with ascending stimulus values play during any given quarter hour; each 15-minute segment ends in silence. Each segment of a 24-hour program is carefully planned. Segments that are considered more stimulating air at 11 a.m. and 3 p.m. (the times when workers typically tire), while more soothing segments play just after lunchtime and towards the end of the day, when workers are likely to be restless.

From the point of view of management, then, Muzak is a useful tool in the effort to maximize both productivity and profits. However, some people object to its presence, labeling it as a type of unregulated air pollution. Still others see it as an Orwellian nightmare, a manipulation of the subconscious. But Muzak's effectiveness seems to lie in the fact that most people never really listen to it. While it may be true that no one actually likes this carefully crafted aural atmosphere, many simply ignore it, allowing its forgettable sounds to soften the contours of the day.

It can be inferred from the statements in the passage that the author regards Muzak as:

A. a paradoxical phenomenon.

B. an unnecessary evil.

C. a violation of privacy.

D. a pleasurable diversion.

ANSWER: A

Explanation:

The author regards Muzak as **a paradoxical phenomenon.** The passage frames Muzak as successful precisely because it is designed not to command attention. Its broad use in workplaces, stores, institutions, and even notable settings contrasts with the claim that few people enjoy it or consciously listen to it. The author repeatedly emphasizes this tension: Muzak receives criticism and is often described as bland, yet it is widely accepted and is presented as having measurable practical effects on productivity, morale, accuracy, speed, and sales. The concluding description—that people "simply ignore it" while its sounds "soften the contours of the day"—preserves a detached, observational tone rather than a strongly approving or condemning one. Thus, the central inference is that the author finds Muzak unusual because a product people do not especially like can nevertheless be pervasive and effective by operating in the background. This answer follows the reading-comprehension principle of identifying the author's overall attitude from repeated framing and concluding emphasis, rather than treating viewpoints attributed to outside critics as the author's own. See the AAMC overview of MCAT preparation and the Khan Academy CARS resources for related passage-analysis guidance.

QUESTION NO: 34

Before birth, the rodent brain is sexually undifferentiated. It is only in the first few days following birth, during a period referred to as the critical period, that the rodent brain differentiates along male or female lines. The hormone testosterone plays a critical role in this development. Specifically, sexual differentiation is determined by the presence of estradiol, an estrogen derivative of testosterone, in certain areas of the brain. Testosterone is converted to estradiol in critical brain cells that contain the enzyme aromatase.

To study the effects of testosterone on the neonatal rodent brain, the following experiments were conducted:

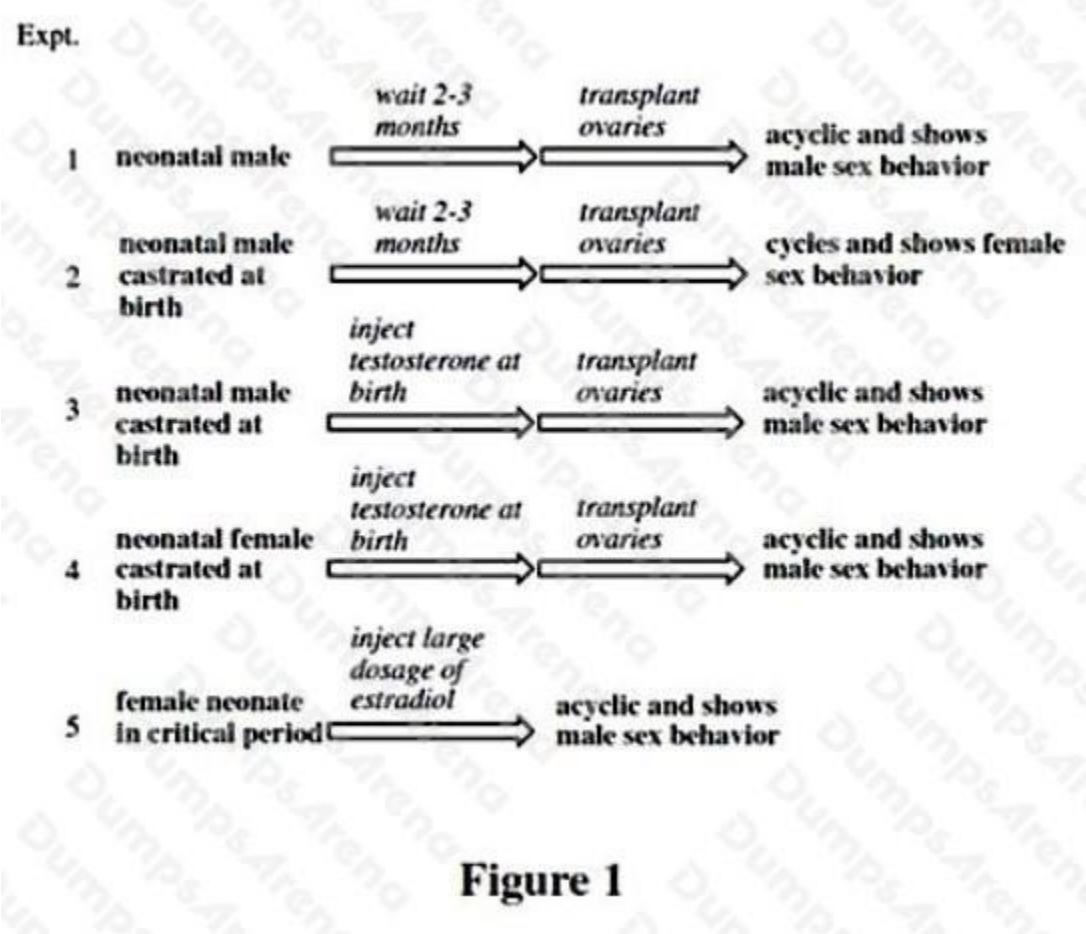


Figure 1

The above research, combined with additional studies, concluded that testosterone has two “organizational” effects on the male rodent brain:

Defeminization

Moderate levels of testosterone-derived estradiol during the critical period are sufficient for defeminization of the brain. Defeminization of the rodent brain results in loss of estrogen positive feedback on LH and FSH secretion and the ensuing loss of cyclicity, as well as loss of female sex behavior.

Masculinization

High levels of estradiol due to high levels of testosterone during the critical period results in masculinization of the brain. Masculinization leads to the induction of male sex behavior including antagonism towards other males and the mounting of females.

A researcher proposes that very low doses of estradiol are required for induction of female sex behavior and cyclicity in the rodent brain. Which of the following observations would best support this hypothesis?

A. Female neonates injected with the anti-estrogen tamoxifen are acyclic and show neither male nor female sex behavior.

B. Female neonates lacking the aromatase enzyme develop normally.

C. Female neonates injected with large doses of estradiol are acyclic and show male sex behavior.

D. Male neonates injected with low dosages of estradiol develop normally.

ANSWER: A

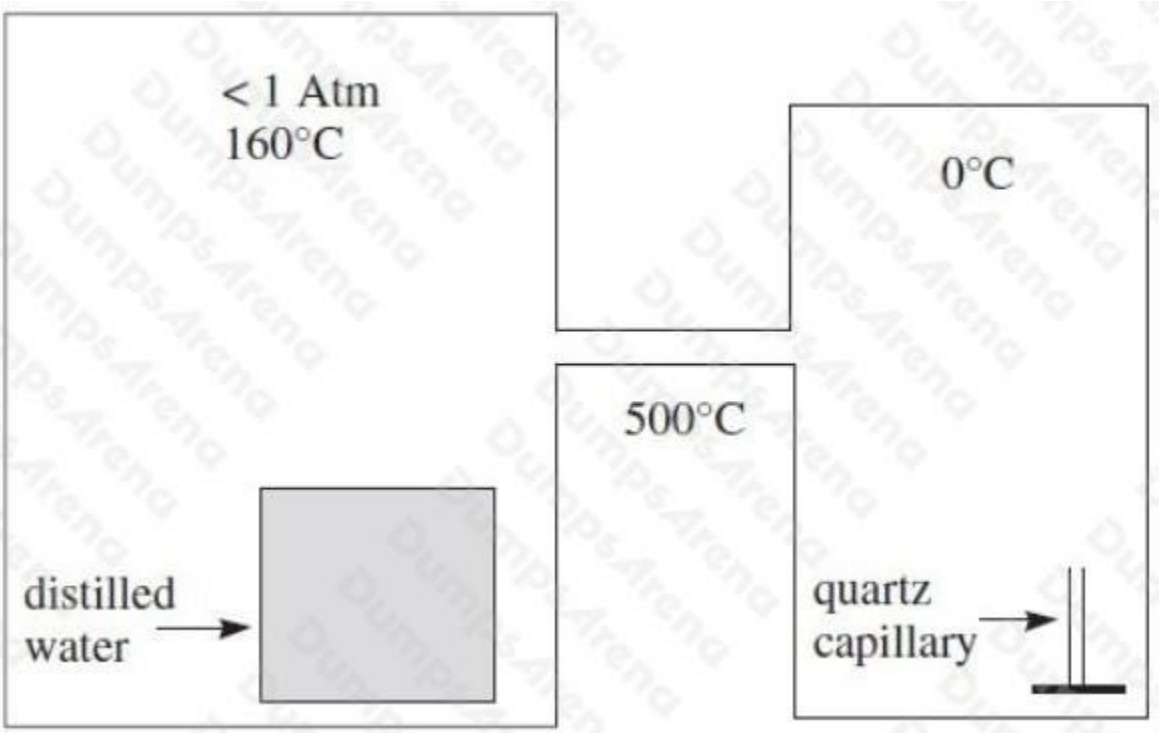
Explanation:

“Female neonates injected with the anti-estrogen tamoxifen are acyclic and show neither male nor female sex behavior.” best supports the proposal because it tests the consequence of blocking estrogenic signaling during the developmental window in which estradiol is proposed to organize female-typical reproductive function. If even a very low estradiol signal is necessary to establish female sex behavior and cyclicity, preventing that signal should leave female neonates unable to develop those outcomes. The observation supplies exactly that predicted result: absence of cyclicity and absence of female sex behavior. The simultaneous absence of male sex behavior is also consistent with the passage’s distinction between the relatively low estradiol exposure proposed for female development and the high estradiol exposure associated with masculinization. Thus, this finding directly supports a requirement for estradiol at low levels, rather than merely showing an effect of high estradiol exposure. Estradiol can act during sensitive developmental periods to organize neural circuits and later reproductive physiology; aromatization of testosterone to estradiol is a well-established mechanism in sexual differentiation of many rodent brain regions. See the NCBI Bookshelf overview of reproductive endocrinology and this PubMed review of steroidal programming of sexual differentiation.

QUESTION NO: 35

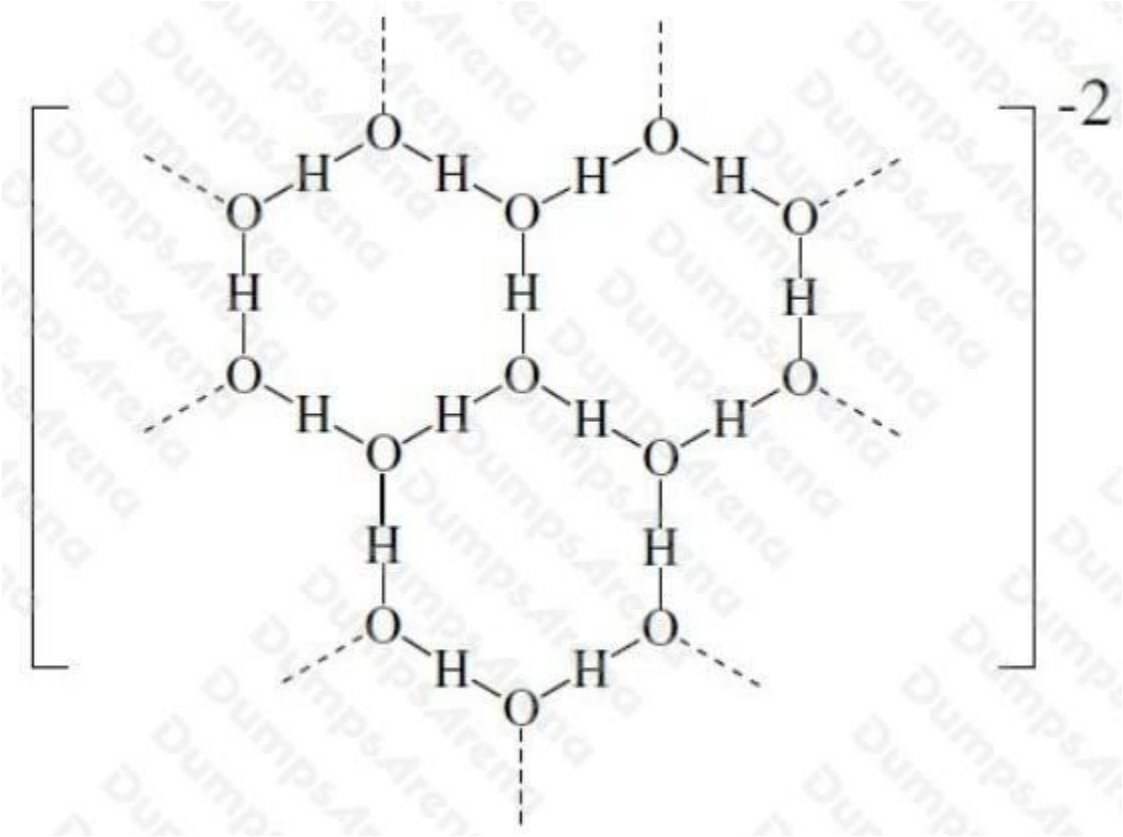
In 1965, Boris Deryagin reported the discovery of an unusual substance formed during the condensation of water vapor in quartz capillaries. The material, called poly-water, appeared to be a polymer of water monomers and differed from normal water in a number of ways. It had a freezing point of −40° C and solidified into a glass-like solid with substantially less volumetric expansion than that of ordinary water upon freezing. It had a density 40% greater than water and a refractive index of 1.48.

An intricate apparatus was used to produce the poly-water. Ordinary distilled water was placed in a chamber held at 160° C with pressure below atmospheric pressure. This chamber was connected to a second chamber by a tube held at 500° C in order to prevent the passage of liquid water. The second chamber was held at 0° C and contained a drawn quartz capillary in which the water vapor condensed, forming poly-water.



Hypothesis 1

Deryagin proposed that polywater was a polymer of water monomers arranged in a network of hexagonal units. The polymerization was catalyzed by the silicate surface of the quartz capillary.



Proposed Structure of Polywater

Hypothesis 2

Another researcher was skeptical. Analysis indicated that polywater was merely a solution of water and dissolved particles including silicon, carbon dioxide, and substantial concentrations of ions Na+ and Cl−. These contaminants dissolved from the quartz capillary and from materials used in the apparatus.

(constants for normal water : density = 1 g/cm3 , index of refraction = 1.33, freezing point depression constant Kf = 1.86° Cm−1)

According to the passage, polywater has all of the following properties EXCEPT:

A. light entering polywater from air will bend more towards the normal than light entering normal water.

B. polywater can be produced in a variety of conditions.

C. 1 µg of water has a larger volume than 1 µg of polywater, at room temperature.

D. polywater exists in the liquid state at 0° C.

ANSWER: B

Explanation:

“polywater can be produced in a variety of conditions.” is the correct EXCEPT choice because the passage provides no evidence that its production occurs under varied conditions. Instead, it describes one highly specific and carefully controlled procedure: distilled water is heated to 160° C under reduced pressure, its vapor passes through a tube maintained at 500° C, and then it condenses in a drawn quartz capillary kept at 0° C. The passage calls this setup an “intricate apparatus,” underscoring that the reported formation depended on particular temperatures, pressure conditions, vapor transport, and the quartz capillary surface. Moreover, the first hypothesis specifically proposes that the silicate surface of the quartz catalyzes formation, making that material an important feature of the stated method rather than evidence of broad producibility. The claim that polywater can be made under a variety of conditions therefore is not a property reported or supported by the passage. This question tests close reading: conclusions must be limited to the experimental observations and conditions explicitly supplied, rather than extending them to untested conditions. For general guidance on interpreting experimental results within the limits of the reported procedure, see OpenStax Chemistry: The Scientific Method and NIH: Reproducibility and Replicability in Science.

QUESTION NO: 36

Historically, two different methods have been used to estimate the fluid pressure in capillary beds.

Method 1

A glass pipette is inserted into the capillary. The level of blood rising in the pipette is measured and used to calculate the pressure. Alternatively, an inert fluid of density ρ can be placed in the pipette and its height h can be measured. The pressure in the capillary is given by ρgh, where g is the acceleration due to gravity.

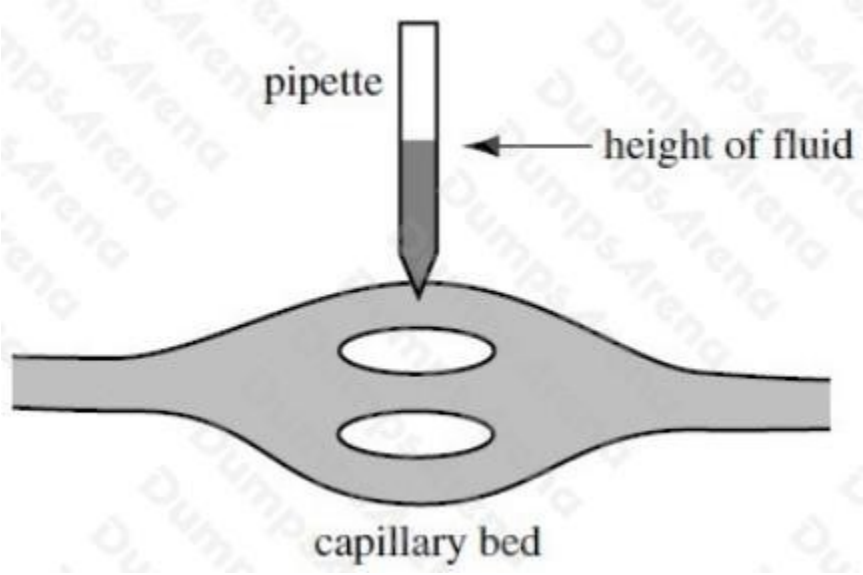


Figure 1

Method 2

The pressure can be measured indirectly in the following way. A section of gut tissue is removed from a specimen and placed on a beam balance. Blood is circulated through the tissue by a pump. The arterial pressure is then decreased. This leads to a decrease in the capillary hydrostatic pressure in the gut capillaries. The constant osmotic pressure of plasma proteins in the capillary causes absorption of fluid from the gut section which will decrease its weight. To prevent a change in the weight of the gut section, the venous pressure is increased. This tends to increase the capillary pressure, reducing the flow of fluid from the gut tissue into the capillaries. The capillary pressure is thus held constant (and the balance kept level) as the arterial pressure is decreased and the venous pressure increased. The arterial and venous pressures meet at the capillary pressure being measured.

(Π = MRT, where Π is the osmotic pressure, M the molarity of the solutes, R the universal gas constant, and T the temperature in Kelvin.)

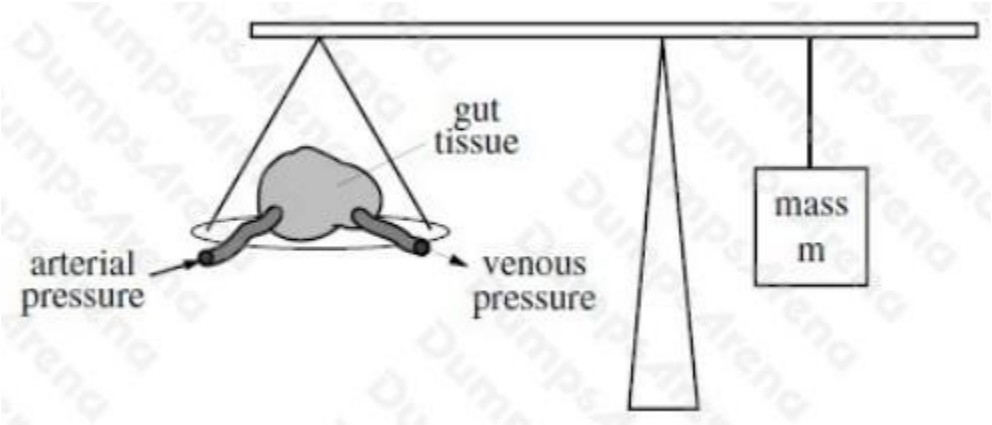
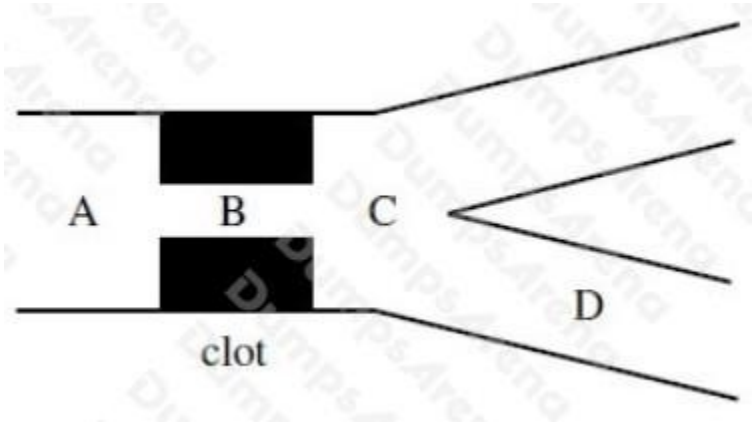


Figure 2

An arteriole is almost completely blocked by a blood clot as shown below. At which point will the velocity of blood flow be the greatest? (Assume ideal laminar flow throughout.)



A. A

B. B

C. C

D. D

ANSWER: B

Explanation:

The point at the clot-induced narrowing has the greatest blood-flow velocity. Under the stated ideal-flow assumption, blood can be treated as an incompressible fluid moving in steady flow. Conservation of mass then requires the volume flow rate to remain constant along one continuous vessel segment. This relationship is expressed by the continuity equation, $A_1v_1 = A_2v_2$, in which A is cross-sectional area and v is average flow velocity. Therefore, velocity varies inversely with cross-sectional area: when the open lumen becomes extremely narrow because of the clot, the same volume of blood per unit time must pass through a much smaller area, so its linear velocity rises substantially.

This conclusion follows from the question's instruction to assume ideal laminar flow; the relevant comparison is the available cross-sectional area at each labeled location, rather than pressure alone. After the vessel divides, flow is distributed between branches, but the severe local constriction remains the smallest effective passageway and consequently produces the maximum velocity. The continuity principle for incompressible fluid flow is summarized by OpenStax College Physics: Flow Rate and Velocity. A complementary discussion of the continuity equation in biological fluid systems appears in NCBI Bookshelf: Physiology, Blood Flow.

QUESTION NO: 37

The mind, just like the body, has its needs. The needs of the body are the foundations of society; those of the mind are its amenities. While government and laws provide for the safety and wellbeing of men when they gather together, the sciences and the arts, which are less despotic but perhaps more powerful, spread garlands of flowers over the iron chains that bind them, stifle in them the sense for that original liberty for which they seem to have been born, cause them to love their own enslavement, and turn them into so-called "civilized people." Necessity raised thrones; the sciences and the arts have strengthened them. O earthly powers: cherish talents and protect those who cultivate them. O civilized people, cultivate them: you happy slaves owe to them that delicate and refined taste of which you are so proud, that gentleness of character and urbanity of manner which make relations among you so amiable and easy – in other words, that semblance of all the virtues, none of which you actually possess…

…How pleasant it would be to live among us, if our external appearance were always a reflection of what is in our hearts, if decency were virtue, if our maxims served as our rules, and if true philosophy were inseparable from the title of philosopher! But so many qualities are seldom found together, and virtue hardly ever walks in such great pomp. Richness of adornment may be the mark of a man of taste, but a healthy, robust man is known by other signs: it is beneath the rustic clothes of a farmer, and not the gilt of a courtier, that strength and vigor of the body will be found. Ornamentation is just as foreign to virtue, which is the strength and vigor of the soul. The good man is an athlete who prefers to compete in the nude: he disdains all those vile ornaments which would hinder the use of his strength, ornaments which were for the most part invented only to hide some deformity.

Before art had molded our manners and taught our passions to speak an affected language, our customs were rustic but natural, and differences in conduct revealed clearly differences in character. Human nature, basically, was no better, but men found security in being able to see through each other easily, and this advantage, which we no longer appreciate, spared them many vices.

Now that more subtle refinements and more delicate taste have reduced the art of pleasing to set rules, a base and deceptive uniformity prevails in our behavior, and all minds seem to have been cast in the same mold. Incessantly politeness and propriety make demands on us, and incessantly we follow usage but never our own inclinations. We no longer dare to appear as we are, and under this perpetual constraint, the men who form this herd called society, when placed in the same circumstances, will all act similarly unless stronger motives direct them to do otherwise. Therefore we will never know well those with whom we deal, for to know our friends we will have to wait for some crises to arise – which is to say that we will have to wait until it is too late, as it is for these very crises that it is essential to know one's friends well.

What vice would not accompany this uncertainty? No more sincere friendships, no more genuine esteem, no more well-based confidence. Suspicion, offenses, fears, coldness, reserve, hatred and betrayal will constantly hide under the same false veil of politeness, under that much touted urbanity which we owe to the enlightenment of our times. The name of the Master of the Universe will no longer be profaned by swearing, but insulted by blasphemies that will not offend our scrupulous ears. Men will not boast of their own merits, but belittle those of others. An enemy will not be crudely insulted, but adroitly slandered. National hatreds will die, but so will patriotism. A dangerous skepticism will take the place of the scorning of ignorance. Some excesses will be forbidden, some vices dishonored, but others will be dignified with the name of virtues, and one must either have them or feign them. Let those who want to praise the sobriety of the sages of our time do so; as for me, I see in it only a refinement of intemperance that is as unworthy of my praise as their hypocritical simplicity.

The author of this passage would most likely have the greatest respect for a person who:

A. is deterred from acting on his own inclinations by the needs of society.

B. does not dilute his natural reactions through the artifice of correct behavior.

C. exhibits his refinement through elaborate clothing and conversation.

D. boasts of his own merit rather than belittling that of others.

ANSWER: B

Explanation:

The author would most respect a person who "does not dilute his natural reactions through the artifice of correct behavior." The passage treats cultivated politeness, refinement, and prescribed social manners as forces that conceal rather than express the self. The author longs for a condition in which outward appearance reflects what people genuinely feel, conduct transparently reveals character, and individuals are not compelled to follow social usage instead of their own inclinations. In that condition, people could know one another before a crisis exposes their true motives. The favored person therefore preserves natural, candid responses rather than reshaping them to satisfy rules of pleasing behavior. This preference follows the passage's central contrast between virtue as inner strength and ornament as a superficial covering that can hide moral deformity. The author's language closely reflects Jean-Jacques Rousseau's critique of the corrupting effects of arts, sciences, and fashionable civility in his *Discourse on the Arts and Sciences*. A full translation is available from Project Gutenberg; useful philosophical context appears in the Stanford Encyclopedia of Philosophy.

QUESTION NO: 38

A researcher injects a fluorescent tracer into a capillary bed and observes that the tracer rapidly appears in the surrounding interstitial fluid. The tracer is small, uncharged, and lipid soluble.

Which of the following mechanisms most likely accounts for its movement into the interstitial fluid?

A. Simple diffusion through endothelial cell membranes.

B. Primary active transport by endothelial cells.

C. Receptor-mediated endocytosis followed by exocytosis.

D. Filtration driven by osmotic pressure alone.

ANSWER: A

Explanation:

Simple diffusion through endothelial cell membranes. Small, uncharged, lipid-soluble molecules can dissolve in the phospholipid bilayers of capillary endothelial cells and move down their concentration gradients. This process does not require ATP, a carrier protein, or vesicular transport. In contrast, large proteins and many polar solutes cross capillary walls less freely.

QUESTION NO: 39

Artificial kidneys have been used for almost 50 years to treat patients with different forms of renal failure. The artificial kidney (dialysis machine) removes unwanted substances from the blood by diffusion. A patient's blood is passed through channels bounded by a porous, semi-permeable membrane that allows the free diffusion in both directions of all plasma constituents except the plasma proteins. Erythrocytes and other cellular components of blood cannot pass through the membrane. The other side of the membrane is exposed to the dialyzing fluid which carries away the unwanted materials.

If the concentration of a material in the blood is greater than in the dialyzing fluid, there will be a net flow of the material from the plasma to the dialyzing fluid. If the concentration of a material in the blood is less than in the dialyzing fluid, there will be a net flow of the material from the dialyzing fluid into the blood. The composition of normal plasma, plasma in an individual suffering renal failure, and dialyzing fluid are shown in Table 1.

Constituent	Normal Plasma (mEq/L)	Plasma w/ renal failure (mEq/L)	Dialyzing Fluid (mEq/L)
Na^+	142	142	133
K^+	5	7	1.0
Cl^-	107	107	105
HCO_3^-	27	14	35.7
Urate	0.3	2	0
Constituent	**Normal Plasma (mg/dl)**	**Plasma w/ renal failure (mg/dl)**	**Dialyzing Fluid (mg/dl)**
Glucose	100	100	125
Urea	26	200	0
Creatinine	1	6	0

Table 1

Dialysis replaces some functions of the kidneys and attempts to correct the effects of renal failure. For example, patients with renal failure develop acidosis due to a buildup of metabolically produced acids in the circulation. Without dialysis, the pH of the blood will drop and coma may occur. Dialyzing fluid contains a relatively high concentration of bicarbonate which diffuses into the circulation and neutralizes the acid.

Healthy kidneys secrete the hormone renin in response to decreased arterial pressure. Renin secretion leads to aldosterone secretion by the adrenal cortex. The body would most likely respond to ingestion of a large volume of isotonic solution by:

A. decreasing renin secretion and increasing sodium and water reabsorption.

B. decreasing renin secretion and decreasing sodium and water reabsorption.

C. increasing renin secretion and increasing sodium and water reabsorption.

D. increasing renin secretion and decreasing sodium and water reabsorption.

ANSWER: B

Explanation:

The correct response is **"decreasing renin secretion and decreasing sodium and water reabsorption."** Ingesting a large volume of isotonic fluid expands extracellular fluid volume and tends to increase effective arterial blood volume and arterial pressure. The kidney responds to this volume/pressure expansion by reducing renin release from juxtaglomerular cells. Because renin initiates the renin-angiotensin-aldosterone system, lower renin activity reduces formation of angiotensin II and subsequently reduces aldosterone secretion by the adrenal cortex.

Aldosterone normally promotes sodium reabsorption in the distal nephron, and water retention accompanies sodium retention when water permeability and physiologic conditions permit. Therefore, reduced aldosterone signaling decreases renal sodium reabsorption and promotes natriuresis; the associated reduction in water reabsorption promotes increased water excretion. This compensatory renal response helps return extracellular volume and blood pressure toward normal after an acute isotonic volume load. The overall sequence is volume expansion, reduced renin-angiotensin-aldosterone activity, and reduced sodium and water conservation.

For an overview of renin release and its role in the renin-angiotensin-aldosterone system, see NCBI Bookshelf: Renin-Angiotensin-Aldosterone System. Renal regulation of sodium balance and extracellular fluid volume is also summarized in the NCBI Bookshelf review of renal physiology.

QUESTION NO: 40

A diploid cell enters meiosis with two homologous pairs of chromosomes. During meiosis I, homologous chromosomes separate normally. During meiosis II, sister chromatids of one chromosome fail to separate in one of the two cells.

Which of the following best describes the resulting gametes?

A. Four normal gametes.

B. Two normal gametes, one gamete with an extra chromosome, and one gamete missing that chromosome.

C. Two gametes with an extra chromosome and two gametes missing that chromosome.

D. Four gametes, each with an extra chromosome.

ANSWER: B

Explanation:

Two normal gametes, one gamete with an extra chromosome, and one gamete missing that chromosome. Nondisjunction in meiosis II affects sister chromatids in only one of the two cells produced by meiosis I. The unaffected cell produces two normal gametes. The affected cell produces one gamete containing both sister chromatids and one gamete lacking that chromosome.

QUESTION NO: 41

A continuous spectrum of light, sometimes called blackbody radiation, is emitted from a region of the Sun called the photosphere. Although the continuous spectrum contains light of all wavelengths, the intensity of the emitted light is much greater at some wavelengths than at others. The relationship between the most intense wavelength of blackbody radiation and the temperature of the emitting body is given by Wien's law, $\lambda = 2.9 \times 106 / T$, where λ is the wavelength in nanometers and T is the temperature in kelvins.

As the blackbody radiation from the Sun passes through the cooler gases in the Sun's atmosphere, some of the photons are absorbed by the atoms in these gases. A photon will be absorbed if it has just enough energy to excite an electron from a lower energy state to a higher one. The absorbed photon will have an energy equal to the energy difference between these two states. The energy of a photon is given by $E = hf = hc/\lambda$ where $h = 6.63 \times 10{-}34$ J·s, Planck's constant, and $c = 3 \times 108$ m/s, the speed of light in a vacuum.

The Sun is composed primarily of hydrogen. Electron transitions in the hydrogen atom from energy state n = 2 to higher energy states are listed below along with the energy of the absorbed photon:

Final Energy State	Energy ($\times 10^{-19}$ J)
$n = 3$	3.02
$n = 4$	4.08
$n = 5$	4.57
$n = 6$	4.84
$n = \infty$	5.44

At the center of the visible spectrum is light with a wavelength of 550 nm. What is the frequency of this light?

A. 9.0 × 108 Hz

B. 1.8 × 1012 Hz

C. 5.4 × 1014 Hz

D. 1.8 × 1016 Hz

ANSWER: C

Explanation:

The correct frequency is **5.4×10^{14} Hz**. Frequency and wavelength for electromagnetic radiation are related by $c = f\lambda$, where c is the speed of light, f is frequency, and λ is wavelength. This relationship also follows directly from the passage's photon-energy expression, $hf = hc/\lambda$: cancelling Planck's constant gives $f = c/\lambda$.

First convert 550 nm to meters, because the supplied speed of light is in meters per second: 550 nm = 550×10^{-9} m = 5.50×10^{-7} m. Substitution gives $f = (3.0 \times 10^{8}\ m/s)/(5.50 \times 10^{-7}\ m)$. Dividing the coefficients and subtracting exponents yields approximately $0.545 \times 10^{15}\ s^{-1}$, or 5.45×10^{14} Hz. Rounded appropriately, this is 5.4×10^{14} Hz. Hertz means cycles per second, so its units are consistent with frequency. This magnitude is also appropriate for visible light. The fundamental wavelength-frequency relation is described by NIST and in OpenStax Physics.

QUESTION NO: 42

What is the function of the gall bladder?

A. to produce insulin

B. to store insulin

C. to store bile

D. to produce bile

ANSWER: C

Explanation:

The gall bladder's principal function is **to store bile**. Bile is continuously produced by the liver and travels through the biliary ducts. Between meals, rather than entering the small intestine in large amounts, bile is diverted into the gall bladder. There it is stored and concentrated through absorption of water and electrolytes. When dietary fat enters the duodenum, intestinal signaling—especially via the hormone cholecystokinin—causes the gall bladder to contract and deliver bile into the small intestine. Bile salts help emulsify fats, increasing their surface area so pancreatic lipase can digest them efficiently, and they support absorption of lipids and fat-soluble vitamins. Thus, the gall bladder serves as a storage reservoir and concentration site for liver-produced bile, releasing it when digestion requires it. This relationship is summarized by the NCBI Bookshelf

overview of gallbladder anatomy and physiology and the National Institute of Diabetes and Digestive and Kidney Diseases discussion of bile and gallbladder function.

QUESTION NO: 43

Every atomic orbital contains plus and minus regions, defined by the value of the quantum mechanical function for electron density. When orbitals from different atoms overlap to form bonds, an equal number of new molecular orbitals results. These are of two types: σ or π bonding orbitals, formed by overlap between orbital regions with the same sign, and antibonding σ* or π* orbitals, formed by overlap between regions with opposite signs. Bonding orbitals have lower energy than their component atomic orbitals, and antibonding orbitals have higher energy. The electron pairs reside in the lower-energy bonding orbitals; the higher-energy, less stable orbitals remain empty when the molecule is in its ground state.

A benzene ring has six unhybridized pz orbitals (one from each carbon atom), which together from six molecular π orbitals, each one delocalized over the entire ring. Of the possible π orbital structures for benzene, the one with the lowest energy has the plus region of all six p orbital functions on one side of the ring. The six electrons occupying the orbitals fill the three most stable molecular orbitals, leaving the other three empty.

Molecular orbitals are filled from the lowest to the highest energy level. The number of bonds between atoms is determined by the number of filled bonding orbitals minus the number of filled antibonding orbitals; each antibonding orbital cancels out a filled bonding orbital. For a diatomic molecule, orbitals in the n = 2 energy level are filled as follows: σ2s, σ*2s, σ2pz, π2px and π2py (equal in energy), π*2px and π*2py (equal in energy), σ*2pz. (The designation of the three p orbitals as px, py, and pz are interchangeable.)

Absorption of a photon can raise an electron to a higher-energy molecular orbital. The excited electron does not immediately change its spin, which is opposite to that of the electron with which it was previously paired. This singlet state is relatively unstable: the molecule may interact with another molecule, or fluoresce and return to its ground state. Alternatively, there may be a change in spin direction somewhere in the system; the molecule then enters the so-called triplet state, which generally has lower energy. The molecule now cannot return quickly to its ground state, since the excited electron no longer has a partner of opposite spin with which to pair. It also cannot return to the singlet state, because the singlet has greater energy. Consequently, the triplet state, which has two unpaired electrons in separate orbitals, is long-lived by atomic standards, with a lifetime that may be ten seconds or more. During this period, the molecule is highly reactive.

Which of the following four depictions of molecular π orbitals represents the highest energy state for a 6- carbon polyene molecule? (The signs given are the signs for the mathematical functions defining the p orbitals on one side of the molecule.)

A. – – – – – –

B. + + + – – –

C. + + – – + +

D. + – + – + –

ANSWER: D

Explanation:

“+ – + – + –” represents the highest-energy π molecular orbital of a six-carbon linear polyene. Molecular-orbital energy depends on the phase relationship between adjacent overlapping p orbitals, not on whether a lobe is labeled plus or minus in isolation. Adjacent p orbitals with matching phases overlap constructively, producing bonding interaction and lowering the orbital energy. A phase change between neighboring p orbitals creates a node between those atoms, eliminates stabilizing overlap there, and contributes antibonding character.

In “+ – + – + –,” the phase reverses at every one of the five adjacent carbon–carbon overlaps. Thus, this orbital has the greatest possible number of nodes for a chain of six aligned p orbitals: five nodes. The number of nodes increases successively as π molecular-orbital energy increases. Consequently, the orbital with alternating signs across all six carbons is the most antibonding π orbital, commonly designated ψ_6 for a six-p-orbital polyene system. It is therefore the highest-energy member of the six π molecular orbitals, irrespective of how many π electrons occupy the molecule in its ground state. This nodal-energy ordering is a central molecular-orbital principle used in conjugated-system analysis. See Chemistry LibreTexts on conjugated π molecular orbitals and OpenStax Chemistry on molecular-orbital bonding.

QUESTION NO: 44

As Alice Echols went on to claim, “Nothing seems to conjure up the 1970s quite so effectively as disco. Even at the time, critics remarked upon disco's neat encapsulation of that decade’s zeitgeist. ‘It must be clear by now to everyone with an ear or an eye that this era,’ wrote journalist Andrew Kopkind in 1979, ‘is already the Disco Years, whether it will be called by that name or not.’ A former sixties radical, Kopkind was by turns fascinated, bemused, and appalled by the disco epoch, and he likely imagined that in years to come fellow cultural critics would share his interest. But the seventies have not loomed large in our national imagination, except perhaps as comic relief. For many Americans, these were the forgettable years.

That forgettability owes a lot to the 1960s, the outsized decade that dwarfs all others in recent memory. The sixties will always be remembered for their audacity, whether found in the courage of civil rights protesters who put their bodies on the line or in those doomed but beautiful rock stars who tried breaking through to the other side. By contrast, the seventies seem the decade when nothing, or nothing good, happened – an era memorable for the country’s hapless presidents, declining prestige, bad fashions, ludicrous music, and such over-the-top narcissism that Tom Wolfe dubbed it the ‘Me Decade.’ Before the decade was out, this narrative of decline had become routine. ‘After the poetry of the Beatles comes the monotonous bass-pedal bombardment of Donna Summer,’ huffed one New York Times writer in 1979. It is a measure of the era's persistent bad press that a recent book challenging this view carries the pleading title Something Happened.

As for the sixties, it doesn't matter how much silliness went down, we still invest those times with seismic significance. Take Joe Cocker's performance at Woodstock. His spasmodic thrashing about and his vocals, slurred to the point of incomprehensibility, are something of a joke today. Cringe-inducing though it may be, however, Cocker's performance is never made to stand in for the whole of the sixties. The sixties remain enveloped in the gauzy sentimentalism of what might have been. Yet the iconic image of John Travolta as dance-floor king Tony Manero in white polyester suit, arm thrust to the disco heavens, has come to symbolize the narcissistic imbecility and inconsequentiality of the disco years.

Were it not for the Rubaiyat, I, too, might well regard the seventies as a lamentable and regrettable period in American history. The Rubaiyat was, yes, a disco. It was located in the heart of sixtiesland: Ann Arbor, Michigan, the home of the University of Michigan and legendary incubator of radical activism. At the height of the seventies, the town's annual Hash Bash – a smoke-in to reform marijuana laws – was still going strong and so were its two food co-ops-one reform, the other orthodox when it came to selling white foods (that is, rice, sugar, and flour of the white variety). Ann Arbor also had bookstores galore, including the original, wonderful Borders Bookstore, and any number of hippie-ish restaurants and bars such as the Fleetwood Diner, the Del Rio, and the Blind Pig. Musically, it prided itself on its vintage music (it hosted one of the earliest blues festivals), but at heart it was a rock town besotted with Iggy Pop and the Stooges and Sonic’s Rendezvous, a band fronted by Patti Smith’s future husband, Fred Smith. Its leading music store, Schoolkids’ Records, stocked disco, but never played it. All of this is to say that disco-averse Ann Arbor came close to providing something of a safe haven from glitterball culture.

The Rubaiyat was no red-velvet-rope disco where fashionista doormen determined who was sufficiently fabulous to gain entry. This would never have worked in a town where down jackets and army surplus were hardly an unusual sight. The club did have some pretensions to classiness, but the mismatched, sagging booths and bordello red defeated occasional efforts at upmarket sophistication. What the Rubaiyat did have were better-than-average speakers, a heterogeneous clientèle, and a weekend cover of three dollars.” Echols,

A. (2011). Hot stuff: Disco and the Remaking of American Culture. New York: W. W. Norton.
The author's likely purpose in introducing details about the Rubaiyat is to:
demonstrate that the popularity of disco must have been overwhelming since it made its way to a hippie town like Ann Arbor.

B. criticize disco as a genre whose fans often feign glamorousness although it is sleazy.

C. emphasize that disco's adherents were real people, so they do not deserve to be mocked.

D. show that the audience for disco was diverse and does not necessarily match the popular stereotypes about the genre.

ANSWER: D

Explanation:

The correct answer is “show that the audience for disco was diverse and does not necessarily match the popular stereotypes about the genre.” The Rubaiyat anecdote deliberately moves from a broad cultural caricature of disco toward a concrete counterexample. Ann Arbor is presented as a notably disco-averse, politically radical, rock-oriented college town: a setting that seems unlikely to host a conventional glitterball-era club. Yet the Rubaiyat operated there and drew a “heterogeneous clientèle.” Its inexpensive cover charge, unpretentious furnishings, and lack of selective fashion-based admission further establish that this was not the exclusive, glamorous nightclub implied by popular images of disco. These details matter because the author has just described the durable tendency to reduce the era to a dismissive stereotype, especially through the image of a white-suited dance-floor king. Her personal recollection gives disco a more socially varied and locally specific

reality, supporting her larger effort to reconsider the cultural meaning of the seventies. The account is drawn from Alice Echols's cultural history Hot Stuff: Disco and the Remaking of American Culture, which examines disco's place in American social and cultural life. Background on the book is also available from Goodreads.

QUESTION NO: 45

As Alice Echols went on to claim, "Nothing seems to conjure up the 1970s quite so effectively as disco. Even at the time, critics remarked upon disco's neat encapsulation of that decade's zeitgeist. 'It must be clear by now to everyone with an ear or an eye that this era,' wrote journalist Andrew Kopkind in 1979, 'is already the Disco Years, whether it will be called by that name or not.' A former sixties radical, Kopkind was by turns fascinated, bemused, and appalled by the disco epoch, and he likely imagined that in years to come fellow cultural critics would share his interest. But the seventies have not loomed large in our national imagination, except perhaps as comic relief. For many Americans, these were the forgettable years.

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A. Disco music is interesting sociologically but not musically due to the repetitive nature of its sound.

B. Disco music expressed the viewpoints of minority groups, and ultimately contributed to their acceptance in the mainstream.

C. Disco did not really disappear at the end of the 1970s; similar styles of dance music proliferated under different names.

D. A dramatic technical break occurred in American music in the early 70s between riff-based rock and beat-based dance music.

ANSWER: B

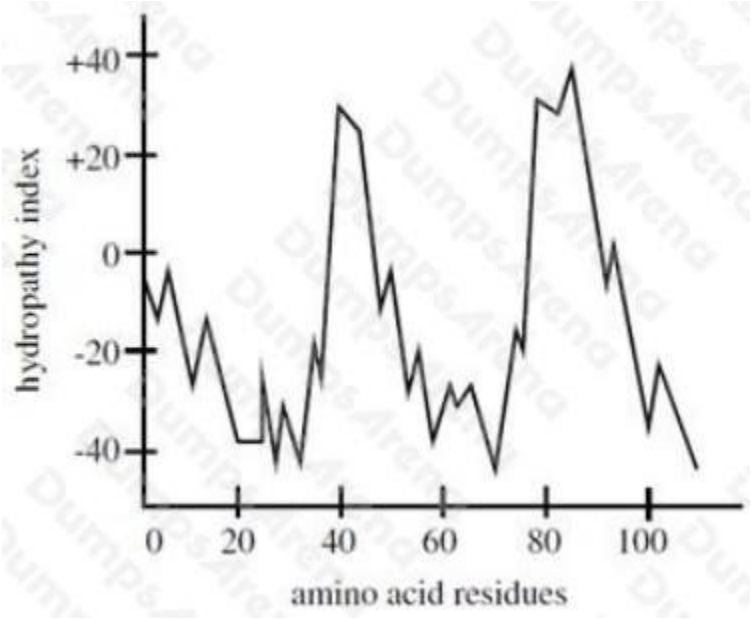
Explanation:

"Disco music expressed the viewpoints of minority groups, and ultimately contributed to their acceptance in the mainstream" most strongly supports the author's effort to reconsider disco and the 1970s. The passage objects to the inherited picture of

the decade as culturally trivial, narcissistic, and historically insignificant. It also emphasizes the contrast with the 1960s, whose lasting importance is linked in part to civil-rights activism and social change. Evidence that disco gave minority communities a meaningful public voice and helped broaden mainstream acceptance would directly establish that disco was connected to consequential cultural and political developments rather than mere empty fashion or escapism. That conclusion reinforces the author's broader claim that the usual dismissive account of the 1970s overlooks important experiences and achievements. It also fits the passage's attention to the Rubaiyat's heterogeneous clientele: the club is presented as a concrete setting that complicates stereotypes of disco culture. Alice Echols's *Hot Stuff* examines disco as part of the remaking of American culture, rather than treating it solely as a musical fad; see the publisher's description at W. W. Norton. Background on disco's development within urban club cultures is also available from Encyclopaedia Britannica.

QUESTION NO: 46

A hydropathy plot indicates the hydrophilicity (negative values) and hydrophobicity (positive values) of different regions of a protein. According to the hydropathy plot below, how many cellular membrane spanning regions are possible in this protein?



A. 1

B. 2

C. 3

D. 4

ANSWER: B

Explanation:

The correct answer is **2**. A membrane-spanning segment must contain a sufficiently long stretch of predominantly hydrophobic amino acids, because it crosses the nonpolar hydrocarbon core of the phospholipid bilayer. On a hydropathy plot, these candidate transmembrane segments appear as sustained positive hydropathy peaks rather than as brief positive fluctuations. The plotted protein has two distinct hydrophobic regions of appropriate extent, so it can contain two membrane-spanning regions. This pattern is consistent with an integral membrane protein that crosses a cellular membrane twice, with hydrophilic portions positioned on either side of the bilayer or in loops exposed to aqueous environments.

Hydropathy analysis is a predictive tool: it identifies sequence regions whose chemical properties are compatible with partitioning into a membrane. Typical membrane alpha-helices require roughly 20 hydrophobic residues to traverse the bilayer's hydrophobic interior, so the width and sustained elevation of each peak are important along with its positive value. The two qualifying peaks therefore support the conclusion of two possible membrane-spanning segments. Further background on membrane-protein topology and hydropathy-based prediction is available from NCBI Bookshelf: Membrane Proteins and UniProt: Transmembrane regions.

QUESTION NO: 47

The mind, just like the body, has its needs. The needs of the body are the foundations of society; those of the mind are its amenities. While government and laws provide for the safety and wellbeing of men when they gather together, the sciences and the arts, which are less despotic but perhaps more powerful, spread garlands of flowers over the iron chains that bind them, stifle in them the sense for that original liberty for which they seem to have been born, cause them to love their own enslavement, and turn them into so-called “civilized people.” Necessity raised thrones; the sciences and the arts have strengthened them. O earthly powers: cherish talents and protect those who cultivate them. O civilized people, cultivate them: you happy slaves owe to them that delicate and refined taste of which you are so proud, that gentleness of character and urbanity of manner which make relations among you so amiable and easy – in other words, that semblance of all the virtues, none of which you actually possess…

…How pleasant it would be to live among us, if our external appearance were always a reflection of what is in our hearts, if decency were virtue, if our maxims served as our rules, and if true philosophy were inseparable from the title of philosopher! But so many qualities are seldom found together, and virtue hardly ever walks in such great pomp. Richness of adornment may be the mark of a man of taste, but a healthy, robust man is known by other signs: it is beneath the rustic clothes of a farmer, and not the gilt of a courtier, that strength and vigor of the body will be found. Ornamentation is just as foreign to virtue, which is the strength and vigor of the soul. The good man is an athlete who prefers to compete in the nude: he disdains all those vile ornaments which would hinder the use of his strength, ornaments which were for the most part invented only to hide some deformity.

Before art had molded our manners and taught our passions to speak an affected language, our customs were rustic but natural, and differences in conduct revealed clearly differences in character. Human nature, basically, was no better, but men found security in being able to see through each other easily, and this advantage, which we no longer appreciate, spared them many vices.

Now that more subtle refinements and more delicate taste have reduced the art of pleasing to set rules, a base and deceptive uniformity prevails in our behavior, and all minds seem to have been cast in the same mold. Incessantly politeness and propriety make demands on us, and incessantly we follow usage but never our own inclinations. We no longer dare to appear as we are, and under this perpetual constraint, the men who form this herd called society, when placed in the same circumstances, will all act similarly unless stronger motives direct them to do otherwise. Therefore we will never know well those with whom we deal, for to know our friends we will have to wait for some crises to arise – which is to say that we will have to wait until it is too late, as it is for these very crises that it is essential to know one’s friends well.

What vice would not accompany this uncertainty? No more sincere friendships, no more genuine esteem, no more well-based confidence. Suspicion, offenses, fears, coldness, reserve, hatred and betrayal will constantly hide under the same false veil of politeness, under that much touted urbanity which we owe to the enlightenment of our times. The name of the Master of the Universe will no longer be profaned by swearing, but insulted by blasphemies that will not offend our scrupulous ears. Men will not boast of their own merits, but belittle those of others. An enemy will not be crudely insulted, but adroitly slandered. National hatreds will die, but so will patriotism. A dangerous skepticism will take the place of the scorning of ignorance. Some excesses will be forbidden, some vices dishonored, but others will be dignified with the name of virtues, and one must either have them or feign them. Let those who want to praise the sobriety of the sages of our time do so; as for me, I see in it only a refinement of intemperance that is as unworthy of my praise as their hypocritical simplicity.

Which of the following is given as a supporting example for the author’s concept of the ideal man?

A. One who exhibits courteous behavior.

B. One who maintains a pleasant demeanor.

C. One who rejects ornamentation.

D. One who cultivates talent.

ANSWER: C

Explanation:

“One who rejects ornamentation” is correct because the passage explicitly presents the ideal or “good” man as someone whose inner virtue is not obscured by outward display. The author defines virtue as “the strength and vigor of the soul,” then argues that ornamentation is foreign to that strength. His central supporting image is the athlete who prefers to compete nude: the athlete refuses decorative additions because they would impede the free use of his natural power. The example is figurative rather than a literal prescription about clothing. It illustrates the author’s broader ideal of authenticity, moral robustness, and conduct that openly reflects one’s true character. The contrast between rustic clothing and a courtier’s gilt reinforces that the author values substance over polished appearance. Thus, rejecting ornamentation is the concrete

behavior supplied by the passage to exemplify the ideal man's refusal to hide weakness or manufacture a socially pleasing exterior. This theme is characteristic of Jean-Jacques Rousseau's critique of how arts, refinement, and social manners can distance people from natural virtue; see Stanford Encyclopedia of Philosophy: Jean-Jacques Rousseau and the text of Rousseau's Discourse on the Arts and Sciences.

QUESTION NO: 48

Several techniques have been developed to determine the order of a reaction. The rate of a reaction cannot be predicted on the basis of the overall equation, but can be predicted on the basis of the rate-determining step. For instance, the following reaction can be broken down into three steps. A + D → F + G

Step 1

A → B + C(slow)

Step 2

B + D → E + F(fast)

Step 3

E + C → G (fast)

Reaction 1

In this case, the first step in the reaction pathway is the rate-determining step. Therefore, the overall rate of the reaction must equal the rate of the first step, k1 [A] where k1 is the rate constant for the first step. (Rate constants of the different steps are denoted by kx , where x is the step number.)

In some cases, it is desirable to measure the rate of a reaction in relation to only one species. In a second-order reaction, for instance, a large excess of one species is included in the reaction vessel. Since a relatively small amount of this large concentration is reacted, we assume that the concentration essentially remains unchanged. Such a reaction is called a pseudo first-order reaction. A new rate constant, k', is established, equal to the product of the rate constant of the original reaction, k, and the concentration of the species in excess. This approach is often used to analyze enzyme activity.

In some cases, the reaction rate may be dependent on the concentration of a short-lived intermediate. This can happen if the rate-determining step is not the first step. In this case, the concentration of the intermediate must be derived from the equilibrium constant of the preceding step. For redox reactions, the equilibrium can be correlated with the voltage produced by two half-cells by means of the Nernst equation. This equation states that at any given moment:

$$E = E^0 - \left(\frac{RT}{nF}\right) \ln \left([\mathrm{C}]^c[\mathrm{D}]^d / [\mathrm{A}]^a[\mathrm{B}]^b\right)$$

Equation 1

When

a A + b B → c C + d D

Reaction 2

Note: R = 8.314 J/K·mol; F = 9.6485 × 104 C/mol.)

If Step 2 above were the rate-determining step of Reaction 1, which of the following equations would correctly define the rate?

A. Rate = k1k2[D] / k−1[C]

B. Rate = k1k2[D] / k−1k−2[C]

C. Rate = k1k2[A][D] / k−1[C]

D. Rate = k1k2[A][D] / k−1k−2[C]

ANSWER: C

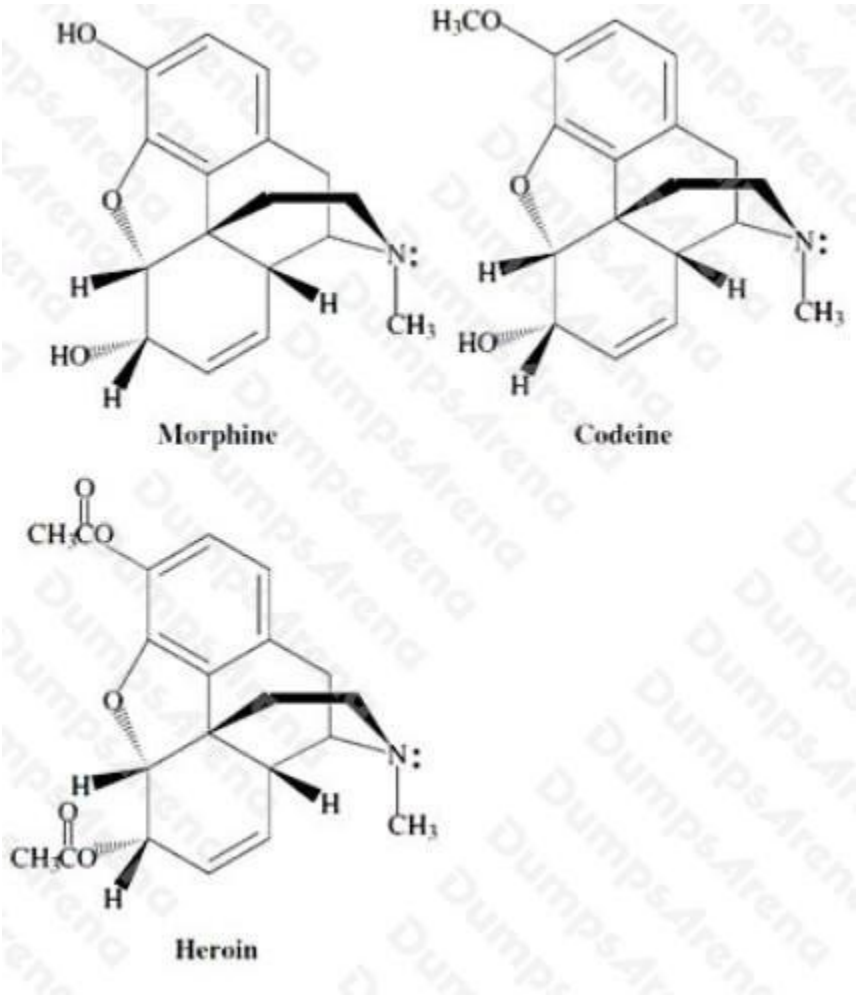
Explanation:

The correct rate expression is *Rate = k1k2[A][D] / k−1[C]*. If the second elementary step is rate-determining, its immediate rate law is rate = k2[B][D], because that step consumes the intermediate B and reactant D. The intermediate concentration cannot remain in the final experimentally useful rate expression, so it must be related to measurable species through the preceding rapid equilibrium.

For the first reversible step, the equilibrium constant is K = [B][C]/[A]. Microscopic reversibility also relates this equilibrium constant to the forward and reverse elementary rate constants: K = k1/k−1. Solving the equilibrium relationship for the intermediate gives [B] = k1[A]/(k−1[C]). Substitution into the rate-determining-step law produces k2[D] × k1[A]/(k−1[C]), which simplifies directly to the stated expression. This derivation illustrates the pre-equilibrium approach: a fast reversible step establishes an equilibrium concentration of an intermediate before the slower step controls the net reaction rate. A useful overview of elementary-step rate laws and mechanisms is available from Chemistry LibreTexts, and the equilibrium-constant relation for reversible elementary reactions is discussed by IUPAC Gold Book.

QUESTION NO: 49

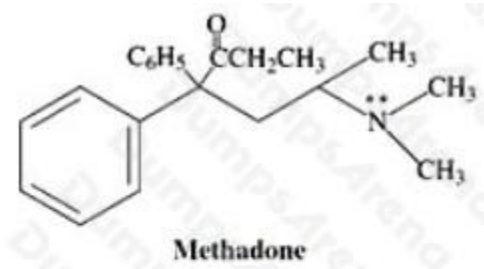
Morphine alkaloids derived from the opium poppy have long been used as analgesics. Codeine, the methyl ether of morphine, is a naturally occurring alkaloid with medicinal properties very similar to those of morphine. Thousands of derivatives of morphine have been synthesized and tested for their biological effects. For example, the diacylated derivative of morphine, heroin, is a highly addictive drug. Much effort has gone into understanding how morphine and its derivatives function.



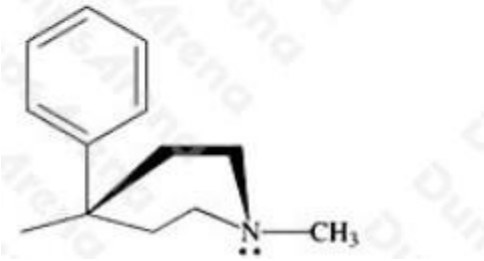
Studies have shown that certain common structural features of alkaloids are required for the compound to exhibit biological activity. These structural requirements are summarized by the so called “morphine rule”:

Demerol and methadone, shown in Figure 2, are two synthetic alkaloids designed to satisfy the “morphine rule.” Synthetic alkaloids such as these have been found to mimic certain physiological properties of morphine and its derivatives, and have

found pharmacological application due to other, more desirable biological effects. Methadone has been used widely in the United States and Great Britain as a treatment for heroin addiction; it reduces the physical symptoms accompanying withdrawal without producing many of the other effects of heroin.



Methadone

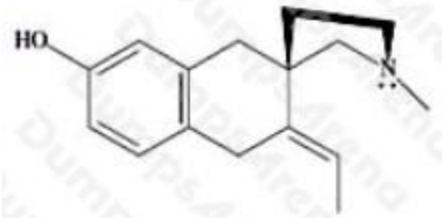


Meperidine

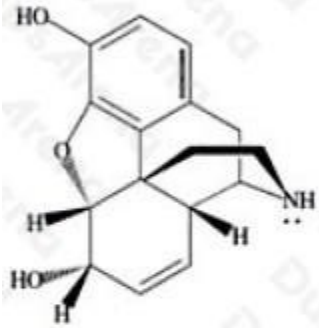
(demerol) Figure 2

Which of the following compounds would be most likely to have morphine-like biological effects?

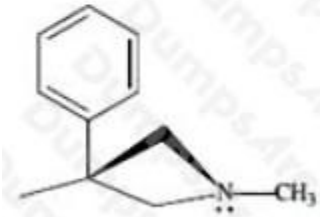
A.



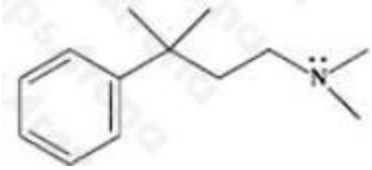
B.



C.



D.



A. Option A

B. Option B

C. Option C

D. Option D

ANSWER: D

Explanation:

The structure shown as “Option D” is most likely to produce morphine-like biological effects because it fulfills the stated morphine-rule pharmacophore. It contains an aromatic ring bonded to a quaternary carbon center, providing the required hydrophobic/aromatic portion of the scaffold. That same central carbon is connected through a two-carbon spacer to a tertiary amine, placing a protonatable nitrogen at the required distance from the aromatic-bearing carbon. This spacing and substitution pattern are the essential structural relationships identified in the passage from morphine, meperidine, and methadone.

At physiological pH, a tertiary amine can be protonated, enabling favorable ionic interactions with an opioid receptor binding site, while the aromatic region can contribute hydrophobic and van der Waals interactions. The combination of an aromatic moiety, a suitably substituted central carbon, and the correctly separated tertiary amine therefore gives this structure the greatest likelihood of mimicking the receptor-binding behavior associated with morphine-like analgesic activity. This is

consistent with the general importance of a basic nitrogen and aromatic region in opioid ligand recognition. See the NCBI overview of opioid analgesics and the IUPAC definition of a tertiary amine.

QUESTION NO: 50

An automobile reaches a velocity of 30 m/s after accelerating at 4 ms−2 for 5 seconds. What was its initial velocity?

A. −10 m/s

B. 0 m/s

C. 10 m/s

D. 20 m/s

ANSWER: C

Explanation:

The correct answer is **10 m/s**. For motion with constant acceleration, final velocity is related to initial velocity by the kinematics equation $v_f = v_i + at$, where v_f is final velocity, v_i is initial velocity, a is acceleration, and t is elapsed time. The automobile's acceleration over five seconds produces a velocity increase of 20 m/s: 4 m/s^2 × 5 s = 20 m/s. Since its final velocity is 30 m/s, subtract this 20 m/s increase from the final velocity: 30 m/s − 20 m/s = 10 m/s. Thus, the automobile was already moving at 10 m/s at the start of the five-second interval. The units also verify the calculation: multiplying acceleration in meters per second squared by time in seconds gives meters per second, which can be combined directly with velocity. This is the standard constant-acceleration relationship used in introductory mechanics; see OpenStax, Motion Equations for Constant Acceleration and The Physics Classroom, Kinematic Equations.

QUESTION NO: 51

A researcher measures the rate of an enzyme-catalyzed reaction at several substrate concentrations while maintaining a constant enzyme concentration. Addition of a competitive inhibitor increases the substrate concentration required to reach one-half of the maximum reaction velocity, but does not change the maximum velocity.

Which of the following best explains this result?

A. The inhibitor binds reversibly at the enzyme's active site.

B. The inhibitor irreversibly denatures the enzyme.

C. The inhibitor prevents product release from the enzyme.

D. The inhibitor reduces the total concentration of enzyme molecules.

ANSWER: A

Explanation:

The inhibitor binds reversibly at the enzyme's active site. A competitive inhibitor reduces the apparent affinity of the enzyme for substrate because substrate and inhibitor compete for the same binding site. At sufficiently high substrate concentrations, substrate can outcompete the inhibitor, so the same maximum velocity can still be achieved. The increased substrate concentration needed to reach one-half maximal velocity corresponds to an increased apparent K_m.

QUESTION NO: 52

…Squeaking sand produces sounds with very high frequencies – between 500 and 2,500 hertz, lasting less than a quarter of a second. The peals are musically pure, often containing four or five harmonic overtones. Booming sand makes louder, low-frequency sounds of 50 to 300 hertz, which may last as long as 15 minutes in larger dunes (although typically they last for

seconds or less). In addition, they are rather noisy, containing a multitude of nearby frequencies. Booms have never been observed to contain more than one harmonic of the fundamental tone.

These dramatic differences once led to a consensus that although both types of sand produce acoustic emissions, the ways in which they do so must be substantially different… In the late 1970s, however, Peter K. Haff, then at the California Institute of Technology, produced squeaks in booming sand, suggesting a closer connection between the two.

Both kinds of sand must be displaced to make sounds. Walking on some sand, for example, forces the sand underfoot to move down and out, producing squeaks. In the case of booming sand, displacement occurs during avalanches. It is within the avalanche that sound begins and where the answers must be hiding.

Before an avalanche can occur, winds must build a dune up to a certain angle, usually about 35 degrees for dry desert sand. Once an angle is achieved, the sand on the leeward side of the dune begins to slump. Intact layers of sand slip over the layers below, like a sheared deck of cards. At the same time, the individual grains in the upper layers tumble over the grains underneath, momentarily falling into the spaces between them and bouncing out again to continue their downward journey. Their concerted up-and-down motion is believed to be the secret source of sound. Fully developed avalanches, in which sliding plates of sand remain intact for most of their motion, have the greatest acoustic output. In some places, where large amounts of sand are involved, booming can be heard up to 10 kilometers away.

Because it is caused by large volumes of shearing sand, the roaring is also loud. In fact, sounds made by booming sand can be nearly deafening, and the vibrations causing them can be so intense that standing in their midst is nearly impossible.

A good place to start in exploring the vibrational properties of sand is with the grains themselves. The mean diameter of most sand grains, whether acoustically active or not, is about 300 microns. Usually the grains in a booming dune are very similar in size, especially near the leeward crest, where the sound most often originates; such uniformity allows for more efficient shearing. Otherwise, the smaller grains impede the smooth motion of the larger ones.

Similar sizes do not alone allow sand to boom. On the contrary, the booming sands of Korizo and Gelf Kebib, also in Libya, feature an uncharacteristically broad range of particle sizes. Moreover, silent dune sand often contains grains somewhat similar to nearby booming sand.

Grains of booming sand also tend to have uncommonly smooth surfaces, with protrusions on the scale of mere microns. Booming dunes are often found at the downwind end of large sand sources; having bounced and rolled across the desert for long distances, the sand grains in these dunes are usually highly polished. Over time a grain can also be polished by repeated shifts within a moving dune. And squeaking sand as well tends to be exceptionally smooth…

…Another important factor is humidity, because moisture can modify the friction between grains or cause sand to clump together, thus precluding shearing. Sounds occur in those parts of the dune that dry the fastest. Precipitation may be rare in the desert, but dunes retain water with remarkable efficiency. Sand near the surface dries quickly, however, and sand around a dune's crest tends to dry the fastest.

A dune is found to be comprised of smooth grains and produces sounds that last less than a second. What further information, if any, would enable one to unambiguously characterize the sand as squeaking sand?

A. The grains are not uniform in size.

B. The sound is generated by walking upon it rather than through avalanches.

C. The information given is already sufficient to conclude that the sand is squeaking sand.

D. The sand cannot possibly be squeaking sand from the information given.

ANSWER: B

Explanation:

"The sound is generated by walking upon it rather than through avalanches." supplies the decisive distinguishing fact. The passage explicitly connects squeaks with displacement caused when a person walks on sand: pressure underfoot forces grains downward and outward, producing the characteristic squeaking emission. It separately identifies an avalanche as the setting in which booming sand begins to sound. Thus, once the sound-production mechanism is known to be walking rather than an avalanche, the sand can be classified unambiguously as squeaking sand under the relationships established in the passage.

The details already supplied—smooth grains and a sound lasting under one second—do not independently identify the phenomenon, because smoothness is described as a trait of both squeaking and booming sands, and booming events can commonly persist for seconds or less. The mode of displacement, however, directly connects the observation to the

passage's stated mechanism for squeaks. This distinction is consistent with research on singing or booming dunes, which examines sound generated during granular flow and avalanching, including the collective motion of sand grains: Physical Review Letters: "The Booming of Avalanches". For broader context on acoustically active dunes and their granular mechanisms, see Encyclopaedia Britannica: singing sand.

QUESTION NO: 53

A person, standing in an elevator which goes up with constant upward acceleration, exerts a push on the floor of elevator whose value:

A. is always equal to his weight.

B. is always lesser than his weight.

C. is always greater than his weight.

D. is greater when his acceleration is than 'g'.

ANSWER: C

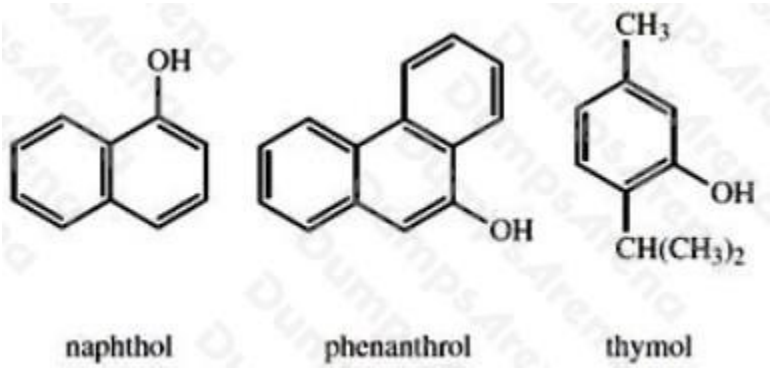
Explanation:

"is always greater than his weight." is correct. While the elevator accelerates upward, the floor must exert an upward normal force on the person that is sufficient both to balance the person's gravitational force and to produce the stated upward acceleration. Applying Newton's second law in the upward direction gives $N - mg = ma$, where N is the normal force, m is the person's mass, g is gravitational acceleration, and a is the elevator's positive upward acceleration. Therefore, $N = m(g + a)$. Since a is greater than zero, the normal force is greater than mg, the person's actual weight.

By Newton's third law, the person exerts an equal-magnitude downward force on the elevator floor. Thus, the push on the floor is also $N = m(g + a)$, which is greater than the person's weight. This increased contact force is what produces the familiar sensation of feeling heavier in an upward-accelerating elevator; it is commonly called apparent weight. The conclusion applies throughout the period of constant upward acceleration and does not depend on the elevator's instantaneous velocity. For a discussion of normal force and apparent weight in accelerating elevators, see OpenStax Physics: Normal, Contact Force and The Physics Classroom: Elevator Rides and Apparent Weight.

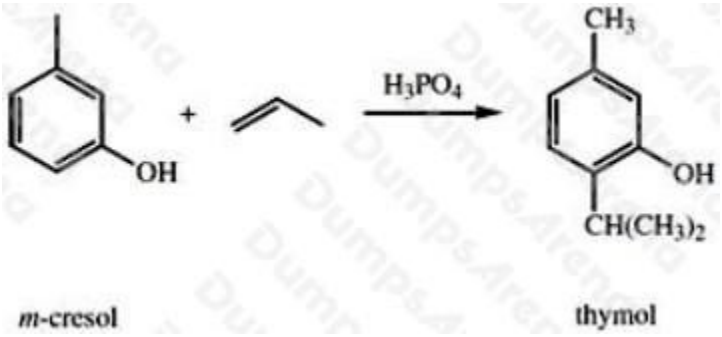
QUESTION NO: 54

Compounds containing a hydroxyl group attached to a benzene ring are called phenols. Derivatives of phenols, such as naphthols and phenanthrols, have chemical properties similar to those of phenols, as do most of the many naturally-occurring substituted phenols. Like other alcohols, phenols have higher boiling points than hydrocarbons of similar molecular weight. Like carboxylic acids, phenols are more acidic than their alcohol counterparts. Phenols undergo a number of different reactions; both their hydroxyl groups and their benzene rings are highly reactive. A number of chemical tests can be used to distinguish phenols from alcohols and carboxylic acids.

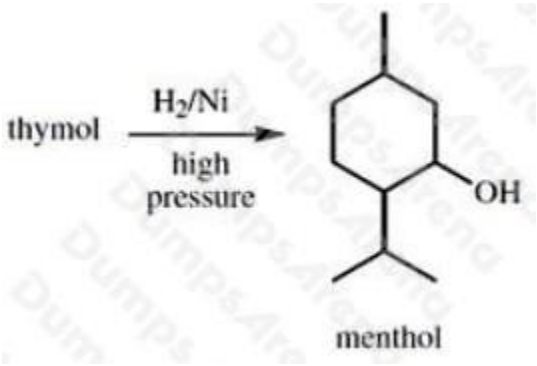


Thymol, a naturally occurring phenol, is an effective disinfectant that is obtained from thyme oil. Thymol can also be synthesized from m-cresol, as shown in Reaction A below. Thymol can then be converted to menthol, another naturally-occurring organic compound; this conversion is shown in Reaction B.

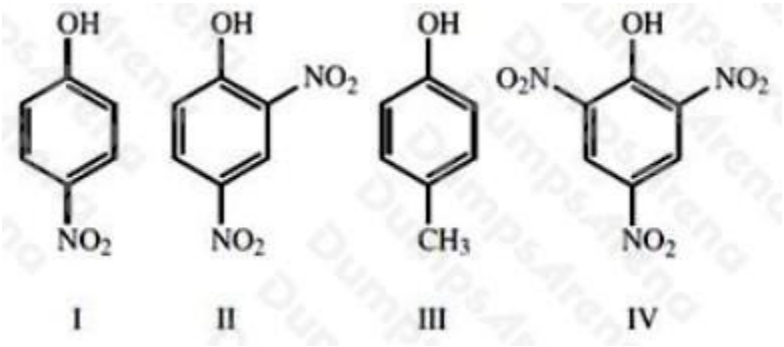
Reaction A



Reaction B



Which of the following shows the order of decreasing acidity among the four compounds below?



A. I, III, IV, II

B. IV, I, II, III

C. IV, III, II, I

D. IV, II, I, III

ANSWER: D

Explanation:

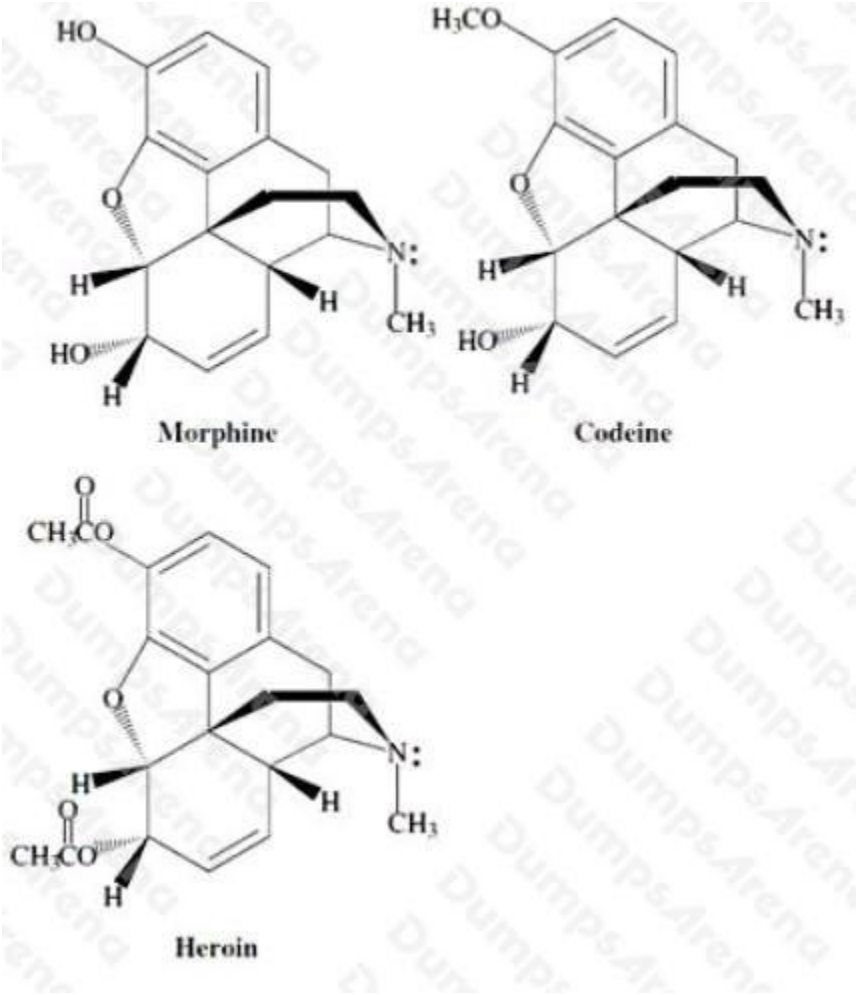
The correct decreasing-acidity order is **IV, II, I, III**. Acidity is determined by the relative stability of the conjugate base formed after the phenolic proton is removed. Deprotonation of a phenol produces a phenoxide ion, whose negative charge can be delocalized into the aromatic ring by resonance. Substituents that withdraw electron density from that ring further stabilize this negatively charged conjugate base and therefore increase phenol acidity.

Nitro groups are especially strong electron-withdrawing substituents through both inductive and resonance effects. Consequently, the compound bearing three nitro groups has the most strongly stabilized phenoxide ion and is the most acidic. The dinitro-substituted phenol follows, then the mononitro-substituted phenol. In contrast, the methyl substituent in the cresol compound donates electron density weakly by inductive effects and hyperconjugation, making formation of its phenoxide ion comparatively less favorable. It is therefore the least acidic member of this set.

This use of conjugate-base stabilization is a central approach for comparing organic acidities. The resonance behavior and acidity of phenols are discussed in OpenStax Organic Chemistry: Phenols and in Chemistry LibreTexts: The Acidity of Phenols.

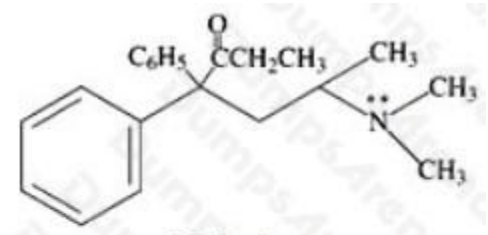
QUESTION NO: 55

Morphine alkaloids derived from the opium poppy have long been used as analgesics. Codeine, the methyl ether of morphine, is a naturally occurring alkaloid with medicinal properties very similar to those of morphine. Thousands of derivatives of morphine have been synthesized and tested for their biological effects. For example, the diacylated derivative of morphine, heroin, is a highly addictive drug. Much effort has gone into understanding how morphine and its derivatives function.

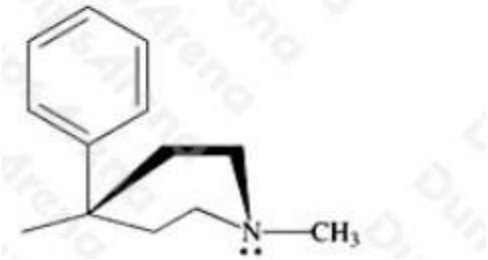


Studies have shown that certain common structural features of alkaloids are required for the compound to exhibit biological activity. These structural requirements are summarized by the so called “morphine rule”:

Demerol and methadone, shown in Figure 2, are two synthetic alkaloids designed to satisfy the “morphine rule.” Synthetic alkaloids such as these have been found to mimic certain physiological properties of morphine and its derivatives, and have found pharmacological application due to other, more desirable biological effects. Methadone has been used widely in the United States and Great Britain as a treatment for heroin addiction; it reduces the physical symptoms accompanying withdrawal without producing many of the other effects of heroin.



Methadone



Meperidine

(demerol)

Figure 2

Researchers have discovered that the stereochemistry of the alkaloids is critical to their physiological effects. For example, (−)-methadone produces powerful analgesic effects while (+)methadone produces no effect. Which of the following is the most likely explanation for this difference in activity?

A. (+)-Methadone does not follow the “morphine rules.”

B. Alkaloids bind to stereospecific receptors.

C. Analgesic effects require the rotation of plane polarized light.

D. (−)-Methadone is the naturally occurring enantiomer

ANSWER: B

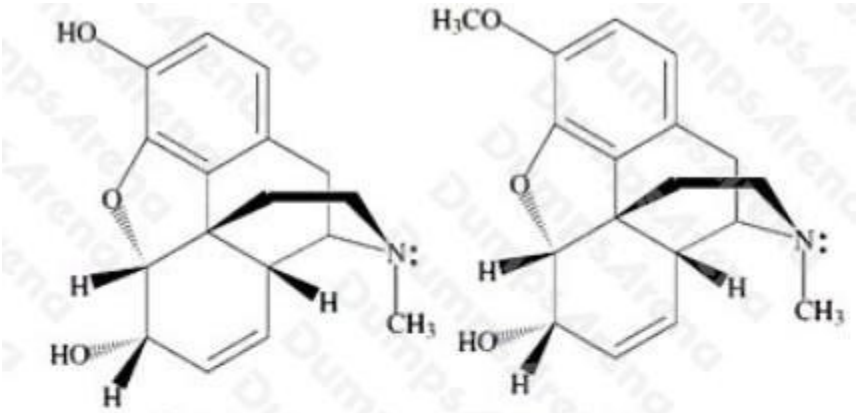
Explanation:

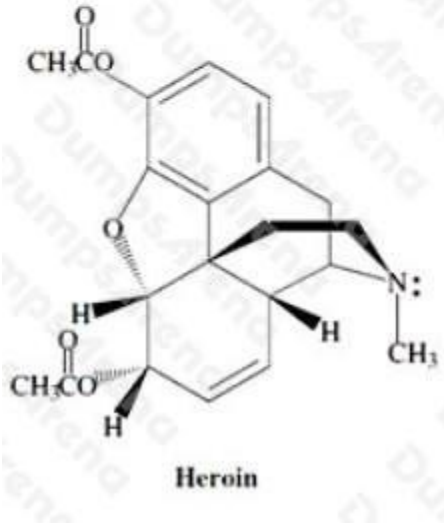
Alkaloids bind to stereospecific receptors. The two forms of methadone are enantiomers: they have the same atomic connectivity but differ in their three-dimensional arrangement. This distinction matters in a biological system because drug receptors are macromolecules, usually proteins, with chiral three-dimensional binding sites. A receptor can therefore recognize one enantiomer with a geometry that permits strong binding and activation of the signaling pathway responsible for analgesia, while the mirror-image enantiomer may fit poorly or fail to activate that receptor.

The observed contrast—potent analgesia from (−)-methadone and no analgesic effect from (+)-methadone—is exactly the type of result expected from stereoselective molecular recognition. The plus and minus signs describe the direction in which each enantiomer rotates plane-polarized light; they are not themselves the biological cause. Instead, the relevant cause is the match between the drug’s spatial arrangement and the chiral receptor’s binding environment. This principle is central to pharmacology because stereoisomers can have substantially different receptor affinities, efficacy, metabolism, and clinical effects. See the stereochemistry discussion in NCBI Bookshelf and the overview of opioid receptors in NCBI Bookshelf.

QUESTION NO: 56

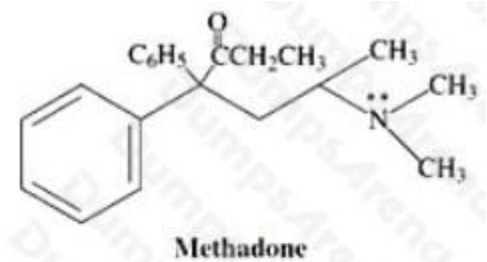
Morphine alkaloids derived from the opium poppy have long been used as analgesics. Codeine, the methyl ether of morphine, is a naturally occurring alkaloid with medicinal properties very similar to those of morphine. Thousands of derivatives of morphine have been synthesized and tested for their biological effects. For example, the diacylated derivative of morphine, heroin, is a highly addictive drug. Much effort has gone into understanding how morphine and its derivatives function.



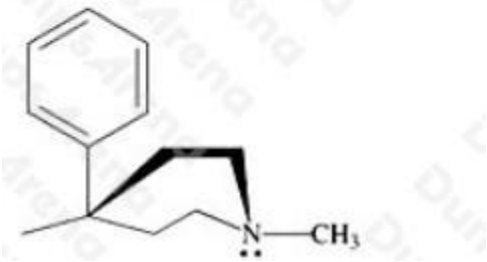


Studies have shown that certain common structural features of alkaloids are required for the compound to exhibit biological activity. These structural requirements are summarized by the so called “morphine rule”:

Demerol and methadone, shown in Figure 2, are two synthetic alkaloids designed to satisfy the “morphine rule.” Synthetic alkaloids such as these have been found to mimic certain physiological properties of morphine and its derivatives, and have found pharmacological application due to other, more desirable biological effects. Methadone has been used widely in the United States and Great Britain as a treatment for heroin addiction; it reduces the physical symptoms accompanying withdrawal without producing many of the other effects of heroin.



Methadone



Meperidine

(demerol)

Figure 2

One of the requirements of the “morphine rule” is that an aromatic ring be attached to a quaternary carbon in order for the molecule to be biologically active. The quaternary carbon of any morphine-like substance must be:

I. a stereocenter

II. sp3 hybridized

III. sp2 hybridized

A. I only

B. II only

C. I and II only

D. I and III only

E. a stereocenter
II. sp3 hybridized
III. sp2 hybridized

ANSWER: B

Explanation:

The correct answer is **II only**. A quaternary carbon is a carbon atom bonded through four single (sigma) bonds to four substituents; in the usual organic-chemistry usage, it is specifically bonded to four other carbon atoms. Four electron domains around carbon give a tetrahedral electron geometry. To make the four equivalent orbitals needed for these four sigma bonds, one s orbital combines with three p orbitals, producing four sp^3 hybrid orbitals. Thus, the carbon required by the morphine rule must be sp^3 hybridized.

Whether that same carbon is a stereocenter depends on the identities of all four groups attached to it, rather than on its being quaternary. A tetrahedral carbon is stereogenic only when its four substituents are distinguishable. The decisive, universal structural requirement in the question is therefore tetrahedral sp^3 bonding. This hybridization also permits the three-dimensional arrangement that positions the aromatic ring within the pharmacophore described by the morphine rule. For background on carbon hybridization and tetrahedral bonding, see Chemistry LibreTexts: sp3 Hybridization and the Structure of Methane. The definition and structural role of quaternary carbon atoms are also summarized by IUPAC Gold Book: quaternary carbon atom.

QUESTION NO: 57

The lining of the digestive tract and the respiratory tract develops from which germ layer?

I. Endoderm

II. MesodermIII. Ectoderm

A. I only

B. II only

C. III only

D. I and II

E. I, II, and III

ANSWER: A

Explanation:

The correct answer is **I only**, because the epithelial lining of both the digestive tract and the respiratory tract is derived from the endoderm. During early embryonic development, endoderm forms the primitive gut tube. This tube gives rise to the epithelial tissues lining most of the gastrointestinal tract, as well as associated structures such as the liver and pancreas. A ventral outgrowth from the embryonic foregut, the respiratory diverticulum, develops into the epithelial lining of the larynx, trachea, bronchi, and lungs. Thus, although these organ systems have supporting tissues, blood vessels, and muscles with other embryologic origins, the question specifically asks about their lining, which is endodermal in origin.

A useful developmental framework is that endoderm generally produces internal epithelial linings and many glandular epithelia. This relationship between endoderm, the gut tube, and the respiratory epithelium is described in OpenStax Anatomy and Physiology: Embryonic Development and in the NCBI Bookshelf overview of embryonic germ layers.

QUESTION NO: 58

If a person throws a stone vertically upwards while sitting in a train moving with constant velocity, the stone will fall:

A. in his hand.

B. behind him.

C. in front of him.

D. outside the train.

ANSWER: A

Explanation:

in his hand. is correct because a train moving at constant velocity is an inertial reference frame, provided that it is not accelerating or turning. Before the stone is released, it already shares the train passenger's horizontal velocity. Throwing it vertically upward changes its vertical motion, but it does not remove that pre-existing horizontal velocity. During the stone's flight, gravity accelerates it downward while its horizontal velocity remains the same as the passenger's and the train's, assuming air resistance is negligible or the air inside the carriage moves with the train.

Consequently, relative to the person in the train, the stone rises and falls along a vertical path. By the time it returns to the height from which it was thrown, it has traveled horizontally by exactly the same amount as the person, so it returns to the thrower's hand. This illustrates Galilean relativity: the laws of mechanics, including projectile motion, have the same form in all frames moving at constant velocity relative to one another. OpenStax discusses inertial frames and the equivalence of constant-velocity reference frames in its treatment of classical mechanics: Inertial Frames of Reference and Newton's Laws. For the related principle that an object maintains its motion unless acted on by a net external force, see Newton's First Law of Motion.

QUESTION NO: 59

It is critical for the human body blood to maintain its pH at approximately 7.4. Decreased or increased blood pH are called acidosis and alkalosis respectively; both are serious metabolic problems that can cause death. The table below lists the major buffers found in the blood and/or kidneys.

Table 1 Buffer pKa of a typical conjugate acid:*

$HCO_3^- \rightleftharpoons CO_2 + H_2O$

Histidine side chains

$HPO_4^{2-} \rightleftharpoons H_2PO_4^-$

Organic phosphates

N-terminal amino groups

$NH_3 \rightleftharpoons NH_4^+$

6.1

6.3

6.8

7.0

8.0

9.2

*For buffers in many of these categories, there is a range of actual pKa values.

The relationship between blood pH and the pKa of any buffer can be described by the Henderson-Hasselbalch equation:

pH = pKa + log([conjugate base] / [conjugate acid])

Equation 1

Bicarbonate, the most important buffer in the plasma, enters the blood in the form of carbon dioxide, a byproduct of metabolism, and leaves in two forms: exhaled CO2 and excreted bicarbonate. Blood pH can be adjusted rapidly by changes in the rate of CO2 exhalation. The reaction given below, which is catalyzed by carbonic anhydrase in the erythrocytes, describes how bicarbonate and CO2 interact in the blood.

$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^-$

Reaction 1

What would be the order of conjugate acid strength in the following buffers?

A. Histidine side chains = organic phosphates > NH4+

B. NH4+ > organic phosphates > histidine side chains

C. Histidine side chains > organic phosphates > NH4+

D. NH4+ > organic phosphates = histidine side chains

ANSWER: C

Explanation:

Histidine side chains > organic phosphates > NH4+ is correct because acid strength is inversely related to pKa: the lower the pKa of a conjugate acid, the more readily it donates a proton and therefore the stronger the acid. The table places the relevant typical pKa values in increasing order from histidine side chains (about 6.1), to organic phosphates (about 6.8), to ammonium, NH4+ (about 9.2). Consequently, protonated histidine side chains are the strongest conjugate acids among these buffers, organic phosphate conjugate acids have intermediate strength, and NH4+ is the weakest conjugate acid. This comparison concerns the tendency of each protonated buffer species to lose H+, rather than the amount of buffer present or its physiological importance in a particular compartment. The Henderson-Hasselbalch relationship is consistent with this interpretation: pKa is the pH at which conjugate acid and conjugate base are present at equal concentrations, and a smaller pKa corresponds to greater acid dissociation. See the acid-strength discussion in OpenStax Chemistry 2e and the buffer/Henderson-Hasselbalch overview in NCBI Bookshelf.

QUESTION NO: 60

The amount of lactic acid in muscles rises when they start lacking:

A. carbon dioxide.

B. oxygen.

C. glucose.

D. hydrogen carbonate.

ANSWER: B

Explanation:

The correct answer is **oxygen.** During vigorous exercise, muscle cells may use oxygen faster than the circulatory and respiratory systems can deliver it. When oxygen availability becomes insufficient for the energy demand, cells rely more heavily on anaerobic glycolysis to continue producing ATP. In this pathway, glucose is broken down to pyruvate, and pyruvate is converted to lactate. This conversion regenerates NAD^+, a molecule required for glycolysis to continue generating ATP in the absence of adequate oxygen. Consequently, lactate concentration rises in active muscle and can subsequently enter the bloodstream. Although the term “lactic acid” is commonly used in introductory biology questions, under physiological conditions the predominant form is lactate. Once sufficient oxygen is available again, lactate can be oxidized by tissues or transported to the liver, where its carbon skeleton can contribute to glucose production through the Cori cycle. This relationship between reduced oxygen availability, anaerobic metabolism, and lactate accumulation is a central concept in exercise physiology and cellular energy metabolism. See StatPearls: Physiology, Lactate and OpenStax Biology 2e: Oxidative Phosphorylation.

QUESTION NO: 61

Several models have been developed for relating changes in dissociation constants to changes in the tertiary and quaternary structures of oligomeric proteins. One model suggests that the protein's subunits can exist in either of two distinct conformations, R and T. At equilibrium, there are few R conformation molecules: 10 000 T to 1 R and it is an important feature of the enzyme that this ratio does not change. The substrate is assumed to bind more tightly to the R form than to the T form, which means that binding of the substrate favors the transition from the T conformation to R.

The conformational transitions of the individual subunits are assumed to be tightly linked, so that if one subunit flips from T to R the others must do the same. The binding of the first molecule of substrate thus promotes the binding of the second and if substrate is added continuously, all of the enzyme will be in the R form and act on the substrate. Because the concerted transition of all of the subunits from T to R or back, preserves the overall symmetry of the protein, this model is called the symmetry model. The model further predicts that allosteric activating enzymes make the R conformation even more reactive with the substrate while allosteric inhibitors react with the T conformation so that most of the enzyme is held back in the T shape.

Experiment Evaluating Non-Symmetry Model Enzymes

Experiments were performed with enzyme conformers that did not obey the symmetry model. The data is summarized in Figure 1.

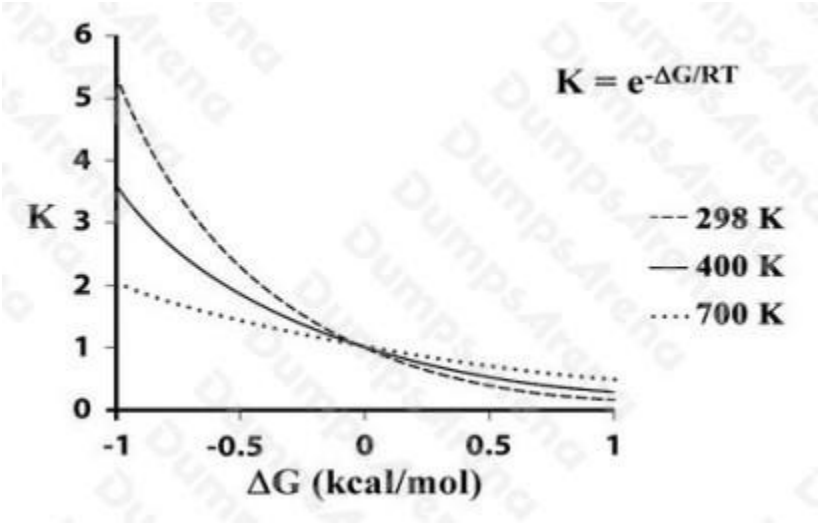


Figure 1: Equilibrium distribution of two conformers at different temperatures given the free energy of their interconversion. (modified from Mr.Holmium).

What assumption is made about the T and R conformations and the substrate?

A. In the absence of any substrate, the T conformation predominates.

B. In the absence of any substrate, the R conformation predominates.

C. In the absence of any substrate, the T and R conformations are in equilibrium.

D. In the absence of any substrate, the enzyme exists in another conformation, S.

ANSWER: A

Explanation:

“In the absence of any substrate, the T conformation predominates.” is correct because the passage explicitly specifies the equilibrium distribution before substrate binding as 10,000 molecules in the T conformation for every 1 molecule in the R conformation. Thus, although both conformations are present and interconvert, the unliganded enzyme overwhelmingly occupies the T state. This is the essential starting condition of the concerted, or symmetry, model of allostery: the T state is favored in the absence of ligand, whereas the substrate has greater affinity for the R state. As substrate binds preferentially to the small population already in the R state, it stabilizes that conformation and shifts the conformational equilibrium toward R. The linked, concerted behavior of subunits then accounts for cooperative substrate binding. The stated 10,000:1 ratio directly supports the conclusion that T predominates before any substrate is added. This ligand-dependent shift between pre-existing conformational states is a central feature of the Monod-Wyman-Changeux allosteric model, originally described in The Journal of Molecular Biology and summarized by NCBI Bookshelf.

QUESTION NO: 62

Hypoxia refers to a physiological condition in which the body lacks sufficient oxygen for normal cellular functioning. Prolonged hypoxia generally leads to an inhibition of mental capacity and a reduction in the work capacity of muscle. Severe cases of hypoxia can lead to coma or even death. Depending on the cause, hypoxia can be classified into four general types:

Hypoxic hypoxia is a type of hypoxia that occurs when the partial pressure of oxygen in the blood is too low. For example, climbers at high altitude, where the air contains less oxygen, might experience hypoxic hypoxia because the partial pressure of oxygen in the air inhaled is very low, leading to insufficient partial pressure of oxygen in the blood.

Anemic hypoxia describes a diminished ability of the blood to transport oxygen. Several factors can influence the oxygen-carrying capacity of the blood. Primary causes of anemic hypoxia include a lower than normal number of functional erythrocytes or an insufficient quantity of hemoglobin, the oxygen-carrying molecules of the blood. Abnormal hemoglobin can also decrease the blood’s capacity to carry oxygen and lead to anemic hypoxia.

Ischemic hypoxia is caused by a decreased delivery of blood to the tissues. Localized circulatory deficiencies, such as blood clots, and global circulatory deficiencies, such as heart failure, decrease the delivery of blood to the tissues, and can therefore cause ischemic hypoxia.

Histotoxic hypoxia results from the inability of cells to utilize the oxygen available in the blood. Causes of histotoxic hypoxia include the poisoning of cellular enzymes involved in aerobic respiration, as well as the decreased metabolic capacity of the oxidative enzymes due to vitamin deficiency. Cyanide poisoning causes histotoxic hypoxia by blocking the action of cytochrome oxidase in the electron transport chain so that tissues cannot use oxygen even though it is available.

Exposure to high levels of radiation has been demonstrated to cause anemia. The most likely explanation is that radiation damages the:

A. blood vessels.

B. spleen.

C. thymus.

D. bone marrow.

ANSWER: D

Explanation:

bone marrow. High-dose ionizing radiation can damage rapidly dividing cells, making hematopoietic stem and progenitor cells in bone marrow particularly vulnerable. Bone marrow is the principal site of hematopoiesis—the continual production of circulating blood cells, including erythrocytes. When radiation injures this tissue, erythrocyte production falls. The resulting reduction in red-cell mass and/or hemoglobin decreases the blood's oxygen-carrying capacity, producing anemia and thereby contributing to anemic hypoxia as defined in the passage.

This conclusion follows directly from the role of marrow in maintaining the blood-cell supply. Mature erythrocytes have a finite lifespan, so the body must continuously replace them through differentiation of marrow stem cells. Suppression or destruction of this marrow-producing compartment therefore becomes clinically evident as anemia, particularly after substantial whole-body or marrow-targeted radiation exposure. The National Cancer Institute describes bone marrow as the soft tissue within bones where blood cells are made, and notes that radiation can injure the marrow and reduce blood-cell counts. The CDC likewise identifies bone-marrow damage and reduced production of blood cells as important consequences of acute radiation exposure. See the National Cancer Institute definition of bone marrow and the CDC guidance on acute radiation syndrome.

QUESTION NO: 63

The nuclei of certain unstable isotopes will spontaneously decay, producing a more stable nucleus and releasing a particle or quantity of energy. Alpha decay releases a helium nucleus, beta decay emits an electron, while gamma decay is the emission of a high energy photon. Each type of radioactive decay is characterized, in part, by the half-life of the radioactive material – the time required for half of the nuclei in a sample to undergo decay. Examples of such decays are shown in Figure 1.

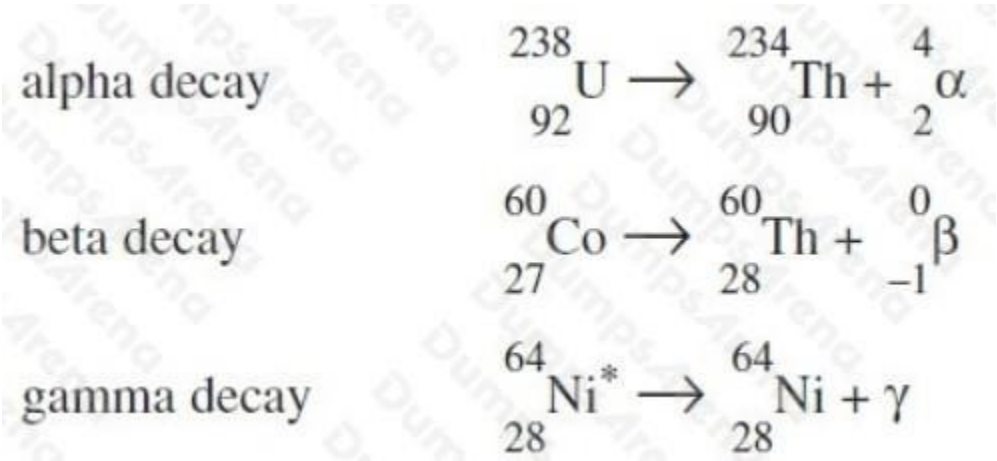


Figure 1

A Geiger counter can be used to detect the decay of radioactive materials. A simple Geiger counter consists of a hollow metal cylinder with a wire along its axis. The cylinder is filled with low pressure argon gas and a high voltage difference is applied between the wire and the cylinder. When alpha, beta, or gamma radiation passes through the cylinder, it interacts with the gas particles and leads to the formation of ions which cause a discharge between the wire and the cylinder. The consequent current may be used to drive a speaker, producing the characteristic clicking sound of the Geiger counter each time a pulse of current occurs. The Geiger counter circuitry is shown in Figure 2.

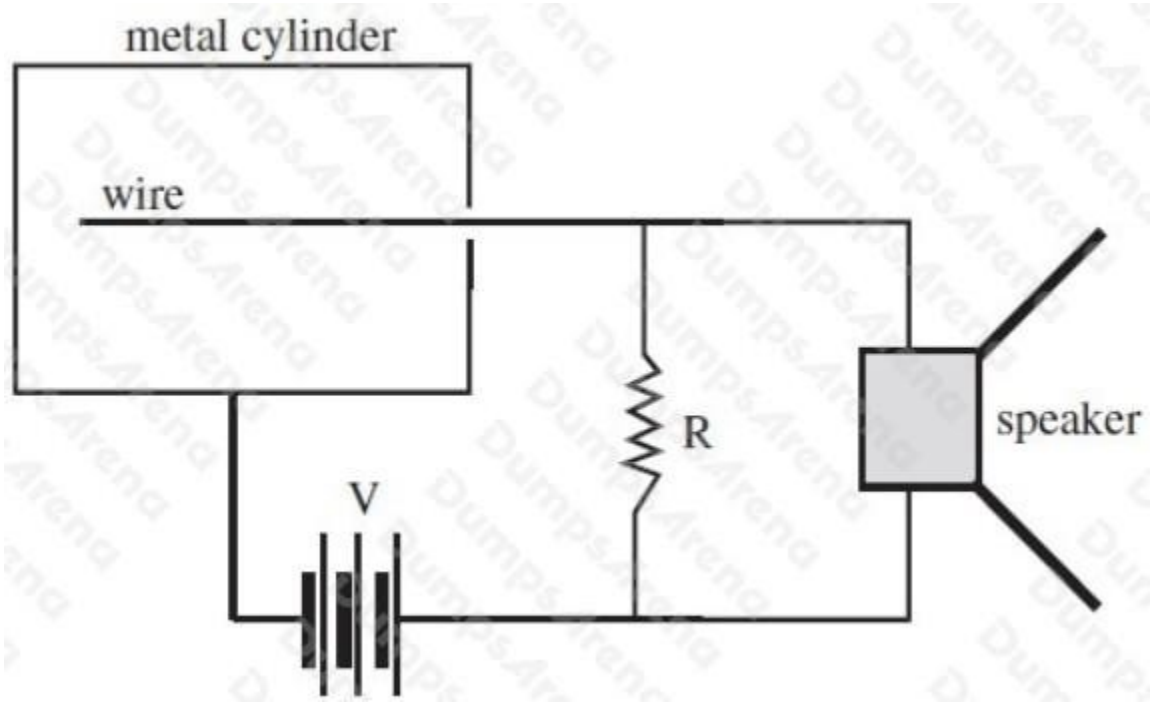


Figure 2

Which of the following statements is true concerning two isolated radioactive samples examined separately with a Geiger counter?

A. The sample with the shorter half-life will produce a higher frequency of clicks.

B. The sample with the longer half-life will produce a higher frequency of clicks.

C. The sample with the shorter half-life will generate a larger current.

D. The half-life cannot be determined from the click frequency alone.

ANSWER: D

Explanation:

The half-life cannot be determined from the click frequency alone. A Geiger counter's click rate is related to the activity of the particular sample being measured: the number of nuclear decays occurring per unit time that result in detectable radiation. Activity depends both on the decay constant, which is related to half-life, and on the number of undecayed radioactive nuclei present. In equation form, activity is $A = \lambda N$, where λ is the decay constant and N is the number of radioactive nuclei. Thus, although a shorter half-life corresponds to a greater decay constant for the same isotope population, a sample's count rate also depends on its amount, age, isotope, radiation type, position relative to the detector, and detection efficiency. A large sample with a relatively long half-life can therefore produce a higher click rate than a small sample with a short half-life. To infer a half-life experimentally, measurements must be made over time under controlled, consistent counting conditions, so that the decrease in activity can be analyzed. The U.S. Nuclear Regulatory Commission discusses half-life and radioactive decay at NRC: Half-Life, and the relationship between activity and decay is summarized by the National Institute of Standards and Technology.

QUESTION NO: 64

"Bebop lives!" cries the newest generation of jazz players. During the 1980s, musicians like Wynton Marsalis revived public interest in bebop, the speedy, angular music that first bubbled up out of Harlem in the early 1940s, changing the face of jazz. That Marsalis and others thought of themselves as celebrating and preserving a noble tradition is, in one sense, inevitable. After the excesses of experimental or "free" jazz in the 1960s and the electronic jazz-rock "fusion" of the 70s, it is hardly surprising that people should hearken back to a time when jazz was "purer," perhaps even at the apex of its development. But the recent enthusiasm for bebop is also ironic in light of the music's initial public reception.

In its infancy, during the first two decades of the 20th century, jazz was played by small groups of musicians improvising variations on blues tunes and popular songs. Most of the musicians were unable to read music, and their improvisations were fairly rudimentary. Nevertheless, jazz attained international recognition in the 1920s. Two of the people most responsible for its rise in popularity were Louis Armstrong, the first great jazz soloist, and Fletcher Henderson, leader of the first great jazz band. Armstrong, with his buoyant personality and virtuosic technical skills, greatly expanded the creative range and importance of the soloist in jazz. Henderson, a pianist with extensive training in music theory, foresaw the orchestral possibilities of jazz played by a larger band. He wrote out arrangements of songs for his band members that preserved the spirit of jazz, while at the same time giving soloists a more structured musical background upon which to shape their solo improvisations. In the 1930s, jazz moved further into the mainstream with the advent of the Swing Era. Big bands in the Henderson mold, led by musicians like Benny Goodman, Count Basie and Duke Ellington, achieved unprecedented popularity with jazz-oriented “swing” music that was eminently danceable.

Against this musical backdrop, bebop arrived on the scene. Like other modernist movements in art and literature, bebop music represented a departure from tradition in both form and content, and was met with initial hostility. Bebop tempos were unusually fast, with the soloist often playing at double time to the backing musicians. The rhythms were tricky and complex, the melodies intricate and frequently dissonant, involving chord changes and notes not previously heard in jazz. Before bebop, jazz players had improvised on popular songs such as those produced by TinPan Alley, but bebop tunes were often originals with which jazz audiences were unfamiliar.

Played mainly by small combos rather than big bands, bebop was not danceable; it demanded intellectual concentration. Soon, jazz began to lose its hold on the popular audience, which found the new music disconcerting. Compounding public alienation was the fact that bebop seemed to have arrived on the scene in a completely mature state of development, without that early phase of experimentation that typifies so many movements in the course of Western music. This was as much the result of an accident of history as anything else. The early development of bebop occurred during a three-year ban on recording in this country made necessary by the petrol and vinyl shortages of World War II. By the time the ban was lifted, and the first bebop records were made, the new music seemed to have sprung fully-formed like Athena from the forehead of Zeus. And though a small core of enthusiasts would continue to worship bebop pioneers like Charlie Parker and Dizzy Gillespie, many bebop musicians were never able to gain acceptance with any audience and went on to lead lives of obscurity and deprivation.

The author mentions Wynton Marsalis and Charlie Parker as:

A. pioneers of jazz-rock “fusion.”

B. architects of the bebop movement.

C. Swing Era musicians hostile to bebop.

D. bebop musicians of different eras.

ANSWER: D

Explanation:

The correct answer is *bebop musicians of different eras.* The passage introduces Wynton Marsalis as one of the musicians who renewed public interest in bebop during the 1980s. His role is therefore tied to a later revival and preservation of an established jazz tradition. Charlie Parker is named near the end of the passage as one of the original bebop pioneers whom a dedicated group of listeners continued to admire. Thus, the two names frame the historical trajectory described by the author: Parker represents bebop’s formative period in the 1940s, while Marsalis represents its renewed prominence decades later.

This comparison supports the passage’s central irony. By the time Marsalis and his contemporaries celebrated bebop as a revered, “pure” tradition, the music had long since moved from its disruptive beginnings. The author emphasizes that early bebop departed sharply from prevailing jazz practices and initially alienated much of its audience. Mentioning musicians associated with distinct points in bebop’s history helps illustrate its transformation from controversial innovation to valued musical heritage. Biographical context for Parker and Marsalis is available from Encyclopaedia Britannica’s Charlie Parker biography and the National Endowment for the Arts profile of Wynton Marsalis.

QUESTION NO: 65

…Until last year many people – but not most economists – thought that the economic data told a simple tale. On one side, productivity – the average output of an average worker – was rising. And although the rate of productivity increase was very

slow during the 1970's and early 1980's, the official numbers said that it had accelerated significantly in the 1990's. By 1994 an average worker was producing about 20 percent more than his or her counterpart in 1978.

On the other hand, other statistics said that real, inflation- adjusted wages had not been rising at anything like the same rate. In fact, some of the most commonly cited numbers showed real wages actually falling over the last 25 years. Those who did their homework knew that the gloomiest numbers overstated the case… Still, even the most optimistic measure, the total hourly compensation of the average worker, rose only 3 percent between 1978 and 1994…

…But now the experts are telling us that the whole thing may have been a figment of our statistical imaginations… a blue-ribbon panel of economists headed by Michael Boskin of Stanford declared that the Consumer Price Index [C.P.I.] had been systematically overstating inflation, probably by more than 1 percent per year for the last two decades, mainly failing to take account of changes in the patterns of consumption and improvements in product quality…

…The Boskin report, in particular, is not an official document – it will be quite a while before the Government actually issues a revised C.P.I., and the eventual revision may be smaller than Boskin and his colleagues propose. Still, the general outline of the resolution is pretty clear. When all the revisions are taken into account, productivity growth will probably look somewhat higher than it did before, because some of the revisions being proposed to the way we measure consumer prices will also affect the way we calculate growth. But the rate of growth of real wages will look much higher – and so it will now be roughly in line with productivity, which will therefore reconcile numbers on productivity and wages with data that show a roughly unchanged distribution of income between capital and labor. In other words, the whole story about workers not sharing in productivity gains will turn out to have been based on a statistical illusion.

It is important not to go overboard on this point. There are real problems in America, and our previous concerns were by no means pure hypochondria. For one thing, it remains true that the rate of economic progress over the past 25 years has been much slower than it was in the previous 25. Even if Boskin's numbers are right, the income of the median family – which officially has experienced virtually no gain since 1973 – has risen by only about 35 percent over the past 25 years, compared with 100 percent over the previous 25. Furthermore, it is quite likely that if we "Boskinized" the old data – that is, if we tried to adjust the C.P.I. for the 50's and 60's to take account of changing consumption patterns and rising product quality – we would find that official numbers understated the rate of progress just as much if not more than they did in recent decades…

…Moreover, while workers as a group have shared fully in national productivity gains, they have not done so equally. The overwhelming evidence of a huge increase in income inequality in America has nothing to do with price indexes and is therefore unaffected by recent statistical revelations. It is still true that families in the bottom fifth, who had 5.4 percent of total income in 1970, had only 4.2 percent in 1994; and that over the same period the share of the top 5 percent went from 15.6 to 20.1. And it is still true that corporate C.E.O.'s, who used to make about 35 times as much as their employees, now make 120 times as much or more…

…While these are real and serious problems, however, one thing is now clear: the truth about what is happening in America is more subtle than the simplistic morality play about greedy capitalists and oppressed workers that so many would-be sophisticates accepted only a few months ago. There was little excuse for buying into that simplistic view then; there is no excuse

now…

It can be inferred from the passage that in the 1950s and 1960s:

A. workers accounted for approximately the same percentage of national income as in 1994.

B. workers experienced more substantial yearly pay increases than did workers in the 1970's and 1980's.

C. workers' wages, according to a revised C.P.I., increased at a rate higher than economic progress.

D. workers' incomes accurately reflected the period's economic progress.

ANSWER: B

Explanation:

The passage supports the inference that workers experienced more substantial yearly pay increases than did workers in the 1970's and 1980's. The author contrasts the recent 25-year period with the preceding 25 years, which substantially overlaps the 1950s and 1960s. Even accepting the proposed correction for inflation measurement, median-family income rose only about 35 percent in the recent period, whereas it rose about 100 percent in the earlier period. The author also states directly that the rate of economic progress during the more recent 25 years was much slower than during the preceding 25 years. Together, these comparisons establish that income gains in the earlier decades were materially stronger on an annual basis than those experienced in the later decades named in the question. The later discussion of potentially "Boskinizing" historical

figures does not undo that comparison; it reinforces the possibility that measured progress in the earlier period was understated. The inference depends on comparing the passage's stated income-growth figures and time periods, rather than assuming an exact measurement of every worker's pay. For context on the historical Consumer Price Index and its role in converting nominal earnings into real purchasing power, see the U.S. Bureau of Labor Statistics Consumer Price Index page and the BLS discussion of the Boskin Commission's findings.

QUESTION NO: 66

Slight gaps are intentionally left between blocks of a building:

A. to drain water accumulated on the roof.

B. to avoid cracks due to temperature impacts.

C. to allow light to internal of room.

D. None of them.

ANSWER: B

Explanation:

to avoid cracks due to temperature impacts. is correct because these intentional separations function as expansion joints (also called movement joints). Building materials expand when warmed and contract when cooled. Because a building can contain long, continuous sections of concrete, masonry, steel, or other materials, normal temperature changes can produce substantial cumulative movement across its length. A properly designed joint provides space for adjoining blocks to move independently rather than forcing stress to build up within rigid structural or finish materials.

This accommodation of thermal movement helps preserve the integrity, serviceability, and weather resistance of the building. It reduces the likelihood of uncontrolled cracking, distortion, or damage at vulnerable interfaces as temperatures vary daily and seasonally. Joint width, spacing, and sealant selection are engineering design considerations that depend on material properties, expected temperature range, building geometry, and exposure conditions. The Whole Building Design Guide describes expansion joints as separations that accommodate movement in building assemblies: Whole Building Design Guide—Building Envelope Design Guide. The National Park Service also discusses the importance of allowing material movement when addressing masonry and building-envelope performance: National Park Service Preservation Briefs.

QUESTION NO: 67

A compound contains 75% carbon and 25% hydrogen by mass. What is the molecular formula of the compound?

A. CH4

B. CH3

C. C2H4

D. C2H6

E. Cannot be determined from the given information; the empirical formula is CH4.

ANSWER: E

Explanation:

Cannot be determined from the percentage composition alone; the empirical formula is CH_4. Assume a 100 g sample, which contains 75 g of carbon and 25 g of hydrogen. Converting each mass to moles gives approximately 6.24 mol carbon (75 ÷ 12.01) and 24.80 mol hydrogen (25 ÷ 1.008). Dividing both values by the smaller amount gives a simplest whole-number ratio of one carbon atom to four hydrogen atoms. Thus, CH_4 is the empirical formula: it expresses the simplest atom ratio consistent with the stated mass percentages.

A molecular formula requires additional information, specifically the compound's molar mass or an equivalent measurement. The molecular formula must be a whole-number multiple of the empirical formula, represented as $(CH_4)_n$. Without knowing n, the percentages cannot establish that the molecule contains exactly one carbon and four hydrogen atoms. For example, CH_4 would be the molecular formula only if the measured molar mass were approximately 16.04 g/mol. The distinction between empirical and molecular formulas, including the need for molar mass to obtain the latter, is described in OpenStax Chemistry 2e and Chemistry LibreTexts.

QUESTION NO: 68

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%

What is the molality of a stock solution that is 10% SDS by mass?

A. 0.028 m

B. 0.100 m

C. 0.347 m

D. 0.385 m

ANSWER: D

Explanation:

0.385 m is correct because molality is defined as the amount of solute in moles divided by the mass of the *solvent* in kilograms, rather than by the volume or total mass of the solution. This definition is given by the IUPAC Gold Book. For convenience, consider 100 g of a solution that is 10% SDS by mass. It contains 10 g of sodium dodecyl sulfate and 90 g of water, which is 0.090 kg of solvent. SDS has a molar mass of approximately 288.38 g/mol, consistent with the value reported by PubChem. Therefore, the amount of SDS is 10 g ÷ 288.38 g/mol, or about 0.0347 mol. Dividing by the solvent mass gives 0.0347 mol ÷ 0.090 kg = 0.385 mol/kg. Thus, a 10% mass-by-mass SDS stock has a molality of approximately 0.385 m. The choice of a 100 g sample is only a convenient basis; any proportional quantity of this same solution produces the identical molality.

QUESTION NO: 69

The most active non-metal has:

A. medium electronegativity.

B. high electronegativity.

C. low electronegativity.

D. large atom radii.

ANSWER: B

Explanation:

high electronegativity. is correct because nonmetal reactivity depends largely on an atom's ability to attract and gain electrons during chemical bonding. Electronegativity measures the pull an atom exerts on shared electrons in a bond; a high value reflects a strong attraction for electrons. Highly reactive nonmetals therefore readily accept electron density from other atoms, especially metals, and tend to form negative ions or strongly polar covalent bonds. Across a period of the periodic table, electronegativity generally increases from left to right as effective nuclear charge increases and atomic radius decreases. It generally decreases down a group because valence electrons are farther from the nucleus and are more shielded by inner electrons. Fluorine, located near the upper right of the periodic table, has the highest electronegativity of all elements and is consequently the most chemically active nonmetal. Its strong attraction for electrons explains its readiness to react and form compounds. Periodic trends for electronegativity and their connection to nonmetallic character are summarized by OpenStax Chemistry via LibreTexts and the Encyclopaedia Britannica overview of electronegativity.

QUESTION NO: 70

Four major blood types exist in the human ABO blood system: types A, B, AB, and O; and there are three alleles that code for them. The A and B alleles are codominant, and the O allele is recessive. Blood types are derived from the presence of specific polysaccharide antigens that lie on the outer surface of the red blood cell membrane. The A allele codes for the production of the A antigen; the B allele codes for the production of the B antigen; the O allele does not code for any antigen.

While there are many other antigens found on red blood cell membranes, the second most important antigen is the Rh antigen. Rh is an autosomally dominant trait coded for by 2 alleles. If this antigen is present, an individual is Rh+; if it is absent, an individual is Rh−. For example, a person with type AB blood with the Rh antigen is said to be AB+.

These antigens become most important when an individual comes into contact with foreign blood. Because of the presence of naturally occurring substances that closely mimic the A and B antigens, individuals who do not have these antigens on their red blood cells will form antibodies against them. This is inconsequential until situations such as blood transfusion, organ transplant, or pregnancy occur.

Erythroblastosis fetalis is a condition in which the red blood cells of an Rh+ fetus are attached by antibodies produced by its Rh− mother. Unlike ABO incompatibility, in which there are naturally occurring antibodies to foreign antigens, the Rh system requires prior sensitization to the Rh antigen before antibodies are produced. This sensitization usually occurs during the delivery of an Rh + baby. So while the first baby will not be harmed, any further Rh+ fetuses are at risk.

The Coombs tests provide a method for determining whether a mother has mounted an immune response again her baby's blood. The tests are based on whether or not agglutination occurs when Coombs reagent is added to a sample. Coombs reagent contains antibodies against the anti-Rh antibodies produced by the mother. The indirect Coombs test takes the mother's serum, which contains her antibodies but no red blood cells, and mixes it with Rh+ red blood cells. Coombs reagent is then added. If agglutination occurs, the test is positive, and the mother must be producing anti-Rh antibodies. The direct Coombs test mixes the baby's red blood cells with Coombs reagent. If agglutination occurs, the test is positive, and the baby's red blood cells must have been attacked by its mother's anti-Rh antibodies.

How might one most practically assess the risk of erythroblastosis fetalis in a pregnant woman?

A. Test all women for the presence of anti-Rh antibodies.

B. Test all fetuses for the presence of the Rh antigen within the first trimester of pregnancy.

C. Test only Rh– mothers for the presence of anti- Rh antibodies.

D. Test all mothers of Rh+ children for the presence of anti-Rh antibodies.

ANSWER: C

Explanation:

Test only Rh– mothers for the presence of anti- Rh antibodies is the most practical assessment because clinically significant Rh hemolytic disease requires maternal Rh negativity together with maternal sensitization to the Rh antigen. An Rh-negative pregnant patient may have been exposed to Rh-positive red cells during an earlier pregnancy or another sensitizing event and subsequently formed IgG anti-Rh antibodies. Those antibodies can cross the placenta and bind fetal Rh-positive erythrocytes, creating risk for hemolytic disease of the fetus and newborn. Testing the serum of the relevant maternal group for anti-Rh antibodies directly addresses whether sensitization has already occurred. In the terms of the passage, this is performed with the indirect Coombs test: maternal serum is incubated with Rh-positive red blood cells, and agglutination after addition of Coombs reagent indicates anti-Rh antibodies. A positive result identifies a pregnancy requiring further fetal-risk evaluation and monitoring. Modern prenatal care includes maternal blood group and antibody screening early in pregnancy, with particular follow-up for RhD-negative patients; see the American College of Obstetricians and Gynecologists guidance on Rh D alloimmunization and the NCBI review of hemolytic disease of the fetus and newborn.

QUESTION NO: 71

Which of the following is called DIOL?

A. Glycerol

B. Glycol

C. Methanol

D. Ethanol

ANSWER: B

Explanation:

Glycol is correct because "glycol" is a traditional class name for compounds containing two hydroxyl (–OH) groups, which are therefore diols. In common introductory chemistry usage, the term often specifically evokes ethylene glycol, whose systematic name is ethane-1,2-diol. Its structure contains two alcohol functional groups, one on each carbon atom, so it

meets the defining structural feature of a diol. More broadly, a diol is an alcohol with two hydroxyl groups; glycols are commonly diols in which those groups occur on different carbon atoms, especially neighboring carbons. The International Union of Pure and Applied Chemistry recognizes “glycol” as a retained name associated with dihydric alcohols, and ethylene glycol is listed by PubChem as ethane-1,2-diol. Thus, in the terminology intended by this question, glycol is the substance identified as a diol. See the IUPAC Gold Book entry for glycol and PubChem’s ethylene glycol record.

QUESTION NO: 72

A continuous spectrum of light, sometimes called blackbody radiation, is emitted from a region of the Sun called the photosphere. Although the continuous spectrum contains light of all wavelengths, the intensity of the emitted light is much greater at some wavelengths than at others. The relationship between the most intense wavelength of blackbody radiation and the temperature of the emitting body is given by Wien’s law, λ = 2.9 × 106 / T, where λ is the wavelength in nanometers and T is the temperature in kelvins.

As the blackbody radiation from the Sun passes through the cooler gases in the Sun’s atmosphere, some of the photons are absorbed by the atoms in these gases. A photon will be absorbed if it has just enough energy to excite an electron from a lower energy state to a higher one. The absorbed photon will have an energy equal to the energy difference between these two states. The energy of a photon is given by E = hf = hc/λ where h = 6.63 × 10−34 J·s, Planck’s constant, and c = 3 × 108 m/s, the speed of light in a vacuum.

The Sun is composed primarily of hydrogen. Electron transitions in the hydrogen atom from energy state n = 2 to higher energy states are listed below along with the energy of the absorbed photon:

Final Energy State	Energy ($\times 10^{-19}$ J)
$n = 3$	3.02
$n = 4$	4.08
$n = 5$	4.57
$n = 6$	4.84
$n = \infty$	5.44

If the temperature of the Sun’s photosphere is 5800 K, what wavelength of radiation does the Sun emit with the greatest intensity?

A. 2 nm

B. 50 nm

C. 500 nm

D. 4,500 nm

ANSWER: C

Explanation:

The correct answer is **500 nm**. Wien’s displacement law gives the wavelength at which a blackbody’s emitted radiation has its maximum intensity: $\lambda_{max} = (2.9 \times 10^6$ nm·K)/T. Substituting the photosphere temperature, 5800 K, gives $\lambda_{max} = (2.9 \times 10^6$ nm·K)/(5800 K) = 5.0×10^2 nm, or 500 nm. The kelvin units cancel, leaving wavelength in nanometers because the stated Wien constant is expressed in nm·K. A wavelength of 500 nm lies in the visible portion of the electromagnetic spectrum, consistent with the Sun’s approximately blackbody-like emission and the fact that sunlight is strongest at visible wavelengths. The photon-absorption discussion and hydrogen energy-level information provide context for spectral absorption lines, but determining the peak wavelength requires only the provided temperature and Wien’s law. Wien’s law is described by the OpenStax College Physics discussion of blackbody radiation; the NASA Sun facts page also identifies the Sun’s photosphere as having a temperature near 5,500 °C, consistent with approximately 5800 K.

QUESTION NO: 73

In 1972, Georges Ungar reported the discovery of a peptide that appeared to transfer learning. Ungar's claim was based on experiments in which rats placed in a chamber with specially designed dark and light regions were trained to avoid the dark regions of the chamber. Following their training, the rats were killed and brain extracts were prepared. These brain extracts were injected into naive rats which were then observed to acquire the fear of darkness without training. Two hypotheses were proposed to explain these remarkable results:

Hypothesis 1

Ungar concluded that the extracts contained some chemical that transmitted the learned fear of darkness to the naive rats. A fifteen amino-acid polypeptide was isolated from the brain extracts and sequenced. Ungar claimed that this peptide, called scotophobin, was a chemical transmitter of learning. The peptide had the primary structure shown below: C-ser-asp-asn-arg-gln-gln-gly-lys-ser-ala-arg-gln-glygly-tyr-N scotophobin

Hypothesis 2

Other researchers, who tested scotophobin but could not reproduce Ungar's results, argued that scotophobin did not transfer the learned fear of darkness. Instead, they suggested that scotophobin, which is structurally similar to ACTH and vasopressin, acted to increase stress in the rats. Since stress increases sympathetic nervous activity, rats injected with scotophobin would become hyperactive and tend to spend less time in the dark regions of the experimental chamber. They argued that such stress responses in the rats could be misinterpreted as a fear of darkness. Ungar's claim was further weakened by chemical analysis in which both the scotophobin extracts which Ungar had injected into the naive rats and a sample of synthesized scotophobin peptide were subjected to SDS polyacrylamide gel electrophoresis, as shown in Figure 1.

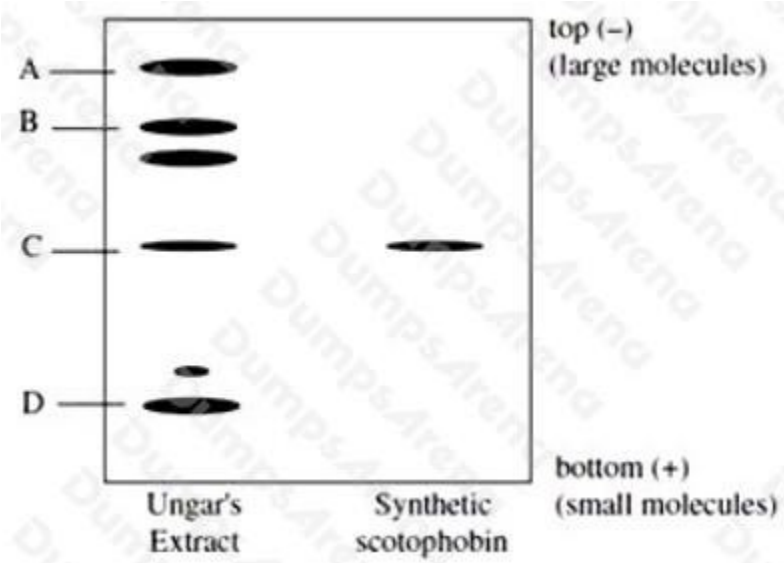


Figure 1

The chemical analysis of Ungar's extract most likely weakened his claim that scotophobin transferred the learned fear of darkness because it showed that:

A. the extract was not pure scotophobin.

B. the extract did not contain scotophobin.

C. scotophobin was not present in sufficient concentrations to illicit a response.

D. scotophobin was similar in structure to other proteins.

ANSWER: A

Explanation:

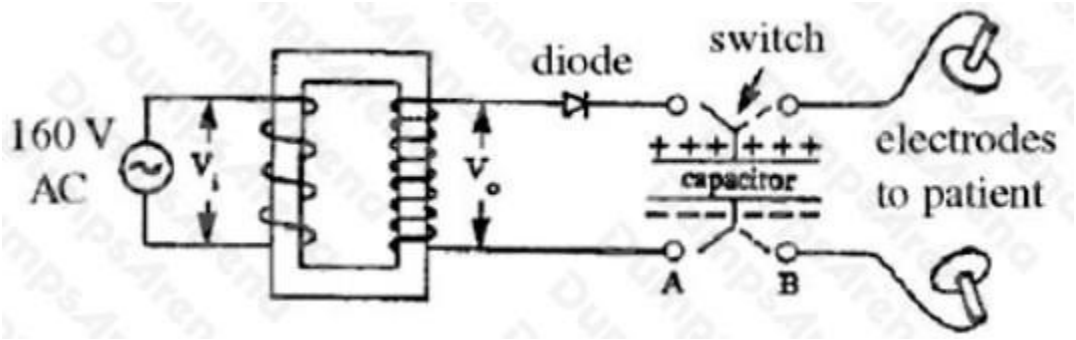
The extract was not pure scotophobin. In polyacrylamide gel electrophoresis, molecules in a sample separate into distinct bands according to their migration through the gel; a purified peptide preparation should therefore yield one principal band under a defined set of conditions. The lane containing synthesized scotophobin provides a comparison for the expected migration position of scotophobin. Although the extract includes material at a corresponding position, it also displays additional bands. Thus, the injected brain extract contained multiple components rather than scotophobin alone.

This is important because the behavioral effect was attributed specifically to scotophobin. When an experimental preparation is a mixture, the observed response cannot be causally assigned to one particular peptide without further purification and testing of the isolated component. One or more additional substances in the extract, or an interaction among components, could have produced the rats' altered behavior. The gel result therefore directly undermines the claimed identification of scotophobin as the sole learning-transfer factor. This interpretation follows the core analytical purpose of gel electrophoresis: assessing separation and sample complexity, as described by NCBI Bookshelf and Bio-Rad's SDS-PAGE overview.

QUESTION NO: 74

The periodic beating of the heart is controlled by electrical impulses that originate within the cardiac muscle itself. These pulses travel to the sinoatrial node and from there to the atria and the ventricles, causing the cardiac muscles to contract. If a current of a few hundred milliamperes passes through the heart, it will interfere with this natural system, and may cause the heart to beat erratically. This condition is known as ventricular fibrillation, and is life-threatening. If, however, a larger current of about 5 to 6 amps is passed through the heart, a sustained ventricular contraction will occur. The cardiac muscle cannot relax, and the heart stops beating. If at this point the muscle is allowed to relax, a regular heartbeat will usually resume.

The large current required to stop the heart is supplied by a device known as a defibrillator. A schematic diagram of a defibrillator is shown below. This device is essentially a "heavy-duty" capacitor capable of storing large amounts of energy. To charge the capacitor quickly (in 1 to 3 seconds), a large DC voltage must be applied to the plates of the capacitor. This is achieved using a step-up transformer, which creates an output voltage that is much larger than the input voltage. The transformer used in this defibrillator has a step-up ratio of 1:50.



The AC voltage that is obtained from the transformer must then be converted to DC voltage in order to charge the capacitor. This is accomplished using a diode, which allows current flow in one direction only. Once the capacitor is fully charged, the charge remains stored until the switch is moved to position B and the plates are placed on the patient's chest. To cut down the resistance between the patient's body and the defibrillator, the electrodes are covered with a wetting gel before use. Care must be taken to insure that the patient is not in electrical contact with the ground while the defibrillator is in use.

If a dielectric was inserted between the plates of the capacitor in the defibrillator when the switch is in position A:

A. the energy stored in the capacitor would increase.

B. the energy stored in the capacitor would decrease.

C. the electric field between the plates would increase.

D. the electric field between the plates would decrease.

ANSWER: A

Explanation:

When the switch is in position A, the capacitor is connected to the charging supply, so the voltage across its plates is held constant by that source. Inserting a dielectric increases the capacitance by a factor equal to the dielectric constant: $C = \kappa C_0$. The dielectric polarizes in the applied field, and the voltage source responds by moving additional free charge onto the capacitor plates as needed to preserve the specified potential difference.

The energy of a capacitor at constant voltage is $U = \frac{1}{2}CV^2$. Because the capacitance rises while the voltage remains unchanged, the stored energy must rise. Thus, **the energy stored in the capacitor would increase.** The extra energy is supplied by the charging circuit, rather than appearing spontaneously from insertion of the dielectric. Although polarization alters the relation between free charge and field inside the material, the fixed plate voltage and plate separation mean that

the overall potential drop remains fixed; for an ideal parallel-plate capacitor, the corresponding average electric field is consequently unchanged.

These constant-voltage capacitor relationships are summarized in OpenStax University Physics: Capacitor with Dielectric and the energy expression is derived in OpenStax University Physics: Energy Stored in a Capacitor.

QUESTION NO: 75

Muzak, the intentionally unobtrusive music that most people associate with elevators and dentists' waiting rooms, represents the paradoxical success story of a product designed to be ignored. Although few people admit to enjoying its blandly melodic sounds, Muzak reaches over 100 million listeners in 14 countries and has played in the White House, the Apollo lunar spacecraft, and countless supermarkets, offices, and factories. This odd combination of criticism and widespread acceptance is not surprising, however, when one considers that Muzak is not created for the enjoyment of its listeners: rather, its purpose is to modify physiological and psychological aspects of an environment.

In the workplace, Muzak is credited with increasing both productivity and profitability. Research into the relationship between music and productivity can be traced to the earliest days of the Muzak Corporation. Developed by a military officer in 1922 as a way of transmitting music through electrical wires, Muzak blossomed in the 1930's following a study which reported that people work harder when they listen to certain kinds of music. Impressed by these findings, the BBC began to broadcast music in English munitions factories during World War II in an effort to combat fatigue. When workers assembling weapons increased their output by 6 percent, the U.S. War Production Board contracted the Muzak Corporation to provide uplifting music to American factories. Today, the corporation broadcasts its "Environmental Music" to countless businesses and institutions throughout the world. And while most people claim to dislike Muzak's discreet cadences, it seems to positively influence both productivity and job satisfaction.

Researchers speculate that listening to Muzak and other soft music improves morale and reduces stress by modifying our physiology. Physiological changes such as lowered heart rate and decreased blood pressure have been documented in hospital studies testing the effect of calming music on cardiac patients. In addition, certain kinds of music seem to effect one's sense of emotional, as well as physical, well being. It is just this sort of satisfaction which is thought to result in increased performance in the workplace. In a study of people performing repetitive clerical tasks, those who listened to music performed more accurately and quickly than those who worked in silence; those who listened to Muzak did better still. Moreover, while Muzak was conceived as a tool for productivity, it also seems to influence a business' profitability. In an experiment in which supermarket shoppers shopped to the mellow sounds of Muzak, sales were increased by as much as 12 percent.

What makes Muzak unique is a formula by which familiar tunes are modified and programmed. Careful instrumentation adds to an overall sound that is neither monotonous nor rousing. But it is the precisely timed programming that separates Muzak from other "easy listening" formats. At the core of the programming is the concept of the "Stimulus Progression." Muzak programs are divided into quarter-hour groupings of songs, and are specifically planned for the time of day at which they will be heard. Each composition is assigned a mood rating between 1 and 6 called a stimulus value; a song with a rating of 2, for example, is slower and less invigorating than one with a value of 5. Approximately six compositions with ascending stimulus values play during any given quarter hour; each 15 minute segment ends in silence. Each segment of a 24-hour program is carefully planned. Segments that are considered more stimulating air at 11 a.m. and 3 p.m. (the times when workers typically tire), while more soothing segments play just after lunchtime and towards the end of the day, when workers are likely to be restless.

From the point of view of management, then, Muzak is a useful tool in the effort to maximize both productivity and profits. However, some people object to its presence, labeling it as a type of unregulated air pollution. Still others see it as an Orwellian nightmare, a manipulation of the subconscious. But Muzak's effectiveness seems to lie in the fact that most people never really listen to it. While it may be true that no one actually likes this carefully crafted aural atmosphere, many simply ignore it, allowing its forgettable sounds to soften the contours of the day.

According to the passage, a 15-minute segment of Muzak with an average stimulus value of 5 would most likely be broadcast at:

A. there is no known way to isolate the DNA responsible for hemoglobin.

B. naked hemoglobin tends to break down in the bloodstream.

C. non-globulating PFCs have significantly abbreviated oxygen-carrying capacities.

D. the use of PFCs may lead to blood clotting.

E. 3 p.m.

ANSWER: E

Explanation:

3 p.m. is correct because the passage defines the stimulus value as a measure of a composition's relative energy: a value of 5 is more invigorating than a value of 2 on the stated 1-to-6 scale. The programming method, termed "Stimulus Progression," uses carefully timed 15-minute segments to match workers' expected patterns of alertness and fatigue. The passage expressly states that more stimulating segments are broadcast at 11 a.m. and 3 p.m., identified as times when workers typically tire. Thus, a segment averaging the relatively high stimulus value of 5 would fit the more stimulating programming scheduled for 3 p.m. This conclusion follows directly from linking the passage's definition of a higher stimulus value with its stated broadcast times for stimulating segments; it does not require outside knowledge about music, workplaces, or Muzak. This is the type of evidence-based, passage-grounded inference assessed in MCAT Critical Analysis and Reasoning Skills questions. The AAMC describes the MCAT as assessing reasoning skills through passage-based questions in its MCAT exam overview. Additional official preparation guidance is available through the AAMC's CARS section resources.

QUESTION NO: 76

A cell with a high intracellular K+ concentration, whose plasma membrane is impermeable to K+, is placed in an ATP-rich medium with a low K+ concentration. After several minutes, it is determined that the extracellular concentrations of both K+ and ATP have decreased, while the intracellular K+ concentration has increased. What is the most likely explanation for this phenomenon?

A. The K+ passively diffused from the medium into the cell.

B. The K+ entered the cell by way of facilitated transport.

C. The ATP formed a temporary lipid-soluble complex with the K+, thus enabling the potassium to enter the cell.

D. The K+ entered the cell by way of active transport.

ANSWER: D

Explanation:

"The K+ entered the cell by way of active transport" is correct because the observations demonstrate energy-dependent uptake of potassium against its concentration gradient. Initially, the cell contains a high concentration of K+ and the surrounding medium contains a low concentration. Nevertheless, extracellular K+ decreases while intracellular K+ increases, meaning K+ has moved into the cell from the lower-concentration side to the higher-concentration side. This is uphill transport and requires an energy source rather than spontaneous movement.

The simultaneous decrease in extracellular ATP supplies the key evidence for an ATP-coupled process. ATP hydrolysis can provide energy to a membrane transport protein, allowing it to undergo conformational changes that move ions across an otherwise impermeable plasma membrane. In cells, ion pumps are classic examples of primary active transport: they use ATP directly to establish or maintain ion concentration gradients. Thus, ATP consumption and net K+ accumulation inside the cell are both explained by active transport through a specific membrane pump or carrier protein. For an overview of ATP-driven membrane transport, see NCBI Bookshelf: Active Transport by ATP-Powered Pumps and OpenStax Biology: Active Transport.

QUESTION NO: 77

The lead-acid battery, also called a lead storage battery, is the battery of choice for starting automobiles. It contains 6 cells connected in series, each composed of a lead oxide cathode "sandwiched" between 2 lead anodes. Insulating separators are placed between the electrodes to prevent internal short-circuits. Aqueous sulfuric acid is the electrolyte.

When the battery is being discharged, the following reaction takes place:

$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O$ Reaction 1

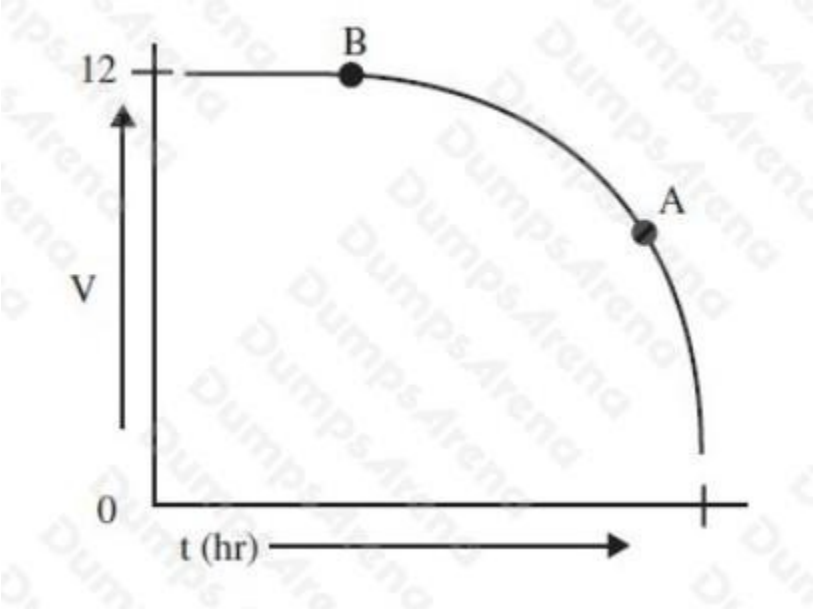
The electrode reactions, both written as reductions, are shown in Table 1.

Table 1

Half-reaction	E°(V)
$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O$	1.69
$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$	−0.36

As a car operates, the battery is recharged by electricity produced by the car's alternator, an AC generator whose ultimate power source is the car's internal combustion engine. In spite of this, batteries eventually lose their power. The battery is said to be "dead" when Reaction 1 has proceeded completely to the right.

The graph below shows the change in potential versus time of a 12-V lead storage battery during discharge.



Which of the following is true?

A. The electrolyte density at point A is greater than it is at point B.

B. The electrolyte density at point A is less than it is at point B.

C. The electrolyte density at point A is the same as it is at point B.

D. The electrolyte density at points A and B cannot be compared without more information.

ANSWER: B

Explanation:

The electrolyte density at point A is less than it is at point B. During discharge, the overall lead-acid cell reaction consumes aqueous sulfuric acid: Pb and PbO_2 react with H_2SO_4 to form solid $PbSO_4$ and water. Thus, as discharge proceeds, sulfuric acid is removed from the electrolyte and water is produced. The concentration of sulfuric acid consequently falls.

A solution's density depends on its composition. Sulfuric-acid solution is denser when it contains a greater proportion of sulfuric acid, so the decreasing acid concentration during discharge causes the electrolyte's specific gravity (and therefore its density) to decrease. Point A represents a later stage of the discharge than point B on the potential-versus-time curve. At point A, more of Reaction 1 has proceeded to the right, meaning more sulfuric acid has been consumed and the electrolyte is less dense than it was at point B.

This density change is the basis for using hydrometers to assess the state of charge of flooded lead-acid batteries. See Battery University: How to Measure State of Charge and Encyclopaedia Britannica: lead-acid storage battery.

QUESTION NO: 78

When a person faces an unexpected threat, which hormone is activated as a defensive response?

A. Cortisone

B. Androgens

C. Adrenaline

D. Nora-adrenaline

ANSWER: C

Explanation:

Adrenaline is the best answer because it is a principal hormone involved in the body's immediate "fight-or-flight" response to an unexpected threat. A perceived danger activates the sympathetic nervous system, which stimulates the adrenal medulla to release adrenaline (also called epinephrine) into the bloodstream. Its rapid effects prepare the body for urgent action: heart rate and cardiac output increase, airways widen to improve oxygen delivery, blood glucose becomes more available as fuel, and blood flow is preferentially directed toward tissues needed for rapid physical response.

This defensive response is designed to occur within seconds, allowing a person to react quickly to acute stress. In clinical and physiological terminology, adrenaline is therefore strongly associated with the immediate alarm phase of stress and emergency adaptation. The adrenal glands and their role in producing stress-related hormones are described by the National Institute of Diabetes and Digestive and Kidney Diseases: https://www.niddk.nih.gov/health-information/endocrine-diseases/adrenal-insufficiency-addisons-disease. A detailed overview of the sympathetic stress response is also available in the NCBI Bookshelf: https://www.ncbi.nlm.nih.gov/books/NBK538143/.

QUESTION NO: 79

Nitric oxide, NO, has recently been found to have widespread physiological effects, acting as a major regulator in the nervous, cardiovascular, and immune systems. The production of NO in the body is regulated by specific NOS enzymes which exist in at least three different isoforms – bNOS, eNOS, and macNOS. Each of these isoforms differ in location and function and serve to mediate different physiological responses to NO. Some physiological roles of NO have been demonstrated as follows:

I. In the central nervous system, NO production is regulated by bNOS. Calcium ion concentrations of 200-400 nM in the central nervous system activate bNOS to catalyze the formation of NO.

NO exerts definite effects on brain function although its specific roles are not well established. bNOS inhibitors have been found to block the release of neurotransmitter from presynaptic neurons. Excess levels of NO are also thought to contribute to neurodegenerative disorders such as Alzheimer's disease.

II. In the blood vessels, NO is produced by eNOS which is activated by Ca^{2+} concentrations of 200-400 nM. NO acts as the major endogenous vasodilator in blood vessels. It diffuses into smooth muscle cells and leads to muscle relaxation by stimulating cGMP formation through activation of guanylyl cyclase. In addition, NO regulates the vascular system by inhibiting platelet aggregation and adhesion.

III. The role of NO in the immune system is regulated by macNOS through a pathway that is not Ca^{2+} dependent. Rather, exposure to cytokines, including interleukin-1 and interferon- γ, leads to synthesis of large amounts of NO by activation of macNOS in response to inflammatory stimuli. The NO produced plays a definitive role in the mediation of the activities of macrophages and neutrophils. NO also acts to inhibit the mechanism of viral replication.

Based on information in the passage, which of the following is a possible effect of NO in the brain?

A. Inhibit the fusing of neurotransmitter vesicles at the presynaptic membrane

B. Promote neurotransmitter release into the synaptic cleft

C. Enhance vasoconstriction to maintain blood pressure

D. Decrease neurotransmitter synthesis by the presynaptic neuron

E. No possible effect of NO in the brain is described.

ANSWER: B

Explanation:

Promote neurotransmitter release into the synaptic cleft is supported by the passage's inhibitor evidence. The passage states that inhibiting bNOS blocks neurotransmitter release from presynaptic neurons. Because bNOS catalyzes nitric oxide production in the central nervous system, blocking this enzyme lowers nitric oxide signaling. The resulting reduction in neurotransmitter release supports the inference that nitric oxide normally facilitates or promotes release under the conditions described. This is an inference from the direction of the intervention: removing nitric oxide production disrupts release, so nitric oxide activity is consistent with promoting that process.

This conclusion also fits nitric oxide's established role as a diffusible signaling molecule in the nervous system. Nitric oxide can function as a neuromodulator, influencing synaptic communication rather than acting solely as a conventional transmitter stored in synaptic vesicles. The question asks for a *possible* brain effect based on the passage, so the appropriate conclusion is the directly supported functional outcome of increased neurotransmitter release, without assuming a more specific molecular mechanism. For additional background on nitric oxide signaling and neuronal nitric oxide synthase, see the NCBI Bookshelf overview of nitric oxide and NCBI Gene record for neuronal nitric oxide synthase.

QUESTION NO: 80

When softball players take batting practice, they often use a machine called an "automatic pitcher," which is essentially a cannon that uses air pressure to launch a projectile. In a prototype automatic pitcher, a softball is loaded into the barrel of the cannon and rests against a flat disk. That disk is locked into place, and a high air pressure is built up behind it. When the disk is released, the softball is pushed along the barrel of the cannon and ejected at a speed of V0.

Figure 1 shows the batter and automatic pitcher. The angle of the barrel to the horizontal is θ. The unit vectors i and j point in the horizontal and vertical directions respectively.

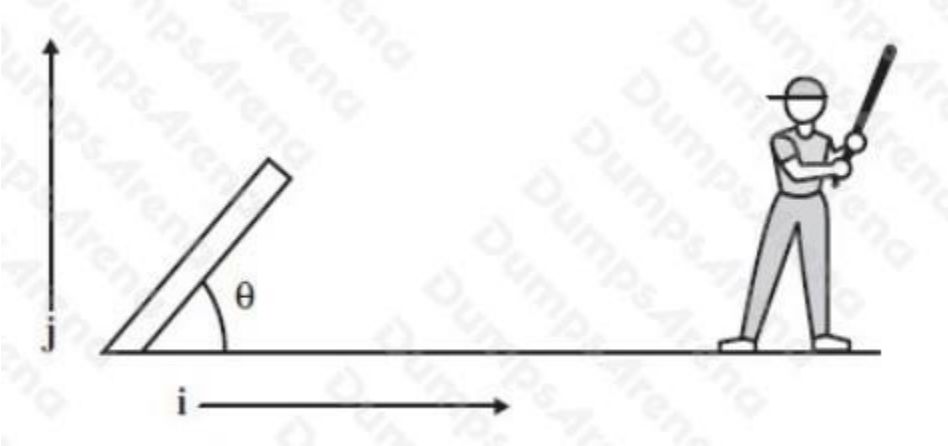


Figure 1

The height above the ground y of the softball as a function of time t is shown in Figure 2, where t = 0 at Point A, t = tB at Point B, and t = tC at Point

C. The softball is ejected from the barrel of the cannon at Point A; it reaches its maximum height at Point B; and the batter hits the softball at Point

C. (Note: Assume that the effects of air resistance are negligible unless otherwise stated.)

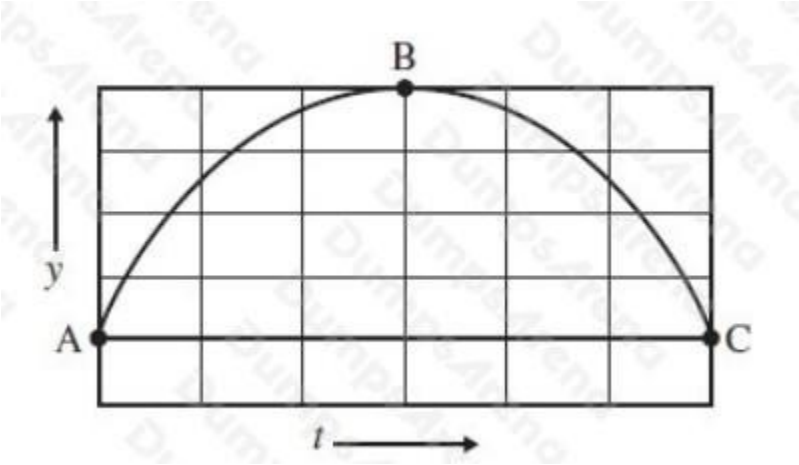


Figure 2

What is the ratio of the horizontal distance traveled by the softball at Point B to the horizontal distance traveled at Point C?

A. 5:1

B. 4:1

C. 3:3

D. 1:2

ANSWER: D

Explanation:

The correct ratio is **1:2**. With air resistance neglected, gravity is the only force acting on the softball after it leaves the barrel. Gravity acts vertically, so the horizontal component of velocity remains constant throughout the flight. Thus, horizontal displacement is proportional to elapsed time: $x = v_x t$, where v_x is the constant horizontal velocity component.

The height-versus-time curve is a parabola, and its maximum occurs at Point B. A projectile's vertical motion is symmetric about this highest point when it is under constant gravitational acceleration. The graph indicates that Point C occurs after twice the elapsed time needed to reach Point B; equivalently, $t_C = 2t_B$. Therefore, the horizontal distance at Point B is $v_x t_B$, while the horizontal distance at Point C is $v_x(2t_B)$. The latter distance is twice the former, yielding $x_B:x_C = 1:2$.

This result follows from treating horizontal and vertical projectile motion independently. For a concise derivation of constant horizontal velocity and parabolic projectile motion, see OpenStax Physics: Projectile Motion and Khan Academy: Introduction to Projectile Motion.

QUESTION NO: 81

The process by which individuals decide and choose to seek assistance for health or mental health problems is called help-seeking. Table 1 displays the percentage of American Indian/Alaska Native and non-Hispanic White adults who received mental health or counseling treatment in 2008.

Help-seeking is a complex process and individuals will choose to obtain treatment for a variety of reasons. One of the strongest individual-related help-seeking predictors amounts to perceiving the need to do so. Other individual-related factors are the educational and the socioeconomic status. There may also be systematic factors that prevent people from doing so, such as general mistrust of health, mental health, and social service institutions, particularly among racial and ethnic minorities. It has been speculated that some of the mistrust stems from research studies, sponsored by medical establishments, where racial and ethnic minorities express concerns of being recruited for the purpose of serving as guinea pigs. Focus groups with African Americans and Chinese immigrants confirmed this anxiety and fear.

Thus, cultural factors also play a role in the help-seeking process. Western cultural norms about medicine are premised on norms of individualism. However, individuals from other cultures and racial and ethnic minority groups tend to be both more

collectivistic and fatalist. Disease, both medical and mental, is believed to occur because of fate. It is not something where one should spend much time and effort fighting; the needs of the family and even of the extended family are to come first.

Table 1 Access to health care: Percentage of adults who received mental health treatment or counseling in the past year, 2008

	American Indian/Alaska Native	Non-Hispanic White	American Indian/Alaska Native/Non-Hispanic White Ratio
Male	8.8	10.8	0.8
Female	10.2	20.8	0.5
Total	9.6	16.0	0.6

Source: Adapted from U.S. Department of Health & Human Services,"Mental Health and American Indians/Alaska Natives"

A practitioner using the theory of planned behavior to inform mental health educational programs would most likely:

A. identify cognitive schemas and their influence on the execution of behaviors.

B. determine the level of dissonance or tension created by attitudes and beliefs.

C. explore levels of self-efficacy in individuals' planning.

D. take into account individuals' intentions, attitudes toward behavior, and subjective norms.

ANSWER: D

Explanation:

The theory of planned behavior is specifically designed to explain and influence deliberate, planned behavior, including decisions to seek professional mental health care. It proposes that a person's behavioral intention is the most immediate predictor of performing a behavior. In turn, intention is shaped by the person's attitude toward performing that behavior, perceived social pressure or subjective norms, and perceived behavioral control over carrying it out. Thus, a practitioner applying this framework would assess and address whether people view counseling favorably, whether influential family members or community groups support help-seeking, and whether individuals believe they can access and use services.

For the population described, educational programming could use this framework to build favorable attitudes toward treatment, communicate supportive community norms, and increase perceived control by clarifying service availability, cost, confidentiality, transportation, and appointment procedures. These elements target the theory's central pathways to stronger intentions and, ultimately, greater help-seeking behavior. The original formulation and a detailed overview of its constructs are available in Icek Ajzen's Theory of Planned Behavior resources. The U.S. National Cancer Institute also summarizes the model's application to health behavior in its Theory at a Glance guide.

QUESTION NO: 82

A helium-neon gas discharge laser as shown in Figure 1 below generates a coherent beam of monochromatic light at a wavelength of 632.8 nm.

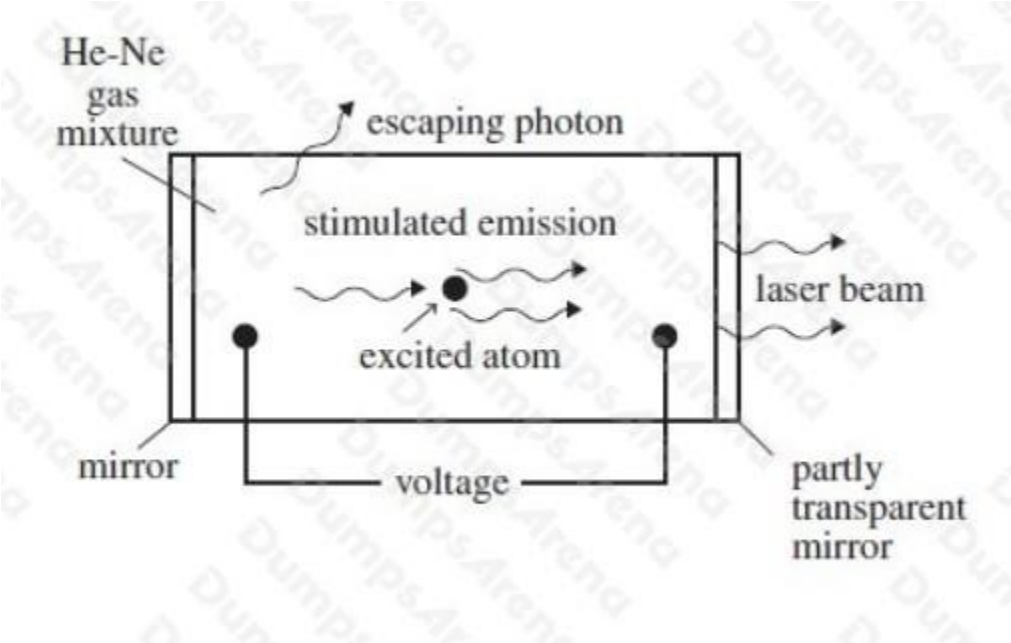


Figure 1

A discharge current of electrons is created in the tube by an applied voltage. When these electrons collide with the helium atoms, they can excite ground-state helium electrons to an energy level of 20.61 eV. The excited electrons cannot decay back to the ground state by emitting a photon because such a transition does not conserve angular momentum. Instead, if the excited helium atom collides with a neon atom, a ground-state electron in the neon atom can be excited to an energy level of 20.66 eV, and the helium electron can return to its ground state.

The above process occurs quite often in the tube until the percentage of neon atoms with electrons in the 20.66-eV energy level is greater than the percentage of neon atoms with electrons in lower levels. This condition is called a population inversion. An excited electron in one of the neon atoms can then spontaneously decay by emitting a photon of wavelength 632.8 nm in a random direction. The photon will stimulate the same transition in another excited electron in a neon atom. The photon radiated by this stimulated emission process travels in the same direction as the original photon. The resulting light is then reflected back and forth inside the tube until it escapes through the partially transparent mirror. (Note: A photon's energy in eV is given by $E = 1240/\lambda$, where λ is the photon's wavelength in nm. The helium and neon ground-state energies are both 0 eV.)

A population inversion exists in the laser tube when:

A. the percentage of neon atoms with electrons in the ground state is greater than the percentage of neon atoms with electrons in higher energy levels.

B. the percentage of neon atoms with electrons in a higher energy level is greater than the percentage of neon atoms with electrons in lower energy levels.

C. the percentage of neon atoms with electrons in a higher energy level is equal to the percentage of neon atoms with electrons in the ground state.

D. all the neon atoms have electrons in the ground state only.

ANSWER: B

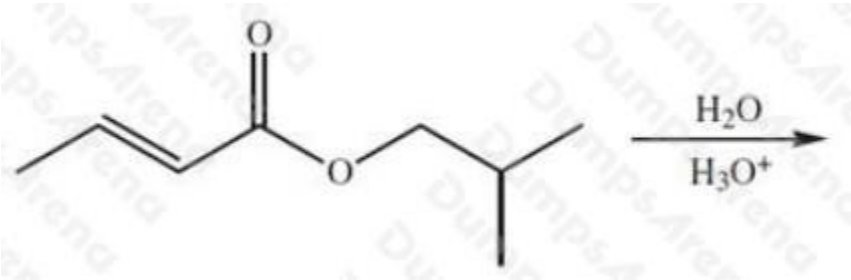
Explanation:

The correct condition is "the percentage of neon atoms with electrons in a higher energy level is greater than the percentage of neon atoms with electrons in lower energy levels." A population inversion is a non-equilibrium distribution in which more atoms or molecules occupy the upper laser level than the lower level associated with the laser transition. This is essential because stimulated emission must occur more frequently than absorption for the light intensity to grow as it travels through the gain medium. In the helium-neon tube described, electrical collisions first excite helium, and energy-transfer collisions then populate an excited neon level. Repeated pumping produces an excess population in that excited neon state relative to lower neon states. A photon with the appropriate transition energy can therefore stimulate additional excited neon atoms to emit matching photons, yielding amplification and coherent laser output. The passage directly defines the inversion using this greater population of neon atoms at 20.66 eV than in lower levels. This principle is consistent with the standard laser

requirement that the upper-state population exceed the lower-state population; see OpenStax College Physics: The Quantum Nature of Light and Encyclopaedia Britannica: Principles of laser operation.

QUESTION NO: 83

Which of the following products may be formed in the reaction below?



A. CH3CH = CHCHO

B. HOOCCH2CH(CH3)2

C. CH3CH(CH3)2

D. HOCH2CH(CH3)2

ANSWER: D

Explanation:

HOCH2CH(CH3)2 is isobutanol (2-methyl-1-propanol), and it may be formed by acid-catalyzed hydrolysis of the ester shown. Ester hydrolysis cleaves the acyl–oxygen bond framework into two recognizable fragments: the acyl portion becomes the corresponding carboxylic acid, while the alkoxy substituent originally attached to the ester oxygen is converted into its corresponding alcohol. In this reaction, the alkoxy fragment is the isobutyl group, CH2CH(CH3)2. Protonation and substitution by water ultimately place a hydrogen on oxygen, producing HOCH2CH(CH3)2 as the alcohol product.

The complementary product is the unsaturated carboxylic acid derived from the ester's acyl fragment, 2-butenoic acid. The carbon–carbon double bond in that fragment is retained during ordinary acidic ester hydrolysis; hydrolysis changes the ester functional group rather than hydrogenating, oxidizing, or otherwise altering the alkene. This product pattern follows the standard reversible acid-catalyzed ester hydrolysis mechanism described in organic chemistry references. See LibreTexts: Hydrolysis of Esters and OpenStax Organic Chemistry: Hydrolysis of Esters.