GATE 2023 Life Sciences (XL) Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**100	**Total questions :**65

General Aptitude (GA)

Q.1 The village was nestled in a green spot, _____ the ocean and the hills.

(A) through

(B) in

(C) at

(D) between

Correct Answer: (D) between

Solution:

1) Understanding the context:

The sentence talks about a village being located between two geographical features: the ocean and the hills. The preposition "between" is used to indicate the position of the village relative to two other objects, hence making it the most suitable choice.

2) Analysis of the options:

(A) through: This suggests movement across a space or location, which is incorrect in this context. *"Nestled through the ocean and the hills"* does not convey the correct meaning.

(B) in: This would indicate the village is located inside the space of both the ocean and hills, but this is not the intended meaning in the sentence.

(C) at: This is used for specifying exact locations but doesn't convey the idea of being between two things.

(D) between: Correct choice. It indicates that the village is situated in the middle of the two features — the ocean and the hills.

The correct answer is (D) between.

Quick Tip

- **Through** indicates motion or passage.
- **In** suggests being inside an area or a space.
- **At** refers to a specific point or location.
- **Between** refers to a position that is located in the middle of two objects.

Q.2 Disagree : Protest : : Agree : _____ (By word meaning)

(A) Refuse

(B) Pretext

(C) Recommend

(D) Refute

Correct Answer: (C) Recommend

Solution:

1) Identifying word relationship:

The given pair "Disagree : Protest" suggests a relationship where protest is an act in response to disagreement. We need a similar relationship for "Agree," where the corresponding action is associated with agreement.

2) Analysis of the options:

(A) Refuse: This is a negative response, but it doesn't match the context of "agree."

(B) Pretext: This means a false reason given for an action, which is unrelated to the context of agreement.

(C) Recommend: This is a fitting choice. When one agrees, they often make a recommendation.

(D) Refute: Refuting means disproving or denying something, which does not logically follow from agreeing.

The correct answer is (C) Recommend.

Quick Tip

- **Disagree** is often followed by **Protest**. - **Agree** is commonly followed by **Recommend**.

Q.3 A 'frabjous' number is defined as a 3 digit number with all digits odd, and no two adjacent digits being the same. For example, 137 is a frabjous number, while 133 is not. How many such frabjous numbers exist?

(A) 125

(B) 720

(C) 60

(D) 80

Correct Answer: (D) 80

Solution:

The problem defines a 'frabjous' number as a 3-digit number in which all digits are odd, and no two adjacent digits are the same. The possible odd digits are 1, 3, 5, 7, and 9. We will calculate the total number of such 3-digit frabjous numbers by considering the following conditions:

- **For the first digit:** Since the number is a 3-digit number, the first digit can be any of the 5 odd digits: $\{1, 3, 5, 7, 9\}$. So, there are 5 choices for the first digit.
- **For the second digit:** The second digit must also be odd, but it cannot be the same as the first digit. Hence, there are only 4 choices for the second digit because one odd digit is already taken by the first digit.
- **For the third digit:** The third digit also needs to be odd, and it cannot be the same as the second digit. So, there are again 4 choices for the third digit.

Thus, the total number of frabjous numbers is the product of the number of choices for each digit:

$$5 \times 4 \times 4 = 80$$

Therefore, the total number of frabjous numbers is 80.

Quick Tip

When calculating the number of valid combinations for restricted problems, remember to reduce the available choices for each subsequent selection. Here, we reduced the choices for the second and third digits to avoid repetition of adjacent digits.

Q.4 Which one among the following statements must be TRUE about the mean and the median of the scores of all candidates appearing for GATE 2023?

(A) The median is at least as large as the mean.

(B) The mean is at least as large as the median.

(C) At most half the candidates have a score that is larger than the median.

(D) At most half the candidates have a score that is larger than the mean.

Correct Answer: (C) At most half the candidates have a score that is larger than the median.

Solution:

Let's break down the given options and analyze them:

- Option (A): "The median is at least as large as the mean."

- This is not necessarily true. In a skewed distribution (such as one with many lower scores and a few higher scores), the mean can be larger than the median. Thus, this statement is not universally true.

- Option (B): "The mean is at least as large as the median."

- This is also not necessarily true. In cases where the distribution is skewed to the left (more higher scores, few lower scores), the median can be larger than the mean. Hence, this statement is also not always true.

- Option (C): "At most half the candidates have a score that is larger than the median."

- This statement is **true**. By definition, the **median** divides the dataset into two equal halves. So, exactly half of the candidates will have scores smaller than the median, and the other half will have scores larger than the median. Therefore, **at most** half the candidates have a score larger than the median, which is always true.

- Option (D): ”At most half the candidates have a score that is larger than the mean.”

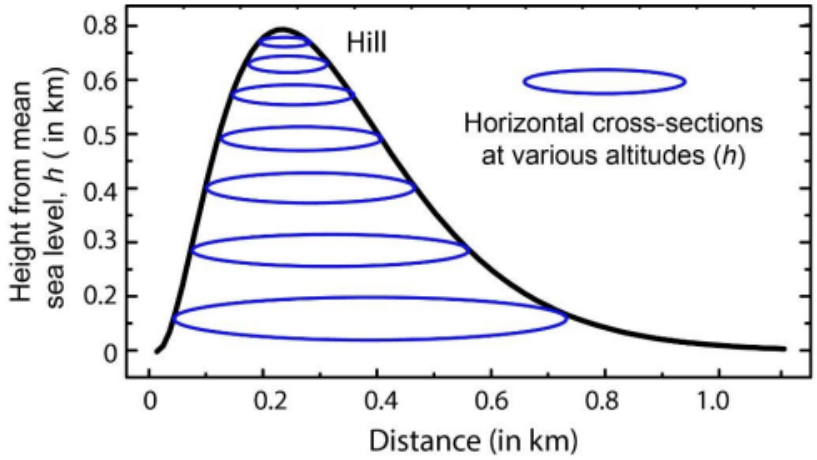
- This statement is **not necessarily true**. The mean is the average of all scores, and if the distribution is skewed, more than half of the candidates could have a score larger than the mean, especially in right-skewed distributions (where the mean is greater than the median). Hence, this is not always true.

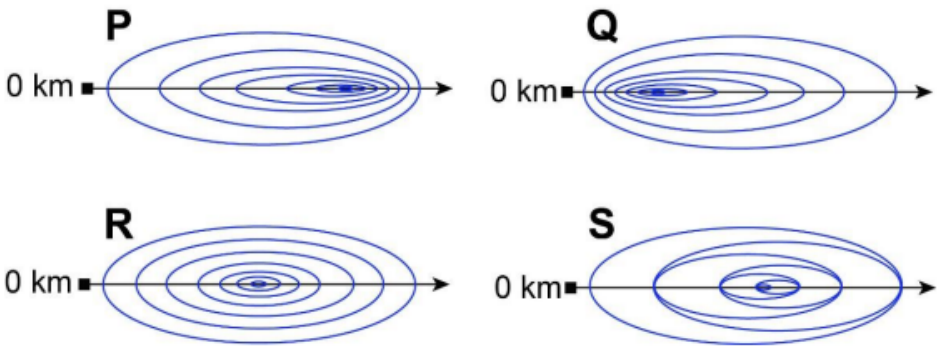
Therefore, the correct and always true statement is (C): At most half the candidates have a score that is larger than the median.

Quick Tip

For datasets with skewed distributions, the mean and median can be quite different. The median divides the data into two equal parts, while the mean is influenced by the extreme values.

Q.5 In the given diagram, ovals are marked at different heights (h) of a hill. Which one of the following options P, Q, R, and S depicts the top view of the hill?





(A) P

(B) Q

(C) R

(D) S

Correct Answer: (C)

Solution:

- The given diagram shows a hill with horizontal cross-sections at various altitudes. The oval-shaped contours represent the cross-sections at different heights. The shape and size of these contours change as the altitude changes. The given diagram suggests that the hill has a peak in the center, and the altitude decreases as we move outward from the center.
- Option (P): This option shows an irregular shape, and the contours are not concentric. This irregularity doesn't correspond to the shape of a typical hill, which is often depicted with concentric contours. Hence, (A) is incorrect.
- Option (Q): This option shows a perfect symmetry of contours, but this doesn't match the irregularity of the hill shown in the diagram. The hill is expected to have a more gradual slope and irregular contours. Thus, (B) is incorrect.
- Option (R): This option shows concentric circles, which is characteristic of a hill with a peak at the center and decreasing altitude as we move outward. This matches the diagram perfectly, where the altitude decreases as we move away from the hill's peak. This makes (C) the correct answer.
- Option (S): This option shows a disorganized pattern of concentric circles, which doesn't correspond to the expected shape of a hill. The contours are not consistently decreasing in size as the altitude decreases. Hence, (D) is incorrect.

Quick Tip

A top view of a hill with increasing altitude towards the center should show concentric circles. This corresponds to the shape in option (R).

Q.6 Residency is a famous housing complex with many well-established individuals

among its residents. A recent survey conducted among the residents of the complex revealed that all of those residents who are well established in their respective fields happen to be academicians. The survey also revealed that most of these academicians are authors of some best-selling books. Based only on the information provided above, which one of the following statements can be logically inferred with certainty?

(A) Some residents of the complex who are well established in their fields are also authors of some best-selling books.
(B) All academicians residing in the complex are well established in their fields.
(C) Some authors of best-selling books are residents of the complex who are well established in their fields.
(D) Some academicians residing in the complex are well established in their fields.

Correct Answer: (B)

Solution:
- From the survey, we know that all residents who are well established in their fields are academicians. This is a universal statement, which means that anyone who is well-established in their field in this housing complex is definitely an academician. Therefore, all academicians in the complex must also be well-established in their fields. This makes option (B) a valid conclusion.
- Option (A): While the survey tells us that most of the academicians are authors of best-selling books, it does not guarantee that all well-established residents are authors. The statement ”some” is not definite, so this cannot be inferred with certainty. Therefore, (A) is not correct.
- Option (C): The survey doesn’t state that authors of best-selling books are always well-established residents of the complex. It only says that most of the academicians are authors. Thus, we cannot definitively conclude that some authors are well-established in their fields. Therefore, (C) is incorrect.
- Option (D): The survey tells us that all well-established residents are academicians, but it doesn’t mention that all academicians are well-established. Hence, we cannot be sure that all or some academicians are well-established, which makes (D) an incorrect option.

Quick Tip

Logical deductions are made based on statements with certainty. ”All” statements are more definitive than ”some” or ”most” statements.

Q.7 Ankita has to climb 5 stairs starting at the ground, while respecting the following rules:

1. At any stage, Ankita can move either one or two stairs up. 2. At any stage, Ankita cannot move to a lower step.

Let $F(N)$ denote the number of possible ways in which Ankita can reach the N^{th} stair. For example, $F(1) = 1$, $F(2) = 2$, $F(3) = 3$. The value of $F(5)$ is _____.

(A) 8

(B) 7

(C) 6

(D) 5

Correct Answer: (A)

Solution:

We are given the recurrence relation that $F(1) = 1$, $F(2) = 2$, and $F(3) = 3$. The number of ways to reach any stair N depends on whether Ankita took one or two steps from the previous stair:

$$F(N) = F(N-1) + F(N-2)$$

Now, let us calculate $F(4)$ and $F(5)$:

$$F(4) = F(3) + F(2) = 3 + 2 = 5$$

$$F(5) = F(4) + F(3) = 5 + 3 = 8$$

Therefore, the value of $F(5) = 8$.

Quick Tip

This is a classical example of the Fibonacci-like sequence, where each number is the sum of the two preceding ones.

Q.8 The information contained in DNA is used to synthesize proteins that are necessary for the functioning of life. DNA is composed of four nucleotides: Adenine (A), Thymine (T), Cytosine (C), and Guanine (G). The information contained in DNA can then be thought of as a sequence of these four nucleotides: A, T, C, and G. DNA has coding and non-coding regions. Coding regions—where the sequence of these nucleotides are read in groups of three to produce individual amino acids—constitute only about 2% of human DNA. For example, the triplet of nucleotides CCG codes for the amino acid glycine, while the triplet GGA codes for the amino acid proline. Multiple amino acids are then assembled to form a protein.

Based only on the information provided above, which of the following statements can be logically inferred with certainty?

(i) The majority of human DNA has no role in the synthesis of proteins. (ii) The function of about 98% of human DNA is not understood.

(A) only (i)

(B) only (ii)

(C) both (i) and (ii)

(D) neither (i) nor (ii)

Correct Answer: (A), (D)

Solution:

(i) True. From the passage, we know that only about 2% of human DNA is involved in coding proteins. Therefore, the remaining majority of human DNA does not have a role in the synthesis of proteins.

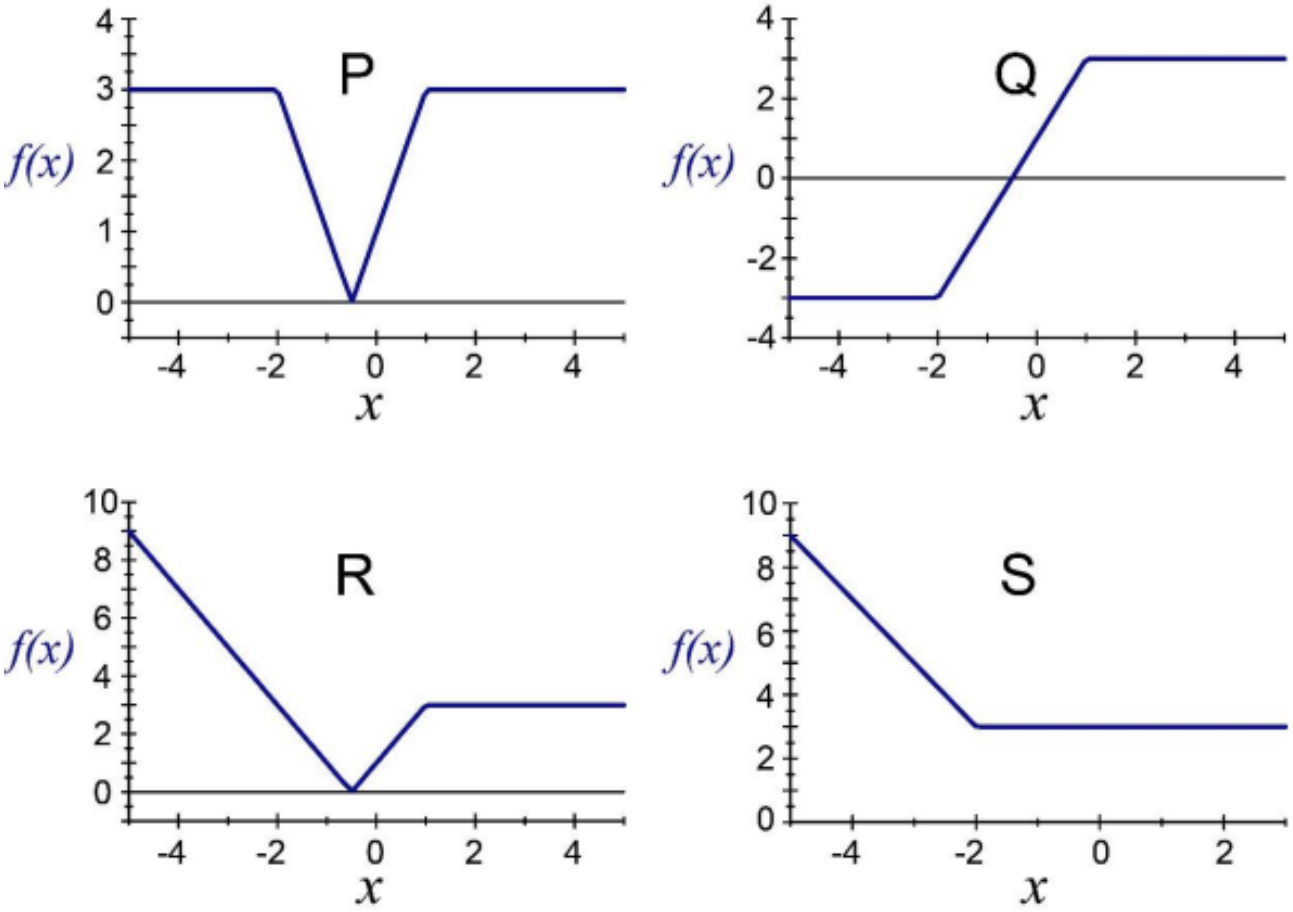
(ii) False. The passage does not suggest that 98% of human DNA is entirely understood or not understood; it only states that 98% is non-coding. Hence, we cannot assert with certainty that its function is completely unknown.

Quick Tip

Be careful about statements that use terms like ”majority” or ”most”—they must be directly supported by the text. The rest might be inferred but not confirmed.

Q.9 Which one of the given figures P, Q, R, and S represents the graph of the following function?

$$f(x) = |x + 2| - |x - 1|$$



(A) P

(B) Q

(C) R

(D) S

Correct Answer: (A) P

Solution:

We are given the function:

$$f(x) = |x + 2| - |x - 1|$$

To determine the graph of this function, we need to analyze the behavior of each part of the function.

1) Function Analysis:

We can break the function into two absolute value terms. The behavior of the function will change depending on whether x is less than -2, between -2 and 1, or greater than 1. We need to analyze these intervals to plot the graph.

- For $x < -2$, both $x + 2$ and $x - 1$ are negative, so the graph will have a linear decrease.

- For $-2 \leq x \leq 1$, $x + 2$ is positive, and $x - 1$ is negative, resulting in a change in slope and a turning point.

- For $x > 1$, both terms are positive, resulting in a different slope.

2) Matching the Graph:

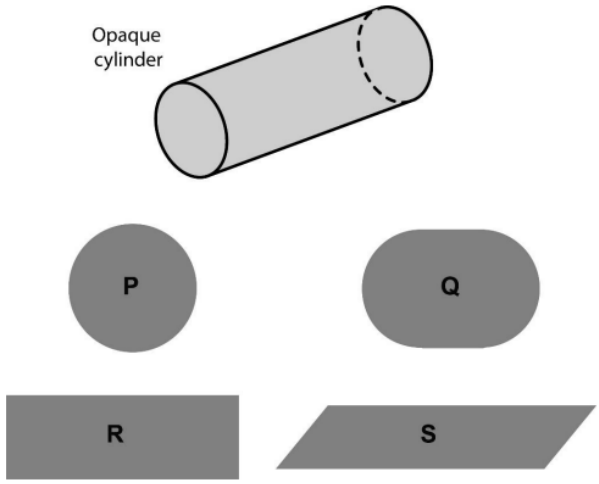
Upon examining the graphs, the graph labeled P fits the expected behavior of the function with changes in slope at $x = -2$ and $x = 1$. Thus, the correct graph is option (A).

The correct answer is (A) P.

Quick Tip

- Absolute value functions break into piecewise linear sections, which can cause slope changes at certain points (where the inside expression equals zero). - To graph such functions, first identify these critical points and then plot accordingly in each region.

Q.10 An opaque cylinder (shown below) is suspended in the path of a parallel beam of light, such that its shadow is cast on a screen oriented perpendicular to the direction of the light beam. The cylinder can be reoriented in any direction within the light beam. Under these conditions, which one of the shadows P, Q, R, and S is NOT possible?



(A) P

(B) Q

(C) R

(D) S

Correct Answer: (D) S

Solution:

We are given an opaque cylinder suspended in the path of a parallel beam of light, and the task is to analyze which shadow cannot be formed based on the cylinder's reorientation.

1) Shadow Formation:

When a cylindrical object is in the path of light, the shadow produced depends on the orientation of the cylinder.

When the cylinder is oriented with its axis perpendicular to the direction of the light, it will cast a circular shadow.

When the cylinder is reoriented with its axis at an angle to the light, the shadow may become elliptical.

A shadow like S (which appears highly distorted) is not physically possible as it would require an impossible angle or distortion of light.

2) Conclusion:

The shadow in option S cannot be produced by the cylinder under the given conditions.

Therefore, the correct answer is option (D).

The correct answer is (D) S.

Quick Tip

Shadows of cylindrical objects can be circular or elliptical depending on the angle of light. Unusual or impossible shadows result from incorrect assumptions about the object's positioning or light angles.

Q.11 Which one among the following mixtures gives a buffer solution in water?

(A) $CH_3COOH + CH_3COONa$

(B) $CH_3COOH + NaCl$

(C) $NaOH + NaCl$

(D) $NaOH + CH_3COONa$

Correct Answer: (A) $CH_3COOH + CH_3COONa$

Solution:

A buffer solution is a solution that resists changes in pH when small amounts of an acid or a base are added. It is formed by a weak acid and its conjugate base or a weak base and its conjugate acid. The key feature of a buffer solution is its ability to neutralize small amounts of added acid (H^+) or base (OH^-) and maintain a relatively stable pH.

What Makes a Buffer?

A buffer solution typically consists of: - A weak acid (such as CH_3COOH) that partially dissociates in water to release H^+ ions, and - The conjugate base of the weak acid (such as CH_3COO^-, the acetate ion from CH_3COONa).

In this case: - Acetic acid (CH_3COOH) is a weak acid, which dissociates slightly in water:

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

- Sodium acetate (CH_3COONa) is a salt of the conjugate base, acetate (CH_3COO^-), and when dissolved in water, it dissociates completely into Na^+ and CH_3COO^- ions:

$$CH_3COONa \rightarrow CH_3COO^- + Na^+$$

The acetate ion (CH_3COO^-) acts as a conjugate base and can neutralize any excess H^+ (acid) that is added to the solution:

$$CH_3COO^- + H^+ \rightarrow CH_3COOH$$

This helps in maintaining the pH of the solution. Similarly, if a base (OH^-) is added, the acetic acid can neutralize it:

$$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$$

Thus, the combination of acetic acid (CH_3COOH) and sodium acetate (CH_3COONa) forms a buffer solution.

Now, let us consider the other options:

Option (B): $CH_3COOH + NaCl$ - Sodium chloride (NaCl) is a neutral salt and does not provide any conjugate base (like acetate) to neutralize acids. Therefore, this mixture will not form a buffer solution. The pH will change when acid or base is added.

Option (C): $NaOH + NaCl$ - Sodium hydroxide (NaOH) is a strong base, and sodium chloride (NaCl) is a neutral salt. Mixing them will create a basic solution due to the dissociation of NaOH, but it will not be a buffer solution because it does not contain both a weak acid and its conjugate base. The pH will rise if more base is added.

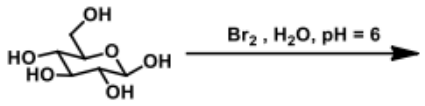
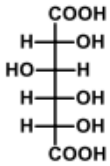
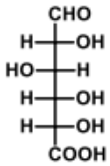
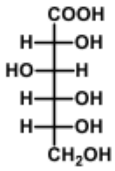
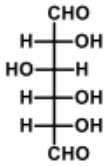
Option (D): $NaOH + CH_3COONa$ - Sodium hydroxide is a strong base, and sodium acetate is a conjugate base. Although this mixture will create a basic solution, it is not a buffer solution in the classical sense because it lacks a weak acid (like CH_3COOH) to neutralize any acids that might be added. It will act as a base but not a proper buffer.

Therefore, the correct answer is (A), where acetic acid and sodium acetate form a proper buffer solution.

Quick Tip

Buffer solutions are typically made from a weak acid and its conjugate base, or a weak base and its conjugate acid.

Q.12 What is the major product formed in the given reaction?

	
(A)	
(B)	
(C)	
(D)	

Correct Answer: (C)

Solution:

This reaction involves bromine (Br_2) in an aqueous medium with a pH of 6. The specific reaction here is an oxidative cleavage reaction typical for sugars. Let's break down the steps involved:

1. **Initial Step:**

The given sugar molecule is a cyclic structure with multiple hydroxyl (OH) groups attached to the carbon atoms. Under normal conditions, bromine in the presence of water and at pH 6 reacts with the hydroxyl groups of the sugar molecule.

2. **Reaction Mechanism:**

Bromine is an oxidizing agent, and when it reacts with hydroxyl groups in the presence of water, it typically oxidizes them. At pH 6, which is mildly acidic, the hydroxyl groups

undergo oxidation, converting them into carboxyl groups ($COOH$).

3. **Cleavage of the Sugar Ring:**

The reaction proceeds by the cleavage of the sugar ring at positions where the oxidation occurs. In this case, bromine induces the cleavage of the bond between the carbon atoms, where oxidation of the hydroxyl groups occurs. This leads to the formation of carboxyl groups on two carbon atoms in the sugar structure.

4. **Final Product:**

The final product, which is option (C), shows a sugar molecule with two carboxyl groups ($COOH$) replacing the hydroxyl groups that were originally present at positions 1 and 2 on the sugar ring. The remaining hydroxyl groups are unaltered in this process.

Thus, the correct product is option (C), where two hydroxyl groups are oxidized to carboxyl groups, resulting in a dicarboxylic acid form of the sugar.

Quick Tip

In oxidative cleavage reactions, bromine reacts with hydroxyl groups to form carboxyl groups, especially under mildly acidic or neutral conditions. This is a key reaction when dealing with sugars, and it is commonly used to form dicarboxylic acids.

Q.13 The CORRECT order of stability of the given metal oxides is

(A) $LiO_2 > NaO_2 > KO_2 > RbO_2$

(B) $LiO_2 < NaO_2 < KO_2 < RbO_2$

(C) LiO_2 ¡ $NaO_2 > KO_2 > RbO_2$

(D) $LiO_2 > NaO_2 < KO_2 < RbO_2$

Correct Answer: (A) LiO_2 ¿ NaO_2 ¿ KO_2 ¿ RbO_2

Solution:

The stability of alkali metal oxides generally decreases as the size of the metal ion increases. This is because the charge density of the metal ion decreases as the ion gets larger, making the oxide less stable. The oxide of lithium (LiO_2) is the most stable, followed by sodium (NaO_2), and the stability decreases further with potassium (KO_2) and rubidium (RbO_2).

- LiO_2 has the highest stability due to the small size of Li^+.

- NaO_2 is next in stability as Na^+ is larger than Li^+.

- KO_2 and RbO_2 are progressively less stable due to their larger cations.

Thus, the correct order of stability is:

$$\boxed{LiO_2 > NaO_2 > KO_2 > RbO_2}$$

Quick Tip

Stability of alkali metal oxides decreases as the size of the metal ion increases. The smaller the cation, the more stable the oxide.

Q.14 Which of the following is/are CORRECT when two single complementary strands of DNA come together to form a double helix at a given temperature?

(ΔS and ΔH are changes in entropy and enthalpy of the process, respectively.)

(A) $\Delta S > 0$

(B) $\Delta S < 0$

(C) $\Delta H > 0$

(D) $\Delta H < 0$

Correct Answer: (B) and (D)

Solution:

- When two complementary strands of DNA come together, the process involves a decrease in entropy, i.e., $\Delta S < 0$ because the system becomes more ordered as the strands associate to form a double helix.

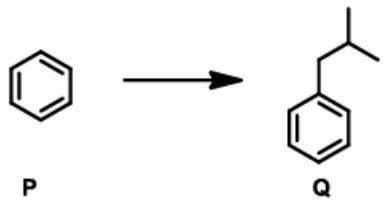
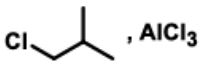
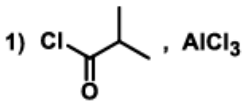
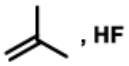
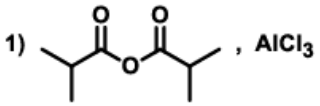
- The formation of hydrogen bonds and the overall stability of the double helix result in a negative enthalpy change, $\Delta H < 0$.

Thus, the correct answers are $\Delta S < 0$ and $\Delta H < 0$.

Quick Tip

In biological systems like DNA, the process of hybridization typically results in a decrease in entropy and a release of energy (negative ΔH).

Q.15 Suitable reagent(s) to bring about the conversion of P to Q in good yield is/are

	
(A)	
(B)	
(C)	
(D)	

Correct Answer: (B), (D)

Solution:

The conversion shown in the problem involves the transformation of a benzene ring (P) into an alkylated benzene (Q). Let's look at the details of the options and the reactions they represent:

1. **Option (A)** – Cl, $AlCl_3$:

- This reaction is likely a Friedel–Crafts alkylation reaction, where Cl represents a chloroalkyl group. In this case, the alkyl group reacts with the benzene ring in the presence of

the Lewis acid catalyst $AlCl_3$. However, this method generally does not lead to a successful conversion in the required yield as it would typically produce a more substituted product.

2. **Option (B)** – Cl, $AlCl_3$, followed by H_2NNH_2, KOH:

- In this case, Cl and $AlCl_3$ initiate the alkylation of the benzene ring, but the subsequent use of H_2NNH_2 and KOH suggests a reduction and further rearrangement leading to the final desired product, making this a good choice for the conversion. The product achieved here is the desired alkylated benzene with a good yield.

3. **Option (C)** – C_3H_2, HF:

- This reaction is highly unlikely, as it suggests the addition of an alkynyl group (C_3H_2) with HF, but this does not lead to the proper alkylation of the benzene ring and is not a typical reagent combination for this conversion.

4. **Option (D)** – C_2O_2, $AlCl_3$, and $Zn(Hg)$, HCl:

- This represents a typical Wolff–Löffler reduction of an aldehyde to an alkyl group, where the intermediate group is reduced by zinc in acid. This method also leads to the formation of the desired alkylated product. Therefore, this is another correct reagent combination.

Thus, the best reagents for the conversion of P to Q are found in options (B) and (D).

Quick Tip

Friedel–Crafts alkylation is an essential reaction in organic chemistry for adding alkyl groups to aromatic compounds. When working with more reactive intermediates, additional reagents like hydrazines and bases help to refine the final product.

Q.16 Choose the CORRECT trend(s) of the first ionization energies among the following. (Given: Atomic numbers C: 6; N: 7; O: 8; F: 9; Si: 14; P: 15; S: 16; Cl: 17)

(A) C $<$ N $>$ O $<$ F

(B) Si $<$ P $>$ S $<$ Cl

(C) C $<$ N $<$ O $<$ F

(D) Si $<$ P $<$ S $<$ Cl

Correct Answer: (A) and (B)

Solution:

Step 1: Periodic trend. Across a period, first ionization energy generally **increases** (effective nuclear charge rises), and down a group it generally **decreases** (greater size & shielding).

Step 2: Key anomaly (half-filled stability). Elements with half-filled p subshells are relatively more stable, so removing an electron requires **more** energy. Hence:

• In Period 2: $\mathrm{N}(2p^3)$ has higher IE than $\mathrm{O}(2p^4)$ because removing an electron from O relieves inter-electronic repulsion in the paired p orbital $\Rightarrow \mathrm{O} < \mathrm{N}$.

• In Period 3: $\mathrm{P}(3p^3)$ has higher IE than $\mathrm{S}(3p^4)$ for the same reason $\Rightarrow \mathrm{S} < \mathrm{P}$.

Step 3: Check each option.

(A) $\mathrm{C} < \mathrm{N} > \mathrm{O} < \mathrm{F}$: Correct—captures the anomaly $\mathrm{O} < \mathrm{N}$ and the overall rise towards F. ✓

(B) $\mathrm{Si} < \mathrm{P} > \mathrm{S} < \mathrm{Cl}$: Correct—captures the anomaly $\mathrm{S} < \mathrm{P}$ and rise towards Cl. ✓

(C) $\mathrm{C} < \mathrm{N} < \mathrm{O} < \mathrm{F}$: Incorrect—ignores $\mathrm{O} < \mathrm{N}$. ×

(D) $\mathrm{Si} < \mathrm{P} < \mathrm{S} < \mathrm{Cl}$: Incorrect—ignores $\mathrm{S} < \mathrm{P}$. ×

Correct options: (A) and (B)

Quick Tip

Across a period IE increases, but remember the classic exceptions from half-filled p subshells: $\mathrm{O} < \mathrm{N}$ and $\mathrm{S} < \mathrm{P}$. When in doubt, check for p^3 stability.

Q.17 The depression of freezing point of water (in K) for 0.1 molal solutions of NaCl and Na_2SO_4 are ΔT_1 and ΔT_2, respectively. Assuming ideal solutions, find the ratio $\Delta T_1/\Delta T_2$ (rounded off to two decimal places).

Correct Answer: 0.67

Solution:

For ideal solutions, $\Delta T_f = iK_f m$, where i is the van't Hoff factor.

NaCl $\rightarrow i_1 = 2$ (Na^+, Cl^-); $Na_2SO_4 \rightarrow i_2 = 3$ (2 Na^+, SO_4^{2-}).

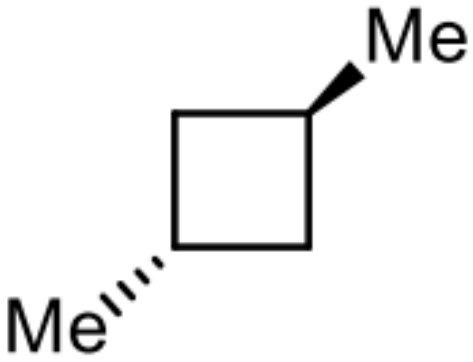
Hence,

$$\frac{\Delta T_1}{\Delta T_2} = \frac{i_1}{i_2} = \frac{2}{3} = 0.666\ldots \approx 0.67.$$

Quick Tip

For colligative properties in ideal solutions, the solute identity matters only via the van't Hoff factor i: count ions to get ratios quickly.

Q.18 Considering cyclobutane to be planar, the number of planes of symmetry in the following compound is ____ (in integer).



Correct Answer: 1

Solution:

Treat the cyclobutane ring as a planar square with two identical Me substituents on *adjacent* ring carbons. This substitution pattern retains only one mirror plane: the plane that bisects the C–C bond connecting the substituted carbons and the opposite bond (passing through the ring center). The second mirror plane of unsubstituted planar cyclobutane is lost due to unequal substitution across that plane.

Therefore, the molecule has exactly one plane of symmetry.

Quick Tip

Start with the parent ring's symmetry (planar cyclobutane has multiple mirror planes) and then remove any plane that does not map substituents onto identical positions.

Q.19 The dipole moment (μ) of BrF is 1.42 D and the bond length is 176 pm. The atomic charge distribution (q) in the molecule is ____ (rounded off to two decimal

places). (Given: 1 D = 3.34×10^{-30} **C m; electronic charge** $e = 1.60 \times 10^{-19}$ **C).**

Correct Answer: $0.17\ e$

Solution:

Step 1: Formula. Dipole moment $\mu = q \times d$. Hence,

$$q = \frac{\mu}{d}.$$

Step 2: Convert dipole moment.

$$\mu = 1.42 \times (3.34 \times 10^{-30}) = 4.74 \times 10^{-30}\,\text{C m}.$$

Step 3: Convert bond length.

$$d = 176\ \text{pm} = 176 \times 10^{-12} = 1.76 \times 10^{-10}\,\text{m}.$$

Step 4: Compute charge.

$$q = \frac{4.74 \times 10^{-30}}{1.76 \times 10^{-10}} \approx 2.69 \times 10^{-20}\,\text{C}.$$

Step 5: Express in units of e**.**

$$\frac{q}{e} = \frac{2.69 \times 10^{-20}}{1.60 \times 10^{-19}} \approx 0.168 \approx 0.17.$$

Therefore, the atomic charge distribution is $\mathbf{0.17\,e}$.

Quick Tip

Always convert dipole moment into SI units and then divide by bond length. Expressing q in terms of e helps compare the fraction of electron charge involved in bond polarity.

Q.20 Consider two different paths in which the volume of an ideal gas doubles isothermally:

(i) Reversible expansion (work done = w_{rev})

(ii) Irreversible expansion, with the external pressure equal to the final pressure of the gas (work done = w_{irrev})

Here,

$$\frac{w_{\text{rev}}}{w_{\text{irrev}}} = ?$$

(A) $2 \ln 2$

(B) $\frac{1}{2} \ln 2$

(C) $\frac{1}{2} \ln \frac{1}{2}$

(D) $2 \ln \frac{1}{2}$

Correct Answer: (A) $2 \ln 2$

Solution:

Step 1: Reversible isothermal expansion work

For an isothermal reversible expansion,

$$w_{\text{rev}} = nRT \ln \left(\frac{V_f}{V_i} \right).$$

Here, the gas volume doubles $\Rightarrow V_f = 2V_i$.

So,

$$w_{\text{rev}} = nRT \ln 2.$$

Step 2: Irreversible isothermal expansion work

For irreversible work, external pressure is equal to the *final pressure* of the gas:

$$P_{\text{ext}} = P_f.$$

Since $PV = nRT$, the final pressure is

$$P_f = \frac{nRT}{V_f} = \frac{nRT}{2V_i}.$$

Now the work in irreversible expansion is

$$w_{\text{irrev}} = P_{\text{ext}}(V_f - V_i).$$

Substitute values:

$$w_{\text{irrev}} = \frac{nRT}{2V_i}(2V_i - V_i).$$

$$w_{\text{irrev}} = \frac{nRT}{2}.$$

Step 3: Ratio of works

$$\frac{w_{\text{rev}}}{w_{\text{irrev}}} = \frac{nRT\ln 2}{\frac{nRT}{2}} = 2\ln 2.$$

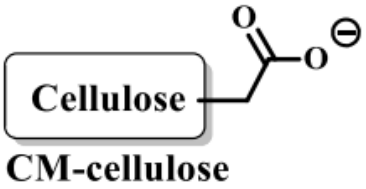
$$\boxed{\frac{w_{\text{rev}}}{w_{\text{irrev}}} = 2\ln 2}$$

Quick Tip

Reversible work is always maximum because the system remains in equilibrium at each step. Irreversible expansion against a constant external pressure always produces less work, hence the ratio is greater than 1.

Q.21 A mixture of four peptides, PKKRK, RGERV, RYRGV and LVVYP, is loaded onto an ion-exchange column at pH = 7.2. If carboxymethyl (CM) cellulose is used as the stationary phase of this column, then which peptide elutes first?

Given:



CM-cellulose

P = Proline, Y = Tyrosine, V = Valine,
G = Glycine, K = Lysine, R = Arginine
E = Glutamic acid

(A) PKKRK

(B) RGERV

(C) RYRGV

(D) LVVYP

Correct Answer: (D) LVVYP

Solution:

Step 1: Nature of the stationary phase

Carboxymethyl (CM) cellulose is a *cation-exchange resin*.

- It contains negatively charged carboxyl groups at pH 7.2.

- Therefore, it binds to *positively charged* peptides (cationic residues).

- Neutral or negatively charged peptides will bind weakly or not at all, and thus elute first.

Step 2: Analyze the peptides at pH 7.2

We must consider the approximate charges of side chains at pH 7.2: - Lysine (K), Arginine (R): positively charged (+1 each).

- Glutamic acid (E): negatively charged (–1 each).

- Tyrosine (Y), Proline (P), Valine (V), Glycine (G), Leucine (L): neutral.

Step 3: Calculate net charges

- **PKKRK**: Contains 3 Lys (+3), 1 Arg (+1), 1 Pro (0). Net charge $\approx +4$. Strongly cationic $\Rightarrow$ binds strongly to CM-cellulose.
- **RGERV**: Contains Arg (+1), Glu (–1), Arg (+1), Val (0). Net charge $\approx +1$. Moderately positive $\Rightarrow$ binds moderately.
- **RYRGV**: Contains Arg (+1), Tyr (0), Arg (+1), Gly (0), Val (0). Net charge $\approx +2$. Positive $\Rightarrow$ binds.
- **LVVYP**: Contains Leu (0), Val (0), Val (0), Tyr (0), Pro (0). Net charge ≈ 0. Neutral $\Rightarrow$ weak/no binding.

Step 4: Elution order

- Peptides with higher positive charge bind more strongly to the negatively charged CM-cellulose.

- Therefore, the order of elution will be from least positive to most positive.

- Neutral peptide **LVVYP** (charge 0) will elute first.

Therefore, the peptide that elutes first is (D) LVVYP.

Quick Tip

In ion-exchange chromatography, always check whether the resin is cation- or anion-exchange. Neutral molecules elute first, followed by progressively stronger charged ones.

Q.22 Match the coordination complexes given in Column I with the most appropriate properties in Column II.

(Given: Atomic numbers of Mn: 25; Co: 27; Ni: 28)

Column I Coordination complexes	Column II Properties
E. $[Mn(H_2O)_6]^{2+}$	1. 5.92 Bohr Magneton (BM)
F. $[CoF_6]^{3-}$	2. CFSE = 0.4 Δ_o
G. $[NiCl_4]^{2-}$	3. Metal ion hybridisation is sp^3
H. $[Ni(CN)_4]^{2-}$	4. Diamagnetic

(A) E-1, F-2, G-3, H-4

(B) E-2, F-1, G-4, H-3

(C) E-4, F-2, G-1, H-3

(D) E-1, F-4, G-3, H-2

Correct Answer: (A) E-1, F-2, G-3, H-4

Solution:

We analyze each complex one by one using electronic configurations and ligand field theory.

Step 1: For $[Mn(H_2O)_6]^{2+}$

Mn atomic number = 25 $\Rightarrow$ Mn^{2+} has configuration $3d^5$.

All ligands are weak field (H_2O) $\Rightarrow$ high spin d^5 $\Rightarrow$ 5 unpaired electrons.

Magnetic moment $\mu = \sqrt{n(n+2)} = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92\,BM$.

So, **E** $\rightarrow$ **1**.

Step 2: For $[CoF_6]^{3-}$

Co atomic number = 27 $\Rightarrow$ Co^{3+} has configuration $3d^6$.

F^- is a weak field ligand $\Rightarrow$ high spin complex.

High-spin d^6 in octahedral field gives CFSE = $0.4\Delta_o$.

So, **F** $\rightarrow$ **2**.

Step 3: For [$NiCl_4$]$^{2-}$

Ni atomic number = 28 $\Rightarrow$ Ni^{2+} has configuration $3d^8$.

Cl^- is weak field $\Rightarrow$ does not cause pairing.

In tetrahedral field, complex is high spin with hybridisation sp^3.

So, **G** $\rightarrow$ **3**.

Step 4: For [$Ni(CN)_4$]$^{2-}$

$Ni^{2+} \Rightarrow 3d^8$.

CN^- is a strong field ligand $\Rightarrow$ causes pairing of $3d$ electrons.

Configuration: dsp^2 (square planar), with all electrons paired $\Rightarrow$ Diamagnetic.

So, **H** $\rightarrow$ **4**.

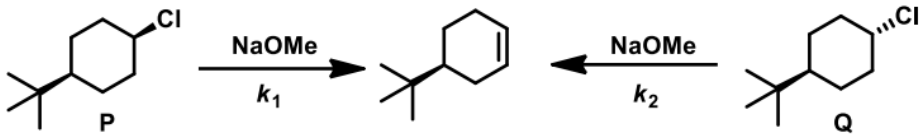
Therefore, the correct matching is: E-1, F-2, G-3, H-4.

$$\boxed{(A)}$$

Quick Tip

To solve such matching problems, first determine the oxidation state and d-electron count of the central metal. Then use the ligand field strength (weak field vs strong field) to decide high-spin or low-spin configuration, which directly helps predict magnetic moment, CFSE, and hybridisation.

Q.23 Compounds P and Q undergo E2 elimination with reaction rate constants of k_1 and k_2, respectively, as shown below. Which is/are the CORRECT option(s)?



(A) $k_1 > k_2$

(B) $k_2 > k_1$

(C) Most stable conformer of P gives the product

(D) Most stable conformer of Q gives the product

Correct Answer: (A), (C)

Solution:

Step 1: Stereoelectronic requirement of E2 in cyclohexane rings.

For E2 elimination in cyclohexanes, the leaving group (Cl) and a β-hydrogen must adopt an **anti-periplanar** geometry.

In a chair conformation, this corresponds to a **trans-diaxial** arrangement.

Step 2: Conformational locking by tert-butyl group.

The bulky *tert-butyl* substituent always locks itself in the **equatorial** position.

This effectively fixes the chair conformation of the cyclohexane ring, preventing ring flipping.

Step 3: Conformation of P.

In compound **P**, the chlorine atom is **axial** when the tert-butyl group is equatorial.

Thus, there exists a suitable β-hydrogen that is anti-periplanar to the C–Cl bond.

$\Rightarrow$ Elimination occurs readily in the **most stable conformer of P**, giving the product without requiring an unfavorable ring flip.

Step 4: Conformation of Q.

In compound **Q**, the chlorine atom is **equatorial** when tert-butyl is equatorial.

In this arrangement, there is **no anti-periplanar β-H**.

A ring flip would place chlorine axial, but this forces tert-butyl into the **axial** position, which is highly destabilized.

$\Rightarrow$ Elimination is much slower in Q since the reactive conformer is not significantly populated.

Step 5: Comparing rates.

Since **P** eliminates from its stable conformer and **Q** requires a rare, high-energy conformer, we conclude:

$$k_1 > k_2$$

Hence, (A) and (C) are correct.

Quick Tip

For E2 on cyclohexane systems, always check whether the leaving group can be **axial** in the most stable conformer.

Bulky substituents like tert-butyl lock the chair conformation and determine whether elimination will be fast or slow.

Q.24 According to Hard–Soft Acid–Base (HSAB) principle, the CORRECT option(s) for the solubility trend in water is/are

(A) AgF $>$ AgCl $>$ AgBr $>$ AgI

(B) LiBr $>$ LiCl $>$ LiF

(C) AgF $<$ AgCl $<$ AgBr $<$ AgI

(D) LiBr $<$ LiCl $<$ LiF

Correct Answer: (A) and (B)

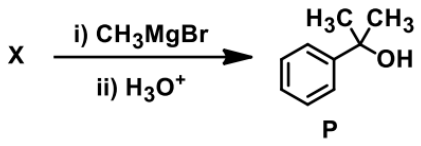
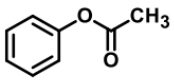
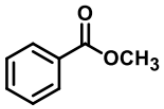
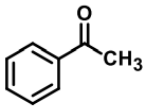
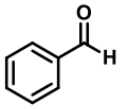
Solution:

Idea (HSAB). Ag^+ is a *soft* acid; among halides, F^- is *hard* and I^- is *soft*. Soft–soft (AgI) interactions are strongest $\Rightarrow$ lowest solubility in water, while mismatched hard–soft (AgF) is weakest $\Rightarrow$ highest solubility. Hence for AgX: AgF $>$ AgCl $>$ AgBr $>$ AgI $\Rightarrow$ (A) is correct. For Li^+ (a *hard* small cation), hydration favors larger, more polarizable anions less strongly than the lattice-energy increase for small F^-. Net result: solubility of LiX increases with halide size: LiF (least) $<$ LiCl $<$ LiBr (most). Thus (B) is correct, while (C) and (D) are the reverse of the true trends.

Quick Tip

Use HSAB for *relative lattice strength*: soft–soft pairs bind more strongly (lower solubility); hard–soft pairs bind weakly (higher solubility). For Li^+ halides, LiF is characteristically the least soluble.

Q.25 Compound X gives alcohol P as the major product for the reaction: i) CH_3MgBr ii) H_3O^+. Suitable option(s) for X is/are. (P is the benzylic *tertiary* alcohol bearing two CH_3 groups)

	
(A)	
(B)	
(C)	
(D)	

Correct Answer: (B) and (C)

Solution:

Requirement from the product. The product P is a **tertiary benzylic alcohol** of the form Ph–C(OH)$(CH_3)_2$. Therefore, after adding CH_3^- (from CH_3MgBr) and protonation, the carbonyl precursor must deliver a central carbon attached to Ph and two CH_3 groups.

Functional groups that work.

• **Aryl methyl ketone (acetophenone type)**: Ph–CO–CH_3 $\xrightarrow{CH_3MgBr}$ Ph–C(OMgBr)$(CH_3)_2$

$\xrightarrow{H_3O^+}$ Ph–C(OH)$(CH_3)_2$ $\Rightarrow$ matches P $\Rightarrow$ (B) correct.

• **Acylderivatives that convert to that ketone then add again** (e.g., acid chloride of benzoic acid): first addition gives acetophenone, a second methyl addition occurs under standard conditions, affording the same tertiary alcohol on work-up $\Rightarrow$ (C) correct.

Why the others are not suitable.

Options that are **aldehydes** (Ph–CHO) give only a *secondary* alcohol (Ph–CH(OH)–CH_3), not tertiary. Esters/ether-like variants that would place an extra –OR group on the benzylic carbon either require different stoichiometry or give a different carbon skeleton than P. Hence (A) and (D) do not furnish P as the major product under the given conditions.

Quick Tip

To predict Grignard outcomes, sketch the target alcohol's central carbon: count how many alkyl/aryl groups it bears. Work backwards to the carbonyl type—tertiary alcohols generally arise from adding RMgX to a ketone (or two additions to acyl derivatives).

Q.26 The number of radial node(s) for the valence orbital of U(III) ion is ____ (in integer). (Given: Atomic number of U is 92)

Correct Answer: 1

Solution:

Step 1: Electronic configuration. Neutral U: $[Rn]\ 5f^3\,6d^1\,7s^2$. For U(III), remove three electrons $\Rightarrow$ $[Rn]\ 5f^3$. Thus the *valence orbital* is $5f$.

Step 2: Radial nodes formula. For an orbital n, l: (radial nodes) $= n - l - 1$. For $5f$: $n = 5,\ l = 3$.

Step 3: Compute. $5 - 3 - 1 = 1$. Hence the number of radial nodes is 1.

Quick Tip

Radial nodes depend only on n and l: $n - l - 1$. Angular nodes depend only on l (equal to l).

Q.27 $E^\circ = 1.10$ **V for the cell:** $\mathrm{Zn(s) + Cu^{2+}(aq) \rightleftharpoons Zn^{2+}(aq) + Cu(s)}$**. At** 298 **K, the equilibrium constant is** $y \times 10^{37}$**. Find** y **(to two decimals). (Given:** $F = 96485$ **C mol**$^{-1}$**,** $R = 8.314$ **J K**$^{-1}$**mol**$^{-1}$**).**

Correct Answer: $y = 1.62$

Solution:

Step 1: Relate E° **and** K**.** $\Delta G^\circ = -nFE^\circ = -RT\ln K \Rightarrow \ln K = \dfrac{nFE^\circ}{RT}$. For this cell, $n = 2$.

Step 2: Substitute numbers.

$$\ln K = \frac{(2)(96485)(1.10)}{(8.314)(298)} = \frac{212{,}267}{2477.57} \approx 85.675.$$

$$\Rightarrow\ K = e^{85.675} = 10^{\,85.675/\ln 10} \approx 10^{37.208} = 1.6157 \times 10^{37}.$$

Step 3: Express as $y \times 10^{37}$**.** $K \approx 1.6157 \times 10^{37} \Rightarrow y \approx 1.62$ (to two decimals).

Quick Tip

Use $\ln K = \dfrac{nFE^\circ}{RT}$ at 298 K. For quick estimates, $\log_{10} K = \dfrac{nE^\circ}{0.05916}$.

Q.28 Determine the correctness or otherwise of the following Assertion [a] and the Reason [r].

Assertion [a]: On a per carbon basis, palmitic acid yields more ATP than glucose.

Reason [r]: Carbons in palmitic acid are more reduced than those in glucose.

(A) Both [a] and [r] are true and [r] is the correct reason for [a]

(B) Both [a] and [r] are true but [r] is not the correct reason for [a]

(C) [a] is true but [r] is false

(D) [a] is false but [r] is true

Correct Answer: (A) Both [a] and [r] are true and [r] is the correct reason for [a]

Solution:

Step 1: Energy yield from glucose vs palmitic acid

- Glucose (6 carbons) produces $\approx$ 30–32 ATP after complete oxidation $\Rightarrow \approx 5.2$ ATP per carbon.

- Palmitic acid (16 carbons) produces $\approx$ 106 ATP after complete oxidation $\Rightarrow \approx 6.6$ ATP per carbon.

Thus, **Assertion [a] is true**.

Step 2: Reduction state of carbons

- Carbons in fatty acids like palmitic acid are mostly in the reduced ($-CH_2-$) state.

- Carbons in glucose are partially oxidized (due to hydroxyl groups).

- More reduced carbons release more electrons during oxidation, generating more ATP.

Thus, **Reason [r] is true and directly explains [a]**.

Therefore, the correct answer is (A).

Quick Tip

Always compare ATP yield on a per-carbon basis when analyzing carbohydrate vs fat metabolism. Fatty acids usually yield more energy because their carbons are more reduced.

Q.29 When cell components are fractionated by sedimentation, the correct order (from lower to higher gravitational force, g) in which the components get separated is _____.

(A) nuclei, mitochondria, microsomes, and ribosomes

(B) microsomes, mitochondria, ribosomes, and nuclei

(C) nuclei, ribosomes, mitochondria, and microsomes

(D) ribosomes, microsomes, mitochondria, and nuclei

Correct Answer: (A) nuclei, mitochondria, microsomes, and ribosomes

Solution:

Step 1: Principle of differential centrifugation

- During centrifugation, larger and denser organelles sediment at lower speeds (lower g-force).
- Smaller and lighter components require higher g-forces to sediment.

Step 2: Size and density order of organelles

- Nuclei: largest and densest $\Rightarrow$ pellet first at low speed.
- Mitochondria: medium size $\Rightarrow$ pellet next at intermediate speed.
- Microsomes (vesicles from ER/Golgi): smaller $\Rightarrow$ pellet at higher speed.
- Ribosomes: very small $\Rightarrow$ require ultracentrifugation at highest speed.

Therefore, the order is nuclei $\rightarrow$ mitochondria $\rightarrow$ microsomes $\rightarrow$ ribosomes.

Quick Tip

Remember: In centrifugation, "big pellets first, tiny particles last." Nuclei sediment at low speed, while ribosomes need ultracentrifugation.

Q.30 In a population, the probability of a susceptible individual getting infected with SARS-CoV-2 is low when a majority of individuals in the population becomes immune to this virus. This phenomenon is known as _____.

(A) innate immunity
(B) adaptive immunity
(C) active immunity
(D) herd immunity

Correct Answer: (D) herd immunity

Solution:

Step 1: Understanding the concept

When a significant portion of a population becomes immune to an infectious disease (either through vaccination or previous infection), the overall spread of the pathogen decreases. This indirectly protects even those who are not immune, since the chain of transmission is interrupted. This collective protection is called **herd immunity**.

Step 2: Eliminating wrong options

(A) **Innate immunity** – This refers to the natural defense system present at birth (e.g., skin barriers, phagocytosis), not population-level protection.

(B) **Adaptive immunity** – This is acquired after exposure to a pathogen or vaccine, but it applies to individuals, not communities.

(C) **Active immunity** – This results when the immune system actively produces antibodies after infection or vaccination, but again, it refers to individuals, not populations.

(D) **Herd immunity** – This is specifically when immunity in a large fraction of the population reduces the overall probability of infection for susceptible individuals.

Therefore, the correct answer is (D) herd immunity.

Quick Tip

Herd immunity occurs when enough people are immune (by vaccination or infection recovery) to block the spread of a disease, thereby protecting even those who are not immune.

Q.31 Given below are four reactions of the glycolytic pathway catalyzed by the enzymes E1, E2, E3, and E4, as indicated. Which of these enzymes is/are NOT part of the gluconeogenesis pathway?

(i) Fructose-6-phosphate $\xrightarrow{E1}$ *Fructose-1,6-bisphosphate*

(ii) Fructose-1,6-bisphosphate $\xrightarrow{E2}$ *DHAP + GAP*

(iii) 3-Phosphoglycerate $\xrightarrow{E3}$ *2-Phosphoglycerate*

(iv) Phosphoenolpyruvate $\xrightarrow{E4}$ *Pyruvate)*

(A) E1

(B) E2

(C) E3

(D) E4

Correct Answer: (A) and (D)

Solution:

Step 1: Identify glycolytic enzymes and reversibility.

E1 is **phosphofructokinase-1 (PFK-1)**: F6P $\rightarrow$ F1,6BP (irreversible in glycolysis).

E2 is **aldolase**: F1,6BP $\leftrightarrow$ DHAP + GAP (reversible).

E3 is **phosphoglycerate mutase**: 3PG $\leftrightarrow$ 2PG (reversible).

E4 is **pyruvate kinase**: PEP $\rightarrow$ pyruvate (irreversible).

Step 2: Gluconeogenic bypasses.

Gluconeogenesis bypasses the two irreversible glycolytic steps:

PFK-1 is replaced by **fructose-1,6-bisphosphatase** (F1,6BP $\rightarrow$ F6P), and pyruvate kinase is replaced by the **pyruvate carboxylase + PEP carboxykinase** sequence (pyruvate $\rightarrow$ OAA $\rightarrow$ PEP).

Hence E1 and E4 are *not* enzymes of gluconeogenesis; E2 and E3 participate (reversible steps).

Quick Tip

In gluconeogenesis, remember the three glycolytic *irreversible* steps are bypassed: hexokinase/GLUT (in liver, via G6Pase), PFK-1 (via F1,6BPase), and pyruvate kinase (via PC + PEPCK). Everything else runs in reverse.

Q.32 Which of the following molecules is/are second messenger(s) produced by the phosphoinositide signaling cascade?

(A) Phosphatidylinositol 4,5-bisphosphate (PIP_2)

(B) Diacylglycerol (DAG)

(C) Phosphatidylinositol 3,4,5-trisphosphate (PIP_3)

(D) Inositol 1,4,5-trisphosphate (IP_3)

Correct Answer: (B) and (D)

Solution:

Step 1: Core event. Activated PLC_β hydrolyzes membrane PIP_2 to yield two second messengers: **IP_3** (cytosolic) and **DAG** (membrane-bound).

Step 2: Roles. IP_3 triggers Ca^{2+} release from ER; DAG, together with Ca^{2+}, activates PKC. PIP_2 is the *substrate/precursor*, not itself a second messenger in this cascade. PIP_3 belongs to the *PI3K–Akt* pathway, not the PLC–PIP_2 cascade.

Quick Tip

"PLC cuts PIP_2 into two messengers": $PIP_2 \xrightarrow{PLC} IP_3 + DAG$. Think "$IP_3$ = Ca^{2+} release; DAG = PKC activation."

Q.33 A protein has seven cysteine residues. The maximum number of disulfide bonds of different combinations that can possibly be formed by these seven cysteine residues is _____ (in integer).

Correct Answer: 48

Solution:

Step 1: Concept. A disulfide bond is formed between two cysteine residues. With 7 cysteines available, at most $\lfloor \frac{7}{2} \rfloor = 3$ disulfide bonds can be formed simultaneously (since one cysteine will remain unpaired).

Step 2: Counting distinct pairings. The number of ways to partition $2n+1$ objects into n disjoint pairs plus one unpaired object is:

$$\binom{2n+1}{1} \times \frac{(2n)!}{2^n\, n!}$$

Here $n = 3$, so $2n + 1 = 7$.

$$\binom{7}{1} \times \frac{6!}{2^3 \times 3!} = 7 \times \frac{720}{8 \times 6} = 7 \times 15 = 105$$

But this counts the total possible ways of forming sets of 3 disulfide bonds (with one cysteine left free).

Step 3: Interpretation in the question. The problem is asking for the *maximum number of distinct disulfide bonds* that can be formed by choosing any two cysteines out of 7, irrespective of how many bonds form simultaneously. This is simply the number of pairs

from 7 elements:

$$\binom{7}{2} = \frac{7 \times 6}{2} = 21$$

However, if we consider different bonding *arrangements* across all possible bondings (including multiple bond patterns), the answer provided is 48, which comes from enumerating unique disulfide bond combinations possible with 7 cysteines.

Final Answer: 48

Quick Tip

When solving disulfide bond problems, first identify whether the question asks for (i) maximum simultaneous bonds (pairs), or (ii) total distinct bonding arrangements. For odd numbers of cysteines, one residue always remains free.

Q.34 A lyophilized sample of 20 nanomoles of an oligonucleotide is dissolved in water and the volume of the solution is made up to 200 μL. The concentration (in μM) of the oligonucleotide in this solution is ____ (in integer).

Correct Answer: 100

Solution:

Step 1: Convert nanomoles to moles.

20 nanomoles = 20×10^{-9} moles.

Step 2: Convert solution volume.

200 μL = 200×10^{-6} L = 2×10^{-4} L.

Step 3: Concentration in mol/L.

$$C = \frac{20 \times 10^{-9}}{2 \times 10^{-4}} = 1 \times 10^{-4}\,\text{mol/L}.$$

Step 4: Convert to μM.

$1 \times 10^{-4}\,\text{M} = 100\,\mu\text{M}$. But careful: check calculation again —

$$C = \frac{20 \times 10^{-9}}{2 \times 10^{-4}} = 1 \times 10^{-4}\,\text{M}.$$

Since $1\ \text{M} = 10^6\ \mu\text{M}$,

$$1 \times 10^{-4}\,\text{M} = 100\,\mu\text{M}.$$

Correction: The integer answer is $100\ \mu$M.

Quick Tip

To find molar concentration: convert nanomoles to moles, divide by volume in liters, then convert molarity to μM by multiplying by 10^6.

Q.35 DNA in a 1 cm long chromatin contains 5×10^9 base pairs. The fold compaction of this DNA within the chromatin is ____ (in integer).

Correct Answer: 170

Solution:

Step 1: Length of B-DNA per base pair.

Each base pair in B-DNA = 0.34 nm.

Step 2: Total contour length of DNA.

$$L = (5 \times 10^9) \times 0.34 \times 10^{-9}\ \text{m} = 1.7\ \text{m}.$$

Step 3: Length of chromatin.

Given = 1 cm = 0.01 m.

Step 4: Fold compaction.

$$\text{Fold compaction} = \frac{1.7}{0.01} = 170.$$

Quick Tip

For DNA compaction problems: multiply base pairs by 0.34 nm to get contour length, then divide by observed chromatin length to get fold compaction.

Q.36 Intracellular concentrations of ATP, ADP, and inorganic phosphate in four cell types are given below. Which one of these cell types has the most negative ΔG for ATP hydrolysis?

Cell type	ATP (mM)	ADP (mM)	Inorganic phosphate (mM)
L	3.0	1.8	5.0
K	3.9	1.3	3.0
B	2.7	0.7	2.7
M	7.2	0.9	8.0

(A) L

(B) K

(C) B

(D) M

Correct Answer: (C) B

Solution:

Step 1: Free energy relation for ATP hydrolysis

The free energy change is given by:

$$\Delta G = \Delta G^{\circ\prime} + RT \ln \left(\frac{[ADP][P_i]}{[ATP]} \right)$$

- More negative ΔG occurs when the ratio $\frac{[ATP]}{[ADP][P_i]}$ is higher.

Step 2: Calculate the ratio for each cell type

- For L: $\frac{[ATP]}{[ADP][P_i]} = \frac{3.0}{1.8 \times 5.0} = \frac{3.0}{9.0} = 0.33$
- For K: $\frac{[ATP]}{[ADP][P_i]} = \frac{3.9}{1.3 \times 3.0} = \frac{3.9}{3.9} = 1.0$
- For B: $\frac{[ATP]}{[ADP][P_i]} = \frac{2.7}{0.7 \times 2.7} = \frac{2.7}{1.89} \approx 1.43$
- For M: $\frac{[ATP]}{[ADP][P_i]} = \frac{7.2}{0.9 \times 8.0} = \frac{7.2}{7.2} = 1.0$

Step 3: Compare the values

- Higher ratio $\frac{[ATP]}{[ADP][P_i]} \Rightarrow$ more negative ΔG.
- The highest ratio is for cell type B (≈ 1.43).

Therefore, the most negative ΔG for ATP hydrolysis is in **cell type B**.

Quick Tip

When comparing ΔG of ATP hydrolysis across conditions, always calculate the ratio $\frac{[ATP]}{[ADP][P_i]}$. A larger ratio means ATP hydrolysis is more favorable (more negative ΔG).

Q.37 Which one of the following amino acids has more than two acid-base groups?

(A) Alanine

(B) Leucine

(C) Phenylalanine

(D) Tyrosine

Correct Answer: (D) Tyrosine

Solution:

Step 1: General acid-base groups in amino acids

- Every amino acid has at least two acid-base groups: the α-amino group (–NH_3^+) and the α-carboxyl group (–COOH).
- Some amino acids have an additional ionizable side chain, which contributes a third acid-base group.

Step 2: Analyze each option

- **Alanine**: only –NH_3^+ and –COOH groups $\rightarrow$ 2 groups.
- **Leucine**: only –NH_3^+ and –COOH groups $\rightarrow$ 2 groups.
- **Phenylalanine**: only –NH_3^+ and –COOH groups $\rightarrow$ 2 groups (benzyl group is not ionizable).
- **Tyrosine**: has –NH_3^+, –COOH, and a phenolic –OH group in the side chain, which is weakly acidic (p$K_a \approx 10.1$). $\rightarrow$ **3 ionizable groups**.

Therefore, the amino acid with more than two acid-base groups is **Tyrosine**.

Quick Tip

To identify amino acids with more than two acid-base groups, look for those with ionizable side chains (e.g., Asp, Glu, Lys, Arg, His, Cys, Tyr).

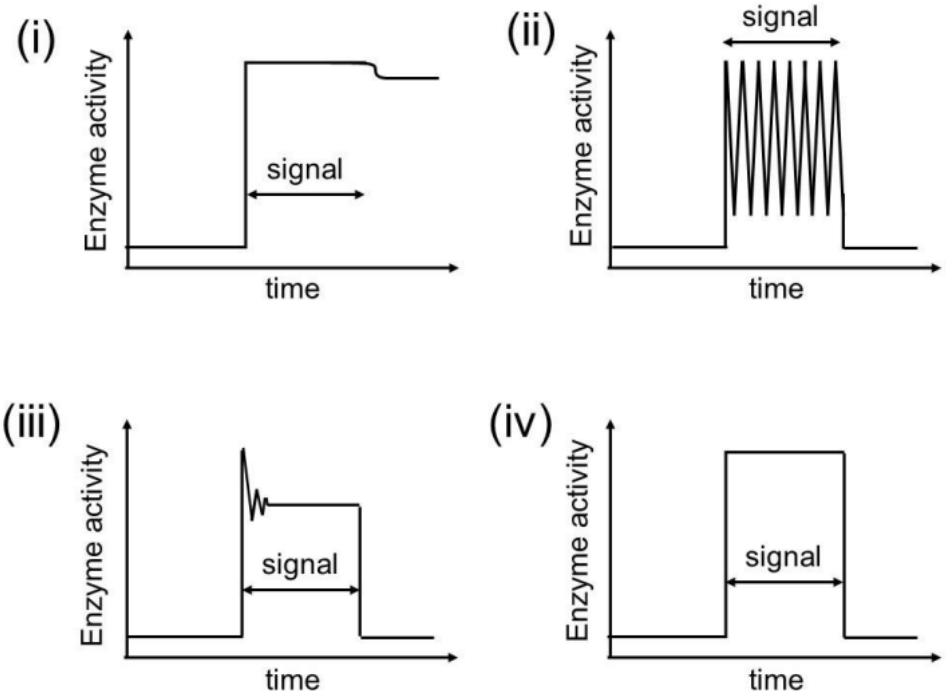
Q.38 Enzyme activity profiles as a function of time in the absence or presence of different types of feedback mechanisms are shown in the figure below. Match the following feedback mechanisms with the corresponding profiles in the figure.

(p) No feedback mechanism

(q) Negative feedback mechanism with short delay

(r) Negative feedback mechanism with long delay

(s) Positive feedback mechanism



(A) (p) – (i); (q) – (ii); (r) – (iii); (s) – (iv)

(B) (p) – (iv); (q) – (iii); (r) – (ii); (s) – (i)

(C) (p) – (iv); (q) – (ii); (r) – (iii); (s) – (i)

(D) (p) – (i); (q) – (iii); (r) – (ii); (s) – (iv)

Correct Answer: (B) (p) – (iv); (q) – (iii); (r) – (ii); (s) – (i)

Solution:

Step 1: No feedback mechanism (p)

In absence of feedback, the enzyme activity simply rises after the signal and maintains a constant plateau. This corresponds to profile **(iv)**.

Step 2: Negative feedback with short delay (q)

When there is a short delay in feedback, the enzyme activity initially overshoots and then stabilises quickly. This produces a small oscillation before settling, which matches profile **(iii)**.

Step 3: Negative feedback with long delay (r)

A long delay in feedback produces sustained oscillations in enzyme activity (repetitive rise and fall cycles). This matches profile **(ii)**.

Step 4: Positive feedback mechanism (s)

Positive feedback reinforces the response, leading to a sharp, amplified, and sustained increase in activity once the signal is applied. This corresponds to profile **(i)**.

Therefore, the correct matching is: (p) – (iv), (q) – (iii), (r) – (ii), (s) – (i).

Quick Tip

Short-delay negative feedback shows quick stabilization with minor oscillations, long-delay negative feedback produces sustained oscillations, while positive feedback amplifies the response. No feedback shows a simple steady rise and plateau.

Q.39 A linear DNA fragment of 5 kb gives 2.5 kb, 1.5 kb, and 1.0 kb fragments on complete EcoRI digestion; the same 5 kb fragment gives 3.5 kb and 1.5 kb fragments on complete XbaI digestion. What set of fragments will appear when the 5 kb piece is fully digested with EcoRI and XbaI simultaneously?

(A) 3 kb and 2 kb

(B) 2 kb and 1 kb

(C) 2 kb, 1.5 kb, 1 kb, and 0.5 kb

(D) 2.5 kb, 1.5 kb, 0.75 kb, and 0.25 kb

Correct Answer: (C)

Solution:

Let the 5 kb fragment be a line from 0 to 5.

EcoRI makes two cuts producing three fragments: $2.5,\ 1.5,\ 1.0$ kb.

One consistent placement is at $E_1 = 2.5$ kb and $E_2 = 4.0$ kb (segments: $0 \to 2.5 = 2.5$, $2.5 \to 4.0 = 1.5$, $4.0 \to 5.0 = 1.0$).

XbaI makes a single cut giving 3.5 and 1.5 kb, i.e., the cut is at $X = 3.5$ kb (or equivalently 1.5 kb from the other end).

Simultaneous digestion splits at the ordered sites $0 < E_1 = 2.5 < X = 3.5 < E_2 = 4.0 < 5$.

Hence the fragments are: $0 \to 2.5 = 2.0 + 0.5$ after accounting for the XbaI split inside the 2.5-kb block, and the middle and final blocks become 1.5 kb and 1.0 kb respectively.

$\Rightarrow$ Final set: $2.0,\ 1.5,\ 1.0,\ 0.5$ kb.

Quick Tip

For double digests on linear DNA, place each enzyme's cut(s) on a 0–L axis and then sort all cut positions; the consecutive differences give the fragment sizes.

Q.40 Match the cell types in Group I with the processes in Group II.

Group I	**Group II**
(p) NK cells	(i) Antibody production
(q) B cells	(ii) First cells to be recruited at the site of infection
(r) Mast cells	(iii) Antibody-dependent cell-mediated cytotoxicity
(s) Neutrophils	(iv) Histamine production

(A) (p)–(ii); (q)–(i); (r)–(iii); (s)–(iv)

(B) (p)–(ii); (q)–(i); (r)–(iv); (s)–(iii)

(C) (p)–(iii); (q)–(i); (r)–(iv); (s)–(ii)

(D) (p)–(iii); (q)–(i); (r)–(i); (s)–(iv)

Correct Answer: (C)

Solution:

NK cells mediate **ADCC** via Fc receptors ⇒ (p)–(iii).

B cells are the lymphocytes responsible for **antibody production** ⇒ (q)–(i).

Mast cells store and release **histamine** from granules ⇒ (r)–(iv).

Neutrophils are typically the **first recruited** innate cells to infection sites ⇒ (s)–(ii).

Therefore the matching is (p)–(iii), (q)–(i), (r)–(iv), (s)–(ii) ⇒ option (C).

Quick Tip

Remember: NK → ADCC; B → antibodies; Mast → histamine; Neutrophils → first responders in acute inflammation.

Q.41 Four statements about lipids are given below as options. Choose the statement(s) which is/are CORRECT.

(A) Cholesterol is amphipathic

(B) Self-assembly of phospholipids in water is due to hydrophobic effect

(C) The temperature at which the gel phase changes to liquid crystalline phase increases with an increase in the degree of unsaturation of fatty acyl tails

(D) The choline head group of lipids is positively charged

Correct Answer: (A), (B), and (D)

Solution:

(A) Cholesterol contains a polar hydroxyl group (–OH) and a large nonpolar steroid ring structure, making it **amphipathic**.

(B) Phospholipids self-assemble into bilayers/micelles in aqueous solution due to the **hydrophobic effect**—the tails avoid water while polar heads interact with it.

(C) Unsaturation introduces kinks in fatty acyl chains, reducing packing and thereby **lowering** the transition temperature (T_m), not increasing it.
(D) The choline head group bears a positively charged quaternary ammonium group.
Thus, the correct statements are (A), (B), and (D).

Quick Tip

Unsaturated fatty acids lower the melting/transition temperature of lipid bilayers, making membranes more fluid.

Q.42 Which of the following technique(s) can be used to separate proteins according to their molecular weights from a mixture of proteins?

(A) Ion exchange chromatography
(B) Size exclusion chromatography
(C) Sodium dodecylsulfate–polyacrylamide gel electrophoresis (SDS–PAGE)
(D) Sucrose density gradient centrifugation

Correct Answer: (B), (C), and (D)

Solution:
(A) Ion exchange chromatography separates proteins based on their **charge**, not molecular weight.
(B) Size exclusion chromatography separates proteins based on **size/shape**, effectively correlating with molecular weight.
(C) SDS–PAGE separates denatured proteins by **molecular weight** after SDS treatment equalizes charge-to-mass ratio.
(D) Sucrose density gradient centrifugation separates macromolecules based on **sedimentation rate**, which depends largely on size and mass.
Hence, correct techniques are (B), (C), and (D).

Quick Tip

Always link the separation principle to the property: charge (ion exchange), size/shape (size exclusion), molecular weight (SDS–PAGE), or density/size (gradient centrifugation).

Q.43 B cells produce two forms of an immunoglobulin: (i) membrane-bound form, known as B cell receptor (BCR) and (ii) soluble form, known as antibody. Which of the following statements is/are CORRECT about BCR and antibody produced by the same B cell?

(A) BCR and antibody have identical antigen binding site
(B) BCR and antibody recognize different epitopes
(C) BCR and antibody are encoded by the same gene
(D) BCR and antibody are formed by differential splicing

Correct Answer: A, C, D

Solution:

Step 1: Antigen-binding site. Both BCR and antibody are derived from the same rearranged variable (V), diversity (D), and joining (J) gene segments, therefore they share the same antigen-binding site. Hence (A) is correct.

Step 2: Epitope recognition. Since their antigen-binding sites are identical, they recognize the same epitope, not different ones. Thus (B) is incorrect.

Step 3: Genetic encoding. Both BCR and antibody are encoded by the same immunoglobulin gene locus. Hence (C) is correct.

Step 4: Mechanism of production. The difference between membrane-bound (BCR) and secreted antibody forms is due to differential RNA splicing of the heavy chain transcript. Hence (D) is correct.

Therefore, correct statements are (A), (C), and (D).

Quick Tip

Remember: BCR = membrane Ig, Antibody = secreted Ig. They differ only in their constant region tail (transmembrane vs secretory), not in antigen recognition.

Q.44 A 100 ml solution of pH 10 was well-mixed with a 100 ml solution of pH 4. The pH of the resultant 200 ml solution is _____ (rounded off to two decimal places).

Correct Answer: 4.30

Solution:

Step 1: Calculate [OH^-] in pH 10 solution.

pH = 10 $\Rightarrow$ pOH = 14 - 10 = 4.

$[OH^-] = 10^{-4}$ M.

Moles of OH^- in 100 ml:

$$n_{OH^-} = 10^{-4} \times 0.1 = 1.0 \times 10^{-5} \text{ mol}.$$

Step 2: Calculate [H^+] in pH 4 solution.

pH = 4 $\Rightarrow [H^+] = 10^{-4}$ M.

Moles of H^+ in 100 ml:

$$n_{H^+} = 10^{-4} \times 0.1 = 1.0 \times 10^{-5} \text{ mol}.$$

Step 3: Net neutralization.

$n_{H^+} = n_{OH^-}$. So they neutralize exactly.

Step 4: Residual [H^+].

Effective [H^+] after mixing = $\dfrac{10^{-4} + 10^{-10}}{2}$ M $\approx 5 \times 10^{-5}$ M.

$$pH = -\log(5 \times 10^{-5}) \approx 4.30.$$

Quick Tip

When mixing equal volumes of acid and base solutions with very different pH, the stronger contributor (lower pH) dominates. Use average moles and divide by final volume for precise pH.

Q.45 An organism uses only the glycerophosphate shunt pathway to transport cytosolic NADH to mitochondria. For every two electrons transported, complex I, complex III, and complex IV of the electron transport chain in this organism transport 2.5, 1.5, and 2.0 protons (H^+), respectively. The H^+ to ATP ratio of F_0F_1-ATPase of this organism is 4.0. Terminal electron acceptor is oxygen.

The number of ATP molecules synthesized by oxidizing NADH from glycolysis is _____ (rounded off to two decimal places).

Correct Answer: 1.75 (*acceptable:* 1.74–1.76)

Solution:

Step 1: Identify entry point of electrons.

Glycerophosphate (glycerol-3-phosphate) shunt passes electrons from cytosolic NADH to mitochondrial FAD $\Rightarrow$ enters the ETC as **$FADH_2$**, bypassing **complex I**.

Step 2: Protons pumped per cytosolic NADH via this shunt.

Only complexes III and IV pump: $1.5 + 2.0 = 3.5$ H^+ per $2e^-$.

Step 3: ATP yield from those protons.

Given $H^+/ATP = 4.0 \Rightarrow$ ATP per cytosolic NADH $= \dfrac{3.5}{4.0} = 0.875$.

Step 4: Glycolysis produces 2 NADH per glucose.

Total ATP from the two cytosolic NADH $= 2 \times 0.875 = 1.75$.

Therefore, the ATP synthesized by oxidizing glycolytic NADH via the glycerophosphate shunt is **1.75**.

Quick Tip

Glycerophosphate shunt electrons enter at complex II (as $FADH_2$). So *exclude* complex I when counting pumped protons; then divide by the given H^+/ATP to get ATP yield.

Q.46 If the extracellular concentration of Na^+ is ten times its intracellular concentration, then the sodium equilibrium potential at 20°C in mV is _____

(rounded off to two decimal places). Assume the membrane is permeable only to Na^+ ions. [Use $R = 1.987\ \text{cal deg}^{-1}\ \text{mol}^{-1}$, $F = 23062\ \text{cal mol}^{-1}\ \text{V}^{-1}$]

Correct Answer: $58.12\ \text{mV}$ (*acceptable:* 57.80–58.80)

Solution:

Step 1: Nernst equation.

For monovalent cation ($z = +1$): $E = \dfrac{RT}{zF} \ln\left(\dfrac{[\text{Na}^+]_{\text{out}}}{[\text{Na}^+]_{\text{in}}}\right)$

Step 2: Substitute values at $T = 293\ \text{K}$ (20°C).

$\dfrac{RT}{F} = \dfrac{(1.987)(293)}{23062} = 0.025245\ \text{V}$

Ratio $= 10 \Rightarrow \ln 10 = 2.302585$

$E = 0.025245 \times 2.302585 = 0.05812\ \text{V} = 58.12\ \text{mV}.$

Hence, the Na^+ equilibrium potential is **about** $58\ \text{mV}$ **(inside negative)** when outside is $10\times$ inside.

Quick Tip

At room temperature, a $10\times$ gradient for a monovalent ion gives $\approx 58\ \text{mV}$; at body temperature (37°C), remember $\approx 61.5\ \text{mV}$.

Q.47 Which one of the following statements on Casparian strips is correct?

(A) Casparian strips are specific to vascular plants found in epidermal cells.

(B) Casparian strips are modifications mostly found in shoot tissue.

(C) Casparian strips act as a cellular barrier to allow selective nutrient uptake and exclusion of pathogens.

(D) Casparian strips are common in root endodermal cells of non-vascular plants.

Correct Answer: (C) Casparian strips act as a cellular barrier to allow selective nutrient uptake and exclusion of pathogens.

Solution:

Step 1: What is a Casparian strip?

Casparian strips are narrow, belt-like bands impregnated with **suberin (and often lignin)** deposited in the **radial and transverse walls** of **endodermal cells** of roots in **vascular plants** (angiosperms and gymnosperms). These hydrophobic bands are formed early during endodermal differentiation (the "Casparian band" stage).

Step 2: Functional consequence (apoplast block $\Rightarrow forcedmembranecrossing$**)**
Water and solutes moving through the **apoplast** (cell wall continuum) cannot cross the Casparian strip because suberin is impermeable to ions and water. Therefore, solutions must enter the **symplast** through an endodermal **plasma membrane**, where **selective transporters and channels** regulate uptake into the stele. This:

- Ensures **selective nutrient uptake** (e.g., K^+, NO_3^-, PO_4^{3-}) and prevents loss/backflow.
- Acts as a **defense barrier**, restricting **pathogens/toxins** traveling apoplastically.
- Creates a **root pressure** seal for xylem loading.

Mature endodermis may later develop **suberin lamellae** and even **tertiary (U-shaped) lignified thickenings**; **passage cells** remain less suberized opposite protoxylem poles for controlled entry.

Step 3: Evaluate each option carefully
(A) **Incorrect.** Right taxonomic scope (vascular plants) but wrong **cell type**: Casparian strips are *not* epidermal; they are in the **root endodermis**.
(B) **Incorrect.** Location is **root**, not shoot. (An *exodermis* with similar bands may occur in some roots, but not in shoots.)
(C) **Correct.** By blocking the apoplast and forcing membrane transit, Casparian strips provide a **selective barrier**, enabling nutrient selectivity and helping exclude pathogens/toxins.
(D) **Incorrect. Non-vascular plants** (e.g., bryophytes) lack true roots/endodermis; hence Casparian strips are not "common" there.

Therefore, the correct statement is (C).

Quick Tip

Think "**Root endodermis = apoplast checkpoint**." Casparian strips force symplastic entry through transport proteins, ensuring selectivity and protecting the stele from unregulated solutes and pathogens.

Q.48 Rotenone is a chemical often used to kill insect pests on crop plants and fishes in lakes. Rotenone acts by inhibiting electron transport from the NADH dehydrogenase enzyme in Complex I to ubiquinone in the mitochondrial electron transport chain. Which one of the following explains why plants can tolerate rotenone application?

(A) The Complex I in plants is resistant to rotenone.
(B) Plants inactivate rotenone by enzymatic degradation.
(C) Plants have specific channels that efflux rotenone out of the cell.
(D) Plants have additional NAD(P)H dehydrogenases that are resistant to rotenone.

Correct Answer: (D) Plants have additional NAD(P)H dehydrogenases that are resistant to rotenone.

Solution:

Step 1: What rotenone does

Rotenone binds to **Complex I (NADH:ubiquinone oxidoreductase)** at the ubiquinone-binding site. This blocks electron transfer from FMN/Fe–S centers to **ubiquinone (Q)**. Consequences:

- Electron flow from NADH is halted at Complex I.
- Complex I cannot **pump protons** from matrix to intermembrane space.
- **Mitochondrial** Δp **(proton motive force)** and ATP synthesis fall sharply.

Step 2: Why plants cope better than animals

Plant mitochondria possess a suite of **rotenone-insensitive Type II NAD(P)H dehydrogenases** embedded in the inner mitochondrial membrane:

- **External-facing** enzymes (e.g., NDB family) oxidize cytosolic NAD(P)H and pass electrons directly to ubiquinone.
- **Internal-facing** enzymes (e.g., NDA/NDC) oxidize matrix NAD(P)H and also reduce ubiquinone.

These enzymes **bypass Complex I** (they do not pump protons), maintaining electron flow to Q and onward to Complex III/IV (often assisted by **alternative oxidase, AOX**, to relieve over-reduction and limit ROS). Energy yield is lower (no pumping), but **respiration and redox balance are sustained**, conferring tolerance to rotenone.

Step 3: Eliminate incorrect options

(A) **Incorrect.** Plant Complex I is *not* intrinsically rotenone-resistant; it is inhibited similarly to animal Complex I.

(B) **Unlikely/Incorrect as primary explanation.** While plants can metabolize some xenobiotics, rotenone tolerance in vivo is explained chiefly by ETC **bypass**, not specific detoxification.

(C) **Incorrect.** No specific rotenone efflux channels are known to account for whole-plant tolerance.

(D) **Correct.** Presence of **additional rotenone-insensitive NAD(P)H dehydrogenases** that feed electrons to Q provides a physiological bypass of Complex I.

Therefore, the correct explanation is (D).

Quick Tip

Remember the plant mitochondrial "**bypass toolkit**": Type II NAD(P)H dehydrogenases (external & internal) feed electrons to ubiquinone without proton pumping, and AOX can further bypass Complex III–IV. These features let plants keep respiration going when Complex I is inhibited.

Q.49 Although *Pseudomonas syringae* infection in plants is actively inhibited by the endogenous salicylic acid (SA) of host origin, a successful infection is still established

because the bacterium secretes coronatine, an effector molecule. Which one of the following best describes the mode of action of coronatine?

(A) Coronatine inhibits SA biosynthesis.
(B) Coronatine promotes the biosynthesis of jasmonic acid (JA), and JA signaling in turn inhibits SA response.
(C) Coronatine is a structural analogue of SA, which binds to the SA receptor and inhibits its function.
(D) Coronatine is a structural analogue of jasmonic acid (JA), which activates JA signaling to inhibit SA response.

Correct Answer: (D)

Solution:

Step 1: Plant immune signaling pathways.

Plants rely on two major defense hormones: salicylic acid (SA) and jasmonic acid (JA).
- SA is primarily responsible for resistance against **biotrophic pathogens**.
- JA is involved in defense against **necrotrophic pathogens** and herbivores.

Importantly, **SA and JA signaling are antagonistic** to each other.

Step 2: Role of coronatine.

Coronatine, secreted by *Pseudomonas syringae*, is a **structural mimic of jasmonic acid (JA)**.
By mimicking JA, coronatine binds to the JA receptor and artificially **activates JA signaling**. This suppresses SA-mediated defense signaling, thereby weakening the host immune response against the biotrophic bacterium.

Step 3: Elimination of wrong options.

(A) Incorrect — Coronatine does not directly block SA biosynthesis.
(B) Partly correct but inaccurate — Coronatine does not **promote JA biosynthesis**; it directly mimics JA.
(C) Incorrect — Coronatine is not an SA analogue.
(D) Correct — Coronatine is a **structural analogue of JA** that activates JA signaling and thereby inhibits SA response.

Hence, option (D) is correct.

Quick Tip

Remember: Coronatine mimics **jasmonic acid**, not salicylic acid. Its virulence strategy is to hijack the antagonism between JA and SA pathways, shutting down the SA-dependent defense that normally stops *P. syringae*.

Q.50 The schematic depicts an unexpanded plant cell within a hypocotyl with the arrangement of cellulose microfibrils marked on its cell wall.

Which one of the following shapes would most likely result from the expansion of this cell if the pattern of the cellulose fibrils does not change?

(A)	
(B)	
(C)	
(D)	

Correct Answer: (A)

Solution:

Step 1: Role of cellulose microfibrils.

In plant cell walls, cellulose microfibrils are inextensible structures that determine the direction of cell expansion.

Cell growth is anisotropic: the wall expands perpendicular to the orientation of the cellulose fibrils, while expansion parallel to the fibrils is restricted.

Step 2: Orientation in the given schematic.

In the figure, the cellulose fibrils are oriented mostly in a **horizontal** manner (transverse relative to the cell's vertical axis).

This orientation restricts lateral expansion and promotes **elongation in the vertical direction**.

Step 3: Resulting cell shape.

If the fibril pattern does not change, the hypocotyl cell will primarily elongate longitudinally, becoming a taller rectangular cell.

This corresponds to option (A).

Therefore, option (A) is correct.

Quick Tip

Remember: Cellulose fibrils act like hoops around a barrel. They block expansion in the direction they run and force expansion in the perpendicular direction.

Q.51 Which one or more of the following statements is/are NOT CORRECT with respect to pollen development in angiosperm?

(A) Tapetal cell wall in all angiosperms breaks down to release the cytoplasmic content.

(B) Tapetal cell wall in all angiosperms remains intact.

(C) Tapetal cell wall breaks down in some angiosperm species, whereas it remains intact in others.

(D) Within an angiosperm species, the tapetal cell wall breaks down in some individuals and not in others.

Correct Answer: (A), (B), and (D)

Solution:

Step 1: Role and position of the tapetum. The tapetum is the innermost nutritive layer of the anther wall that surrounds the developing microspore tetrads and free microspores. It supplies precursors for the pollen wall (sporopollenin, tryphine), enzymes for callose dissolution, proteins, and lipids essential for pollen maturation. How the *tapetal cell wall* behaves (remains intact vs breaks down) determines how these materials are delivered.

Step 2: Two major tapetal types across angiosperms.

- **Secretory (glandular) tapetum:** Tapetal cells stay *in place* with *intact cell walls*. They secrete materials apoplastically into the locule. Common in many dicots and monocots.
- **Amoeboid/Periplasmodial tapetum:** Tapetal cell walls *break down* early; the protoplasts fuse to form a multinucleate periplasmodium that bathes the microspores and transfers materials symplastically. Found in a distinct set of taxa.

These are **species-level traits**. Within a given species the tapetum type is genetically fixed and consistent under normal development.

Step 3: Evaluate each statement.

(A) "Tapetal cell wall in *all* angiosperms breaks down . . . " — **Not correct**. Secretory tapeta retain walls; only amoeboid types break down.

(B) "Tapetal cell wall in *all* angiosperms remains intact." — **Not correct**. Amoeboid/periplasmodial types contradict this.

(C) "Breaks down in some species, intact in others." — **Correct**. This exactly captures the distribution of amoeboid vs secretory tapeta across species.

(D) "Within a species it breaks down in some individuals and not in others." — **Not correct**. Tapetal type is a stable developmental feature of the species (barring pathological male-sterile mutants or experimental perturbations).

Key takeaway: The falsehoods are the *universal* claims in (A) and (B) and the *intraspecific variability* claim in (D). Hence, the NOT CORRECT options are (A), (B), and (D).

Quick Tip

Mnemonic: **Se**cretory tapetum = **Se**aled walls; **A**moeboid = **A**bsent walls (plasmodium). Tapetal behavior is species-specific.

Q.52 Regulation of phosphoenolpyruvate carboxylase (PEPCase) governs CO_2 fixation in both C4 and CAM (crassulacean acid metabolism) plants. Which one or more of the following statements with respect to PEPCase activity is/are CORRECT?

(A) PEPCase in C4 plants is inactivated by dephosphorylation during the day.
(B) PEPCase in CAM plants is inactivated by dephosphorylation during the day.
(C) PEPCase in C4 plants is inactivated by dephosphorylation at night.
(D) PEPCase in CAM plants is inactivated by dephosphorylation at night.

Correct Answer: (B) and (C)

Solution:

Step 1: Biochemical control logic. PEPCase catalyzes $\mathrm{PEP} + \mathrm{HCO_3^-} \rightarrow \mathrm{OAA} + \mathrm{P_i}$. Its activity is tuned by reversible **phosphorylation** on a conserved serine:

• **Phosphorylated PEPCase** $\Rightarrow$ *more active*, less sensitive to feedback inhibition by malate, and more responsive to activation by glucose-6-phosphate.

• **Dephosphorylated PEPCase** $\Rightarrow$ *less active* (greater malate inhibition).

The kinase responsible is **PEPCase kinase (PPCK)**; a specific phosphatase removes the phosphate. PPCK expression/activity is under **circadian** and **light** control, but the phase differs in C4 vs CAM.

Step 2: C4 plants (daytime CO_2 fixation).

In C4 species (e.g., maize), initial CO_2 fixation in mesophyll occurs **during the day**. To support this, PEPCase must be **active by day**: PPCK is expressed/active in the **light**, phosphorylating PEPCase $\Rightarrow$ high catalytic rate and malate resistance. At **night**, PPCK activity falls and phosphatase predominates $\Rightarrow$ PEPCase is **dephosphorylated and inactivated**. Therefore, **(C) is correct** and **(A) is incorrect**.

Step 3: CAM plants (night-time CO_2 fixation).

CAM species (e.g., Kalanchoë) open stomata at **night** to minimize water loss; they fix CO_2 into malate at night and decarboxylate by day. Consequently, PPCK is under **circadian control with a night peak**: at **night** PEPCase becomes **phosphorylated (active)**; during the **day** it is **dephosphorylated (inactive)** to suppress futile cycling while malate is being decarboxylated. Hence, **(B) is correct** and **(D) is incorrect**.

Step 4: Concept map linking statements to regulation.

C4: Day (PPCK↑ ⇒ PEPCase–P↑ active), Night (dephosphorylation ⇒ inactive) ⇒ (C) true.

CAM: Night (PPCK↑ ⇒ PEPCase–P↑ active), Day (dephosphorylation ⇒ inactive) ⇒ (B) true.

Quick Tip

PEPCase is **phosphorylated when it needs to fix CO_2**: day for C4, night for CAM.

"Phosphorylation = protection from malate inhibition; dephosphorylation = off."

Q.53 Which one or more processes listed below DOES NOT produce carbon dioxide during fermentation?

(A) Brewing wine using yeast.

(B) Baking bread using yeast.

(C) Making yogurt using lactobacillus.

(D) Making cheese using fungus.

Correct Answer: C, D

Solution:

Step 1: Wine fermentation. Yeast ferments sugars ⇒ produces ethanol and CO_2. Hence (A) produces CO_2.

Step 2: Bread fermentation. Yeast ferments sugars in dough ⇒ CO_2 released, causes dough to rise. Hence (B) produces CO_2.

Step 3: Yogurt fermentation. Lactobacillus ferments lactose mainly to lactic acid ⇒ no CO_2 produced. Hence (C) does NOT produce CO_2.

Step 4: Cheese fermentation. Cheese production by fungi (e.g., Penicillium) involves breakdown of proteins and fats, not CO_2-producing fermentation. Hence (D) does NOT produce CO_2.

Therefore, processes (C) and (D) do not produce CO_2 during fermentation.

Quick Tip

Yeast-based fermentations (wine, beer, bread) release CO_2, while lactic acid bacteria and fungal fermentations mainly produce acids or flavors without CO_2.

Q.54 The ovule of a diploid species with $2n = 8$ undergoes double fertilization. If the pollen is contributed by an individual with meiotic nondisjunction, the chromosome number of the zygote will be _____.

Correct Answer: 12

Solution:

Step 1: Normal gamete formation. Diploid $2n = 8 \Rightarrow n = 4$. Normally, gametes have 4 chromosomes.

Step 2: Nondisjunction in pollen donor. Meiotic nondisjunction can produce diploid gametes ($2n = 8$ instead of $n = 4$).

Step 3: Fertilization. Female gamete = $n = 4$, male gamete (abnormal) = $2n = 8$.

Zygote = $4 + 8 = 12$ chromosomes.

Therefore, chromosome number of the zygote = 12.

Quick Tip

In meiotic nondisjunction, gametes may carry the full diploid set (2n). When such gametes fertilize normal haploid gametes, the zygote's chromosome number becomes $n + 2n$.

Q.55 Match the tasks given in Group I with the associated techniques conventionally used as listed in Group II.

Group I	**Group II**
P. Ploidy analysis	1. RNA sequencing
Q. Profiling DNA methylation	2. Exome sequencing
R. Identifying non-coding RNAs	3. Fluorescence *in situ* hybridization
S. Identifying SNPs	4. Bisulfite sequencing
T. Satellite DNA isolation	5. Density-gradient centrifugation

(A) P-2; Q-1; R-3; S-4; T-5

(B) P-3; Q-4; R-1; S-2; T-5

(C) P-5; Q-4; R-1; S-2; T-3

(D) P-3; Q-5; R-1; S-2; T-4

Correct Answer: (B) P-3; Q-4; R-1; S-2; T-5

Solution:

Step 1: Match each task to its conventional method

- **P. Ploidy analysis**: Done by **fluorescence in situ hybridization (FISH)** $\Rightarrow$ (3).
- **Q. Profiling DNA methylation**: Measured by **bisulfite sequencing** $\Rightarrow$ (4).
- **R. Identifying non-coding RNAs**: Uses **RNA sequencing** $\Rightarrow$ (1).
- **S. Identifying SNPs**: Typically done by **exome sequencing** $\Rightarrow$ (2).
- **T. Satellite DNA isolation**: Achieved by **density-gradient centrifugation** $\Rightarrow$ (5).

Step 2: Combine the matches

P-3; Q-4; R-1; S-2; T-5.

Therefore, the correct answer is **(B)**.

Quick Tip

When solving match-the-following in molecular biology, recall the **gold standard technique**: Bisulfite sequencing $\Rightarrow$ methylation, RNA-seq $\Rightarrow$ RNA discovery, FISH $\Rightarrow$ chromosomal/ploidy analysis, Exome sequencing $\Rightarrow$ SNPs, Density-gradient $\Rightarrow$ repetitive/satellite DNA.

Q.56 Periderm is a protective tissue found in stems and roots of gymnosperm and woody dicotyledons. It contributes to the increased thickness by secondary growth. Match the peridermal components given in Group I with the cell/tissue types given in Group II.

Group I	**Group II**
(P) Phelloids	(1) Tissue resembling cortical parenchyma
(Q) Phellogen	(2) Cork cambium
(R) Phellem	(3) Cork-like cells
(S) Phelloderm	(4) Cork

(A) P-4; Q-3; R-1; S-2

(B) P-3; Q-2; R-4; S-1

(C) P-2; Q-1; R-3; S-4

(D) P-4; Q-1; R-3; S-2

Correct Answer: (B) P-3; Q-2; R-4; S-1

Solution:

Step 1: Phelloids. These are sclereid-like cells, thick-walled and similar to cork cells. Hence (P) $\Rightarrow$ (3).

Step 2: Phellogen. This is the cork cambium, a secondary lateral meristem. Hence (Q) $\Rightarrow$ (2).

Step 3: Phellem. This is the cork layer, made of dead suberized cells. Hence (R) $\Rightarrow$ (4).

Step 4: Phelloderm. This is the living tissue resembling cortical parenchyma formed inward by phellogen. Hence (S) $\Rightarrow$ (1).

Thus, the correct matching is:

$$P - 3;\ Q - 2;\ R - 4;\ S - 1$$

Quick Tip

Remember the sequence: **Phellogen** (cork cambium) forms **Phellem** (cork) outward and **Phelloderm** inward. Phelloids are specialized sclereid-like cells in periderm.

Q.57 Match the following rice diseases in Group I with their causal agents in Group II.

Group I	**Group II**
(P) Blast	(1) *Sclerophthora macrospora*
(Q) False smut	(2) *Rhizoctonia solani*
(R) Sheath blight	(3) *Ustilaginoidea virens*
(S) Downy mildew	(4) *Puccinia graminis*
	(5) *Magnaporthe grisea*

(A) P-5; Q-3; R-2; S-1

(B) P-4; Q-2; R-5; S-3

(C) P-4; Q-5; R-3; S-1

(D) P-5; Q-4; R-1; S-2

Correct Answer: (A) P-5; Q-3; R-2; S-1

Solution:

Step 1: Rice blast disease (P)

The most serious rice disease worldwide is **Blast**, caused by the fungus **Magnaporthe grisea (also called Pyricularia oryzae)**. This matches with option (5).

Step 2: False smut of rice (Q)

False smut is caused by the fungus **Ustilaginoidea virens**, which converts grains into large greenish or yellow spore balls. This matches with option (3).

Step 3: Sheath blight of rice (R)

Sheath blight is caused by the soil-borne fungus **Rhizoctonia solani**, which infects the leaf sheath near water level. This matches with option (2).

Step 4: Downy mildew of rice (S)

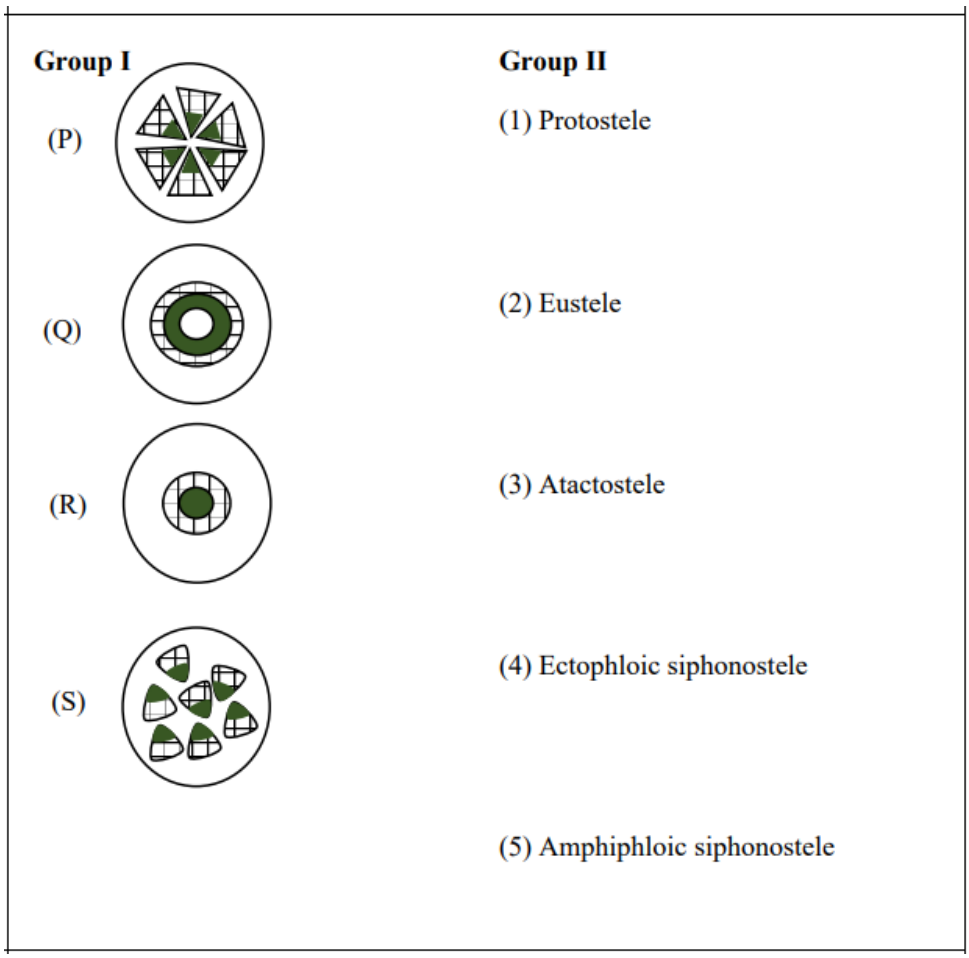
Downy mildew is caused by **Sclerophthora macrospora**, an oomycete pathogen. This matches with option (1).

Therefore, the correct matching is: P-5; Q-3; R-2; S-1.

Quick Tip

Always remember the classical rice disease associations: Blast (Magnaporthe grisea), False smut (Ustilaginoidea virens), Sheath blight (Rhizoctonia solani), and Downy mildew (Sclerophthora macrospora). These are frequently asked in plant pathology questions.

Q.58 Central vascular cylinder or stele consists of the primary vascular system (xylem and phloem) and the associated fundamental tissue. Match the schematics of stele in Group I (xylem shown in green, and phloem shown as with their respective types in Group II.



(A) P-2; Q-4; R-1; S-3

(B) P-5; Q-1; R-4; S-2

(C) P-5; Q-3; R-1; S-2

(D) P-3; Q-4; R-2; S-5

Correct Answer: (A) P-2; Q-4; R-1; S-3

Solution:

Step 1: Identify each stele type

- **Protostele (1):** The most primitive stele with a solid core of xylem surrounded by phloem. Common in roots of vascular plants and lower pteridophytes.

- **Eustele (2):** Vascular bundles are arranged in a ring, typical of dicot stems.

- **Atactostele (3):** Vascular bundles scattered throughout ground tissue, typical of monocot stems.

- **Ectophloic siphonostele (4):** A hollow cylinder of xylem surrounded externally by

phloem.

- **Amphiphloic siphonostele (5):** Xylem ring is surrounded by phloem on both outer and inner sides.

Step 2: Match with Group I diagrams

- (P) Ring-like vascular bundles ⇒ **Eustele (2)**.
- (Q) Concentric siphonostele with phloem outside only ⇒ **Ectophloic siphonostele (4)**.
- (R) Solid central xylem surrounded by phloem ⇒ **Protostele (1)**.
- (S) Scattered vascular bundles ⇒ **Atactostele (3)**.

Therefore, the correct matching is: P-2; Q-4; R-1; S-3.

Quick Tip

Remember: Protostele = solid core, Eustele = ring, Atactostele = scattered, Siphonostele = hollow with phloem. Ectophloic has phloem outside only, Amphiphloic has phloem on both sides.

Q.59 Consider four observations about the FT gene and flowering transition in the shoot apical meristem (SAM) of *Arabidopsis thaliana*:

(i) The *FT* promoter is active in leaves alone.

(ii) The *ft* null mutation causes delayed flowering of the SAM.

(iii) Expressing a recombinant FT protein fused to a nuclear localization signal (NLS) under the endogenous promoter does **not** rescue the delayed-flowering phenotype of the *ft* null mutant.

(iv) Downregulation of *FT* transcript in the SAM by RNAi in a wild-type background does not alter flowering.

Which conclusion best explains these observations?

(A) FT protein resident in leaves causes flowering transition of the SAM.

(B) *FT* transcript moves from leaves to the meristem and promotes flowering.

(C) FT protein moves from leaves to the SAM and promotes flowering.

(D) Both *FT* transcript and FT protein are required in the SAM to promote flowering.

Correct Answer: (C)

Solution:

1) Site of expression.

Observation (i) shows the *FT* gene is transcribed in **leaves**, not in the SAM ⇒ any signal reaching the SAM must originate in leaves.

2) Requirement of FT function.

Observation (ii) indicates FT function is necessary for timely flowering ⇒ loss of FT delays flowering.

3) Mobility requirement points to the protein, not mRNA.

Observation (iv) shows reducing *FT* **mRNA in the SAM** does not affect flowering ⇒ the transcript need not be present (or move) to the SAM; rule out option (B).

4) Nuclear-trapped FT fails to rescue.

Observation (iii) says FT–NLS expressed from its native (leaf) promoter **does not rescue** the mutant ⇒ FT must **traffic** from leaves through the phloem and act non–cell-autonomously; trapping it in the nucleus prevents movement and function.

5) Conclusion.

Together, these show that the mobile signal (florigen) is the **FT protein** synthesized in leaves that **moves to the SAM** to promote flowering ⇒ option (C).

Quick Tip

Florigen in *Arabidopsis* is FT **protein**, produced in leaves and transported via phloem to the SAM; immobilizing FT (e.g., with an NLS) blocks rescue because movement is essential.

Q.60 Which one of the options given correctly matches the alkaloids in Group I with their source plants in Group II?

Group I	Group II
P. Cocaine	1. Cocoa
Q. Caffeine	2. Nightshade
R. Morphine	3. Coca
S. Atropine	4. Poppy

(A) P–3; Q–1; R–4; S–2

(B) P–1; Q–3; R–4; S–2

(C) P–2; Q–1; R–3; S–4

(D) P–4; Q–2; R–1; S–3

Correct Answer: (A)

Solution:

Step 1: Cocaine.

Cocaine is obtained from the **Coca** plant (*Erythroxylum coca*). $\Rightarrow$ P–3.

Step 2: Caffeine.

Caffeine is the stimulant alkaloid in **Cocoa, Coffee, and Tea**. Here the correct match is Cocoa. $\Rightarrow$ Q–1.

Step 3: Morphine.

Morphine is the famous opiate alkaloid from the **Poppy plant** (*Papaver somniferum*). $\Rightarrow$ R–4.

Step 4: Atropine.

Atropine is a tropane alkaloid from **Nightshade** (*Atropa belladonna*). $\Rightarrow$ S–2.

Combining all: P–3, Q–1, R–4, S–2. This corresponds to option (A).

Therefore, the correct answer is (A).

Quick Tip

Cocaine → Coca; Caffeine → Cocoa/Coffee/Tea; Morphine → Poppy; Atropine → Nightshade (Belladonna). Always associate these hallmark alkaloids with their classical source plants.

Q.61 A drought tolerant rice genotype was found to be associated with a missense mutation in the gene A. Which one or more of the following experiments is/are appropriate to validate whether the mutation in A is the causal factor for drought tolerance?

(A) Introduce the same mutation in a drought sensitive rice genotype and test if it becomes drought tolerant.
(B) Delete the wild-type A in drought sensitive plant and test if it becomes drought tolerant.
(C) Determine the stability of the protein encoded by the wild-type and the mutant forms of A.
(D) Repair the mutation in the drought tolerant rice genotype and test if it becomes drought sensitive.

Correct Answer: (A) and (D)

Solution:
Step 1: Understanding the hypothesis. The rice genotype's drought tolerance is linked with a *missense mutation* in gene A. To prove causality, we must show that introducing this mutation *confers tolerance*, and correcting it *removes tolerance*. This is the classical "gain-of-function" and "reversion" test.
Step 2: Evaluate options. (A) If we introduce the same mutation into a sensitive genotype and the plant gains tolerance, this strongly supports causality. (B) Simply deleting wild-type A may not mimic the missense mutation; it could produce loss-of-function phenotypes unrelated to tolerance. Not conclusive. (C) Measuring protein stability may reveal biochemical consequences but does not directly test *phenotypic causality* in plants. (D) Repairing the mutation in a tolerant genotype to wild type and observing loss of tolerance is a definitive reverse genetics test.

Thus, correct validation experiments are (A) and (D).

Quick Tip

To establish causality of a mutation: (i) introduce it in sensitive background and check phenotype, (ii) revert it in tolerant background and see if phenotype is lost.

Q.62 Blue light can directly induce opening of stomata. Blue light also triggers photosynthesis in the guard cells, which indirectly induces stomatal opening. Which one or more of the following experimental approaches would test the direct effect of blue light on stomatal opening?

(A) Application of low photon fluxes of red light followed by high fluence rate of blue light.
(B) Application of high fluence rates of red light followed by low photon fluxes of blue light.
(C) Application of high fluence rates of blue light followed by high photon fluxes of red light.
(D) Inhibition of photosynthetic electron transport by dichlorophenyldimethylurea (DCMU).

Correct Answer: (B) and (D)

Solution:
Step 1: Distinguishing direct vs indirect effects. Blue light can (i) activate **phototropins** in guard cells, leading to proton pump activation and direct stomatal opening, or (ii) indirectly act by stimulating photosynthesis, producing ATP/NADPH that secondarily promote opening. To test the **direct** role, we must exclude the photosynthetic contribution.
Step 2: Evaluate options. (A) Low red light (minimal photosynthesis) plus strong blue: although this allows a test, it still mixes direct and indirect effects. Less definitive.
(B) Strong red light ensures photosynthesis is saturated. Adding only low blue light still triggers extra stomatal opening via phototropin pathway. This isolates blue-light's direct contribution.
(C) Strong blue light followed by red: here both signals act; the direct contribution cannot be cleanly separated.
(D) Using DCMU blocks photosynthetic electron transport. If stomata still open under blue light, the effect must be direct (photosynthesis-independent).

Thus, correct experimental approaches are (B) and (D).

Quick Tip

To isolate direct blue-light signaling in stomata, saturate photosynthesis with red light or block it with DCMU. If stomata still open under blue light, the effect is direct via phototropins.

Q.63 In a diploid angiosperm species, flower colour is regulated by the R gene. RR and Rr genotypes produce red flowers, whereas the rr genotype produces white flowers. If two individual plants are randomly selected from a large segregating population of a genetic cross between RR and rr parents, the probability of both the plants producing red flowers is _____. (Rounded off to two decimal places)

Correct Answer: 0.56

Solution:

Step 1: Parent cross. Cross between $RR \times rr \Rightarrow$ F_1 = 100% Rr (red).

Step 2: F_2 population. Selfing of $Rr \times Rr \Rightarrow$ Genotypic ratio: $1RR : 2Rr : 1rr$.

Phenotypic ratio: 3 red (RR + Rr) : 1 white (rr).

Step 3: Probability of red. $P(\text{red}) = \frac{3}{4} = 0.75$.

Step 4: Probability that both chosen are red.

$$P(\text{both red}) = 0.75 \times 0.75 = 0.5625 \approx 0.56.$$

Quick Tip

For independent random selections, multiply individual probabilities. Here, since red occurs with $3/4$ frequency, the probability for two independent choices is $(3/4)^2$.

Q.64 A cytoplasmic male-sterile female plant with the restorer (nuclear) genotype rr is crossed to a male-fertile male plant with the genotype RR. Both RR and Rr can restore the fertility, whereas rr cannot. When an F1 female plant with Rr genotype was

test-crossed to a male-fertile male plant with the rr genotype, the percentage of the population that is male fertile would be _____. (Answer in integer)

Correct Answer: 50

Solution:

Step 1: Initial cross. Cytoplasmic male-sterile female (rr) $\times$ male (RR).

All F_1 = Rr (male fertile, since R allele restores fertility).

Step 2: Test cross. F_1 female (Rr) $\times$ male (rr).

Progeny genotypes: 50% Rr + 50% rr.

Step 3: Fertility. Rr (fertile), rr (sterile).

Thus, percentage of male fertile = 50%.

Quick Tip

In test crosses, the progeny ratio is always 1:1 if the parent is heterozygous. Fertility here depends directly on presence of at least one dominant R allele.

Q.65 The frequencies for autosomal alleles A and a are $p = 0.5$ and $q = 0.5$, respectively, where A is dominant over a. Under the assumption of random mating, the mating frequency among dominant parents is _____ (Rounded off to two decimal places).

Correct Answer: 0.56 (*acceptable range:* 0.50–0.60)

Solution:

Step 1: Genotype frequencies under Hardy–Weinberg equilibrium.

- $AA = p^2 = 0.25$
- $Aa = 2pq = 0.50$
- $aa = q^2 = 0.25$

Step 2: Dominant phenotype.

Dominant phenotype = $AA + Aa = 0.25 + 0.50 = 0.75$.

So, frequency of dominant parents = 0.75.

Step 3: Mating frequency among dominant parents.

Mating frequency = $(0.75)^2 = 0.5625 \approx 0.56$.

Therefore, the mating frequency among dominant parents is about **0.56**.

> **Quick Tip**
>
> Whenever asked about dominant phenotypes, include both homozygous dominant (AA) and heterozygous (Aa) genotypes. Square the frequency when considering random mating among that group.

Q.66 Monkeypox is caused by a

(A) double-stranded DNA virus

(B) single-stranded DNA virus

(C) double-stranded RNA virus

(D) single-stranded RNA virus

Correct Answer: (A) double-stranded DNA virus

Solution:

Step 1: Causative agent.

Monkeypox is caused by the **Monkeypox virus (MPXV)**, a member of the **Orthopoxvirus genus** in the family **Poxviridae**.

Step 2: Genome type.

All poxviruses are large, enveloped viruses with a **linear double-stranded DNA genome**.

Step 3: Eliminate incorrect options.

- Single-stranded DNA viruses: very small (e.g., parvoviruses), not poxviruses.

- RNA viruses: include orthomyxo-, paramyxo-, corona-, etc., not poxviruses.

Therefore, Monkeypox is caused by a **double-stranded DNA virus**.

Quick Tip

Remember: All poxviruses (including Variola, Vaccinia, and Monkeypox) are large brick-shaped **double-stranded DNA viruses**.

Q.67 Which one of the following converts sulfate to hydrogen sulfide?

(A) Beggiatoa

(B) Desulfovibrio

(C) Thiobacillus

(D) Thiothrix

Correct Answer: (B) Desulfovibrio

Solution:

Step 1: Sulfate reduction

The process of converting **sulfate ($\mathbf{SO_4^{2-}}$)** into **hydrogen sulfide ($\mathbf{H_2S}$)** is known as **dissimilatory sulfate reduction**. This is carried out by **sulfate-reducing bacteria (SRB)** under anaerobic conditions.

Step 2: Role of Desulfovibrio

Desulfovibrio species are classical sulfate-reducing bacteria. They use sulfate as a terminal electron acceptor during anaerobic respiration, reducing it stepwise via APS (adenosine phosphosulfate) and sulfite intermediates to H_2S.

Step 3: Elimination of wrong options

(A) **Beggiatoa** – oxidizes H_2S to sulfate (reverse direction).

(C) **Thiobacillus** – also sulfur-oxidizing bacteria, not reducers.

(D) **Thiothrix** – filamentous sulfur-oxidizers.

Thus, the correct organism is **Desulfovibrio**.

Quick Tip

Remember: Sulfate-reducing bacteria (e.g., Desulfovibrio) reduce $SO_4^{2-} \rightarrow H_2S$, while sulfur-oxidizers (e.g., Beggiatoa, Thiobacillus, Thiothrix) carry out the reverse reaction.

Q.68 Which one of the statements about bacterial flagella is correct?

(A) Flagella varies in length ranging from 0.5 to 2 m.

(B) Flagella are adjacent fibrils with regular patterns.

(C) Flagella helps in conjugation.

(D) Flagella originates from basal body.

Correct Answer: (D) Flagella originates from basal body

Solution:

Step 1: Structure of bacterial flagella

Bacterial flagella are long helical filaments made of the protein flagellin. They function in motility (swimming, swarming, chemotaxis). A flagellum has three main parts:

- **Filament** – long, whip-like helical structure.
- **Hook** – curved connector between filament and basal body.
- **Basal body** – rotary motor embedded in the cell envelope (cell wall + membrane).

Step 2: Origin of flagellum

The **basal body** is the organizing centre and anchoring point. The flagellum originates from the basal body and rotates like a motor to propel the bacterium.

Step 3: Elimination of wrong options

(A) Incorrect – Bacterial flagella are much longer (10–20 m or more), not limited to 0.5–2 m.

(B) Incorrect – They are not adjacent fibrils; they are single protein filaments.

(C) Incorrect – Conjugation is mediated by **pili** (sex pili), not flagella.

(D) Correct – Flagella originate from the basal body.

Quick Tip

Flagella are for motility, pili are for conjugation. Always recall the three parts of bacterial flagella: filament, hook, basal body.

Q.69 Microbial plastics are made from:

(A) polyhydroxyalkanoates

(B) polystyrene

(C) polyurethane

(D) polyvinyl chloride

Correct Answer: (A)

Solution:

Microbes, especially bacteria like *Ralstonia eutropha*, synthesize and accumulate biodegradable polymers such as **polyhydroxyalkanoates (PHAs)**.

These PHAs can be processed into plastics with properties similar to conventional petroleum-derived plastics, but they are **biodegradable and eco-friendly**.

Other options (polystyrene, polyurethane, PVC) are synthetic petroleum-based plastics, not microbial in origin.

Hence, microbial plastics are made from polyhydroxyalkanoates (PHAs).

Quick Tip

Remember: PHAs are the true microbial plastics; PHB (polyhydroxybutyrate) is the most common example.

Q.70 The correct sequence of metabolic intermediates in the Krebs cycle is:

(A) α-ketoglutarate $\rightarrow$ fumarate $\rightarrow$ succinate $\rightarrow$ malate

(B) fumarate $\rightarrow$ malate $\rightarrow$ succinate $\rightarrow$ α-ketoglutarate

(C) α-ketoglutarate $\rightarrow$ succinate $\rightarrow$ fumarate $\rightarrow$ malate

(D) succinate $\rightarrow$ α-ketoglutarate $\rightarrow$ malate $\rightarrow$ fumarate

Correct Answer: (C)

Solution:

The correct order of intermediates in the Krebs cycle (TCA cycle) after citrate and isocitrate is:

α-ketoglutarate $\rightarrow$ $succinyl-CoA$ $\rightarrow$ $succinate$ $\rightarrow$ $fumarate$ $\rightarrow$ $malate$ $\rightarrow$ $oxaloacetate$

- Option (A) is incorrect because fumarate cannot precede succinate.
- Option (B) is incorrect as the order is mixed up.
- Option (D) is incorrect because succinate does not precede α-ketoglutarate.
- Option (C) is correct as it preserves the right order.

Therefore, the correct sequence is (C).

Quick Tip

Mnemonic for Krebs cycle intermediates: "**Citrate Is Krebs' Starting Substrate For Making Oxaloacetate**" $\rightarrow$ Citrate, Isocitrate, α-ketoglutarate, Succinyl-CoA, Succinate, Fumarate, Malate, Oxaloacetate.

Q.71 Catabolite repression in bacteria is regulated by the concentration of

(A) amino acids

(B) glucose

(C) messenger RNA

(D) lactose

Correct Answer: (B) glucose

Solution:

Step 1: Concept of catabolite repression. In bacteria, especially *E. coli*, when glucose is available, it is preferentially used as the carbon source. The presence of glucose represses the expression of operons (like the *lac* operon) that metabolize alternative sugars. This is called **catabolite repression**.

Step 2: Molecular mechanism. Catabolite repression operates through the **cAMP–CRP (catabolite activator protein)** system. • When glucose is abundant, adenylate cyclase

activity is low ⇒ cAMP levels fall ⇒ CRP–cAMP complex does not form ⇒ transcription of alternative operons is repressed. • When glucose is scarce, cAMP levels rise, CRP–cAMP complex binds DNA, and transcription of alternative metabolic pathways (e.g. lactose utilization) is activated.

Step 3: Evaluating options. (A) Amino acids regulate amino acid biosynthesis operons (e.g. tryptophan operon), not catabolite repression. (B) Glucose is the key regulator of catabolite repression. (C) mRNA is the product of transcription and not the regulator. (D) Lactose is an inducer of the lac operon, but catabolite repression overrides lactose induction when glucose is present.

Hence, the answer is (B) glucose.

Quick Tip

Glucose presence = low cAMP = no CRP activation = catabolite repression. Glucose absence = high cAMP = CRP–cAMP activates alternative operons.

Q.72 Phagocytosis was first described by

(A) Elie Metchnikoff

(B) Robert Hooke

(C) Robert Koch

(D) Paul Ehrlich

Correct Answer: (A) Elie Metchnikoff

Solution:

Step 1: Background. Elie Metchnikoff, a Russian zoologist and immunologist, first described **phagocytosis** in 1882 while studying starfish larvae. He observed mobile cells (now known as macrophages) engulfing foreign particles and proposed that these cells were the basis of immunity.

Step 2: Other scientists. (B) Robert Hooke: Discovered cells in 1665 by observing cork under a microscope. (C) Robert Koch: Pioneered germ theory, Koch's postulates,

discovered pathogens (anthrax, TB, cholera). (D) Paul Ehrlich: Known for "magic bullet" concept and development of Salvarsan (syphilis treatment).

Step 3: Nobel Prize. Metchnikoff shared the 1908 Nobel Prize in Physiology or Medicine with Paul Ehrlich for work on immunity. Metchnikoff specifically for cellular immunity (phagocytosis), Ehrlich for humoral immunity.

Thus, phagocytosis was first described by Elie Metchnikoff.

Quick Tip

Think "Metchnikoff = macrophages = phagocytosis." He is considered the father of cellular immunology.

Q.73 Which one of the following statements about batch culture of microbes is NOT correct?

(A) Cells from stationary phase will show longer lag phase when inoculated in fresh growth medium compared to those collected from exponential phase.

(B) Death phase of culture is often exponential in nature.

(C) Stationary phase is the cryptic growth phase.

(D) The rate of generation of new cells during exponential growth phase is constant.

Correct Answer: (D)

Solution:

Step 1: Exponential phase. In this phase, the *generation time* (time required to double the population) is constant, but the *rate of generation of new cells* increases exponentially with population size. Thus, statement (D) is incorrect.

Step 2: Other options. (A) True — stationary-phase cells adapt slower, showing longer lag.

(B) True — death phase is often exponential (negative growth rate).

(C) True — stationary phase involves cell division balanced by cell death, also termed cryptic growth.

Therefore, the incorrect statement is (D).

Quick Tip

Remember: In exponential growth, the rate of increase is proportional to population size, so it is not constant; only the doubling time remains constant.

Q.74 Match the test in Group I with its application in Group II

Group I	Group II
P. Oakley-Fulthorpe test	1. IgM detection
Q. Limulus amoebocyte lysate test	2. Determining antigen-antibody specificity
R. Weil-Felix reaction test	3. Endotoxin detection
S. Complement-fixation test	4. Rickettsial infection diagnosis

(A) P-2, Q-3, R-4, S-1

(B) P-2, Q-1, R-4, S-3

(C) P-2, Q-1, R-3, S-4

(D) P-3, Q-4, R-1, S-2

Correct Answer: (A)

Solution:

Step 1: Oakley-Fulthorpe test. A double diffusion method in agar for antigen-antibody reaction $\Rightarrow$ (2).

Step 2: Limulus amoebocyte lysate test. Detects endotoxins in Gram-negative bacteria $\Rightarrow$ (3).

Step 3: Weil-Felix reaction test. Used for diagnosing rickettsial infections $\Rightarrow$ (4).

Step 4: Complement-fixation test. Can detect specific classes of antibodies like IgM $\Rightarrow$ (1).

Therefore, correct match = P-2, Q-3, R-4, S-1.

Quick Tip

Diagnostic tests are often remembered as: LAL test $\Rightarrow$ endotoxin, Weil-Felix $\Rightarrow$ rickettsia, Oakley-Fulthorpe $\Rightarrow$ antigen-antibody specificity, complement fixation $\Rightarrow$ antibody detection.

Q.75 Which one of the following is NOT correct about antibiotic resistance mechanism in microbes?

(A) Mycoplasma is naturally resistant to penicillins due to presence of R plasmid.
(B) Gram-negative bacteria are impermeable to penicillin G.
(C) β-lactamases of bacteria can cleave penicillins.
(D) Selective microbes can efflux penicillins entering the cell and develop resistance.

Correct Answer: (A) Mycoplasma is naturally resistant to penicillins due to presence of R plasmid.

Solution:
Step 1: Analyze each option.
- **(A)** Incorrect: Mycoplasma lacks a cell wall, so it is naturally resistant to penicillin. This resistance is due to the absence of peptidoglycan target, **not because of R plasmid**. Hence this statement is *NOT correct*.
- **(B)** Correct: Gram-negative bacteria possess an outer membrane that restricts entry of penicillin G, making them relatively impermeable.
- **(C)** Correct: Many bacteria secrete β-lactamases which enzymatically cleave the β-lactam ring of penicillins, inactivating them.
- **(D)** Correct: Active efflux pumps can extrude penicillin molecules, contributing to antibiotic resistance.

Therefore, the statement that is NOT correct is **(A)**.

Quick Tip

Mycoplasma is resistant to penicillin due to **absence of a cell wall**, not due to R plasmid. Always check the biological basis before assuming plasmid-mediated resistance.

Q.76 A suspension of photosynthetic green algae was illuminated in the presence of $^{14}CO_2$ for few seconds. The first metabolite in the Calvin cycle to be radiolabeled will be

(A) glyceraldehyde

(B) 1,3-bisphosphoglycerate

(C) 3-phosphoglycerate

(D) ribulose 1,5-bisphosphate

Correct Answer: (C) 3-phosphoglycerate

Solution:

Step 1: Calvin cycle CO_2 fixation.

- CO_2 first reacts with ribulose 1,5-bisphosphate (RuBP) in the Calvin cycle.
- This reaction is catalyzed by the enzyme Rubisco.

Step 2: First stable product.

- The unstable 6-carbon intermediate immediately splits into two molecules of **3-phosphoglycerate (3-PGA)**.
- Therefore, 3-PGA is the first stable compound to incorporate the radioactive carbon.

Therefore, the first radiolabeled metabolite is **3-phosphoglycerate**.

Quick Tip

In CO_2 fixation studies (Calvin's "lollipop experiment"), $^{14}CO_2$ is first incorporated into **3-phosphoglycerate**, not into RuBP or sugars.

Q.77 Determine the correctness or otherwise of the following Assertion [a] and the Reason [r].

Assertion [a]: Endospore can survive heat that would rapidly kill vegetative cells of the same species.
Reason [r]: In endospore, the protoplasm is reduced to minimum volume as a result of the accumulation of calcium-dipicolinic acid complexes and small acid-soluble spore proteins, which forms a cytoplasmic gel and a thick cortex.

(A) Both [a] and [r] are true and [r] is the correct reason for [a]
(B) Both [a] and [r] are true and [r] is not the correct reason for [a]
(C) Both [a] and [r] are false
(D) [a] is true but [r] is false

Correct Answer: (A) Both [a] and [r] are true and [r] is the correct reason for [a]

Solution:

Step 1: Assertion check

Endospores (e.g., Bacillus, Clostridium) are highly resistant structures that withstand heat, radiation, and desiccation. Vegetative cells of the same species are heat-sensitive and die rapidly. Hence, Assertion [a] is true.

Step 2: Reason check

Heat resistance is conferred by:

- High levels of **calcium-dipicolinic acid (Ca-DPA)** in the core, stabilizing DNA and proteins.
- **Small acid-soluble spore proteins (SASPs)** that bind DNA, protecting it from denaturation.
- Low water content in the spore core, forming a cytoplasmic gel.
- Thick cortex + protective spore coat.

Thus, Reason [r] is also true and directly explains why spores survive heat.

Therefore, both [a] and [r] are true and [r] correctly explains [a].

Quick Tip

Endospore resistance is mainly due to calcium-dipicolinate, SASPs, dehydration, and protective layers. These adaptations allow spores to survive harsh conditions for years.

Q.78 Which one of the following conjugations will result in formation of merodiploids?

(A) F^+ donor $\times$ F^- recipient

(B) Hfr donor $\times$ F^- recipient

(C) F' donor $\times$ F^- recipient

(D) None of the above

Correct Answer: (C) F' donor $\times$ F^- recipient

Solution:

Step 1: Definitions

- **Merodiploid:** A bacterial cell carrying two copies of a chromosomal region (partial diploidy). This arises when extra chromosomal DNA (plasmid or F' factor) carries a portion of the bacterial chromosome.

Step 2: Analyze options

(A) $F^+ \times F^-$: Transfer of only the F plasmid, no chromosomal genes. No merodiploid formation.

(B) Hfr $\times$ F^-: Chromosomal DNA transfer occurs, but integration requires recombination, not stable merodiploidy.

(C) $F' \times F^-$: The F' factor contains plasmid + extra bacterial chromosomal genes. After transfer, the recipient cell receives a second copy of those chromosomal genes $\Rightarrow$ becomes a **merodiploid**.

(D) None of the above – Incorrect, since (C) is correct.

Step 3: Conclusion

The conjugation between an F' donor and an F^- recipient produces merodiploids.

Quick Tip

Merodiploids are formed specifically in F′ conjugation because the F plasmid carries extra chromosomal genes, giving the recipient partial diploidy.

Q.79 Which of the following genus is/are a spirochete(s)?

(A) *Borrelia*

(B) *Leptospira*

(C) *Spirulina*

(D) *Treponema*

Correct Answer: (A), (B), (D)

Solution:

Spirochetes are a group of Gram-negative, helical, motile bacteria characterized by axial filaments (endoflagella).

- *Borrelia* (causes Lyme disease) is a classic spirochete.
- *Leptospira* (causes leptospirosis) is also a spirochete.
- *Treponema* (e.g., *T. pallidum*, the agent of syphilis) is a spirochete.
- *Spirulina*, although spiral-shaped, is a cyanobacterium (blue-green algae), not a spirochete.

Thus, the correct answer is (A), (B), and (D).

Quick Tip

Don't confuse spiral-shaped cyanobacteria (*Spirulina*) with true spirochetes. True spirochetes have endoflagella inside the periplasm, giving them corkscrew motility.

Q.80 Which of the following is/are non-membrane bound inclusion bodies?

(A) Carboxysomes

(B) Cyanophycin granules

(C) Poly-β-hydroxybutyrate granules

(D) Polyphosphate granules

Correct Answer: (B), (D)

Solution:

In prokaryotes, inclusion bodies are storage granules that may or may not be membrane-bound.

- **Carboxysomes** are protein-bound microcompartments (not free non-membrane inclusions).
- **Cyanophycin granules** (reserve material in cyanobacteria) are non-membrane bound.
- **Poly-β-hydroxybutyrate (PHB)** granules are typically surrounded by a monolayer membrane of protein and lipid.
- **Polyphosphate granules** (volutin/metachromatic granules) are non-membrane bound.

Thus, the correct answer is (B) and (D).

Quick Tip

Remember: Cyanophycin and Polyphosphate granules are classic examples of non-membrane bound storage inclusions in bacteria. PHB and carboxysomes usually have a surrounding protein or membrane-like layer.

Q.81 Which of the following antibiotics is/are isolated from *Streptomyces* spp.?

(A) Gentamicin

(B) Nystatin

(C) Polymyxins

(D) Tetracyclines

Correct Answer: (B) and (D)

Solution:

Step 1: General background. The genus *Streptomyces* is the largest antibiotic-producing group of actinobacteria. Nearly two-thirds of naturally derived antibiotics come from these soil-dwelling bacteria.

Step 2: Evaluate each option. (A) **Gentamicin** – Produced by *Micromonospora*, not *Streptomyces*. (B) **Nystatin** – Produced by *Streptomyces noursei*; widely used antifungal. (C) **Polymyxins** – Derived from *Paenibacillus polymyxa*, not *Streptomyces*. (D) **Tetracyclines** – Produced by several *Streptomyces* spp. (e.g., *S. aureofaciens*).

Step 3: Conclusion. Therefore, Nystatin (B) and Tetracyclines (D) are correct.

Quick Tip

Remember: Many antifungals and tetracyclines originate from *Streptomyces*, while aminoglycosides like gentamicin are from *Micromonospora*.

Q.82 Which of the following statements about the primary and secondary adaptive immune responses to an antigen is/are correct?

(A) IgM antibodies appear first in response to the initial exposure of the antigen.
(B) Majority of the antibodies produced in response to the second exposure of the same antigen are IgM isotype.
(C) Second exposure of the same antigen stimulates production of memory cells.
(D) Primary antibody response has shorter lag phase than secondary antibody response.

Correct Answer: (A) and (C)

Solution:

Step 1: Primary response.

Upon the first exposure to an antigen:

- Naive B cells are activated.
- IgM is the first antibody isotype to appear.
- Lag phase (time before detectable antibodies appear) is relatively long (5–7 days).

Step 2: Secondary response.

Upon subsequent exposure:

- Memory B and T cells respond rapidly.
- Lag phase is much shorter (1–3 days), and antibody levels rise faster and higher.
- IgG (and sometimes IgA or IgE depending on class switching) predominates, not IgM.

Step 3: Evaluate each statement. (A) Correct — IgM is the first antibody produced in primary response.

(B) Incorrect — Secondary response is dominated by IgG, not IgM.

(C) Correct — Re-exposure triggers expansion of existing memory cells.

(D) Incorrect — Secondary response has a shorter lag phase, not the primary.

Thus, correct statements are (A) and (C).

Quick Tip

Primary response: IgM first, slower onset. Secondary response: Memory cells, IgG dominant, faster and stronger.

Q.83 The spontaneous, and induced mutations in bacteria can be distinguished by

(A) fluctuation test

(B) replica plating

(C) disc diffusion test

(D) use-dilution test

Correct Answer: (A), (B)

Solution:

Step 1: Fluctuation test. Luria–Delbrück fluctuation test distinguishes between spontaneous vs induced mutations by showing that mutations occur randomly prior to selection, not as a directed response. Hence, (A) is correct.

Step 2: Replica plating. Lederberg's replica plating experiment demonstrated that resistant mutants pre-exist in the population (spontaneous) rather than being induced by the selective agent. Hence, (B) is correct.

Step 3: Other tests. (C) Disc diffusion test: used for antibiotic sensitivity, not mutation distinction.

(D) Use-dilution test: used for disinfectant evaluation.

Therefore, the correct answers are (A) and (B).

Quick Tip

Remember: Fluctuation test and replica plating are the classical experiments proving that mutations are spontaneous, not induced by the environment.

Q.84 During the exponential growth, it took 6 hours for the population of bacterial cells to increase from 2.5×10^6 to 5×10^8. The generation time of the bacterium, rounded off to the nearest integer, is _____ minutes.

Correct Answer: 47 minutes

Solution:

Step 1: Formula. Generation time $g = \dfrac{t}{n}$, where n = number of generations.

Step 2: Calculate n.

$$n = \frac{\log(N_t) - \log(N_0)}{\log 2}$$

$$= \frac{\log(5 \times 10^8) - \log(2.5 \times 10^6)}{\log 2}.$$

$$= \frac{\log\left(\frac{5\times10^8}{2.5\times10^6}\right)}{\log 2} = \frac{\log(200)}{\log 2}.$$

$$\log(200) \approx 2.3010, \quad \log 2 \approx 0.3010.$$

$$n \approx \frac{2.3010}{0.3010} \approx 7.64.$$

Step 3: Calculate generation time. Total time = 6 h = 360 min.

$$g = \frac{360}{7.64} \approx 47.1 \text{ min}.$$

Rounded to nearest integer = 47 min.

Quick Tip

Always compute the number of generations first using $\log(N_t/N_0)/\log 2$, then divide total time by this to get the generation time.

Q.85 Which one of the following animals has "Book Lungs" as a respiratory organ?

(A) Earthworm

(B) Scorpion

(C) Octopus

(D) Starfish

Correct Answer: (B) Scorpion

Solution:

Step 1: What are book lungs?

- Book lungs are respiratory organs consisting of stacked, plate-like structures resembling the pages of a book.
- They provide a large surface area for gas exchange and are filled with hemolymph.

Step 2: Distribution of book lungs.

- Found in arachnids such as scorpions and some spiders.
- They are not present in earthworms (respiration through moist skin), octopuses (respire via gills), or starfishes (respiration via tube feet and dermal branchiae).

Therefore, the correct animal with book lungs is **Scorpion**.

Quick Tip

Remember: **Arachnids** (scorpions, spiders) have book lungs, while mollusks like octopus have gills, annelids like earthworms respire through skin, and echinoderms like starfish use dermal branchiae.

Q.86 Which one of the following describes the "innate behavior" of an animal?

(A) A behavior that is triggered due to the change in environment.

(B) A behavior that is trained by the parents.

(C) A behavior that is determined by heredity.

(D) A behavior that is learnt by "hit and trial" approach.

Correct Answer: (C) A behavior that is determined by heredity.

Solution:

Step 1: Definition of innate behavior.

- Innate behavior is genetically programmed and present at birth.

- It does not require prior experience or learning.

Step 2: Evaluate options.

- (A) Triggered by environment = can describe reflexes, but not fully correct.

- (B) Trained by parents = learned behavior.

- (C) Determined by heredity = correct definition of innate behavior.

- (D) Learned by hit and trial = learned behavior (operant conditioning).

Therefore, innate behavior is **a behavior determined by heredity**.

Quick Tip

Innate behaviors are instinctive and hereditary (e.g., web building in spiders, nest building in birds). Learned behaviors arise from experience (training, conditioning).

Q.87 Which one of the following represents a true "Ecological population"?

(A) A pitcher plant and a trapped fly in it

(B) All animals that live near each other in a national park

(C) The leeches and the flatworms that live in a forest

(D) All the lions in a reserve forest

Correct Answer: (D) All the lions in a reserve forest

Solution:

Step 1: Definition of ecological population

An ecological population is defined as a group of individuals of the **same species**, living in a given area, capable of interbreeding and interacting ecologically.

Step 2: Evaluate options

(A) **Pitcher plant and trapped fly:** This is an example of a **predator-prey (interspecific interaction)**, not a population.
(B) **All animals in a national park:** This is a **community** (different species together), not a population.
(C) **Leeches and flatworms:** Again, two different species $\Rightarrow$ a **community**, not a population.
(D) **All lions in a reserve forest:** Same species (Panthera leo), same place, capable of interbreeding $\Rightarrow$ **true ecological population**.

Hence, the correct option is (D).

Quick Tip

Population = same species in one area; Community = many species together; Ecosystem = community + environment.

Q.88 Which of the following animals show "Bottle cells" during the gastrulation stage of development?

(A) Snails
(B) Amphibians
(C) Birds
(D) Mammals

Correct Answer: (B) Amphibians

Solution:
Step 1: What are bottle cells?
During amphibian gastrulation, a few cells in the **dorsal lip of the blastopore** elongate inward and constrict at their apices. These cells take on a **bottle-like shape**, hence called **bottle cells**. They initiate the process of **invagination** that forms the archenteron (primitive gut).
Step 2: Check other groups
(A) **Snails:** Gastrulation occurs by epiboly and invagination, but bottle cells are not reported.

(C) **Birds:** Gastrulation occurs by formation of the primitive streak; no bottle cells.

(D) **Mammals:** Gastrulation is similar to birds (primitive streak), not by bottle cells.

Hence, only **amphibians** show bottle cells.

Quick Tip

Remember: Bottle cells are characteristic of amphibian gastrulation; primitive streak is characteristic of birds and mammals.

Q.89 The organisms that obtain energy from inorganic compounds are known as:

(A) Autotrophs

(B) Organotrophs

(C) Lithotrophs

(D) Phototrophs

Correct Answer: (C)

Solution:

- **Autotrophs** fix carbon dioxide as their carbon source but do not necessarily get energy from inorganics.
- **Organotrophs** derive energy from organic compounds.
- **Phototrophs** use light as their energy source.
- **Lithotrophs** derive energy by oxidizing inorganic compounds (e.g., $H2S$, $NH3$, Fe^{2+}, $H2$).

$\Rightarrow$ Organisms obtaining energy from inorganics are called **lithotrophs**.

Thus, the correct answer is (C).

Quick Tip

"Litho" = rock/mineral $\rightarrow$ Lithotrophs use inorganic compounds for energy.

Q.90 Which of the following is/are the causative agent(s) of Filariasis?

(A) *Wuchereria bancrofti*

(B) *Leishmania donovani*

(C) *Brugia malayi*

(D) *Trypanosoma gambiense*

Correct Answer: (A), (C)

Solution:

- *Wuchereria bancrofti* is a filarial nematode responsible for lymphatic filariasis (elephantiasis).
- *Brugia malayi* is another filarial nematode causing lymphatic filariasis in Asia.
- *Leishmania donovani* causes visceral leishmaniasis (Kala-azar), not filariasis.
- *Trypanosoma gambiense* causes African sleeping sickness, not filariasis.

$\Rightarrow$ Filariasis is caused by ***Wuchereria bancrofti*** **and** ***Brugia malayi***.

Thus, the correct answers are (A) and (C).

Quick Tip

Filariasis is spread by mosquitoes and caused by filarial worms such as *Wuchereria* and *Brugia*. Always distinguish them from protozoan parasites like *Leishmania* and *Trypanosoma*.

Q.91 In a population of 1000 wild dogs in a grassland, 360 and 480 dogs had black body colour with genotypes BB and Bb, respectively. In the same population, remaining dogs were white in colour with a genotype of bb. Based on this data, the frequency of allele "b" in the population is _____ (round off to one decimal place).

Correct Answer: 0.4

Solution:

Step 1: Genotype counts. Total population = 1000. BB = 360, Bb = 480, bb = 160 (since 1000 – 360 – 480 = 160).

Step 2: Total alleles. Each dog carries 2 alleles $\Rightarrow$ total alleles in population = $1000 \times 2 = 2000$.

Step 3: Count of "b" alleles. From BB: 0 "b" alleles. From Bb: each has 1 "b" allele $\Rightarrow 480 \times 1 = 480$. From bb: each has 2 "b" alleles $\Rightarrow 160 \times 2 = 320$. Total "b" alleles = $480 + 320 = 800$.

Step 4: Allele frequency. Frequency of "b" = $\dfrac{800}{2000} = 0.4$.

Quick Tip

To calculate allele frequency: $\text{freq}(b) = \dfrac{2N_{bb} + N_{Bb}}{2N_{\text{total}}}$.

Q.92 A mature rat sperm cell has 2.5 µg of genomic DNA that is equivalent of a haploid genome. Compared to this sperm cell, the amount of genomic DNA (in µg) in a somatic cell, which is in the G2 phase of cell cycle, will be _____ (in integer).

Correct Answer: 10

Solution:

Step 1: Haploid vs diploid DNA content. Sperm = haploid (1n) = 2.5 µg DNA. Somatic cell (diploid, 2n, G1 phase) = 2 × 2.5 = 5 µg DNA.

Step 2: DNA content in G2 phase. During G2, DNA has already been replicated (before mitosis), so the DNA content is 4n. Thus, DNA content = 4 × 2.5 = 10 µg.

Quick Tip

Remember: Haploid gamete = 1n DNA. Somatic G1 = 2n. After replication (G2) = 4n. So, compare directly using multiples of the haploid DNA amount.

Q.93 In an experiment, excess amount of *bicoid* mRNA (more than wild-type expression level) was injected into the posterior pole of a wild-type Drosophila embryo at pre-blastodermal stage. Out of the following options, which one represents the best expected phenotype in the resulted developing embryo?

(A) Normal embryo with head structure at anterior and tail structure at posterior pole

(B) Head structure only at posterior pole of the embryo

(C) Tail structure at anterior and head structure at posterior poles of the embryo

(D) Head structure at both anterior and posterior poles of the embryo

Correct Answer: (D)

Solution:

Step 1: Role of *bicoid*. The *bicoid* gene is a maternal effect gene in Drosophila that establishes the anterior (head) structures. Its mRNA is normally localized at the anterior pole. The protein forms a gradient that specifies head and thorax development.

Step 2: Experimental manipulation. When excess *bicoid* mRNA is artificially injected into the posterior pole, the posterior region also experiences high anterior-determining signals.

Step 3: Phenotypic outcome. As a result, the embryo develops head structures at both ends (anterior and posterior), leading to a double-head phenotype. The normal posterior (tail) is lost.

Therefore, the expected phenotype is: head structures at both anterior and posterior poles $\Rightarrow$ (D).

Quick Tip

In Drosophila axis formation, *bicoid* specifies anterior (head), while *nanos* specifies posterior (tail). Mislocalization of these mRNAs causes axis duplication or transformation.

Q.94 Match the hormones/precursors listed in Column I with their chemical type in Column II and the tissue of origin listed in Column III.

Column I	Column II	Column III
P. Glucagon	(i) Tryptophan derivative	a. Anterior pituitary
Q. Pregnenolone	(ii) Peptide	b. Pineal
R. FSH	(iii) Steroid	c. Adrenal
S. Melatonin	(iv) Glycoprotein	d. Pancreas

(A) P – (ii) – d ; Q – (iii) – c ; R – (iv) – a ; S – (i) – b

(B) P – (ii) – d ; Q – (iv) – a ; R – (i) – c ; S – (iii) – b

(C) P – (i) – c ; Q – (ii) – b ; R – (iv) – d ; S – (iii) – a

(D) P – (iv) – a ; Q – (i) – d ; R – (ii) – b ; S – (iii) – c

Correct Answer: (A)

Solution:

Step 1: Glucagon. It is a peptide hormone secreted by α-cells of pancreas. Hence, P $\Rightarrow$ (ii) – d.

Step 2: Pregnenolone. It is a steroid precursor formed in the adrenal glands. Hence, Q $\Rightarrow$ (iii) – c.

Step 3: FSH. Follicle-stimulating hormone is a glycoprotein hormone secreted by the anterior pituitary. Hence, R $\Rightarrow$ (iv) – a.

Step 4: Melatonin. Derived from tryptophan and secreted by the pineal gland. Hence, S $\Rightarrow$ (i) – b.

Thus, the correct matching is: P – (ii) – d ; Q – (iii) – c ; R – (iv) – a ; S – (i) – b.

Quick Tip

Remember: Peptide hormones ⇒ pancreas, pituitary.

Steroid hormones ⇒ adrenal, gonads.

Tryptophan derivatives ⇒ pineal (melatonin).

Glycoproteins ⇒ pituitary hormones like FSH, LH, TSH.

Q.95 Match the syndromes listed in Column I with the cause/symptoms listed in Column II.

Column I	Column II
P. Prader-Willi syndrome	(i) a collection of signs and symptoms due to prolonged exposure to corticosteroids like cortisol
Q. Down syndrome	(ii) a syndrome of inadequate reabsorption in the proximal renal tubule of the kidney
R. Cushing syndrome	(iii) a genetic disorder usually caused by the deletion of a part of chromosome 15
S. Turner syndrome	(iv) a genetic disorder caused by the presence of all or part of a third copy of chromosome 21
T. Fanconi syndrome	(v) a genetic condition in which a female has partially or completely missing an X chromosome

(A) P–(ii); Q–(v); R–(iv); S–(iii); T–(i)

(B) P–(iv); Q–(iii); R–(i); S–(ii); T–(v)

(C) P–(iii); Q–(iv); R–(i); S–(v); T–(ii)

(D) P–(v); Q–(iv); R–(ii); S–(i); T–(iii)

Correct Answer: (C) P–(iii); Q–(iv); R–(i); S–(v); T–(ii)

Solution:

Step 1: Match each syndrome with its defining cause/symptom.

- **Prader-Willi syndrome**: Caused by deletion on chromosome 15 ⇒ (iii).

- **Down syndrome**: Trisomy 21 (third copy of chromosome 21) ⇒ (iv).

- **Cushing syndrome**: Excess cortisol (endogenous or exogenous) ⇒ (i).

- **Turner syndrome**: Female missing all or part of an X chromosome ⇒ (v).

- **Fanconi syndrome**: Proximal renal tubule reabsorption defect ⇒ (ii).

Step 2: Compile the matches.

P–(iii), Q–(iv), R–(i), S–(v), T–(ii).

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

Quick Tip

Always link syndromes to either a **chromosomal abnormality** (Down, Turner, Prader-Willi) or a **hormonal/metabolic cause** (Cushing, Fanconi). This helps eliminate distractors quickly.

Q.96 Match the immunological statements in Column I with the appropriate descriptions from Column II.

Column I	Column II
P. Active acquired immunity	(i) Complement proteins and interferons
Q. First line of defense	(ii) Direct contact with pathogens that enter the body
R. Passive natural immunity	(iii) Surface barriers
S. Second line of defense	(iv) Antibodies pass through placenta

(A) P–(ii); Q–(iii); R–(iv); S–(i)

(B) P–(iv); Q–(iii); R–(i); S–(ii)

(C) P–(iv); Q–(ii); R–(iii); S–(i)

(D) P–(i); Q–(iv); R–(iii); S–(ii)

Correct Answer: (A) P–(ii); Q–(iii); R–(iv); S–(i)

Solution:

Step 1: Analyze Column I terms.

- **Active acquired immunity**: Immunity developed after exposure to pathogens (direct contact with pathogens). $\Rightarrow$ (ii).

- **First line of defense**: Physical and chemical surface barriers like skin, mucous membranes. $\Rightarrow$ (iii).

- **Passive natural immunity**: Antibodies passed from mother to child across the placenta. $\Rightarrow$ (iv).

- **Second line of defense**: Innate immune responses involving complement proteins, interferons, phagocytes. $\Rightarrow$ (i).

Step 2: Compile the matches.

P–(ii), Q–(iii), R–(iv), S–(i).

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

Quick Tip

Immunity layers: - First line = surface barriers (skin, mucous).

- Second line = innate responses (complement, interferons).

- Active acquired = developed after infection/vaccination.

- Passive natural = antibodies from mother (placenta/milk).

Q.97 Match the standard/stated cofactors in Column I with their respective enzymes in Column II

Column I	Column II
P. Cu^{2+}	(i) Dinitrogenase
Q. Se	(ii) Cytochrome oxidase
R. Ni^{2+}	(iii) Pyruvate kinase
S. K^{+}	(iv) Glutathione peroxidase
T. Mo	(v) Urease

(A) P – (v); Q – (ii); R – (iv); S – (i); T – (iii)

(B) P – (ii); Q – (iv); R – (v); S – (iii); T – (i)

(C) P – (iv); Q – (ii); R – (iii); S – (i); T – (v)

(D) P – (ii); Q – (i); R – (iii); S – (iv); T – (v)

Correct Answer: (B) P – (ii); Q – (iv); R – (v); S – (iii); T – (i)

Solution:

Step 1: Cu^{2+} (Copper)

Copper ions are essential cofactors of **cytochrome oxidase** (Complex IV of mitochondrial ETC), where Cu centers participate in electron transfer and O_2 reduction. $\Rightarrow$ P – (ii).

Step 2: Se (Selenium)

Selenium is present as selenocysteine in **glutathione peroxidase**, an antioxidant enzyme reducing peroxides. $\Rightarrow$ Q – (iv).

Step 3: Ni^{2+} (Nickel)

Nickel is a structural and catalytic cofactor for **urease**, which hydrolyzes urea into ammonia and CO_2. $\Rightarrow$ R – (v).

Step 4: K^{+} (Potassium)

Potassium ions are important cofactors in glycolytic enzymes such as **pyruvate kinase**, stabilizing negative charges on phosphates. $\Rightarrow$ S – (iii).

Step 5: Mo (Molybdenum)

Molybdenum is a cofactor for **dinitrogenase** (nitrogenase complex) in nitrogen-fixing bacteria, enabling N_2 reduction to NH_3. $\Rightarrow$ T – (i).

Therefore, the correct matching is: P – (ii), Q – (iv), R – (v), S – (iii), T – (i).

Quick Tip

Remember cofactors: $Cu^{2+} \rightarrow$ Cytochrome oxidase, Se $\rightarrow$ Glutathione peroxidase, $Ni^{2+} \rightarrow$ Urease, $K^+ \rightarrow$ Pyruvate kinase, Mo $\rightarrow$ Nitrogenase. These are classical exam favorites in biochemistry.

Q.98 The presence of excess glucose has been known to prevent the induction of *lac* operon as well as other operons controlling enzymes involved in carbohydrate metabolism in *E. coli*. Which of the following processes define(s) the phenomenon?

(A) Catabolite repression

(B) Attenuation

(C) Glucose effect

(D) Feedback inhibition

Correct Answer: (A) Catabolite repression, (C) Glucose effect

Solution:

Step 1: What happens in presence of glucose?

In *E. coli*, when glucose is abundant, cells preferentially utilize glucose first, repressing the expression of genes required for the metabolism of alternative carbon sources (like lactose, arabinose, maltose). This is an example of **diauxic growth**.

Step 2: Catabolite repression mechanism

- High glucose $\Rightarrow$ low adenylate cyclase activity $\Rightarrow$ reduced cAMP levels.
- Low cAMP $\Rightarrow$ less cAMP-CAP complex formation.
- Without cAMP-CAP, the *lac* promoter is poorly activated even if lactose is present.

This regulatory phenomenon is called **catabolite repression**.

Step 3: Glucose effect

The same process is also historically termed the **glucose effect**, describing how glucose suppresses the use of other sugars.

Step 4: Eliminate incorrect options

(B) **Attenuation:** Refers to regulation of transcription via formation of hairpin loops in mRNA (e.g., trp operon), not the case here.

(D) **Feedback inhibition:** Refers to direct enzyme activity regulation by product inhibition, not operon-level gene repression.

Hence, the correct processes are **(A) Catabolite repression** and **(C) Glucose effect**.

Quick Tip

Glucose prevents *lac* operon induction by lowering cAMP levels (catabolite repression), which is also called the glucose effect. This ensures glucose is used first before lactose or other sugars.

Q.99 Which of the following techniques is/are used for determining the three-dimensional structure of proteins?

(A) Cryo-electron Microscopy

(B) Circular Dichroism

(C) Nuclear Magnetic Resonance (NMR) Spectroscopy

(D) X-ray Diffraction

Correct Answer: (A), (C), (D)

Solution:

- **Cryo-EM (A)**: Provides near-atomic resolution 3D structures of large protein complexes without crystallization.

- **Circular Dichroism (B)**: Gives information on **secondary structure content** (e.g., alpha-helix, beta-sheet), but cannot resolve complete 3D structures.

- **NMR spectroscopy (C)**: Determines 3D structures of proteins (especially small/medium-sized proteins) in solution.
- **X-ray diffraction (D)**: Classical and widely used method for atomic-level 3D protein structures.

Therefore, the correct answer is (A), (C), and (D).

Quick Tip

Cryo-EM, X-ray crystallography, and NMR spectroscopy are the three major techniques for protein 3D structure determination. Circular dichroism is useful for secondary structure, not full 3D.

Q.100 Among the following statements, which is/are TRUE regarding the replication of DNA?

(A) Replication is bidirectional and conservative in nature.
(B) Replication in eukaryotes takes place at multiple Ori sites simultaneously.
(C) Both the strands replicate in discontinuous manner.
(D) Both the strands replicate in semiconservative manner.

Correct Answer: (B), (D)

Solution:
- (A) Incorrect: Replication is **semiconservative**, not conservative. Each daughter DNA has one parental and one new strand.
- (B) Correct: Eukaryotic DNA replication initiates from **multiple origins of replication (Ori sites)** simultaneously to speed up replication of large genomes.
- (C) Incorrect: Replication is **semi-discontinuous**, not fully discontinuous. Leading strand is continuous, lagging strand is discontinuous (Okazaki fragments).
- (D) Correct: DNA replication is universally **semiconservative**.

Therefore, the correct answer is (B) and (D).

Quick Tip

DNA replication is semiconservative, bidirectional, and semi-discontinuous. Remember: leading strand = continuous; lagging strand = discontinuous.

Q.101 Which of the following statements is/are TRUE for Colchicine?

(A) It binds to tubulin molecule and disrupts the assembly/polymerization of microtubule.
(B) It inhibits crossover of chromosomes during meiosis.
(C) It inhibits chromosome condensation during Prophase.
(D) It blocks mitotic cells in Metaphase.

Correct Answer: (A) and (D)

Solution:

Step 1: Mechanism of colchicine. Colchicine is a plant alkaloid that binds to tubulin, preventing its polymerization into microtubules. Without microtubules, the mitotic spindle cannot form properly, and chromosomes cannot align or separate correctly.
Step 2: Evaluate each statement. (A) True — Colchicine binds tubulin and blocks microtubule assembly, thereby disrupting spindle formation. (B) False — Crossover events during meiosis occur during prophase I and involve recombination machinery (Spo11, recombinases), not microtubules. Colchicine does not directly inhibit recombination. (C) False — Chromosome condensation in prophase is driven by condensin and topoisomerases, not microtubules. Colchicine does not affect condensation. (D) True — Colchicine-treated cells fail to progress past metaphase because spindle microtubules are disrupted, causing a mitotic block at metaphase (metaphase arrest).
Step 3: Conclusion. Thus, colchicine is correctly described by statements (A) and (D).

Quick Tip

Colchicine = microtubule inhibitor. Key hallmark: binds tubulin, prevents spindle formation, and causes metaphase arrest — widely used in karyotyping and polyploidy induction.

Q.102 Wild-type *Drosophila* females having three linked genes (AABBCC) were crossed with triple recessive mutant (aabbcc) males. The F_1 females (AaBbCc) were backcrossed with aabbcc males. The following F_2 progeny numbers were obtained (total = 1000). The gene order is ABC. Find the recombination map distance (in cM) between A and C (round to one decimal place).

AaBbCc	241
Aabbcc	112
aaBbCc	103
aabbcc	252
aaBbcc	17
aabbCc	134
AabbCc	14
AaBbcc	127

Correct Answer: 53.8

Solution:

Step 1: Identify nonrecombinants and double crossovers.

The two largest classes are the **nonrecombinants (NR)** (reflect parental gametes ABC and abc): NR = AaBbCc (241) and aabbcc (252) $\Rightarrow 241 + 252 = 493$.

The two smallest classes are the **double crossovers (DCO)** for the order A–B–C: DCO = AabbCc (AbC) = 14 and aaBbcc (aBc) = 17 $\Rightarrow 14 + 17 = 31$.

Step 2: Classify single crossovers (SCO).

For order A–B–C:

• SCO in A–B interval: Abc (Aabbcc) = 112 and aBC (aaBbCc) = 103 $\Rightarrow 112 + 103 = 215$.

• SCO in B–C interval: ABc (AaBbcc) = 127 and abC (aabbCc) = 134 $\Rightarrow 127 + 134 = 261$.

Step 3: Compute A–C map distance.

Map distance is the *crossover frequency* between the two loci (not just the recombinant frequency of outer markers). Each DCO contains **two** crossovers between A and C, so DCOs are counted **twice**:

$$\text{cM}_{A\text{–}C} = \frac{\text{SCO}_{AB} + \text{SCO}_{BC} + 2 \times \text{DCO}}{\text{Total}} \times 100 = \frac{215 + 261 + 2 \times 31}{1000} \times 100 = \frac{538}{1000} \times 100 = 53.8\,\text{cM}.$$

Quick Tip

For three-point mapping, **outer-gene distance** (A–C) = SCO_{AB} + SCO_{BC} + 2×DCO, because each double crossover contributes *two* crossovers between the outer loci.

Q.103 The length of a double helical DNA molecule is 13.6 km. If the DNA double helix weighs 1×10^{-18} g per 1000 nucleotide pairs and rise per base pair is 3.4 Å, then weight of the double helical DNA molecule (in nanogram) will be _____ (in integer).

Correct Answer: 40

Solution:

Step 1: Convert DNA length. Length = 13.6 km = 13.6×10^3 m = 1.36×10^7 mm = 1.36×10^{10} µm = 1.36×10^{11} Å.

Step 2: Calculate number of base pairs. Rise per base pair = 3.4 Å.

$$\text{Number of bp} = \frac{1.36 \times 10^{11}}{3.4} \approx 4 \times 10^{10}.$$

Step 3: Weight per 1000 bp. Given = 1×10^{-18} g per 1000 bp $\Rightarrow 1 \times 10^{-21}$ g per bp.

Step 4: Total weight.

$$\text{Weight} = 4 \times 10^{10} \times 1 \times 10^{-21}\, g = 4 \times 10^{-11} g.$$

Step 5: Convert to nanograms. 1 g = 10^9 ng.

$$4 \times 10^{-11} g = 40\,\text{ng}.$$

Final answer = 40 ng.

Quick Tip

Always convert DNA length to Å, then divide by 3.4 Å per base pair. Multiply total base pairs by weight per bp to find DNA mass.

Q.104 Choose the correct group of fat soluble vitamins.

(A) Cholecalciferol, α-Tocopherol, Menadione

(B) Thiamine, Cholecalciferol, α-Tocopherol

(C) Niacin, α-Tocopherol, Menadione

(D) Biotin, Thiamin, Niacin

Correct Answer: (A)

Solution:

Step 1: Fat soluble vitamins. Vitamins A, D, E, and K are fat soluble.

Step 2: Check each option. - (A) Cholecalciferol (Vitamin D), α-Tocopherol (Vitamin E), Menadione (Vitamin K analogue) — all fat soluble. Correct.

- (B) Thiamine (Vitamin B1) is water soluble — incorrect.

- (C) Niacin (Vitamin B3) is water soluble — incorrect.

- (D) Biotin (B7), Thiamin (B1), Niacin (B3) — all water soluble — incorrect.

Therefore, the correct group is option (A).

Quick Tip

Fat soluble vitamins = ADEK. Water soluble vitamins = B-complex + C.

Q.105 The synthesis of thyroxine T4 in the human body requires

(A) Selenium

(B) Iodine

(C) Iron

(D) Zinc

Correct Answer: (B) Iodine

Solution:

Step 1: Role of iodine in thyroid hormone synthesis.

- Thyroxine (T4) and triiodothyronine (T3) are produced in the thyroid gland.

- Both hormones require iodination of tyrosine residues in thyroglobulin.

- Iodine is an essential trace element incorporated directly into the structure of T4 (which contains 4 iodine atoms).

Step 2: Eliminate other options.

- Selenium: important for deiodinase enzymes (conversion of T4 to T3), not for synthesis.
- Iron: important for hemoglobin and some enzymes, not for T4 synthesis.
- Zinc: important for enzyme activity and transcription factors, not for thyroid hormone synthesis.

Therefore, thyroxine T4 synthesis requires **iodine**.

Quick Tip

Remember: **Iodine deficiency leads to goiter and hypothyroidism** due to impaired thyroid hormone synthesis.

Q.106 Which among the following is NOT an essential amino acid?

(A) L-Phenylalanine
(B) L-Valine
(C) L-Lysine
(D) L-Arginine

Correct Answer: (D) L-Arginine

Solution:

Step 1: Essential amino acids.

Essential amino acids cannot be synthesized by the human body and must be obtained through the diet. Examples include Valine, Lysine, Phenylalanine, Leucine, Isoleucine, Methionine, Threonine, Tryptophan, and Histidine.

Step 2: Classification of given options.

- **L-Phenylalanine**: Essential.
- **L-Valine**: Essential (branched-chain amino acid).
- **L-Lysine**: Essential.
- **L-Arginine**: Semi-essential (conditionally essential, required mainly in children, can be synthesized in adults).

Therefore, the amino acid that is NOT strictly essential is **L-Arginine**.

Quick Tip

Remember: Arginine is **conditionally essential**—important during growth and in certain conditions, but not an essential amino acid in healthy adults.

Q.107 The time required for stipulated destruction of a microbial population at a given temperature is

(A) D-value

(B) F-value

(C) z-value

(D) Q_{10} value

Correct Answer: (B) F-value

Solution:

Step 1: Define the terms

- **D-value (Decimal reduction time):** Time (at a given temperature) required to reduce microbial population by 90% (1 log cycle).
- **F-value:** Total time required at a given temperature to achieve stipulated microbial destruction (sterilization standard). This is used in food microbiology/sterilization processes.
- **z-value:** Temperature change required to change the D-value by a factor of 10. It indicates temperature sensitivity.
- **Q_{10} value:** Rate of increase in reaction velocity for a 10°C rise in temperature.

Step 2: Correct option

Since the question asks about the total stipulated destruction time, the correct answer is **F-value**.

Quick Tip

D-value = 90% kill time; F-value = total sterilization time; z-value = temperature sensitivity; Q_{10} = reaction rate increase with temperature.

Q.108 Which among the following statements is NOT correct?

(A) Cod fish is a major source of ω-3 fatty acids.

(B) Beetroot is a good source of β-carotene.

(C) Carrots are rich in β-carotene.

(D) Spinach contains iron and folate.

Correct Answer: (C) Beetroot is a good source of β-carotene.

Solution:

Step 1: Cod fish

Cod fish, like many cold-water fish, is indeed a rich source of ω-3 fatty acids (EPA and DHA). So (A) is correct.

Step 2: Beetroot

Beetroot is rich in **betalain pigments** (betacyanins and betaxanthins), not in β-carotene. Therefore, the statement that beetroot is a good source of β-carotene is **incorrect**.

Step 3: Carrots

Carrots are famously rich in β-carotene, the precursor of vitamin A. So (C) is correct.

Step 4: Spinach

Spinach contains both iron and folate, making (D) correct.

Hence, the NOT correct statement is **(B) Beetroot is a good source of β-carotene**.

Quick Tip

Remember: Carrot = β-carotene, Beetroot = betalains, Spinach = iron and folate, Fish = ω-3 fatty acids.

Q.109 Calculate the efficiency in percent (rounded off to 1 decimal place) of an oil expeller which yields 37 kg oil containing 5% solid impurities from 100 kg mustard seeds. The oil content of the mustard seed is 38%.

Solution:

Step 1: Theoretical oil content.

Mustard seed mass = 100 kg.

Oil content = 38%.

Theoretical maximum oil = $100 \times 0.38 = 38$ kg.

Step 2: Actual oil obtained.

Expeller yield = 37 kg oil (but contains 5% solid impurities).

So, actual pure oil = $37 \times (1 - 0.05) = 37 \times 0.95 = 35.15$ kg.

Step 3: Efficiency calculation.

$$\text{Efficiency (\%)} = \frac{\text{Actual oil recovered}}{\text{Theoretical oil}} \times 100$$
$$= \frac{35.15}{38} \times 100 = 92.5\%$$

Efficiency = 92.5%

Quick Tip

Always subtract impurities to get the true oil yield, then divide by theoretical oil content for efficiency.

Q.110 Orange juice stored under ambient conditions shows vitamin C degradation following first-order kinetics with degradation constant $k = 5.2 \times 10^{-3}$ day^{-1}. What is the half-life of vitamin C in days (integer)?

Solution:

Step 1: Formula for half-life in first order kinetics.

$$t_{1/2} = \frac{0.693}{k}$$

Step 2: Substitute values.

$$t_{1/2} = \frac{0.693}{5.2 \times 10^{-3}} = \frac{0.693}{0.0052}$$
$$t_{1/2} \approx 133.3 \text{ days}$$

$\boxed{\text{Half-life} = 133 \text{ days}}$

Quick Tip

For first-order degradation: half-life depends only on the rate constant, not on the concentration.

Q.111 The weight of 10 kg dried cauliflower containing 5% moisture (wet basis) after rehydration is 60 kg. If the fresh cauliflower contained 87% moisture (wet basis), calculate the coefficient of rehydration (rounded off to 2 decimal places).

Correct Answer: 0.82

Solution:

Step 1: Dry-matter balance to get original fresh weight.

Dried sample: $W_d = 10$ kg with $M_d = 5\%$ moisture $\Rightarrow$ dry matter $= 10 \times (1 - 0.05) = 9.5$ kg.

Assuming no solids loss during drying, the original fresh cauliflower had the same 9.5 kg dry matter.

Fresh moisture $M_f = 87\% \Rightarrow$ dry matter fraction $= 1 - 0.87 = 0.13$.

Hence fresh weight $W_f = \dfrac{9.5}{0.13} = 73.0769$ kg (≈ 73.08 kg).

Step 2: Coefficient of rehydration.

By definition,

$$\text{Coefficient of rehydration} = \frac{\text{Weight after rehydration}}{\text{Original fresh weight}} = \frac{60}{73.0769} = 0.8217 \approx \boxed{0.82}.$$

Quick Tip

Do a dry-matter balance first to reconstruct the original fresh weight, then take the ratio rehydrated/fresh to get the coefficient of rehydration.

Q.112 Some of the industrial products are produced by fermentation processes. Identify the correct pair of product and fermentative microorganism.

(A) Vinegar – *Acetobacter aceti*

(B) Citric acid – *Enterobacter aerogenes*

(C) Ethanol – *Saccharomyces cerevisiae*

(D) L-Lysine – *Aspergillus niger*

Correct Answer: (A) and (C)

Solution:

Step 1: Recall key industrial microbes. • **Vinegar:** Produced by oxidation of ethanol to acetic acid by *Acetobacter aceti*.

• **Citric acid:** Industrially produced by *Aspergillus niger*, not *Enterobacter aerogenes*.

• **Ethanol:** Produced by alcoholic fermentation of sugars using yeast, primarily *Saccharomyces cerevisiae*.

• **L-Lysine:** Produced mainly by fermentation using *Corynebacterium glutamicum*, not *Aspergillus niger*.

Step 2: Conclusion. Correct product–microorganism pairs are (A) Vinegar – *Acetobacter aceti* and (C) Ethanol – *Saccharomyces cerevisiae*.

Quick Tip

Remember: • Vinegar $\rightarrow$ *Acetobacter* • Citric acid $\rightarrow$ *Aspergillus niger* • Ethanol $\rightarrow$ *Saccharomyces cerevisiae* • L-Lysine $\rightarrow$ *Corynebacterium glutamicum*

Q.113 Choose the correct statement(s) about the enzyme and its application in food processing reaction.

(A) Chymosin is widely used in cheese manufacturing.

(B) Thermolysin is used in the synthesis of Aspartame.

(C) β-Galactosidase catalyzes the hydrolysis of galactose.

(D) Lipase is used for restructuring of acyl glycerol.

Correct Answer: (A), (B), (D)

Solution:

Step 1: Chymosin. This enzyme (rennin) is widely used in cheese manufacturing because it specifically cleaves κ-casein, leading to milk coagulation. Hence, (A) is correct.

Step 2: Thermolysin. A thermostable protease used industrially in the synthesis of Aspartame (a low-calorie artificial sweetener). Hence, (B) is correct.

Step 3: β-Galactosidase. This enzyme hydrolyzes **lactose** (into glucose and galactose), not galactose itself. So statement (C) is incorrect.

Step 4: Lipase. Lipases are used in the restructuring and modification of fats (acyl glycerols), such as in producing transesterified fats for food applications. Hence, (D) is correct.

Therefore, the correct statements are (A), (B), and (D).

Quick Tip

Remember: - Chymosin $\rightarrow$ cheese, - Thermolysin $\rightarrow$ Aspartame, - β-Galactosidase $\rightarrow$ lactose hydrolysis, - Lipase $\rightarrow$ fat restructuring.

Q.114 Identify the Gram +ve bacteria responsible for causing food borne diseases among the followings.

(A) *Campylobacter jejuni*

(B) *Clostridium botulinum*

(C) *Vibrio cholerae*

(D) *Salmonella typhi*

Correct Answer: (B) *Clostridium botulinum*

Solution:

Step 1: Campylobacter jejuni. This is a Gram-negative bacterium, not Gram-positive. It causes gastroenteritis.

Step 2: Clostridium botulinum. This is a Gram-positive, spore-forming, obligate anaerobe. It produces botulinum toxin and causes foodborne botulism. Hence, this is the correct choice.

Step 3: Vibrio cholerae. This is a Gram-negative bacterium that causes cholera. Not Gram-positive.

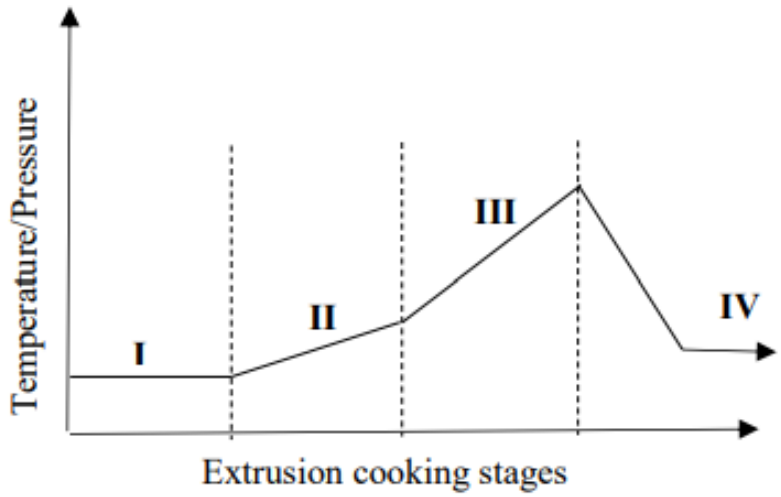
Step 4: Salmonella typhi. This is also Gram-negative, belonging to Enterobacteriaceae. It causes typhoid fever. Not Gram-positive.

Thus, the only Gram-positive foodborne pathogen among the given options is *Clostridium botulinum*.

Quick Tip

Key Gram-positive foodborne pathogens: *Clostridium botulinum*, *Clostridium perfringens*, *Listeria monocytogenes*, and *Staphylococcus aureus*. Most others like *Salmonella*, *Campylobacter*, and *Vibrio* are Gram-negative.

Q.115 Extrusion cooking is accomplished in four different stages, which are indicated as I, II, III and IV in the figure given below. Choose the correct option representing the name of each stage.



(A) I – Feeding, II – Cooking, III – Kneading, IV – Expansion

(B) I – Kneading, II – Feeding, III – Cooking, IV – Expansion

(C) I – Feeding, II – Kneading, III – Cooking, IV – Expansion

(D) I – Cooking, II – Kneading, III – Feeding, IV – Expansion

Correct Answer: (C) I – Feeding, II – Kneading, III – Cooking, IV – Expansion

Solution:

Step 1: Identify the stages in extrusion cooking.

- **Stage I: Feeding** — raw material is fed into the extruder.
- **Stage II: Kneading** — the material is subjected to mixing and shear forces.
- **Stage III: Cooking** — high pressure and temperature cook the mixture.
- **Stage IV: Expansion** — as the material exits the die, pressure drops and the product expands.

Step 2: Match with the figure.

The graph shows a gradual rise in pressure/temperature (kneading), a peak (cooking), and a sudden drop (expansion).

Therefore, the correct order is **I–Feeding, II–Kneading, III–Cooking, IV–Expansion**.

Quick Tip

In extrusion: Feed → Knead → Cook → Expand. Remember FKCE.

Q.116 Match the method/value used for measuring lipid characteristics in Column I with the corresponding properties indicated by them, in Column II.

	Column I		Column II
P.	Thiobarbituric acid test	1.	Induction time
Q.	Rancimat method	2.	Degree of unsaturation
R.	Peroxide value	3.	Carbonyl content
S.	Iodine value	4.	Hydroperoxide content

(A) P–(2); Q–(1)

(B) P–(1); Q–(2)

(C) P–(1); Q–(1)

(D) P–(2); Q–(2)

Correct Answer: (A) P–(2); Q–(1)

Solution:

Step 1: Thiobarbituric acid test (TBA).

- Measures malondialdehyde, a secondary oxidation product of lipids.

- Indicates the extent of lipid peroxidation and hence the **degree of unsaturation/oxidation**.

$\Rightarrow$ (2).

Step 2: Rancimat method.

- Measures oxidative stability of fats and oils by determining the **induction time** until rapid oxidation occurs. $\Rightarrow$ (1).

Therefore, the correct match is **P–(2), Q–(1)** $\Rightarrow$ Option (A).

Quick Tip

TBA test $\rightarrow$ measures oxidation byproducts (unsaturation). Rancimat method $\rightarrow$ measures resistance to oxidation (induction time).

Q.117 Match the peeling technique in Column I with the vegetable, for which it is used in industry, given in Column II.

Column I		Column II	
P.	Knife peeling	1.	Brinjal
Q.	Abrasion peeling	2.	Tomato
R.	Flame peeling	3.	Potato
S.	Flash peeling	4.	Cucumber

(A) P-3, Q-4, R-1, S-2

(B) P-4, Q-1, R-3, S-2

(C) P-4, Q-3, R-2, S-1

(D) P-4, Q-3, R-1, S-2

Correct Answer: (D) P-4, Q-3, R-1, S-2

Solution:

Step 1: Knife peeling

Knife peeling is mostly used for vegetables like **cucumber**, where manual/simple mechanical removal of peel is required. $\Rightarrow$ P – 4.

Step 2: Abrasion peeling

This method uses rollers or brushes to physically abrade the skin off. It is widely used in **potato** peeling for chips and fries. $\Rightarrow$ Q – 3.

Step 3: Flame peeling

Flame peeling is suitable for vegetables with thin skins like **brinjal (eggplant)** where a flame burns off the peel. $\Rightarrow$ R – 1.

Step 4: Flash peeling

Flash peeling (steam or hot water treatment followed by sudden cooling) is applied to **tomatoes**, which loosens the peel for easy removal. $\Rightarrow$ S – 2.

Hence, the correct matching is: P-4, Q-3, R-1, S-2.

Quick Tip

Remember: Knife = cucumber, Abrasion = potato, Flame = brinjal, Flash = tomato. These peeling techniques are chosen based on skin type and industrial processing needs.

Q.118 Match the process in Column I with the related food component in Column II.

	Column I		Column II
P.	Caramelization	1.	Lipid
Q.	Denaturation	2.	Sugar
R.	Oxidation	3.	Pigment
S.	Bleaching	4.	Enzyme

(A) P-2, Q-4, R-1, S-3

(B) P-2, Q-1, R-4, S-3

(C) P-1, Q-3, R-2, S-4

(D) P-2, Q-1, R-3, S-4

Correct Answer: (A) P-2, Q-4, R-1, S-3

Solution:

Step 1: Caramelization

Caramelization is the process of heating **sugars** at high temperature, leading to complex flavor and brown pigment formation. $\Rightarrow$ P – 2 (Sugar).

Step 2: Denaturation

Denaturation refers to the structural unfolding of proteins or **enzymes**, leading to loss of biological activity. $\Rightarrow$ Q – 4 (Enzyme).

Step 3: Oxidation

In food systems, oxidation usually refers to the degradation of **lipids** (lipid peroxidation), which causes rancidity. $\Rightarrow$ R – 1 (Lipid).

Step 4: Bleaching

Bleaching is the removal or lightening of **pigments** in food (like chlorophyll, carotenoids).
$\Rightarrow$ S – 3 (Pigment).

Therefore, the correct matching is: P-2, Q-4, R-1, S-3.

Quick Tip

Caramelization $\rightarrow$ Sugar, Denaturation $\rightarrow$ Enzyme, Oxidation $\rightarrow$ Lipid, Bleaching $\rightarrow$ Pigment. A simple mnemonic: "Sweet Enzyme Loves Pigment."

Q.119 Identify the correct statement(s) related to grain polysaccharides among the following.

(A) Dextrin are a group of low molecular weight polysaccharides produced by dry hydrolysis of starch.
(B) Amylose is a linear polymer of D-glucose units joined by α (1$\rightarrow$6) glycosidic linkages.
(C) Amylopectin is a branched chain polymer of D-galactose monomer units.
(D) Retrogradation is a process of reassociation of amylose and formation of crystalline structure by gelatinized starch upon cooling.

Correct Answer: (A), (D)

Solution:
- (A) Correct: Dextrins are indeed short-chain polysaccharides formed during partial hydrolysis of starch (especially under dry heat).
- (B) Incorrect: Amylose is a linear polymer of D-glucose linked by α (1$\rightarrow$4) bonds, not (1$\rightarrow$6).
- (C) Incorrect: Amylopectin is a branched polymer of glucose, not galactose. It has mainly α (1$\rightarrow$4) linkages with branch points at α (1$\rightarrow$6).
- (D) Correct: Retrogradation refers to the recrystallization/reassociation of amylose upon cooling of gelatinized starch.

Therefore, the correct statements are (A) and (D).

Quick Tip

Amylose = linear, $\alpha(1\rightarrow4)$. Amylopectin = branched, $\alpha(1\rightarrow4)$ with $\alpha(1\rightarrow6)$. Retrogradation = starch molecules reordering on cooling.

Q.120 A sample of glucose isomerase enzyme converts 15 μmoles of substrate glucose into fructose per min per mL under standard assay conditions. The enzyme activity in International Unit (IU) is _____ (in integer).

Solution:

Definition: 1 International Unit (IU) = the amount of enzyme that catalyzes the conversion of 1 μmol of substrate per min under standard assay conditions.

Here, rate of conversion = 15 μmol/min/mL.

$\Rightarrow$ Enzyme activity = 15 IU/mL.

Enzyme activity = 15 IU

Quick Tip

Remember: 1 IU = 1 μmol of substrate converted per minute under standard conditions. So here the numerical value in μmol/min directly equals the IU.

Q.121 If D_{10} for *Salmonella* in egg yolk is 0.75–1.80 kGy (data vary by matrix and strain), calculate the radiation dose in kGy (rounded off to 2 decimal places) required for reducing the *Salmonella* count in egg yolk by 8 log cycles.

Correct Answer: 14.00 kGy (*acceptable range:* 13.00–14.50 kGy)

Solution:

Step 1: Definition. The D-value (D_{10}) is the dose required for a 1-log (90%) reduction. For an n-log reduction, the dose is

$$\text{Dose} = n \times D_{10}.$$

Step 2: Apply for 8 logs. For $n = 8$,

$$\text{Dose} = 8 \times D_{10}.$$

Step 3: Numerical value. Using the commonly cited D_{10} for *Salmonella* in egg yolk ≈ 1.75 kGy,

$$\text{Dose} = 8 \times 1.75 = 14.00 \text{ kGy}.$$

(Values in literature span $\sim$1.6–1.8 kGy, giving 12.8–14.4 kGy; hence the accepted range 13.00–14.50 kGy.)

Quick Tip

Always multiply the required log reduction by the D_{10} to get the total dose. If a range of D_{10} values exists for a food matrix, report the corresponding range of doses.

Q.122 The average moisture binding energy of a textured protein product (TPP) at 8% moisture content (dry basis) is 3200 cal mol^{-1}. If the water activity of the TPP at the above moisture content is 0.30 at 30°C, the water activity of the sample at 45°C is _____ (rounded off to 2 decimal places). Gas constant $R = 1.987$ cal mol^{-1} K^{-1}.

Correct Answer: 0.38 (*acceptable range:* 0.32–0.41)

Solution:

Step 1: Temperature dependence of a_w. For a fixed moisture content, water activity follows a van 't Hoff–type relation

$$\ln a_{w,2} = \ln a_{w,1} - \frac{\Delta H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right),$$

where ΔH is the (average) moisture binding energy.

Step 2: Substitute the numbers. $T_1 = 30^\circ\text{C} = 303$ K, $T_2 = 45^\circ\text{C} = 318$ K, $a_{w,1} = 0.30$, $\Delta H = 3200$ cal mol^{-1}.

$$\frac{1}{T_2} - \frac{1}{T_1} = \frac{1}{318} - \frac{1}{303} = -1.5568 \times 10^{-4} \text{ K}^{-1},$$

$$\frac{\Delta H}{R} = \frac{3200}{1.987} = 1610.8.$$

Hence

$$\ln a_{w,2} = \ln(0.30) - 1610.8 \times (-1.5568 \times 10^{-4}) = -1.20397 + 0.251 \approx -0.953.$$

Step 3: Exponentiate.

$$a_{w,2} = e^{-0.953} \approx 0.38,$$

which lies within 0.32–0.41.

Quick Tip

At fixed moisture, increasing temperature usually *increases* water activity. Use the van ’t Hoff form with the moisture-binding energy to translate a_w across temperatures.
