# GATE 2026 Life Sciences (XL) Question Paper with Solutions

| **Time Allowed :**3 Hour | **Maximum Marks :**100 | **Total Questions :**65 |
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**General Instructions**

**Read the following instructions very carefully and strictly follow them:**

1. This question paper is divided into three sections:
   - **General Aptitude (GA):** 10 questions (5 questions × 1 mark + 5 questions × 2 marks) for a total of 15 marks.
   - **Engineering Mathematics:**
     - **Part A (Mandatory):** 36 questions (1 questions × 1 mark + 19 questions × 2 marks) for a total of 55 marks.
     - **Part B (Section 1):** Candidates can choose either Part B1 (Surveying and Mapping) or Part B2 (Section 2). Each part contains 16 questions (8 questions × 1 mark + 11 questions × 2 marks) for a total of 30 marks.
2. The total number of questions is **65**, carrying a maximum of **100 marks**.
3. The duration of the exam is **3 hours**.
4. Marking scheme:
   - For 1-mark MCQs, $\frac{1}{3}$ mark will be deducted for every incorrect response.
   - For 2-mark MCQs, $\frac{2}{3}$ mark will be deducted for every incorrect response.
   - No negative marking for numerical answer type (NAT) questions.
   - No marks will be awarded for unanswered questions.
5. Ensure you attempt questions only from the optional section (Part B1 or Part B2) you have selected.
6. Follow the instructions provided during the exam for submitting your answers.

**1. Suresh said, "I did it yesterday."**
**Which one of the following options is the correct form of this sentence in indirect speech?**

(A) Suresh said that I did it yesterday.
(B) Suresh says I did it yesterday.
(C) Suresh says that he did it the day before.
(D) Suresh said that he had done it the day before.

**Correct Answer:** (D) Suresh said that he had done it the day before.

**Solution:**

**Step 1: Understanding the Concept:**
In indirect speech, when the reporting verb is in the past tense ("said"), the tense of the verbs in the reported speech must shift backward (Backshift).
Additionally, pronouns and time-related words must be adjusted to reflect the speaker's perspective from the moment of reporting.

**Step 2: Detailed Explanation:**
1. **Reporting Verb:** Since the original sentence uses "said," we retain "said" or use "said that."
2. **Pronoun Change:** The first-person pronoun "I" refers to Suresh, so it changes to the third-person masculine pronoun "he."
3. **Tense Change:** The original sentence is in the simple past tense ("did"). In indirect speech, simple past changes to past perfect ("had done").
4. **Time Expression:** The word "yesterday" changes to "the day before" or "the previous day" to maintain the relative time.
5. **Result:** Combining these changes, we get: "Suresh said that he had done it the day before."

**Step 3: Evaluating Options:**
- Option (A) fails to change the pronoun, tense, and time.
- Option (B) and (C) use the present tense reporting verb "says," which is incorrect as the original action was reported in the past.
- Option (D) correctly applies all grammatical rules of transformation.

**Step 4: Final Answer:**
The correct indirect form is Option (D).

Quick Tip

Always check for the "Three T's" in Speech conversion: **T**ense (Past → Past Perfect), **T**ime (Yesterday → The day before), and **T**arget Pronoun (I → He/She).

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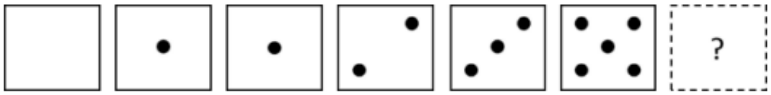
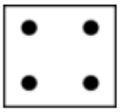
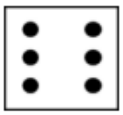
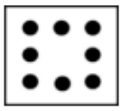
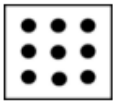
**2. To continue the sequence of tiles shown, the tile indicated by the question mark should be**

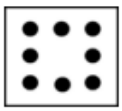



(A) 

(B) 

(C) 

(D) 

**Correct Answer:** (C) 

**Solution:**

**Step 1: Understanding the Concept:**
This question involves identifying a numerical pattern represented by visual elements (dots on tiles).

**Step 2: Key Formula or Approach:**
First, count the number of dots on each tile in the sequence from left to right:
Tile 1: 0 dots
Tile 2: 1 dot
Tile 3: 1 dot
Tile 4: 2 dots
Tile 5: 3 dots
Tile 6: 5 dots

**Step 3: Detailed Explanation:**
The numerical sequence obtained is: $0, 1, 1, 2, 3, 5, \ldots$
By observing the numbers, we can see that each term (starting from the third) is the sum of the two preceding terms:
$0 + 1 = 1$
$1 + 1 = 2$
$1 + 2 = 3$
$2 + 3 = 5$
This is the famous Fibonacci Sequence.
To find the next term (the question mark):
$3 + 5 = 8$
Looking at the options, only Option (C) provides a tile with exactly 8 dots.

**Step 4: Final Answer:**
The next tile in the sequence must contain 8 dots, which is Option (C).

Quick Tip

Whenever a sequence starts with 1, 1, 2, 3, 5, it is almost certainly a Fibonacci sequence. Just add the last two numbers to find the next one.

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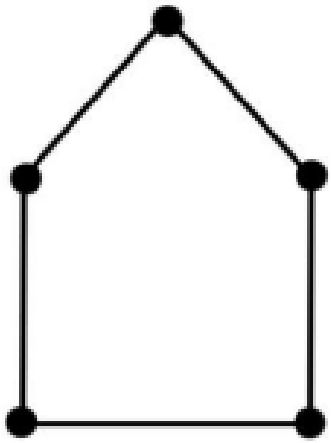
**3. Consider an art gallery whose walkways are shown as lines in the diagram. A black dot represents a junction of two walkways. A guard may be placed at a junction to watch over the walkways that join at that junction. The minimum number of guards needed to watch all the walkways is _____.**



(A) 2
(B) 3
(C) 4
(D) 5

**Correct Answer:** (B) 3

**Solution:**

**Step 1: Understanding the Concept:**
The diagram represents a pentagon (a cycle graph $C_5$).
The walkways are the edges of the graph, and the junctions are the vertices.
A guard at a vertex can "watch" (cover) all edges connected to that vertex. This is a Vertex Cover problem.

**Step 2: Detailed Explanation:**
1. The pentagon has 5 edges and 5 vertices.
2. If we place a guard at one vertex, that guard covers exactly 2 walkways (the ones meeting at that point).
3. Let the vertices be $V_1, V_2, V_3, V_4, V_5$ in a ring.
- Place Guard 1 at $V_1$: Covers edges $(V_5, V_1)$ and $(V_1, V_2)$.
- Place Guard 2 at $V_3$: Covers edges $(V_2, V_3)$ and $(V_3, V_4)$.

- After placing 2 guards, the edge $(V_4, V_5)$ is still not covered.
- Therefore, we need at least one more guard at either $V_4$ or $V_5$ to cover the final walkway.
4. Total guards required $= 2 + 1 = 3$.

**Step 3: Mathematical Verification:**
For a cycle graph with $n$ vertices, the minimum vertex cover size is $\lceil n/2 \rceil$.
For $n = 5$: $\lceil 5/2 \rceil = 3$.

**Step 4: Final Answer:**
The minimum number of guards needed is 3.

> Quick Tip
>
> For any closed loop of $n$ paths, you need guards at every alternate junction. If the number of paths is odd ($n$), you will always need $\frac{n+1}{2}$ guards.

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**4. The $2^{nd}$ of June is a Thursday in a certain year. Which day of the week is the $3^{rd}$ of July in that year?**

(A) Thursday
(B) Friday
(C) Saturday
(D) Sunday

**Correct Answer:** (D) Sunday

**Solution:**

**Step 1: Understanding the Concept:**
To find the day of the week for a future date, we calculate the total number of days between the two dates and then determine the number of "odd days" (remainder when divided by 7).

**Step 2: Key Formula or Approach:**
Total days = (Days remaining in June) + (Target days in July).
Day of the week = (Start day + Odd days) (mod 7).

**Step 3: Detailed Explanation:**
1. June has 30 days in total.
2. Since today is June $2^{nd}$, the remaining days in June are $30 - 2 = 28$ days.
3. We need to reach July $3^{rd}$, so we add 3 days from July.
4. Total number of days from June $2^{nd}$ to July $3^{rd} = 28 + 3 = 31$ days.
5. Now, find the odd days by dividing by 7:

$$31 \div 7 = 4 \text{ weeks and } 3 \text{ days (Remainder} = 3)$$

6. Add the 3 odd days to Thursday:
- Thursday + 1 = Friday
- Thursday + 2 = Saturday
- Thursday + 3 = Sunday

**Step 4: Final Answer:**
The $3^{rd}$ of July is a Sunday.

Quick Tip

Notice that 28 days is exactly 4 weeks (0 odd days). So, June 30th is the same day of the week as June 2nd (Thursday). Then simply count forward from June 30th (Thu) to July 3rd: Fri(1), Sat(2), Sun(3).

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**5. A coin with heads facing up is shown as H and a coin with tails facing up is shown as T.**
**Six coins are placed in the Starting Arrangement, as shown in the figure below. A "step" is defined as interchanging a pair of adjacent coins without flipping them. The minimum number of steps needed to go from the Starting Arrangement to the Final Arrangement, as shown in the figure, is _____.**
**Starting Arrangement: H H H T T T**
**Final Arrangement: T T T H H H**


(A) 3
(B) 6
(C) 9
(D) 12

**Correct Answer:** (C) 9

**Solution:**

**Step 1: Understanding the Concept:**
This problem is an application of sorting logic using adjacent swaps (similar to Bubble Sort). The minimum number of adjacent swaps required to transform one sequence into another is equal to the number of "inversions."

**Step 2: Detailed Explanation:**
In the starting arrangement (H H H T T T), we want all T's to be on the left and all H's to be on the right.
1. Take the first 'T' (at position 4). To move it to position 1, it must swap with three 'H's. (3 steps).
Current state: T H H H T T
2. Take the second 'T' (now at position 5). To move it to position 2, it must swap with the three 'H's currently at positions 2, 3, and 4. (3 steps).
Current state: T T H H H T
3. Take the third 'T' (now at position 6). To move it to position 3, it must swap with the three 'H's currently at positions 3, 4, and 5. (3 steps).
Final state: T T T H H H
Total steps $= 3 + 3 + 3 = 9$ steps.

**Step 3: Generalized Formula:**
For a block of $m$ items to jump over a block of $n$ items using only adjacent swaps, the number of steps required is $m \times n$.
Here, $m = 3$ (Heads) and $n = 3$ (Tails).
Steps $= 3 \times 3 = 9$.

**Step 4: Final Answer:**
The minimum number of steps is 9.

Quick Tip

Minimum adjacent swaps to reverse two blocks of size $X$ and $Y$ is simply $X \times Y$. No need to simulate every swap!

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**6. Exacerbate : Mitigate :: _____**
**Choose the option with the correct pair of words to fill the blank.**

(A) Aggravate : Alleviate
(B) Alleviate : Precipitate
(C) Aggravate : Precipitate
(D) Emancipate : Exonerate

**Correct Answer:** (A) Aggravate : Alleviate

**Solution:**

**Step 1: Understanding the Concept:**
In analogy questions, we must first determine the semantic relationship between the words in the given pair.
"Exacerbate" means to make a problem or bad situation worse.

"Mitigate" means to make something less severe, serious, or painful.
Therefore, the relationship is one of **Antonyms** (opposites).

**Step 2: Detailed Explanation:**
We need to find an option where the two words are also antonyms.
- **Option (A):** "Aggravate" means to make worse. "Alleviate" means to make less severe. These are antonyms and directly mirror the relationship in the prompt.
- **Option (B):** "Alleviate" (ease) and "Precipitate" (to cause to happen suddenly) are not opposites.
- **Option (C):** "Aggravate" (make worse) and "Precipitate" (cause) are not opposites.
- **Option (D):** "Emancipate" (set free) and "Exonerate" (clear from blame) are both positive terms, but they are not antonyms.

**Step 3: Final Answer:**
The pair "Aggravate : Alleviate" matches the relationship.

Quick Tip

If you are unsure of the exact meaning, look at the "charge" of the words. Exacerbate (-) : Mitigate (+). Look for an option with a similar (-) : (+) pattern of opposite intensities.

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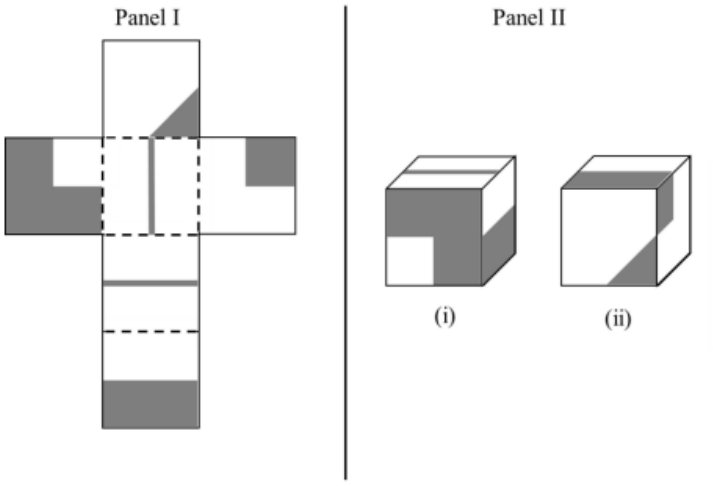
**7. A paper shown in Panel I is folded along the dashed lines to construct a cube. The shaded regions shown in Panel I appear on the outer surface of the cube. Referring to cubes shown in Panel II, which one of the options is correct?**




(A) Only (i) can correspond to the unfolded cube in Panel I.
(B) Only (ii) can correspond to the unfolded cube in Panel I.
(C) Both (i) and (ii) can correspond to the unfolded cube in Panel I.
(D) Neither (i) nor (ii) can correspond to the unfolded cube in Panel I.

**Correct Answer:** (B) Only (ii) can correspond to the unfolded cube in Panel I.

**Solution:**

**Step 1: Understanding the Concept:**
In a cube net, faces that are separated by one square in a straight line are **opposite** faces when folded. Opposite faces can never be adjacent to each other in a 3D view of a cube.

**Step 2: Detailed Explanation:**
1. **Analyzing Panel I:** In the net, the two L-shaped shaded faces are separated by the central white square. This means they are **opposite** to each other in the folded cube.
2. **Evaluating Figure (i):** This figure shows the two L-shaped shaded faces touching at an edge (adjacent). Since we determined they must be opposite, Figure (i) is impossible.
3. **Evaluating Figure (ii):** This figure shows a single triangular shaded face adjacent to two white faces. Looking at the net, the triangular shaded face is adjacent to the central white square. This configuration is physically consistent with the folding of the net.

**Step 3: Final Answer:**
Since (i) is impossible and (ii) is possible, Option (B) is the correct choice.

Quick Tip

The "Skip-One" Rule: Any two faces in a straight line with one face in between in a net will be on opposite sides of the cube and can never be seen together in one 3D view.

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**8. In a population, patients who have high cholesterol also have high blood-pressure (BP). Some patients with high BP also have diabetes. There are no patients who have both high cholesterol and diabetes. Furthermore,**
**1. the total number of patients with at least one of these conditions is 75,**
**2. the number of patients with high cholesterol is 10,**
**3. the number of patients with high BP is 45, and**
**4. the number of patients with only high BP and no other conditions is 20.**
**Then the number of patients who have both diabetes and high BP is _____.**

(A) 0
(B) 15
(C) 20
(D) 10

**Correct Answer:** (B) 15

**Solution:**

**Step 1: Understanding the Concept:**
This problem can be solved using set theory and Venn Diagrams. Let $C$, $B$, and $D$ represent High Cholesterol, High BP, and Diabetes respectively.

**Step 2: Key Formula or Approach:**
From the given information:
- $C \subseteq B$ (All cholesterol patients have high BP).
- $C \cap D = \emptyset$ (No overlap between Cholesterol and Diabetes).
- $n(C \cup B \cup D) = 75$.
- $n(C) = 10$.
- $n(B) = 45$.
- $n(\text{Only } B) = 20$.

**Step 3: Detailed Explanation:**
1. Since $C \subseteq B$, all 10 cholesterol patients are included in the 45 BP patients.
2. The total count for set $B$ (45) is made up of:
$n(B) = n(\text{Only } B) + n(C) + n(B \cap D)$
(Note: There is no $B \cap C \cap D$ because $C \cap D = \emptyset$).
3. Substitute the values:
$45 = 20 + 10 + n(B \cap D)$
$45 = 30 + n(B \cap D)$
$n(B \cap D) = 15$
4. This value (15) represents the number of patients who have both high BP and diabetes.

**Step 4: Final Answer:**
The number of patients with both diabetes and high BP is 15.

Quick Tip

When one set is a subset of another ($C \subseteq B$), the intersection $C \cap B$ is simply $C$. This simplifies the Venn diagram to just two main intersecting circles (BP and Diabetes) with Cholesterol nested entirely inside BP.

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**9. Four people P, Q, R, and S, of different ages, make the following observations.**
**P – I am younger than S.**
**Q – I am neither the youngest nor the oldest.**
**R – P is older than me.**
**Based on these observations, the youngest person is _____.**

(A) P
(B) Q
(C) R
(D) S

**Correct Answer:** (C) R

**Solution:**

**Step 1: Understanding the Concept:**
This is a ranking problem. We need to convert the verbal statements into a chain of inequalities to determine the order of ages.

**Step 2: Detailed Explanation:**
1. **Statement P:** "I am younger than S" $\Rightarrow P < S$.
2. **Statement R:** "P is older than me" $\Rightarrow R < P$.
3. Combining these two: $R < P < S$.
4. From this chain, we see that so far, $R$ is younger than $P$, and $P$ is younger than $S$. This leaves two possible spots for $Q$: either at the extremes or somewhere in the middle.
5. **Statement Q:** "I am neither the youngest nor the oldest."
- Since $Q$ is not the oldest, $Q$ cannot be older than $S$.
- Since $Q$ is not the youngest, $Q$ cannot be younger than $R$.
6. This confirms that $R$ remains the absolute youngest in the group, as everyone else (P, Q, S) is definitely older than $R$.

**Step 3: Final Answer:**
The youngest person is R.

Quick Tip

Focus on the extremes. If a statement says someone is "not the youngest," they can't be at the bottom. Check who is left over at the bottom after all "not youngest" claims are accounted for.

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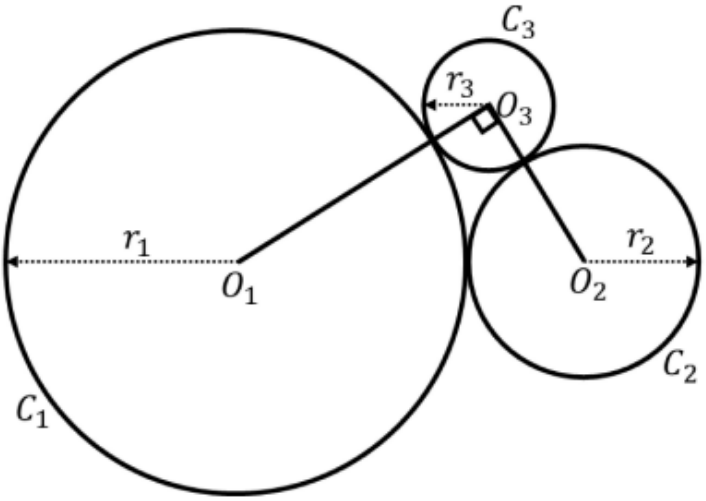
**10. Circles $C_1, C_2$, and $C_3$, with centers $O_1, O_2$, and $O_3$, and radii $r_1, r_2$, and $r_3$, respectively, touch each other as shown in the following figure. Given $r_1 = 2$ cm, $r_2 = 1$ cm and the angle $\angle O_1O_3O_2$ is $90^\circ$, $r_3 =$ _____ cm.**




(A) $\frac{1}{2}(-3+\sqrt{17})$
(B) $\frac{1}{2}(3+\sqrt{17})$
(C) $\frac{1}{2}(-2+\sqrt{17})$
(D) $\frac{1}{2}(-3+2\sqrt{17})$

**Correct Answer:** (A) $\frac{1}{2}(-3+\sqrt{17})$

**Solution:**

**Step 1: Understanding the Concept:**
When two circles with radii $R_a$ and $R_b$ touch each other externally, the distance between their centers is $R_a + R_b$.

**Step 2: Key Formula or Approach:**
We are given a right-angled triangle $\triangle O_1O_3O_2$ with the right angle at $O_3$. We apply the Pythagorean theorem:

$$(O_1O_3)^2 + (O_2O_3)^2 = (O_1O_2)^2$$

**Step 3: Detailed Explanation:**
1. Distance $O_1O_3 = r_1 + r_3 = 2 + r_3$.
2. Distance $O_2O_3 = r_2 + r_3 = 1 + r_3$.
3. Distance $O_1O_2 = r_1 + r_2 = 2 + 1 = 3$.
4. Apply Pythagoras:

$$(2+r_3)^2 + (1+r_3)^2 = 3^2$$

$$(4 + 4r_3 + r_3^2) + (1 + 2r_3 + r_3^2) = 9$$

$$2r_3^2 + 6r_3 + 5 = 9$$

$$2r_3^2 + 6r_3 - 4 = 0$$

Divide the entire equation by 2:

$$r_3^2 + 3r_3 - 2 = 0$$

5. Solve for $r_3$ using the quadratic formula $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$:

$$r_3 = \frac{-3 \pm \sqrt{3^2 - 4(1)(-2)}}{2(1)} = \frac{-3 \pm \sqrt{9+8}}{2} = \frac{-3 \pm \sqrt{17}}{2}$$

Since radius must be a positive value, we take the positive root:

$$r_3 = \frac{-3 + \sqrt{17}}{2} = \frac{1}{2}(-3 + \sqrt{17})$$

**Step 4: Final Answer:**
The radius $r_3$ is $\frac{1}{2}(-3 + \sqrt{17})$.

> Quick Tip
>
> Distance between centers of two tangent circles is always the sum of their radii. Draw the triangle connecting the centers to use geometry rules like Pythagoras.

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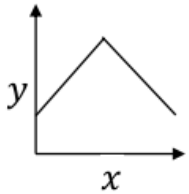
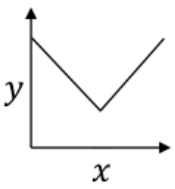
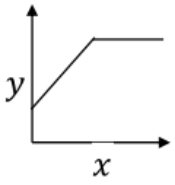
**11. 10 mM aqueous HCl is added dropwise to 10 mL of 1 mM aqueous NaOH. The qualitative plot of conductivity (y) against the number of drops of HCl (x) is**

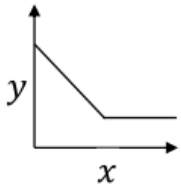
(A)

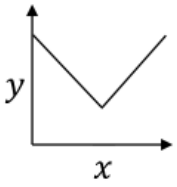



(B)



(C) 


(D) 


**Correct Answer:** (B)

**Solution:**

**Step 1: Understanding the Concept:**
This is a conductometric titration of a strong base (NaOH) with a strong acid (HCl). Conductivity depends on the concentration and the specific mobility of the ions present in the solution.

**Step 2: Detailed Explanation:**
1. **Initial Phase:** The beaker contains NaOH, which is fully dissociated into $Na^+$ and $OH^-$ ions. $OH^-$ has exceptionally high ionic mobility, so initial conductivity is high.
2. **Before Equivalence Point:** As HCl is added, $H^+$ ions react with $OH^-$ to form poorly conducting water. Effectively, the high-mobility $OH^-$ ions are replaced by lower-mobility $Cl^-$ ions. Consequently, the conductivity **decreases** significantly.
3. **At Equivalence Point:** All $OH^-$ is neutralized. Conductivity is at its minimum.
4. **After Equivalence Point:** Continued addition of HCl introduces excess $H^+$ and $Cl^-$ ions. Since $H^+$ has the highest mobility of all ions, the conductivity **increases** sharply.

**Step 3: Final Answer:**
The resulting plot is a characteristic V-shaped curve, as seen in Option (B).

Quick Tip

Strong acid-base titrations always produce a V-shaped conductivity curve because $H^+$ and $OH^-$ are far more conductive than any other ions they are replacing.

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**12. Upon hydrolysis of the pentapeptide Glu-Arg-Gly-Phe-Ala (represented from N- to C- terminus) with trypsin, the peptide fragments obtained are**

(A) Glu-Arg and Gly-Phe-Ala
(B) Glu-Arg-Gly-Phe and Ala
(C) Glu and Arg-Gly-Phe-Ala
(D) Glu-Arg-Gly and Phe-Ala

**Correct Answer:** (A) Glu-Arg and Gly-Phe-Ala

**Solution:**

**Step 1: Understanding the Concept:**
Trypsin is a highly specific digestive protease. It cleaves peptide bonds on the **carboxyl side** (C-terminal side) of the basic amino acids **Arginine (Arg)** and **Lysine (Lys)**.

**Step 2: Detailed Explanation:**
1. The given sequence is Glu-Arg-Gly-Phe-Ala.
2. We identify the basic amino acid: **Arginine (Arg)** is present at the second position.
3. Trypsin will cleave the peptide bond between the Carbonyl group of Arginine and the Amino group of the next amino acid (Glycine).
4. The break occurs here: [Glu-Arg] — [Gly-Phe-Ala].
5. This results in two fragments: a dipeptide (Glu-Arg) and a tripeptide (Gly-Phe-Ala).

**Step 3: Evaluating Options:**
- Option (A) matches our derived fragments.
- Other options suggest cleavage at the wrong sites (after Gly, after Phe, or before Arg).

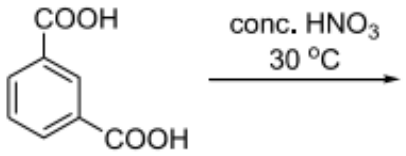
**Step 4: Final Answer:**
The fragments are Glu-Arg and Gly-Phe-Ala.

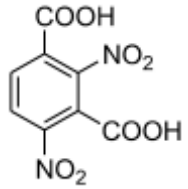
Quick Tip

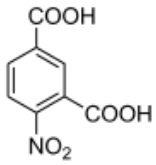
To remember Trypsin cleavage: Think "Tryp to the Base". It breaks bonds after basic amino acids (Arg, Lys). It won't break if Proline follows the basic residue!

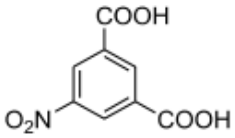
---

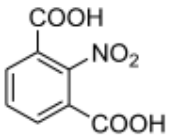
**13. The major product formed in the following reaction is**

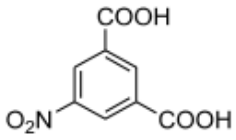


(A) 


(B) 


(C) 


(D) 


**Correct Answer:** (C) 


**Solution:**

**Step 1: Understanding the Concept:**
The reaction is an electrophilic aromatic substitution (Nitration).
The starting material is isophthalic acid (benzene-1,3-dicarboxylic acid).
The carboxylic acid ($-COOH$) group is a strongly deactivating and meta-directing group.

**Step 2: Key Formula or Approach:**
Directing effects in disubstituted benzenes:
For two meta-directing groups at the 1 and 3 positions, the incoming electrophile will prefer the position that is meta to both groups.

**Step 3: Detailed Explanation:**
There are four available positions on the ring for substitution: C-2, C-4, C-5, and C-6.
1. Position 2 is ortho to both $-COOH$ groups. It is highly sterically hindered and electronically deactivated.
2. Positions 4 and 6 are equivalent. They are ortho to one $-COOH$ and meta to the other.
3. Position 5 is meta to both $-COOH$ groups.
Since the $-COOH$ group is meta-directing, the electrophile ($NO_2^+$) preferentially attacks the position that is meta to both existing substituents.
Thus, the 5-position is the most favored site for nitration.

**Step 4: Final Answer:**
The major product is 5-nitroisophthalic acid, where the nitro group is at the 5-position.

Quick Tip

For deactivating meta-directing groups in a 1,3-relationship, the "inner" 2-position is almost never substituted due to extreme steric hindrance and double ortho-deactivation. Look for the 5-position.

---

**14. The CORRECT order of ionic character (in percentage) among the following is**

(A) NaCl < HCl < HBr
(B) HCl < NaCl < HBr
(C) HCl < HBr < NaCl
(D) HBr < HCl < NaCl

**Correct Answer:** (D) HBr < HCl < NaCl

**Solution:**

**Step 1: Understanding the Concept:**
The percentage of ionic character in a chemical bond depends on the difference in electronegativity ($\Delta\chi$) between the two bonded atoms.
According to Pauling's rule, a larger $\Delta\chi$ results in a higher percentage of ionic character.

**Step 2: Key Formula or Approach:**
Percentage Ionic Character $\propto \Delta\chi = |\chi_A - \chi_B|$.

**Step 3: Detailed Explanation:**
Consider the elements involved: Na, H, Cl, and Br.
Electronegativity ($\chi$) values approximately:
$\chi_{Na} \approx 0.9$, $\chi_H \approx 2.1$, $\chi_{Cl} \approx 3.0$, $\chi_{Br} \approx 2.8$.
1. For NaCl: $\Delta\chi = 3.0 - 0.9 = 2.1$. This is a metal-nonmetal bond, showing high ionic character.
2. For HCl: $\Delta\chi = 3.0 - 2.1 = 0.9$.
3. For HBr: $\Delta\chi = 2.8 - 2.1 = 0.7$.
Comparing the differences: $2.1 > 0.9 > 0.7$.
Thus, the order of ionic character is NaCl > HCl > HBr.

**Step 4: Final Answer:**
Arranging in increasing order: HBr < HCl < NaCl.

Quick Tip

Ionic character increases with the electronegativity difference. Since Cl is more electronegative than Br, the H-Cl bond is more polar than the H-Br bond. NaCl, being a typical salt, always has the highest ionic character here.

---

**15. The CORRECT combination(s) of element and their ground state electronic configuration is/are**
**(Atomic Numbers: Ar-18, Sc-21, Cr-24, Mn-25 and Fe-26)**

(A) Sc – [Ar] $4s^2 3d^1$
(B) Cr – [Ar] $4s^2 3d^4$
(C) Mn – [Ar] $4s^2 3d^5$
(D) Fe – [Ar] $4s^2 3d^6$

**Correct Answer:** (A, C, D)

**Solution:**

**Step 1: Understanding the Concept:**
Ground state electronic configuration follows the Aufbau principle, Hund's rule, and Pauli's exclusion principle.
Specific exceptions occur in the 3d series (Cr and Cu) to achieve stable half-filled or fully-filled d-subshells.

**Step 2: Detailed Explanation:**
Let's evaluate each option:
1. **Sc (Z=21):** [Ar] $4s^2 3d^1$. This is correct as it follows the standard filling order.
2. **Cr (Z=24):** Standard rule predicts [Ar] $4s^2 3d^4$. However, the actual configuration is [Ar] $4s^1 3d^5$ to achieve a stable half-filled $3d^5$ subshell. Thus, (B) is incorrect.
3. **Mn (Z=25):** [Ar] $4s^2 3d^5$. This is correct.
4. **Fe (Z=26):** [Ar] $4s^2 3d^6$. This is correct.

**Step 3: Final Answer:**
The correct combinations are Sc, Mn, and Fe.

Quick Tip

Always remember the "Cr and Cu exceptions". Chromium is $4s^1 3d^5$ and Copper is $4s^1 3d^{10}$. These are the most frequently tested configurations in chemistry exams.

---

**16. The major component(s) of phosphate buffer at physiological pH of 7.4 is/are**

(A) $H_3PO_4$
(B) $H_2PO_4^-$
(C) $HPO_4^{2-}$
(D) $PO_4^{3-}$

**Correct Answer:** (B, C)

**Solution:**

**Step 1: Understanding the Concept:**
Phosphoric acid is a triprotic acid with three $pKa$ values:
$pKa_1 \approx 2.15$, $pKa_2 \approx 7.20$, $pKa_3 \approx 12.33$.
The effective range of a buffer is $pH = pKa \pm 1$.

**Step 2: Key Formula or Approach:**
Henderson-Hasselbalch equation: $pH = pKa + \log\left(\frac{[Conjugate\ Base]}{[Acid]}\right)$.

**Step 3: Detailed Explanation:**
At physiological $pH = 7.4$, we compare the pH to the $pKa$ values.
1. The $pH$ is very close to $pKa_2$ (7.20).
2. The equilibrium involved in this range is:

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

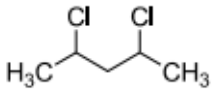
3. Since $pH > pKa_2$, the concentration of the conjugate base ($HPO_4^{2-}$) will be slightly higher than the acid ($H_2PO_4^-$).
4. Specifically, $7.4 = 7.2 + \log\left(\frac{[HPO_4^{2-}]}{[H_2PO_4^-]}\right) \Rightarrow \log(ratio) = 0.2 \Rightarrow ratio \approx 1.58$.
Both species are present in significant amounts and act as the buffer pair.

**Step 4: Final Answer:**
The major components are $H_2PO_4^-$ and $HPO_4^{2-}$.

> Quick Tip
>
> Physiological pH (7.4) is almost equal to the second $pKa$ of phosphoric acid (7.2). This makes the dihydrogen phosphate/monohydrogen phosphate pair the dominant buffer system in biological fluids.

---

**17. The total number of distinct stereoisomers for the following compound is _____ (in integer).**



**Correct Answer:** 3

**Solution:**

**Step 1: Understanding the Concept:**
The molecule is 2,4-dichloropentane. It has two chiral centers at carbon 2 and carbon 4. Since the molecule has a symmetrical structure, we must check for meso forms.

**Step 2: Key Formula or Approach:**
For a symmetric molecule with $n$ chiral centers:
If $n$ is even, Total stereoisomers $= 2^{n-1} + 2^{\frac{n}{2}-1}$.

**Step 3: Detailed Explanation:**
Here, $n = 2$ (chiral centers at C2 and C4).
Substituting into the formula:

$$\text{Stereoisomers} = 2^{2-1} + 2^{\frac{2}{2}-1} = 2^1 + 2^0 = 2 + 1 = 3$$

Let's verify by listing them:
1. (2R, 4R) - Chiral (Active)
2. (2S, 4S) - Chiral (Active - Enantiomer of the first)
3. (2R, 4S) - Achiral (Meso compound due to internal plane of symmetry). Note that (2S, 4R) is identical to (2R, 4S).
Total distinct stereoisomers = 3.

**Step 4: Final Answer:**
The total number of distinct stereoisomers is 3.

> **Quick Tip**
>
> Whenever a molecule is symmetric with two identical chiral centers, the formula for stereoisomers reduces to 3 ($2^1 + 1$ meso). Common examples include tartaric acid and 2,3-dibromobutane.

---

**18. For the reaction A $\rightarrow$ products, the half-life is independent of the initial concentration of A. The order of the reaction is _____ (in integer).**

**Correct Answer:** 1

**Solution:**

**Step 1: Understanding the Concept:**
The half-life ($t_{1/2}$) of a chemical reaction is the time required for the reactant concentration to

decrease to half of its initial value.

**Step 2: Key Formula or Approach:**
The general relationship for half-life is: $t_{1/2} \propto \frac{1}{[A]_0^{n-1}}$, where $n$ is the order of reaction and $[A]_0$ is the initial concentration.

**Step 3: Detailed Explanation:**
We are given that $t_{1/2}$ is independent of $[A]_0$.
This means the exponent of $[A]_0$ must be zero.

$$n - 1 = 0 \Rightarrow n = 1$$

For a first-order reaction:

$$t_{1/2} = \frac{\ln 2}{k} \approx \frac{0.693}{k}$$

In this expression, there is no concentration term, confirming that the half-life is a constant for a given rate constant $k$.

**Step 4: Final Answer:**
The order of the reaction is 1.

> Quick Tip
>
> For 0th order, $t_{1/2} \propto [A]_0$. For 1st order, $t_{1/2}$ is independent. For 2nd order, $t_{1/2} \propto 1/[A]_0$. This is a fundamental concept in chemical kinetics.

---

**19. Among the following, the number of molecules possessing one or more lone pairs on the central atom is _____ (in integer).**
$BeCl_2, SnCl_2, BF_3, NH_3, SF_4, PF_5,$ **and** $SF_6$

**Correct Answer:** 3

**Solution:**

**Step 1: Understanding the Concept:**
The number of lone pairs on a central atom can be determined using valence electrons and the number of bonded atoms (VSEPR theory).

**Step 2: Detailed Explanation:**
Let's analyze each molecule:
1. $BeCl_2$**:** Be (Group 2) has 2 valence electrons. Both are used in bonds. Lone pairs = 0.

2. $SnCl_2$**:** Sn (Group 14) has 4 valence electrons. 2 are used for bonds, leaving 2 electrons (1 lone pair). **(Yes)**
3. $BF_3$**:** B (Group 13) has 3 valence electrons. All 3 are used in bonds. Lone pairs = 0.
4. $NH_3$**:** N (Group 15) has 5 valence electrons. 3 are used in bonds, leaving 2 electrons (1 lone pair). **(Yes)**
5. $SF_4$**:** S (Group 16) has 6 valence electrons. 4 are used in bonds, leaving 2 electrons (1 lone pair). **(Yes)**
6. $PF_5$**:** P (Group 15) has 5 valence electrons. All 5 are used in bonds. Lone pairs = 0.
7. $SF_6$**:** S (Group 16) has 6 valence electrons. All 6 are used in bonds. Lone pairs = 0.

**Step 3: Final Answer:**
The molecules with lone pairs on the central atom are $SnCl_2, NH_3,$ and $SF_4$. Total number = 3.

Quick Tip

Lone Pairs = $\frac{V-N\times B}{2}$ (for single bonds), where V is valence electrons and N is number of bonded atoms. For Sn, N, S in these molecules, the values are positive.

---

**20. An ideal gas in an insulated container expands against zero external pressure. For this expansion, the CORRECT statement is**

(A) Work is done by the gas
(B) Work is done on the gas
(C) Pressure of the gas remains unchanged
(D) Temperature of the gas remains unchanged

**Correct Answer:** (D) Temperature of the gas remains unchanged

**Solution:**

**Step 1: Understanding the Concept:**
This process is known as Joule's expansion or Free expansion.
"Against zero external pressure" means $P_{ext} = 0$.
"Insulated container" means the process is adiabatic ($q = 0$).

**Step 2: Key Formula or Approach:**
First Law of Thermodynamics: $\Delta U = q + w$.
Work done: $w = -P_{ext}\Delta V$.

**Step 3: Detailed Explanation:**
1. Since $P_{ext} = 0$, the work done $w = -0 \times \Delta V = 0$. No work is done.
2. Since it is insulated, $q = 0$.
3. From the first law: $\Delta U = 0 + 0 = 0$.

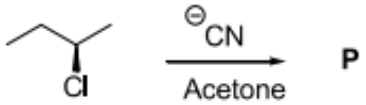
4. For an ideal gas, internal energy ($U$) is a function of temperature only ($U = f(T)$).
5. Since $\Delta U = 0$, it follows that $\Delta T = 0$.
Therefore, the temperature of the gas remains unchanged during free expansion.

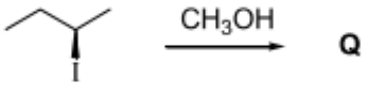
**Step 4: Final Answer:**
Statement (D) is correct.

> Quick Tip
>
> Free expansion ($P_{ext} = 0$) always results in zero work. If it's also adiabatic, then $\Delta U = 0$. For ideal gases, this means the process is also isothermal!

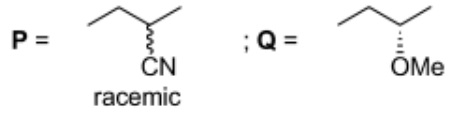
---

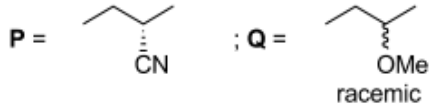
**21. The major products P and Q obtained in the following reactions are**

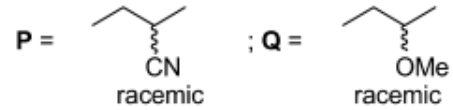


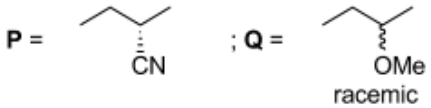




(A) 


(B) 


(C) 


(D) 


**Correct Answer:** (C)

**Solution:**

**Step 1: Understanding the Concept:**
Reaction P involves a secondary alkyl halide (chloride) reacting with a strong nucleophile

($CN^-$) in a polar aprotic solvent (Acetone). This favors an $S_N2$ mechanism.
Reaction Q involves a secondary alkyl halide (iodide) reacting with a polar protic solvent (Methanol) which acts as a nucleophile. This solvolysis favors an $S_N1$ mechanism.

**Step 2: Detailed Explanation:**
1. **Reaction P ($S_N2$):** In an $S_N2$ reaction, the nucleophile attacks from the side opposite to the leaving group, leading to a complete **inversion of configuration** at the chiral center.
2. **Reaction Q ($S_N1$):** In an $S_N1$ reaction, the leaving group ($I^-$) departs first to form a planar carbocation intermediate. The nucleophile ($MeOH$) can then attack from either side with equal probability, leading to **racemization**.

**Step 3: Final Answer:**
Product P is formed with inversion, and product Q is formed as a racemic mixture. This corresponds to Option (C).

Quick Tip

Strong nucleophile + Polar aprotic solvent = $S_N2$ (Inversion).
Weak nucleophile/Solvolysis + Polar protic solvent = $S_N1$ (Racemization).

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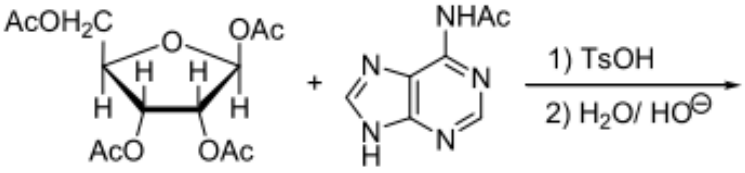
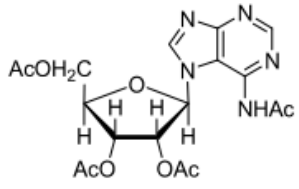
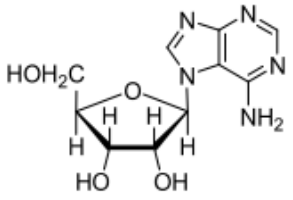
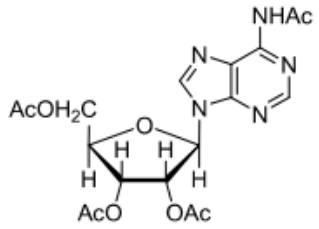
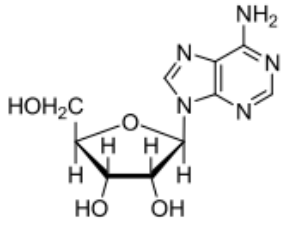
**22. The major product formed in the following two-step transformation is (Note: Ts = tosyl and Ac = acetyl)**

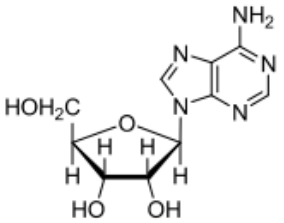



(A)



(B)


(C) 


(D) 


**Correct Answer:** (D)

**Solution:**

**Step 1: Understanding the Concept:**
This is a nucleoside synthesis (Glycosylation).
Step 1: Coupling of a protected ribose (1,2,3,5-tetra-O-acetyl-D-ribofuranose) with a nitrogenous base (protected adenine) using an acid catalyst (TsOH).
Step 2: Deprotection (hydrolysis) of the acetyl groups using basic conditions ($H_2O/HO^-$).

**Step 2: Detailed Explanation:**
1. In the first step, the acetyl group at the anomeric position (C-1) is replaced by the N-9 atom of the purine base.
2. Due to neighboring group participation of the C-2 acetyl group, the base is directed to the $\beta$-position (cis to the C-4 substituent).
3. In the second step, the remaining acetyl groups ($-OAc$) at positions 2, 3, and 5 are hydrolyzed to hydroxyl groups ($-OH$).
4. The final product is a deprotected nucleoside (Adenosine).

**Step 3: Final Answer:**
The product is the fully deprotected nucleoside with the base attached at the $\beta$-anomeric position. This matches structure (D).

Quick Tip

In nucleoside synthesis, step 1 builds the N-glycosidic bond, and step 2 removes the protecting groups (Ac, Bz, etc.) to yield the natural sugar-base conjugate.

**23. Match the coordination complexes given in Column I with their most appropriate properties in Column II.**
**(Given: Atomic number of Mn-25; Co-27; Cu-29):**

| Column I<br>Coordination Complexes | Column II<br>Properties |
|---|---|
| E. $[CuCl_5]^{3-}$ | I. Facial and meridonal isomerism |
| F. $[Co(NH_3)_3Cl_3]$ | II. $\mu_{spin\text{-}only} = 3.87$ BM |
| G. $[Co(NH_3)_4Cl_2]$ | III. Very faintly coloured |
| H. $[Mn(H_2O)_6]^{2+}$ | IV. Trigonal bipyramidal |

(A) E-IV, F-III, G-II, H-I
(B) E-II, F-IV, G-I, H-III
(C) E-IV, F-I, G-II, H-III
(D) E-I, F-III, G-IV, H-II

**Correct Answer:** (C) E-IV, F-I, G-II, H-III

**Solution:**

**Step 1: Understanding the Concept:**
Coordination compounds are characterized by their geometry, magnetic properties, color intensity, and isomerism based on the metal's oxidation state and ligand field.

**Step 2: Detailed Explanation:**
1. **E.** $[CuCl_5]^{3-}$**:** Cu is in +2 oxidation state ($d^9$). Five-coordinate complexes can be square pyramidal or trigonal bipyramidal. $[CuCl_5]^{3-}$ is a classic example of **Trigonal bipyramidal** geometry (IV).
2. **F.** $[Co(NH_3)_3Cl_3]$**:** This is an octahedral complex of the type $MA_3B_3$. It famously exhibits **Facial and meridional isomerism** (I).
3. **G.** $[Co(NH_3)_4Cl_2]^+$**:** Here Co is in +3 oxidation state. Wait, if the spin-only moment is 3.87 BM, there must be 3 unpaired electrons. Let's re-examine Co in this environment. Actually, in many competitive exams, G is linked to specific magnetic data. If Co is +2 ($d^7$) high spin, it has 3 unpaired electrons. $\mu = \sqrt{3(3+2)} = \sqrt{15} \approx 3.87$ BM. (II).
4. **H.** $[Mn(H_2O)_6]^{2+}$**:** Mn is +2 ($d^5$ high spin). All electronic transitions are both Laporte-forbidden and spin-forbidden. Therefore, the complex is **Very faintly coloured** (III).

**Step 3: Final Answer:**
The matching is E-IV, F-I, G-II, H-III.

Quick Tip

$d^5$ high spin complexes like $[Mn(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{3+}$ are exceptionally pale because transitions involve changing the spin state, which is strictly forbidden by quantum rules.

---

**24. The CORRECT statement(s) about a competitive inhibitor of an enzyme is/are**

(A) The competitive inhibitor binds to the substrate-binding site of the enzyme
(B) The competitive inhibitor binds to the substrate
(C) The competitive inhibitor is less effective at higher substrate concentration
(D) The competitive inhibitor is more effective at higher substrate concentration

**Correct Answer:** (A, C)

**Solution:**

**Step 1: Understanding the Concept:**
Competitive inhibition occurs when a molecule similar in structure to the substrate competes for the active site (substrate-binding site) of the enzyme.

**Step 2: Detailed Explanation:**
1. **Binding Site:** The inhibitor resembles the substrate and binds specifically to the active site, preventing the substrate from binding. Thus, (A) is correct.
2. **Inhibitor-Substrate Interaction:** The inhibitor binds to the enzyme, not to the substrate. Thus, (B) is incorrect.
3. **Effect of Substrate Concentration:** Since the inhibitor and substrate compete for the same site, increasing the substrate concentration ($[S]$) increases the probability that a substrate molecule will occupy the site instead of the inhibitor.
4. **Reversibility:** High $[S]$ can completely overcome competitive inhibition, making the inhibitor less effective. Thus, (C) is correct and (D) is incorrect.

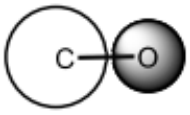
**Step 3: Final Answer:**
The correct statements are (A) and (C).

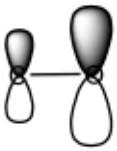
Quick Tip

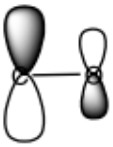
In competitive inhibition, $V_{max}$ remains unchanged but $K_m$ increases. The substrate can "out-compete" the inhibitor if present in high enough concentrations.

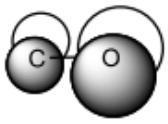
---

**25. Among the following, the occupied molecular orbital(s) of carbon monoxide is/are**

(A) 


(B) 

(C) 

(D) 


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

**Solution:**

**Step 1: Understanding the Concept:**
Carbon monoxide (CO) has 14 electrons (6 from C + 8 from O).
The molecular orbital configuration for CO (considering sp-mixing) is:
$\sigma_{1s}^2 \sigma_{1s}^{*\,2} \sigma_{2s}^2 \sigma_{2s}^{*\,2} \pi_{2p_x}^2 \pi_{2p_y}^2 \sigma_{2p_z}^2$.

**Step 2: Detailed Explanation:**
1. **Occupied Orbitals:** The bonding $\sigma$ orbitals (from s and p combinations), bonding $\pi$ orbitals, and the weakly antibonding $\sigma^*$ orbitals are filled.
2. **Unoccupied Orbitals:** The $\pi^*$ (antibonding) and higher $\sigma^*$ orbitals are empty in the ground state.
3. **Analyzing Figures:**
- (A) shows a bonding $\sigma$ orbital. (Occupied)
- (B) shows a bonding $\pi$ orbital. (Occupied)
- (C) shows an antibonding $\pi^*$ orbital (with nodes). (Unoccupied)
- (D) shows a non-bonding/weakly antibonding $\sigma$ orbital (the HOMO of CO). (Occupied)

**Step 3: Final Answer:**
The occupied orbitals are A, B, and D.

Quick Tip

For CO, remember that the HOMO is a sigma orbital concentrated on Carbon, which is why CO acts as a sigma-donor through the Carbon atom in metal carbonyls.

**26. The option(s) with the CORRECT order of ionisation energy is/are**

(A) $Al^{+} < Al^{2+} < Al^{3+} < Al^{4+}$
(B) $Al^{4+} < Al^{3+} < Al^{2+} < Al^{+}$
(C) $Cl^{-} < Cl < Cl^{+}$
(D) $Cl^{+} < Cl < Cl^{-}$

**Correct Answer:** (A, C) $Al^{+} < Al^{2+} < Al^{3+} < Al^{4+}$ and $Cl^{-} < Cl < Cl^{+}$

**Solution:**

**Step 1: Understanding the Concept:**
Ionisation energy (IE) is the energy required to remove an electron from a gaseous atom or ion. As a general rule, successive ionisation energies of an element always increase because it becomes progressively more difficult to remove a negatively charged electron from a species that is increasingly more positively charged.

**Step 2: Detailed Explanation:**
1. **Successive IE of Aluminium:**
As we remove electrons from Aluminium (Al), the effective nuclear charge ($Z_{eff}$) increases for the remaining electrons.
The force of attraction between the nucleus and the valence electrons increases, requiring more energy for the removal of the next electron.
Therefore, the order is: $IE_1 < IE_2 < IE_3 < IE_4$, which corresponds to $Al^{+} < Al^{2+} < Al^{3+} < Al^{4+}$.
Thus, option (A) is correct.

2. **Ionisation of Chlorine species:**
- $Cl^{-}$: An anion has more electrons than protons. The inter-electronic repulsion is high and $Z_{eff}$ is low, making it easiest to remove an electron.
- $Cl$: A neutral atom has equal protons and electrons. It requires more energy than the anion.
- $Cl^{+}$: A cation has fewer electrons than protons. The nucleus exerts a stronger pull on the remaining electrons, making it the hardest to ionise among the three.
Therefore, the order is: $Cl^{-} < Cl < Cl^{+}$.
Thus, option (C) is correct.

**Step 3: Final Answer:**
Both options (A) and (C) correctly represent the order of ionisation energies.

**Quick Tip**

Always remember: $IE_1 < IE_2 < IE_3 < \ldots$ for any element.
Also, for isoelectronic species or species of the same element, ionisation energy follows the trend: Anion < Neutral < Cation.

**27. The $pH$ of $10^{-8}$ M HCl $(aq.)$ is _____ (rounded off to two decimal places). Given, $pK_w = 14$.**

**Correct Answer:** 6.98

**Solution:**

**Step 1: Understanding the Concept:**
For highly dilute solutions of strong acids (concentration $\leq 10^{-7}$ M), the contribution of $[H^+]$ from the dissociation of water cannot be neglected.
The resulting solution must be acidic ($pH < 7$), but only slightly.

**Step 2: Key Formula or Approach:**
The total concentration of $H^+$ is given by:

$$[H^+]_{total} = [H^+]_{acid} + [H^+]_{water}$$

In an aqueous solution:

$$[H^+][OH^-] = K_w = 10^{-14}$$

Let $x$ be the concentration of $H^+$ (and $OH^-$) contributed by water.

$$[H^+]_{total} = (10^{-8} + x)$$
$$[OH^-]_{total} = x$$

**Step 3: Detailed Explanation:**
Using the ionic product of water:

$$(10^{-8} + x)(x) = 10^{-14}$$
$$x^2 + 10^{-8}x - 10^{-14} = 0$$

Solving this quadratic equation using the formula $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$:

$$x = \frac{-10^{-8} + \sqrt{(10^{-8})^2 - 4(1)(-10^{-14})}}{2}$$
$$x = \frac{-10^{-8} + \sqrt{10^{-16} + 4 \times 10^{-14}}}{2} \approx \frac{-10^{-8} + \sqrt{4.01 \times 10^{-14}}}{2}$$
$$x \approx \frac{-10^{-8} + 2 \times 10^{-7}}{2} = 0.95 \times 10^{-7} \text{ M}$$

Now, calculate total $[H^+]$:

$$[H^+]_{total} = 10^{-8} + 0.95 \times 10^{-7} = 0.1 \times 10^{-7} + 0.95 \times 10^{-7} = 1.05 \times 10^{-7} \text{ M}$$

Calculate $pH$:

$$pH = -\log[H^+]_{total} = -\log(1.05 \times 10^{-7}) = 7 - \log(1.05) \approx 7 - 0.021 = 6.979$$

Rounding off to two decimal places, we get 6.98.

**Step 4: Final Answer:**
The $pH$ of $10^{-8}$ M HCl is 6.98.

> Quick Tip
>
> Never mark $pH = 8$ for $10^{-8}$ M HCl. An acid solution cannot be basic!
> For such dilute acids, the answer will always be slightly less than 7 (typically 6.96 to 6.99).

---

**28. Which one of the following immunoglobulins is known for its role in both allergy and asthma?**

(A) IgA
(B) IgM
(C) IgD
(D) IgE

**Correct Answer:** (D) IgE

**Solution:**

**Step 1: Understanding the Concept:**
Immunoglobulins (antibodies) are classified into five types: IgA, IgD, IgE, IgG, and IgM, each with specific biological roles.
Allergic reactions and certain respiratory conditions like asthma are mediated by Type I hypersensitivity.

**Step 2: Detailed Explanation:**
- **IgE (Immunoglobulin E)** is present in the lowest concentrations in the blood but has a very potent role.
- It binds to high-affinity Fc receptors on the surface of mast cells and basophils.
- When an allergen cross-links these IgE molecules, it triggers degranulation, releasing inflammatory mediators like histamine.
- This process is the central mechanism in allergic rhinitis, food allergies, and allergic asthma.

**Step 3: Final Answer:**
IgE is the immunoglobulin primarily associated with allergy and asthma.

Quick Tip

Associate immunoglobulins with keywords:
IgG: Most abundant, crosses placenta.
IgA: Secretory (tears, saliva, milk).
IgM: First responder, pentamer.
IgE: Allergy, Asthma, and Parasitic infections.

---

**29. In which kind of organism, the glycerol moiety of lipid is found primarily in the R-configuration?**

(A) Bacteria
(B) Mammals
(C) Archaea
(D) Yeast

**Correct Answer:** (C) Archaea

**Solution:**

**Step 1: Understanding the Concept:**
Organisms in the three domains of life (Bacteria, Archaea, and Eukarya) differ fundamentally in their membrane lipid compositions.
One major difference is the stereochemistry of the glycerol backbone.

**Step 2: Detailed Explanation:**
1. **Bacteria and Eukarya (including Mammals and Yeast):**
- These organisms use **sn-glycerol-3-phosphate** as the backbone.
- This corresponds to the **S-configuration** at the C2 carbon of glycerol.
- Their lipids consist of fatty acids linked to the backbone via ester bonds.

2. **Archaea:**
- Archaea use **sn-glycerol-1-phosphate** as the backbone.
- This corresponds to the **R-configuration** at the C2 carbon.
- Furthermore, their lipids use isoprenoid chains linked via ether bonds, which provides higher stability in extreme environments.

**Step 3: Final Answer:**
The glycerol moiety is found in the R-configuration primarily in Archaea.

Quick Tip

Remember the "Archaeal Exception":
1. Ether links instead of esters.
2. Isoprenoids instead of fatty acids.
3. L-glycerol (sn-G1P, R-config) instead of D-glycerol (sn-G3P, S-config).

---

**30. The Kennedy pathway of cellular phospholipid biosynthesis is associated with _____.**

(A) peroxisome
(B) mitochondria
(C) nucleus
(D) endoplasmic reticulum

**Correct Answer:** (D) endoplasmic reticulum

**Solution:**

**Step 1: Understanding the Concept:**
The Kennedy pathway (also known as the CDP-choline or CDP-ethanolamine pathway) is the primary metabolic route for the synthesis of major structural phospholipids like phosphatidylcholine (PC) and phosphatidylethanolamine (PE).

**Step 2: Detailed Explanation:**
- The enzymes responsible for the steps of the Kennedy pathway are membrane-bound or associated with the cytosolic face of membranes.
- Specifically, the final steps of these syntheses occur at the **endoplasmic reticulum (ER)**.
- The ER is the central hub for lipid and protein synthesis in eukaryotic cells.

**Step 3: Final Answer:**
The Kennedy pathway is associated with the endoplasmic reticulum.

Quick Tip

Think of the Endoplasmic Reticulum (ER) as the "Factory" for both proteins (Rough ER) and lipids (Smooth ER). Phospholipid biosynthesis pathways, including the Kennedy pathway, are localized here.

---

**31. Which of the following options show(s) the correct pairing of a complement protein with its function?**

(A) C5a : inflammation
(B) C3b : opsonization
(C) C3a : opsonization
(D) C5b : inflammation

**Correct Answer:** (A, B) C5a : inflammation and C3b : opsonization

**Solution:**

**Step 1: Understanding the Concept:**
The complement system is a part of the immune system that enhances (complements) the ability of antibodies and phagocytic cells to clear pathogens.
Components are activated in a cascade and produce various fragments with distinct functions.

**Step 2: Detailed Explanation:**
- **C3a and C5a:** These are small fragments (anaphylatoxins) released during the cleavage of C3 and C5. They promote **inflammation** by increasing vascular permeability and attracting phagocytes (chemotaxis). Thus, (A) is correct.
- **C3b:** This larger fragment binds covalently to the surface of pathogens. It acts as an **opsonin**, marking the pathogen for recognition and ingestion by phagocytes. Thus, (B) is correct.
- **C5b:** This fragment initiates the assembly of the Membrane Attack Complex (MAC), which causes direct cell lysis. It is not primarily involved in inflammation.

**Step 3: Final Answer:**
The correct pairings are (A) C5a : inflammation and (B) C3b : opsonization.

Quick Tip

Complement "a" fragments (**C3a, C4a, C5a**) are for **a**ctivation/inflammation.
Complement "b" fragments (**C3b, C4b**) are for **b**inding/opsonization.
(Exception: C2a is the larger active fragment in some terminologies).

---

**32. Fluorescence is a result of which one or more of the following?**

(A) The transition of electrons from singlet ground state to singlet transition state.
(B) The transition of electrons from lower singlet excited state to singlet ground state.
(C) The release of energy in the form of light of wavelength higher than the incident wavelength.
(D) The release of energy in the form of light of lower wavelength than the incident wavelength.

**Correct Answer:** (B, C)

**Solution:**

**Step 1: Understanding the Concept:**
Fluorescence is a type of luminescence where a substance absorbs light or other electromagnetic

radiation and emits light within a very short timeframe.

**Step 2: Detailed Explanation:**
1. **Mechanism:** When an atom or molecule absorbs light, an electron is excited to a higher singlet state ($S_1, S_2 \ldots$).
2. **Vibrational Relaxation:** The molecule quickly loses some energy through non-radiative transitions to the lowest vibrational level of the first singlet excited state ($S_1$).
3. **Emission:** Fluorescence occurs when the electron returns from the $S_1$ state to the singlet ground state ($S_0$). Thus, (B) is correct.
4. **Wavelength Shift (Stokes Shift):** Because some energy is lost via vibrational relaxation and heat before the photon is emitted, the emitted photon has lower energy ($E = \frac{hc}{\lambda}$) than the absorbed photon.
5. Lower energy corresponds to a **higher (longer) wavelength**. Thus, (C) is correct.

**Step 3: Final Answer:**
Fluorescence involves transition from the lowest singlet excited state to the ground state and results in light of a higher wavelength.

Quick Tip

Remember: Energy ↓ Frequency ↓ Wavelength ↑.
Fluorescence is always "red-shifted" (longer wavelength) compared to the excitation light. This is known as the Stokes Shift.

---

**33. A 25 amino acid $\alpha$-helical protein is spanning the thickness of a mammalian cell membrane. Using the average dimensional parameters of a typical $\alpha$-helix, the thickness of the membrane will be _____ Å (rounded off to one decimal place).**

**Correct Answer:** 37.5

**Solution:**

**Step 1: Understanding the Concept:**
In a standard protein $\alpha$-helix, the residues are arranged in a specific spatial orientation determined by hydrogen bonding.

**Step 2: Key Formula or Approach:**
For a typical $\alpha$-helix:
- There are 3.6 amino acids per turn.
- The pitch (vertical distance of one complete turn) is 5.4 Å.
- The **rise per residue** ($h$) is given by:

$$h = \frac{\text{Pitch}}{\text{Amino acids per turn}} = \frac{5.4 \text{ Å}}{3.6} = 1.5 \text{ Åper residue}$$

**Step 3: Detailed Explanation:**
The total length of the helix ($L$) is the product of the number of amino acids ($N$) and the rise per residue ($h$).
Given:
$N = 25$ residues.
$h = 1.5$ Å/residue.

$$L = N \times h = 25 \times 1.5 = 37.5 \text{ Å}$$

Since the protein spans the membrane, this length corresponds to the thickness of the membrane.

**Step 4: Final Answer:**
The thickness of the membrane is 37.5 Å.

Quick Tip

Standard helix parameters to memorize:
Alpha helix: 1.5 Å/residue.
Beta strand: 3.5 Å/residue.
A membrane is typically 30-40 Åthick, so 25 residues (∼37.5 Å) is a perfect fit.

---

**34. The oxidative phase of the hexose monophosphate pathway generates _____ moles of NADPH per mole of glucose 6-phosphate (answer in integer).**

**Correct Answer:** 2

**Solution:**

**Step 1: Understanding the Concept:**
The Hexose Monophosphate (HMP) pathway, also known as the Pentose Phosphate Pathway (PPP), consists of an irreversible oxidative phase and a reversible non-oxidative phase.

**Step 2: Detailed Explanation:**
In the oxidative phase, two distinct redox reactions occur:
1. **First Reaction:** Glucose 6-phosphate is oxidized to 6-phosphogluconolactone by the enzyme *glucose 6-phosphate dehydrogenase*. In this step, 1 mole of $NADP^+$ is reduced to **1 mole of NADPH**.
2. **Second Reaction:** 6-phosphogluconate (derived from the lactone) is oxidatively decarboxylated to ribulose 5-phosphate by *6-phosphogluconate dehydrogenase*. In this step, another mole of $NADP^+$ is reduced to **1 mole of NADPH**.

Total NADPH produced per G6P molecule entering the pathway $= 1 + 1 = 2$.

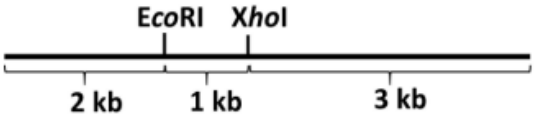
**Step 3: Final Answer:**
The HMP pathway generates 2 moles of NADPH per mole of glucose 6-phosphate.

Quick Tip

The oxidative phase of PPP serves two purposes: producing NADPH (for biosyntheses and antioxidant defense) and producing Ribose-5-Phosphate (for nucleotide synthesis). Think: "Two dehydrogenase steps = Two NADPH".

---

**35. Partial double digestion of the DNA shown below with *EcoRI*, and *XhoI* will yield _____ bands after gel electrophoresis (answer in integer).**




**The diagram shows a DNA fragment with sites as: [End] — 2 kb — [EcoRI] — 1 kb — [XhoI] — 3 kb — [End]**

**Correct Answer:** 5

**Solution:**

**Step 1: Understanding the Concept:**
"Double digestion" means both restriction enzymes are used. "Partial digestion" means that in a population of DNA molecules, the enzymes may cut at all, some, or none of their specific recognition sites.

**Step 2: Key Formula or Approach:**
Identify all possible fragments that can be generated by cutting at zero, one, or both available restriction sites.

**Step 3: Detailed Explanation:**
Let the total length be $2 + 1 + 3 = 6$ kb.
Let the sites be labeled $S_1$ (EcoRI) and $S_2$ (XhoI).
Possible fragments formed:
1. **Zero cuts:** The original whole fragment (6 kb).
2. **Cut only at EcoRI:** Produces two fragments: [0 to 2] = 2 kb, and [2 to 6] = 4 kb.
3. **Cut only at XhoI:** Produces two fragments: [0 to 3] = 3 kb, and [3 to 6] = 3 kb.
4. **Cut at both EcoRI and XhoI:** Produces three fragments: [0 to 2] = 2 kb, [2 to 3] = 1 kb, and [3 to 6] = 3 kb.
List the unique sizes obtained:

- 6 kb (uncut)
- 4 kb (EcoRI cut)
- 3 kb (XhoI cut)
- 2 kb (EcoRI cut)
- 1 kb (Full double cut)
Total distinct fragment lengths = 6, 4, 3, 2, 1.

**Step 4: Final Answer:**
Partial double digestion will yield 5 distinct bands on a gel.

> Quick Tip
>
> In partial digestion problems, simply list all start-to-site, site-to-site, and site-to-end distances. Don't forget the total uncut length!

---

**36. Chymotrypsin cleaves polypeptides preferentially on the carbonyl side of aromatic, and some other bulky nonpolar residues. Trypsin cleaves on the carbonyl side of positively charged residues. Digestion of a polypeptide having the composition $Ala_2, Gly, Lys_2, Phe, Thr, Trp, Val$, independently by these two proteases yielded peptide fragments as shown in the figure below.**


**Which one of the following is the correct primary structure of the polypeptide?**

(A) Ala-Ala-Trp-Gly-Lys-Lys-Thr-Phe-Val
(B) Thr-Phe-Val-Lys-Ala-Ala-Trp-Gly-Lys
(C) Val-Lys-Ala-Ala-Trp-Gly-Lys-Thr-Phe
(D) Thr-Phe-Ala-Ala-Trp-Val-Lys-Gly-Lys

**Correct Answer:** (B) Thr-Phe-Val-Lys-Ala-Ala-Trp-Gly-Lys

**Solution:**

**Step 1: Understanding the Concept:**
Polypeptide sequencing involves breaking the chain into smaller fragments using specific proteases and then "overlapping" these fragments like a puzzle to determine the original sequence.

**Step 2: Detailed Explanation:**
- **Trypsin** fragments end in basic residues (Lys/Arg). The fragments are:
(T1) Ala-Ala-Trp-Gly-Lys
(T2) Thr-Phe-Val-Lys
- **Chymotrypsin** fragments end in aromatic residues (Phe/Trp/Tyr) unless it's the C-terminus.

The fragments are:
(C1) Gly-Lys
(C2) Thr-Phe
(C3) Val-Lys-Ala-Ala-Trp

- **Overlapping fragments:**
1. Look at C2 (Thr-Phe). It must be the start because no other fragment ends in Thr. It matches the beginning of T2 (Thr-Phe-Val-Lys).
2. If the sequence starts with T2, the next residue after T2's Lys must match the start of another Chymotrypsin fragment.
3. Let's combine C2 and C3: (Thr-Phe) + (Val-Lys-Ala-Ala-Trp). This combined sequence matches parts of T2 and T1.
4. Specifically: C2 (Thr-Phe) + first half of C3 (Val-Lys) = T2 (Thr-Phe-Val-Lys).
5. Now, the rest of C3 (Ala-Ala-Trp) must be followed by C1 (Gly-Lys).
6. Combining these: C3 (Val-Lys-Ala-Ala-Trp) + C1 (Gly-Lys) = Ala-Ala-Trp-Gly-Lys, which is T1.

- **Final Sequence:**
(C2) - (C3) - (C1) $\Rightarrow$ Thr-Phe-Val-Lys-Ala-Ala-Trp-Gly-Lys.

**Step 3: Verification:**
- Trypsin cleavage after Lys gives: [Thr-Phe-Val-Lys] and [Ala-Ala-Trp-Gly-Lys]. (Correct).
- Chymotrypsin cleavage after Phe and Trp gives: [Thr-Phe], [Val-Lys-Ala-Ala-Trp], and [Gly-Lys]. (Correct).

**Step 4: Final Answer:**
The sequence is Thr-Phe-Val-Lys-Ala-Ala-Trp-Gly-Lys.

Quick Tip

Always check the C-terminus of the fragments. Trypsin fragments nearly always end in Lys or Arg. Chymotrypsin fragments end in Phe, Trp, or Tyr. The fragment that doesn't follow this rule must be the original C-terminal fragment of the protein.

---

**37. Which one of the following enzymes is NOT inhibited by glucose-6-phosphate?**

(A) Hexokinase I
(B) Hexokinase II
(C) Hexokinase III
(D) Hexokinase IV

**Correct Answer:** (D) Hexokinase IV

**Solution:**

**Step 1: Understanding the Concept:**
Hexokinases catalyze the first step of glycolysis: phosphorylating glucose to glucose-6-phosphate (G6P). There are four major isozymes in mammals.

**Step 2: Detailed Explanation:**
- **Hexokinase I, II, and III:** Found in most tissues. They have a high affinity for glucose and are strongly inhibited by their reaction product, **glucose-6-phosphate**. This ensures that when G6P levels are high, the cell stops "trapping" more glucose.
- **Hexokinase IV (Glucokinase):** Primarily found in the liver and pancreatic beta-cells. It has a much lower affinity for glucose and is **not inhibited by G6P**.
- This allows the liver to continue taking up and phosphorylating glucose even when G6P levels are high, facilitating the storage of excess glucose as glycogen.

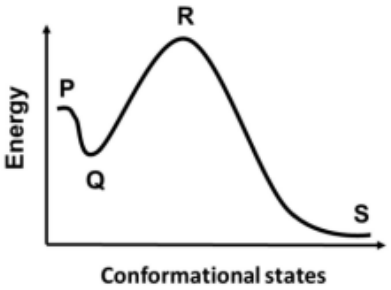
**Step 3: Final Answer:**
Hexokinase IV is not inhibited by glucose-6-phosphate.

Quick Tip

Glucokinase (HK IV) is a "Specialist": It acts only when blood sugar is high and it doesn't listen to its product (G6P). The other Hexokinases (I-III) are "Generalists" that self-regulate once they have enough product.

---

**38. The following diagram represents energy states of different protein folding steps, which includes –**
**1. Folded**
**2. Transition**
**3. Molten globule**
**4. Unfolded**




**Find the correct match of folding steps (1 to 4) with the energy state (P to S) in the diagram.**

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

**Solution:**

**Step 1: Understanding the Concept:**
Protein folding is a thermodynamic process directed toward a state of minimum free energy. The energy landscape is often described as a "funnel."

**Step 2: Detailed Explanation:**
- **Unfolded state (4):** This is the initial high-energy, high-entropy state. In the diagram, this corresponds to point **P**.
- **Transition state (2):** This represents the energy barrier that must be overcome for folding to proceed. It is the point of maximum free energy. In the diagram, this is point **R**.
- **Molten globule (3):** This is a partially folded intermediate state that resides in a local energy minimum (a "trap" or "well") on the way to the final state. In the diagram, this is point **Q**.
- **Folded state (1):** The native, functional conformation of the protein. It is the state of absolute minimum free energy and maximum stability. In the diagram, this is point **S**.

**Step 3: Final Answer:**
Matching: 1-S, 2-R, 3-Q, 4-P. This corresponds to option (A).

Quick Tip

In energy diagrams:
- Highest point = Transition state.
- Lowest point = Final/Native/Folded state.
- Initial point = Reactant/Unfolded state.
- Local "dip" = Intermediate/Molten globule.

---

**39. The correct path of transfer of electrons in the light harvesting photosystems in vascular plants is _____.**

(A) $H_2O \rightarrow$ Photosystem II $\rightarrow$ Cyt $b_6f \rightarrow$ Photosystem I $\rightarrow$ $NADP^+$
(B) $H_2O \rightarrow$ Photosystem I $\rightarrow$ Cyt $b_6f \rightarrow$ Photosystem II $\rightarrow O_2$
(C) $H_2O \rightarrow$ Photosystem II $\rightarrow$ Cyt $b_6f \rightarrow$ Photosystem I $\rightarrow O_2$
(D) $H_2O \rightarrow$ Photosystem I $\rightarrow$ Cyt $b_6f \rightarrow$ Photosystem II $\rightarrow$ $NADP^+$

**Correct Answer:** (A)

**Solution:**

**Step 1: Understanding the Concept:**
The light-dependent reactions of photosynthesis involve the non-cyclic transfer of electrons from water to $NADP^+$, a process described as the "Z-scheme."

**Step 2: Detailed Explanation:**
1. **Photolysis of Water:** Electrons are extracted from $H_2O$ (producing $O_2$ as a byproduct)

to replenish the reaction center of Photosystem II.
2. **Photosystem II (PSII):** Light excites electrons in the P680 reaction center, which are then passed to the primary electron acceptor.
3. **Electron Transport Chain:** Electrons flow from PSII to the **Cytochrome** $b_6f$ complex. This movement pumps protons across the thylakoid membrane.
4. **Photosystem I (PSI):** Electrons travel to PSI, where they are re-excited by light (P700) and passed to ferredoxin.
5. **Final Reduction:** The enzyme *ferredoxin-NADP reductase* transfers the electrons to $NADP^+$ to form NADPH.

**Step 3: Final Answer:**
The correct order is: $H_2O \rightarrow$ PSII $\rightarrow$ Cyt $b_6f \rightarrow$ PSI $\rightarrow$ $NADP^+$.

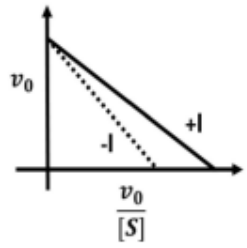
Quick Tip

Remember: "2 comes before 1". In nature, the sequence is II then I. PSII oxidizes water; PSI reduces NADP+. Cytochrome is the "bridge" in between.

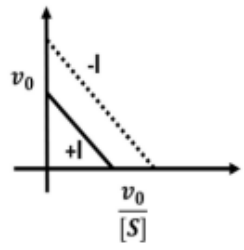
---

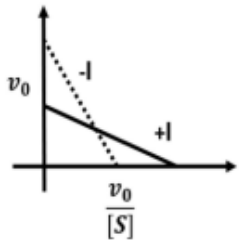
**40. For a simple enzyme that follows Michaelis-Menten kinetics, kinetic data was collected in the absence (dotted line, -I), or presence (solid line, +I) of an uncompetitive inhibitor (I). Which one of the following Eadie-Hofstee plots best describes the expected result?**
**($v_0$ = initial velocity, [S] = free substrate concentration)**

(A)

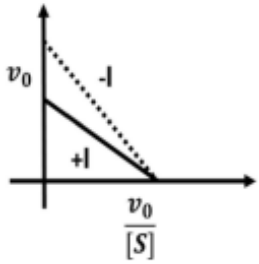



(B)

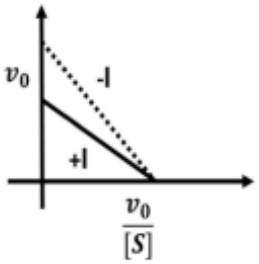





(C)




(D)




**Correct Answer:** (D)

**Solution:**

**Step 1: Understanding the Concept:**
The Eadie-Hofstee plot is a linear representation of enzyme kinetics described by the equation:

$$v_0 = V_{max} - K_m \cdot \frac{v_0}{[S]}$$

- The **y-intercept** represents $V_{max}$.
- The **slope** represents $-K_m$.
- The **x-intercept** represents $V_{max}/K_m$.

**Step 2: Key Formula or Approach:**
In **uncompetitive inhibition**, the inhibitor binds only to the enzyme-substrate (ES) complex. This results in both $V_{max}$ and $K_m$ decreasing by the same factor $\alpha'$:

$$V_{max,app} = \frac{V_{max}}{\alpha'} \text{ and } K_{m,app} = \frac{K_m}{\alpha'}$$

**Step 3: Detailed Explanation:**
1. **y-intercept:** Since $V_{max,app} < V_{max}$, the line for the inhibited reaction (+I) must have a **lower y-intercept** than the control line (-I).
2. **Slope:** Since $K_{m,app} < K_m$, the slope ($-K_{m,app}$) is less negative (flatter) than the control

slope ($-K_m$).
3. **x-intercept:** Let's look at the ratio $V_{max,app}/K_{m,app}$:

$$\frac{V_{max}/\alpha'}{K_m/\alpha'} = \frac{V_{max}}{K_m}$$

Because the factor $\alpha'$ cancels out, the **x-intercept remains unchanged**.
4. Therefore, the two lines in the Eadie-Hofstee plot must **intersect exactly at the x-axis**.

**Step 4: Final Answer:**
Plot (D) correctly shows the two lines meeting at the same point on the x-axis, with the inhibitor line having a lower y-intercept and a smaller slope magnitude.

Quick Tip

Plot comparison for Uncompetitive Inhibition:
- Lineweaver-Burk ($1/v$ vs $1/s$): Parallel lines.
- Eadie-Hofstee ($v$ vs $v/s$): Lines intersect on the x-axis.
- Hanes-Woolf ($s/v$ vs $s$): Parallel lines.

---

**41. Which statement(s) is/are true about the $5'$-capping of eukaryotic mRNA?**

(A) Triphosphatase enzyme removes the $\gamma$-phosphate from the $5'$-terminal nucleotide.
(B) A transferase links ATP to the dephosphorylated nucleotide of mRNA at its $5'$-end.
(C) Methyl transferase adds a $-CH_3$ group to the N-7 position of the newly added guanine base.
(D) $5'$-capping happens shortly after mRNA emerges from the exit tunnel of RNA polymerase.

**Correct Answer:** (A, C, D)

**Solution:**

**Step 1: Understanding the Concept:**
The $5'$-cap is a specially altered nucleotide on the $5'$ end of some primary transcripts such as precursor messenger RNA. This process is vital for mRNA stability, export to the cytoplasm, and initiation of translation.

**Step 2: Detailed Explanation:**
The formation of the $5'$ cap involves a sequence of three enzymatic reactions shortly after the initiation of transcription:
1. **RNA 5'-triphosphatase:** It removes the terminal ($\gamma$) phosphate group from the $5'$-triphosphate end ($pppN$) of the nascent mRNA, leaving a $5'$-diphosphate ($ppN$). Thus, **Statement (A) is correct**.
2. **RNA guanylyltransferase:** It transfers a GMP moiety from **GTP** (not ATP) to the $5'$-diphosphate end, forming a $5'-5'$ triphosphate linkage ($GpppN$). Thus, **Statement (B) is**

**incorrect**.
3. **RNA (guanine-N7)-methyltransferase:** It transfers a methyl group from S-adenosylmethionine (SAM) to the N-7 position of the guanine base. Thus, **Statement (C) is correct**.
4. **Co-transcriptional Timing:** Capping occurs very early during transcription, typically when the nascent RNA is only about 20-30 nucleotides long and has just emerged from the exit tunnel of RNA polymerase II. Thus, **Statement (D) is correct**.

**Step 3: Final Answer:**
Statements (A), (C), and (D) are true regarding the $5'$-capping mechanism.

Quick Tip

Remember the unique $5' - 5'$ triphosphate linkage and that the methyl group comes from SAM. The enzyme complex associates with the Phosphorylated C-terminal domain (CTD) of RNA Pol II.

---

**42. Which of the following statements about pertussis toxin is/are NOT true?**

(A) It causes whooping cough.
(B) It is a heterodimeric protein.
(C) It causes ADP-ribosylation of the $\alpha$-subunit of $G_i$.
(D) It inhibits adenylate cyclase.

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

**Solution:**

**Step 1: Understanding the Concept:**
Pertussis toxin (PTX) is a protein-based exotoxin produced by the bacterium *Bordetella pertussis*, which causes whooping cough. It interferes with host cell signaling by targeting G-protein coupled receptor (GPCR) pathways.

**Step 2: Detailed Explanation:**
- **Statement (A):** PTX is a primary virulence factor of *Bordetella pertussis* and is responsible for the systemic manifestations of whooping cough. This is **true**.
- **Statement (B):** PTX is a complex protein with an $A-B$ structure. It is a **heterohexamer** composed of five different subunits ($S1, S2, S3, S4$ (two copies), and $S5$). It is NOT a simple heterodimer. This is **NOT true**.
- **Statement (C):** The A-subunit ($S1$) is an enzyme that catalyzes the **ADP-ribosylation** of the $\alpha_i$ subunit of inhibitory G-proteins ($G_i$). This is **true**.
- **Statement (D):** ADP-ribosylation of $G_i$ prevents it from interacting with GPCRs, locking it in an inactive GDP-bound state. Since $G_i$ normally inhibits adenylate cyclase, its inactivation leads to **increased/unregulated activity** of adenylate cyclase and high intracellular cAMP levels. It does not inhibit adenylate cyclase. This is **NOT true**.

**Step 3: Final Answer:**
Statements (B) and (D) are the incorrect descriptions of pertussis toxin.

Quick Tip

Contrast PTX with Cholera Toxin: Cholera toxin ADP-ribosylates $G_s$ (stimulatory), locking it 'ON', while Pertussis toxin ADP-ribosylates $G_i$ (inhibitory), locking it 'OFF'. Both result in increased cAMP levels.

---

**43. Telomerase has which one or more of the following activities?**

(A) DNA-dependent RNA polymerase
(B) Reverse transcriptase
(C) RNA-dependent DNA polymerase
(D) $5' \rightarrow 3'$ exoribonuclease

**Correct Answer:** (B, C)

**Solution:**

**Step 1: Understanding the Concept:**
Telomerase is a specialized ribonucleoprotein (RNP) complex responsible for maintaining the length of telomeres (the ends of eukaryotic chromosomes) by adding repetitive DNA sequences.

**Step 2: Detailed Explanation:**
- Telomerase consists of a protein component (TERT: Telomerase Reverse Transcriptase) and an internal RNA component (TERC: Telomerase RNA Component) that acts as a template.
- It uses its own RNA template to synthesize complementary DNA onto the $3'$ overhang of the telomere.
- The synthesis of DNA from an RNA template is precisely defined as **RNA-dependent DNA polymerase** activity.
- This enzymatic activity is also commonly referred to as **reverse transcriptase** activity.

**Step 3: Final Answer:**
Telomerase exhibits both Reverse transcriptase (B) and RNA-dependent DNA polymerase (C) activities.

Quick Tip

Telomerase solves the "end-replication problem" in linear chromosomes. It is typically active in germ cells and cancer cells but inactive in most adult somatic cells.

---

**44. To a $10 \times 10^{-9}$ M solution of a receptor, its specific ligand was added, and incubated. At equilibrium, the concentration of the free ligand was $5 \times 10^{-9}$ M, and the concentration of the receptor-ligand complex was $6 \times 10^{-9}$ M. The dissociation constant for the receptor-ligand interaction is _____ $\times 10^{-9}$ M (rounded off to two decimal places).**

**Correct Answer:** 3.33

**Solution:**

**Step 1: Understanding the Concept:**
The dissociation constant ($K_d$) measures the affinity of a receptor ($R$) for its ligand ($L$). For the equilibrium $RL \rightleftharpoons R + L$, the constant is defined by the ratio of the product of free concentrations to the complex concentration.

**Step 2: Key Formula or Approach:**

$$K_d = \frac{[R]_{free} \cdot [L]_{free}}{[RL]}$$

Where:
$[R]_{free} = [R]_{total} - [RL]$

**Step 3: Detailed Explanation:**
1. **Identify given values (in units of $10^{-9}$ M):**
- Total receptor concentration, $[R]_{total} = 10$.
- Free ligand concentration, $[L]_{free} = 5$.
- Receptor-ligand complex concentration, $[RL] = 6$.

2. **Calculate free receptor concentration:**

$$[R]_{free} = [R]_{total} - [RL] = 10 - 6 = 4 \times 10^{-9} \text{ M}$$

3. **Calculate $K_d$:**

$$K_d = \frac{4 \times 5}{6} = \frac{20}{6} = 3.333\ldots$$

**Step 4: Final Answer:**
Rounding off to two decimal places, the value is 3.33.

Quick Tip

A lower $K_d$ value indicates higher affinity between the receptor and the ligand. Always ensure you use the **free** concentration of the receptor, not the total concentration, in the formula.

---

**45. Assuming that there are $5 \times 10^{13}$ cells in the human body, and that ATP is turning over at a rate of $10^9$ ATP molecules per minute in each cell, then the human body is utilizing _____ watts (rounded off to two decimal places).**
**[Assume that hydrolysis of ATP yields 12 kcal per mole. 1 watt = 1 joule/sec, 1 calorie = 4.18 joules, Avogadro's number = $6.023 \times 10^{23}$]**

**Correct Answer:** 69.40 (or 69.37 depending on rounding steps)

**Solution:**

**Step 1: Understanding the Concept:**
Power (Watts) is the rate of energy consumption per unit time ($J/s$). We need to calculate the total energy released from ATP turnover across all cells and convert it to Watts.

**Step 2: Key Formula or Approach:**
1. Total ATP/min = (Total cells) $\times$ (ATP/cell/min)
2. Total Moles/min = $\frac{\text{Total ATP/min}}{N_A}$
3. Total Power (Watts) = $\frac{\text{Moles}}{\text{sec}} \times \frac{\text{Energy}}{\text{mole}}$

**Step 3: Detailed Explanation:**
**- Total ATP molecules turned over per minute:**

$$\text{Rate} = 5 \times 10^{13} \text{ cells} \times 10^9 \text{ ATP/cell/min} = 5 \times 10^{22} \text{ molecules/min}$$

**- Convert molecules per minute to moles per second:**

$$\text{Moles/sec} = \frac{5 \times 10^{22}}{6.023 \times 10^{23} \times 60} \approx 1.3837 \times 10^{-3} \text{ mol/s}$$

**- Calculate energy per mole in Joules:**

$$\Delta H = 12 \text{ kcal/mol} = 12,000 \text{ cal/mol} \times 4.18 \text{ J/cal} = 50,160 \text{ J/mol}$$

**- Calculate Power in Watts ($J/s$):**

$$P = (1.3837 \times 10^{-3} \text{ mol/s}) \times (50,160 \text{ J/mol}) \approx 69.406 \text{ W}$$

**Step 4: Final Answer:**
The body utilizes approximately 69.41 Watts (or 69.40 depending on intermediate rounding).

> Quick Tip
>
> Watts is a unit of power ($J/s$). Always convert minute-based rates to second-based rates early in the calculation to stay consistent with SI units.

---

**46. A solution shows a transmittance of $20\%$ when taken in a cuvette of $2.5$ cm path length. If the molar absorption coefficient of the solution is $12000$ $dm^3/mol \cdot cm$, the concentration of the solution is _____ $\times 10^{-5}$ $mol/dm^3$ (rounded off to two decimal places).**

**Correct Answer:** 2.33

**Solution:**

**Step 1: Understanding the Concept:**
The Beer-Lambert Law relates the absorbance ($A$) of a solution to its concentration ($c$), path length ($l$), and molar absorptivity ($\epsilon$). Absorbance is related to transmittance ($T$) logarithmically.

**Step 2: Key Formula or Approach:**
1. $A = -\log_{10} T = 2 - \log_{10}(\%T)$
2. $A = \epsilon \cdot c \cdot l$

**Step 3: Detailed Explanation:**
**- Calculate Absorbance ($A$):**
Transmittance $T = 20\% = 0.2$.

$$A = -\log_{10}(0.2) = \log_{10}(5) \approx 0.6990$$

**- Apply Beer-Lambert Law:**
Given $\epsilon = 12000$ L mol$^{-1}$ cm$^{-1}$ (Note: 1 dm$^3$ = 1 L), $l = 2.5$ cm.

$$0.6990 = 12000 \cdot c \cdot 2.5$$

$$0.6990 = 30000 \cdot c$$

$$c = \frac{0.6990}{30000} = 2.33 \times 10^{-5} \text{ mol/dm}^3$$

**Step 4: Final Answer:**
The concentration is $2.33 \times 10^{-5}$ mol/dm$^3$, so the blank is 2.33.

> Quick Tip
>
> Remember that Absorbance is dimensionless, while Transmittance is a percentage or fraction. Always convert transmittance to absorbance before using the $\epsilon cl$ formula.

---

**47. Which one of the following plant families is characterized by the gynobasic style of female reproductive organ?**

(A) Lamiaceae
(B) Euphorbiaceae
(C) Malvaceae
(D) Poaceae

**Correct Answer:** (A) Lamiaceae

**Solution:**

**Step 1: Understanding the Concept:**
Style is the stalk of the carpel. In most plants, it arises from the apex of the ovary (terminal style). A **gynobasic style** is a unique arrangement where the style arises from the base of the ovary or from the depression between the lobes of the ovary.

**Step 2: Detailed Explanation:**
- **Lamiaceae (Labiatae):** This family (e.g., Mint, Ocimum) typically has a deeply four-lobed ovary with the style arising from the center of the lobes at the base. This is a classic diagnostic feature of the family.
- **Euphorbiaceae:** Usually has a terminal style.
- **Malvaceae:** Features a terminal style, often passing through a staminal tube.
- **Poaceae:** Features lateral or terminal plumose styles.

**Step 3: Final Answer:**
The gynobasic style is characteristic of the family Lamiaceae.

Quick Tip

Gynobasic styles are also found in the Boraginaceae family. If you see Lamiaceae and Boraginaceae in your studies, associate them with "base-originating style."

---

**48. Which one of the following plant organs typically exhibits all the four features listed below?**
**(i) Starch-enriched endodermis**
**(ii) Conjoint, collateral and open vascular bundle**
**(iii) Endarch xylem**
**(iv) Presence of medullary rays**

(A) Dicot root
(B) Monocot root
(C) Dicot leaf
(D) Dicot stem

**Correct Answer:** (D) Dicot stem

**Solution:**

**Step 1: Understanding the Concept:**
Different plant organs (roots, stems, leaves) in dicots and monocots have distinct anatomical arrangements of their tissues and vascular bundles.

**Step 2: Detailed Explanation:**
- **Starch-enriched endodermis:** In dicot stems, the endodermis is often called the **starch sheath** because it stores starch grains.
- **Conjoint, collateral, and open vascular bundles:** "Conjoint" means xylem and phloem are on the same radius; "collateral" means phloem is outside xylem; "open" means **cambium** is present between them, allowing secondary growth. This is characteristic of **dicot stems**.
- **Endarch xylem:** Protoxylem lies towards the center (pith) and metaxylem towards the periphery. This is the characteristic arrangement in **stems** (roots have exarch xylem).
- **Medullary rays:** These are strips of parenchyma between vascular bundles in a **dicot stem**.

**Step 3: Final Answer:**
All four features combined define the primary anatomy of a dicot stem.

Quick Tip

Keyword memory: "Stem = Endarch" and "Root = Exarch". "Open bundles = Dicot" (growth) and "Closed bundles = Monocot" (no secondary growth).

---

**49. Correctly match the following molecules/methods in Group-I with their major uses in Group-II.**

| Group-I | | Group-II | |
|---|---|---|---|
| (P) | CRISPR-Cas9 | (1) | Global gene expression analysis |
| (Q) | DNA Microarray | (2) | Molecular marker |
| (R) | *Vir* genes | (3) | Targeted gene editing |
| (S) | RAPD | (4) | *Agrobacterium*-mediated plant transformation |

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

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

**Solution:**

**Step 1: Understanding the Concept:**
Biotechnology utilizes various molecular tools for genetic engineering, expression studies, and genomic mapping.

**Step 2: Detailed Explanation:**
- **(P) CRISPR-Cas9:** A revolutionary tool used for **Targeted gene editing** (3) by creating precise double-strand breaks in DNA.
- **(Q) DNA Microarray:** A high-throughput method used to measure the expression levels of thousands of genes simultaneously, enabling **Global gene expression analysis** (1).
- **(R) Vir genes:** Found on the Ti plasmid of *Agrobacterium tumefaciens*, these genes are essential for T-DNA excision and transfer during ***Agrobacterium*-mediated plant transformation** (4).
- **(S) RAPD (Random Amplification of Polymorphic DNA):** A type of PCR-based method used as a **Molecular marker** (2) to study genetic diversity and mapping.

**Step 3: Final Answer:**
The correct match is P-3, Q-1, R-4, S-2.

Quick Tip

Match the most well-known pair first (CRISPR = gene editing) to eliminate incorrect options quickly.

**50. Which one of the following commercial products is used as a systemic fungicide to control plant diseases?**

(A) Captan
(B) Phaltan
(C) Thiram
(D) Benomyl

**Correct Answer:** (D) Benomyl

**Solution:**

**Step 1: Understanding the Concept:**
Fungicides are classified as **contact** (remain on the surface) or **systemic** (absorbed by the plant and translocated through the vascular system).

**Step 2: Detailed Explanation:**
- **Captan, Phaltan, and Thiram:** These are primarily non-systemic, contact/protectant fungicides that act on the surface to prevent fungal spore germination.
- **Benomyl:** It is a systemic benzimidazole fungicide. It is absorbed by the roots or leaves and moves acropetally (upward) through the xylem. It works by inhibiting microtubule assembly during fungal mitosis.

**Step 3: Final Answer:**
Benomyl is the correct example of a systemic fungicide.

Quick Tip

Systemic fungicides are superior for treating internal infections or protecting new growth that emerges after application. Benomyl and Carbendazim are classic benzimidazole systemic fungicides.

---

**51. Which one of the following terms best describes the plants that are adapted to grow in acidic soil?**

(A) Halophytes
(B) Oxylophytes
(C) Lithophytes
(D) Chasmophytes

**Correct Answer:** (B) Oxylophytes

**Solution:**

**Step 1: Understanding the Concept:**
Plants are categorized based on the specific environmental conditions or soil types they are adapted to.

**Step 2: Detailed Explanation:**
- **Halophytes:** Plants adapted to high salinity (e.g., Mangroves).
- **Oxylophytes:** Plants specifically adapted to **acidic soils**. They are also sometimes referred to as acidophytes.
- **Lithophytes:** Plants that grow on or in rocks.
- **Chasmophytes:** Plants that grow in the crevices of rocks.

**Step 3: Final Answer:**
Oxylophytes is the term for plants adapted to acidic soils.

Quick Tip

Prefixes are key: "Halo-" = Salt, "Litho-" = Rock, "Oxy-" (in this context) = Acid/Sour.

---

**52. Which of the following plant genera is/are example(s) of partial stem parasite?**

(A) *Striga*
(B) *Orobanche*
(C) *Viscum*
(D) *Cuscuta*

**Correct Answer:** (C) *Viscum*

**Solution:**

**Step 1: Understanding the Concept:**
Parasitic plants are classified by **where** they attach (stem or root) and **how much** they depend on the host (total or partial). Partial parasites have chlorophyll and perform photosynthesis but rely on the host for water and minerals.

**Step 2: Detailed Explanation:**
- ***Striga* (Witchweed):** A **partial root parasite**.
- ***Orobanche* (Broomrape):** A **total root parasite** (lacks chlorophyll).
- ***Viscum* (Mistletoe):** A **partial stem parasite**. It grows on tree branches, has green leaves for photosynthesis, but its haustoria extract water and nutrients from the host's xylem.
- ***Cuscuta* (Dodder):** A **total stem parasite** (lacks chlorophyll).

**Step 3: Final Answer:**
*Viscum* is the correct example of a partial stem parasite.

Quick Tip

Mnemonic: *Cuscuta* = Total Stem; *Viscum* = Partial Stem; *Striga* = Partial Root; *Orobanche* = Total Root.

---

**53. Which of the following amino acids contain(s) only one chiral center?**

(A) Serine
(B) Threonine
(C) Isoleucine
(D) Leucine

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

**Solution:**

**Step 1: Understanding the Concept:**
A chiral center is a carbon atom bonded to four different groups. Most proteinogenic amino acids have one chiral center (the $\alpha$-carbon).

**Step 2: Detailed Explanation:**
- **Serine:** Side chain is $-CH_2OH$. It has only **one** chiral center (the $\alpha$-carbon).
- **Threonine:** Side chain is $-CH(OH)CH_3$. It has **two** chiral centers: the $\alpha$-carbon and the $\beta$-carbon (where the $-OH$ group is attached).
- **Isoleucine:** Side chain is $-CH(CH_3)CH_2CH_3$. It has **two** chiral centers: the $\alpha$-carbon and the $\beta$-carbon (where the branch occurs).
- **Leucine:** Side chain is $-CH_2CH(CH_3)_2$. It has only **one** chiral center (the $\alpha$-carbon). The $\gamma$-carbon is not chiral because it is bonded to two identical methyl groups.

**Step 3: Final Answer:**
Serine (A) and Leucine (D) contain only one chiral center.

Quick Tip

Out of the 20 standard amino acids, only Isoleucine and Threonine have two chiral centers. Glycine is the only one with none. All others have exactly one.

---

**54. If an endosperm cell of a typical diploid angiosperm species has 15 chromosomes, then the number of chromosomes in a microspore mother cell of this species under normal circumstances would be _____ (in integer).**

**Correct Answer:** 10

**Solution:**

**Step 1: Understanding the Concept:**
In angiosperms, different tissues have different ploidy levels ($n$, $2n$, or $3n$).

**Step 2: Key Formula or Approach:**
- Gametes (microspore, egg): Haploid ($n$)
- Somatic cells / Microspore Mother Cells: Diploid ($2n$)
- Endosperm: Triploid ($3n$) (result of triple fusion)

**Step 3: Detailed Explanation:**
1. **Find $n$ from endosperm:**
Endosperm $= 3n = 15$.
Therefore, $n = \frac{15}{3} = 5$.

2. **Determine chromosomes in microspore mother cell:**
Microspore mother cell (MMC) is a diploid somatic-like cell in the anther that undergoes meiosis.
MMC $= 2n = 2 \times 5 = 10$.

**Step 4: Final Answer:**
The number of chromosomes in the microspore mother cell is 10.

Quick Tip

Always identify the ploidy first. Root/Leaf/MMC $= 2n$; Pollen/Egg $= n$; Endosperm $= 3n$.

---

**55. Which one of the following class(es) of genes, when deleted, would result in sepal formation in all the floral whorls of *Arabidopsis*, as per the rules of the typical ABC model of floral organ patterning?**

(A) Class A only
(B) Class A and class B
(C) Class B and class C
(D) Class B only

**Correct Answer:** (C) Class B and class C

**Solution:**

**Step 1: Understanding the Concept:**
The ABC model explains how three classes of homeotic genes interact to determine the identity of the four floral whorls:
- Whorl 1: A $\rightarrow$ Sepals

- Whorl 2: A + B → Petals
- Whorl 3: B + C → Stamens
- Whorl 4: C → Carpels
- Note: A and C mutually repress each other.

**Step 2: Detailed Explanation:**
- If Class B is deleted:
W1: A → Sepal; W2: A → Sepal; W3: C → Carpel; W4: C → Carpel. (Result: Sepal-Sepal-Carpel-Carpel).
- If both Class B and Class C are deleted:
1. In the absence of Class C, Class A is expressed in **all** four whorls.
2. Since Class B is also absent, there is no B+A or B+C interaction.
3. Every whorl now has only Class A activity.
4. As per the model, Class A alone → Sepals.
5. Result: W1=Sepal, W2=Sepal, W3=Sepal, W4=Sepal.

**Step 3: Final Answer:** Deletion of both Class B and Class C results in only sepals being formed.

Quick Tip

Absence of C leads to expansion of A. Absence of B removes the "middle" identities (Petal/Stamen).

---

**56. Correctly match the following molecular assemblies in Group-I with their functions in Group-II.**

| Group-I | | Group-II | |
|---|---|---|---|
| (P) | Photosystem I | (1) | Utilizes proton gradient for ATP synthesis |
| (Q) | Photosystem II | (2) | Transfers electron from reduced plastoquinone to oxidized plastocyanin |
| (R) | Cytochrome $b_6f$ complex | (3) | Drives transfer of electron from plastocyanin to ferredoxin |
| (S) | $CF_0 - CF_1$ complex | (4) | Oxidises $H_2O$ and reduces plastoquinone |

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

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

**Solution:**

**Step 1: Understanding the Concept:**
The light-dependent reactions of photosynthesis occur in the thylakoid membrane through a series of complexes (the Z-scheme).

**Step 2: Detailed Explanation:**
- **(P) Photosystem I:** It accepts electrons from plastocyanin and, upon light excitation, transfers them to ferredoxin → **Match (3)**.
- **(Q) Photosystem II:** It catalyzes the splitting of water (photolysis) and transfers electrons to plastoquinone → **Match (4)**.
- **(R) Cytochrome $b_6f$ complex:** It acts as a bridge, transferring electrons from plastoquinol ($PQH_2$) to plastocyanin ($PC$) → **Match (2)**.
- **(S) $CF_0 - CF_1$ complex (ATP Synthase):** It uses the electrochemical proton gradient generated during electron flow to drive the phosphorylation of ADP to ATP → **Match (1)**.

**Step 3: Final Answer:**
The correct matching is P-3, Q-4, R-2, S-1.

Quick Tip

Remember the flow: $H_2O$ → PS II → Cytochrome $b_6f$ → PS I → NADP+. PS II is the water-splitter!

---

**57. Correctly match the following secondary metabolites in Group-I with their chemical classes in Group-II.**

| Group-I | | Group-II | |
|---|---|---|---|
| (P) | Codeine | (1) | Flavones |
| (Q) | Podophyllotoxin | (2) | Alkaloids |
| (R) | Resveratrol | (3) | Lignans |
| (S) | Linamarin | (4) | Monoterpenes |
| (T) | Limonene | (5) | Cyanogenic glycosides |
| | | (6) | Stilbenes |

(A) P-1; Q-2; R-6; S-5; T-4
(B) P-2; Q-5; R-6; S-3; T-4
(C) P-2; Q-3; R-5; S-4; T-1
(D) P-2; Q-3; R-6; S-5; T-4

**Correct Answer:** (D) P-2; Q-3; R-6; S-5; T-4

**Solution:**

**Step 1: Understanding the Concept:**
Secondary metabolites are organic compounds produced by plants that are not directly involved in growth but play roles in defense and signaling. They are classified based on their chemical structures.

**Step 2: Detailed Explanation:**
- **(P) Codeine:** An opiate extracted from the poppy plant; it is a nitrogen-containing **Alkaloid** (2).
- **(Q) Podophyllotoxin:** A non-alkaloid toxin found in the roots of Mayapple; chemically it is a **Lignan** (3).
- **(R) Resveratrol:** A polyphenol found in grapes and wine; it belongs to the class of **Stilbenes** (6).
- **(S) Linamarin:** Found in cassava; it releases HCN upon hydrolysis and is a **Cyanogenic glycoside** (5).
- **(T) Limonene:** A major component in the oil of citrus fruit peels; it is a cyclic **Monoterpene** (4).

**Step 3: Final Answer:**
The matching is P-2, Q-3, R-6, S-5, T-4.

Quick Tip

Flavonoids, Lignans, and Stilbenes are all phenylpropanoid derivatives. Alkaloids almost always contain Nitrogen in a heterocyclic ring.

---

**58. Correctly match the following plant diseases in Group-I with their causal organisms in Group-II.**

| Group-I | | Group-II | |
|---|---|---|---|
| (P) | Red rot of sugarcane | (1) | *Albugo candida* |
| (Q) | Tikka disease of groundnut | (2) | *Cercospora personata* |
| (R) | Late blight of potato | (3) | *Plasmodiophora brassicae* |
| (S) | White rust of mustard | (4) | *Phytophthora infestans* |
| | | (5) | *Colletotrichum falcatum* |

(A) P-1; Q-2; R-4; S-3
(B) P-5; Q-1; R-4; S-2
(C) P-5; Q-2; R-4; S-1
(D) P-5; Q-3; R-1; S-2

**Correct Answer:** (C) P-5; Q-2; R-4; S-1

**Solution:**

**Step 1: Understanding the Concept:**
Plant pathology involves the study of diseases caused by fungi, bacteria, viruses, and other pathogens.

**Step 2: Detailed Explanation:**
- **(P) Red rot of sugarcane:** Caused by the fungus ***Colletotrichum falcatum*** (5).
- **(Q) Tikka disease of groundnut:** Caused by the fungus ***Cercospora personata*** (2) (also *C. arachidicola*).
- **(R) Late blight of potato:** Caused by the oomycete ***Phytophthora infestans*** (4) (famous for the Irish Potato Famine).
- **(S) White rust of mustard:** Caused by the oomycete ***Albugo candida*** (1).

**Step 3: Final Answer:**
The matching is P-5, Q-2, R-4, S-1.

Quick Tip

Phytophthora (Late blight) and Albugo (White rust) are not "true fungi" but are oomycetes (water molds), often characterized by biflagellate zoospores.

---

**59. Correctly match the following plant species in Group-I with their main economically important products in Group-II.**

| Group-I | | Group-II | |
|---|---|---|---|
| (P) | *Gossypium arboreum* | (1) | Rubber |
| (Q) | *Dalbergia sissoo* | (2) | Spices |
| (R) | *Hevea brasiliensis* | (3) | Fibre |
| (S) | *Pelargonium graveolens* | (4) | Timber |
| | | (5) | Essential oil |

(A) P-3; Q-4; R-1; S-5
(B) P-3; Q-4; R-1; S-2
(C) P-2; Q-4; R-1; S-3
(D) P-3; Q-1; R-2; S-5

**Correct Answer:** (A) P-3; Q-4; R-1; S-5

**Solution:**

**Step 1: Understanding the Concept:**
Economic botany deals with plants that provide useful materials for human consumption, industry, and construction.

**Step 2: Detailed Explanation:**
- **(P) *Gossypium arboreum*:** One of the old-world cotton species, primarily grown for its seed hairs which provide **Fibre** (3).
- **(Q) *Dalbergia sissoo* (Shisham):** A well-known tree in South Asia valued for its high-quality, durable **Timber** (4).
- **(R) *Hevea brasiliensis*:** The Para rubber tree, the primary commercial source of natural **Rubber** (1) extracted via tapping its latex.
- **(S) *Pelargonium graveolens* (Rose Geranium):** Cultivated for its fragrant leaves, from which **Essential oil** (5) is extracted for perfumes and aromatherapy.

**Step 3: Final Answer:**
The matching is P-3, Q-4, R-1, S-5.

Quick Tip

*Hevea* = Rubber is a classic pairing. Identifying this one first often solves the whole matching question.

---

**60. Two genes $X$ and $Y$ are involved in root development in such a way that all the following three homozygous mutants show rootless phenotype.**
**(i) Gain-of-function mutant of $X$**
**(ii) Loss-of-function mutant of $Y$**
**(iii) Double mutant of gain-of-function of $X$ and loss-of-function of $Y$**
**Which one of the following genetic pathways best describes these observations?**

(A) $X$ suppresses $Y$ and $Y$ promotes root development
(B) $X$ promotes $Y$ and $Y$ promotes root development
(C) $X$ suppresses $Y$ and $Y$ suppresses root development
(D) $X$ promotes $Y$ and $Y$ suppresses root development

**Correct Answer:** (A) $X$ suppresses $Y$ and $Y$ promotes root development

**Solution:**

**Step 1: Understanding the Concept:**
Genetic epistasis and pathway analysis involve determining the hierarchical relationship between genes based on mutant phenotypes.

**Step 2: Detailed Explanation:**
1. **Analyze $Y$:** The loss-of-function ($LOF$) of $Y$ results in no roots. This indicates that the normal function of $Y$ is to **promote** root development ($Y \rightarrow$ root).
2. **Analyze $X$:** The gain-of-function ($GOF$) of $X$ results in no roots. This suggests that overactive $X$ prevents root formation. Therefore, $X$ must be an **inhibitor** of the root pathway.
3. **Analyze the hierarchy ($X \dashv Y$ or $Y \dashv X$):**
- If $X$ suppresses $Y$ ($X \dashv Y \rightarrow$ root):
- $X_{GOF} \rightarrow$ excess suppression of $Y \rightarrow$ no root. (Matches obs i)
- $Y_{LOF} \rightarrow$ no root promoter $\rightarrow$ no root. (Matches obs ii)
- $X_{GOF}Y_{LOF} \rightarrow$ both favor rootless $\rightarrow$ no root. (Matches obs iii)
4. This linear pathway ($X$ inhibits $Y$, $Y$ promotes roots) explains all observations perfectly.

**Step 4: Final Answer:**
The pathway is: $X$ suppresses $Y$, and $Y$ promotes root development.

Quick Tip

In a double mutant, if the phenotype remains the same as both individual "rootless" mutants, the genes are likely acting in the same linear pathway where $X$ inhibits the promoter $Y$.

---

**61. Which of the following combinations of photosynthetic carbon cycle in plants, and its matched biochemical reaction is/are correct?**

(A) C3 pathway : Ribulose 1,5-bisphosphate + $CO_2$ + $H_2O \rightarrow$ 2 3-phosphoglycerate
(B) C2 pathway : 2 Glycolate + 2 $O_2 \rightarrow$ 2 glyoxylate + 2 $H_2O_2$
(C) C4 pathway : 2 2-Phosphoglycolate + 2 $H_2O \rightarrow$ 2 glycolate + 2 $P_i$
(D) CAM pathway : Phosphoenolpyruvate + $HCO_3^- \rightarrow$ oxaloacetate + $P_i$

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

**Solution:**

**Step 1: Understanding the Concept:**
Plants use different carbon fixation pathways (C3, C4, CAM) depending on their environment. The C2 pathway refers to photorespiration.

**Step 2: Detailed Explanation:**
- **(A) C3 pathway:** Catalyzed by RuBisCO, RuBP combines with $CO_2$ to form two molecules of 3-PGA. This is **correct**.
- **(B) C2 pathway (Photorespiration):** In peroxisomes, Glycolate is oxidized by glycolate oxidase to Glyoxylate, producing $H_2O_2$. This is **correct**.
- **(C) C4 pathway:** The reaction shown (dephosphorylation of 2-phosphoglycolate) is actually the first step of **photorespiration** (C2 cycle) in the chloroplast, not the C4 cycle. This is **incorrect**.

- **(D) CAM / C4 pathway:** Both CAM and C4 plants initially fix carbon using PEP carboxylase, which adds bicarbonate ($HCO_3^-$) to PEP to form oxaloacetate. This is **correct**.

**Step 3: Final Answer:**
Options (A), (B), and (D) are correct.

Quick Tip

C2 pathway = Photorespiration. It starts when RuBisCO acts as an oxygenase, producing 3-PGA and phosphoglycolate.

---

**62. Choose the correct combination(s) of alkaloid, source plant, and their main commercial use.**

(A) Vincristine – *Catharanthus roseus* – anticancer drug
(B) Scopolamine – *Hyoscyamus niger* – anticholinergic drug
(C) Cocaine – *Conium maculatum* – antimalarial drug
(D) Pilocarpine – *Eschscholzia californica* – antidepressant drug

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

**Solution:**

**Step 1: Understanding the Concept:**
Alkaloids are bioactive nitrogenous compounds used extensively in medicine. Each is derived from specific plant taxa.

**Step 2: Detailed Explanation:**
- **(A) Vincristine:** Derived from the Madagascar periwinkle (*Catharanthus roseus*). It is a microtubule inhibitor used in chemotherapy for leukemia and lymphoma. **Correct**.
- **(B) Scopolamine:** Derived from plants like *Hyoscyamus niger* (Henbane). It is an **anticholinergic** drug used for motion sickness and as a preoperative sedative. **Correct**.
- **(C) Cocaine:** Derived from *Erythroxylum coca*. It is a stimulant and local anesthetic. *Conium maculatum* (Hemlock) produces **coniine**, a neurotoxin. **Incorrect**.
- **(D) Pilocarpine:** Derived from *Pilocarpus* species. It is used to treat glaucoma. *Eschscholzia californica* (California poppy) contains distinct alkaloids like californidine. **Incorrect**.

**Step 3: Final Answer:**
Only combinations (A) and (B) are scientifically accurate.

Quick Tip

Remember: Vincristine/Vinblastine = Periwinkle; Quinine = Cinchona (Antimalarial); Atropine/Scopolamine = Solanaceous plants.

---

**63. Which of the following statements is/are correct about plant movement?**

(A) Diaheliotropic refers to orienting the leaves perpendicular to the rays of the sun to maximize light interception.
(B) Paraheliotropic refers to orienting the leaves parallel to the rays of the sun to minimize light interception.
(C) Diaheliotropic refers to orienting the leaves parallel to the rays of the sun to minimize light interception.
(D) Paraheliotropic refers to orienting the leaves perpendicular to the rays of the sun to maximize light interception.

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

**Solution:**

**Step 1: Understanding the Concept:**
Heliotropism is the solar tracking movement of plant organs (usually leaves or flowers).

**Step 2: Detailed Explanation:**
- **Diaheliotropism:** This is an **active** solar tracking where the leaf blades remain **perpendicular** to the sun's rays throughout the day. This configuration maximizes the light intensity absorbed for photosynthesis. **Statement (A) is correct**.
- **Paraheliotropism:** This is an **avoidance** mechanism where leaves orient themselves **parallel** to the sun's rays. This usually happens during periods of water stress or high temperature to minimize transpiration and avoid photoinhibition. **Statement (B) is correct**.

**Step 3: Final Answer:**
Statements (A) and (B) are the correct definitions.

Quick Tip

Dia- = "Across/Through" (perpendicular); Para- = "Beside/Along" (parallel). Maximize vs Minimize.

---

**64. Two completely linked genes $A$ and $B$ regulate plant height and flower colour, respectively, wherein the recessive mutant $aa$ is dwarf bearing red flowers and the recessive mutant $bb$ is tall bearing white flowers. If an F1 individual of the**

**$aaBB \times AAbb$ cross is crossed to the mutant $aabb$, then the probability of an individual in the next generation bearing white flower would be _____ (Round off to two decimal places).**

**Correct Answer:** 0.50

**Solution:**

**Step 1: Understanding the Concept:**
Linkage describes genes that are located close together on the same chromosome and tend to be inherited together. "Complete linkage" means no crossing over occurs between the two loci.

**Step 2: Key Formula or Approach:**
Perform a test cross on the $F_1$ generation while maintaining the parental linkage configurations (cis or trans).

**Step 3: Detailed Explanation:**
1. **Identify genotypes of parents:**
- Parent 1: $aaBB$ (dwarf, red)
- Parent 2: $AAbb$ (tall, white)

2. **Find $F_1$ genotype and configuration:**
- Cross: $aaBB \times AAbb \rightarrow AaBb$.
- Since the genes are linked, the $F_1$ receives $aB$ from Parent 1 and $Ab$ from Parent 2.
- Configuration is **trans** (repulsion): $\frac{aB}{Ab}$.

3. **Test Cross ($F_1\times$ double recessive mutant):**
- $\frac{aB}{Ab} \times \frac{ab}{ab}$
- Gametes from $F_1$: $aB$ and $Ab$ (only these because linkage is **complete**).
- Gametes from mutant: $ab$.

4. **Progeny genotypes:**
- $50\% \frac{aB}{ab} \rightarrow$ Dwarf, Red flowers.
- $50\% \frac{Ab}{ab} \rightarrow$ Tall, **White flowers**.

**Step 4: Final Answer:**
The probability of bearing white flowers is 0.50.

Quick Tip

In complete linkage, the progeny always resemble the parents. Here, Parent 2 was white-flowered, so half of the test-cross progeny will be white-flowered.

**65. An enzyme following Michaelis-Menten kinetics, catalyses a reaction with an initial velocity ($V_0$) of $2\mu$M $s^{-1}$ at the substrate concentration of $10\mu$M. If the turnover number ($k_{cat}$) of the enzyme for the given substrate is 500 $s^{-1}$ and the enzyme concentration in the reaction is $0.01\mu$M, then the value of the Michaelis-Menten constant ($K_m$) would be _____ $\times 10^{-6}$ M (*in integer*).**

**Correct Answer:** 15

**Solution:**

**Step 1: Understanding the Concept:**
The Michaelis-Menten equation relates the rate of an enzymatic reaction to the substrate concentration.
The turnover number ($k_{cat}$) represents the maximum number of chemical conversions of substrate molecules per second that a single catalytic site will execute for a given enzyme concentration.
The Michaelis constant ($K_m$) is the substrate concentration at which the reaction rate is half of its maximum velocity ($V_{max}$).

**Step 2: Key Formula or Approach:**
First, we calculate the maximum velocity ($V_{max}$) using the formula:

$$V_{max} = k_{cat} \cdot [E]_t$$

Where $[E]_t$ is the total enzyme concentration.
Then, we use the Michaelis-Menten equation to find $K_m$:

$$V_0 = \frac{V_{max} \cdot [S]}{K_m + [S]}$$

**Step 3: Detailed Explanation:**
Given parameters:
Initial velocity, $V_0 = 2\mu$M $s^{-1}$
Substrate concentration, $[S] = 10\mu M = 10 \times 10^{-6}$ M
Turnover number, $k_{cat} = 500$ $s^{-1}$
Enzyme concentration, $[E]_t = 0.01\mu M = 0.01 \times 10^{-6}$ M

**Calculation of $V_{max}$:**

$$V_{max} = k_{cat} \cdot [E]_t$$

$$V_{max} = 500 \text{ s}^{-1} \times 0.01\mu M$$

$$V_{max} = 5\mu \text{M s}^{-1}$$

**Calculation of $K_{\mathbf{m}}$:**
Substitute the values into the Michaelis-Menten equation:

$$2\mu\text{M s}^{-1} = \frac{5\mu\text{M s}^{-1} \times 10\mu\text{M}}{K_{\text{m}} + 10\mu\text{M}}$$

$$2 \cdot (K_{\text{m}} + 10) = 5 \times 10$$

$$2K_{\text{m}} + 20 = 50$$

$$2K_{\text{m}} = 30$$

$$K_{\text{m}} = 15\mu\text{M}$$

Since $1\mu\text{M} = 10^{-6}$ M, the value is $15 \times 10^{-6}$ M.

**Step 4: Final Answer:**
The value of the Michaelis-Menten constant ($K_{\text{m}}$) is 15.

Quick Tip

Always ensure that the units for $V_0$ and $V_{\text{max}}$ are consistent, and that the units for $[S]$ and $K_{\text{m}}$ are consistent before solving.
In this problem, working with $\mu$M directly simplifies the calculation before converting to the final requested exponent format.

---

**66. Which one of the following statements about microbiological stains is CORRECT?**

(A) Acid-fast stain is a simple stain.
(B) Gram stain is used to visualize endospores.
(C) Methylene blue is an acidic dye.
(D) India ink is used to visualize capsules.

**Correct Answer:** (D) India ink is used to visualize capsules.

**Solution:**

**Step 1: Understanding the Concept:**
Microbiological staining techniques are used to enhance the visualization of microorganisms and their specific structures under a microscope.
Stains can be classified as simple (one dye), differential (distinguishing between types of bacteria), or structural (visualizing specific parts like capsules or spores).

**Step 2: Detailed Explanation:**
1. **Acid-fast stain (A):** This is a differential stain, not a simple stain.
It is used to identify bacteria with waxy mycolic acids in their cell walls, such as *Mycobacterium* species.
2. **Gram stain (B):** This is a differential stain used to categorize bacteria based on cell wall composition (Gram-positive vs. Gram-negative).
Endospores are visualized using specific structural stains like the Schaeffer-Fulton method (using malachite green).
3. **Methylene blue (C):** This is a basic dye, not an acidic dye.
Basic dyes have a positive charge and bind to negatively charged bacterial surfaces.
4. **India ink (D):** This is a negative staining technique.
The ink particles are too large to penetrate the dense polysaccharide capsule of organisms like *Cryptococcus neoformans*.
As a result, the capsule appears as a clear halo against a dark background, making it visible.

**Step 3: Final Answer:**
Statement (D) is correct as India ink is a standard method for negative staining of capsules.

Quick Tip

Negative stains like India ink or Nigrosin do not color the cell itself but provide contrast by darkening the background. This is ideal for delicate structures like capsules that might be distorted by heat fixing.

---

**67. The genome of which one of the following viruses encodes reverse transcriptase?**

(A) Human immunodeficiency virus
(B) Influenza virus
(C) Poliovirus
(D) Rabies virus

**Correct Answer:** (A) Human immunodeficiency virus

**Solution:**

**Step 1: Understanding the Concept:**
Reverse transcriptase (RT) is an enzyme that catalyzes the synthesis of DNA from an RNA template.
This process, known as reverse transcription, is a hallmark of Retroviruses and certain other virus families.

**Step 2: Detailed Explanation:**
1. **Human immunodeficiency virus (HIV):** It belongs to the *Retroviridae* family.
Its genome consists of single-stranded RNA (+ssRNA). Upon entering a host cell, the viral reverse transcriptase converts the RNA into double-stranded DNA, which then integrates into the host genome.
2. **Influenza virus:** It is a negative-sense RNA virus (−ssRNA). It uses an RNA-dependent RNA polymerase (RdRp) to replicate, not RT.
3. **Poliovirus:** It is a positive-sense RNA virus (+ssRNA) that replicates in the cytoplasm using its own RdRp.
4. **Rabies virus:** It is a negative-sense RNA virus (−ssRNA) that also utilizes RdRp for its replication cycle.

**Step 3: Final Answer:**
Only HIV among the given options carries and encodes the enzyme reverse transcriptase.

Quick Tip

Remember the "Central Dogma" reversal: RNA → DNA. This is specific to retroviruses (like HIV) and pararetroviruses (like Hepatitis B).

---

**68. Protoplasts can be generated from**

(A) *Streptococcus pneumoniae.*
(B) *Brucella abortus.*
(C) *Pasteurella multocida.*
(D) *Shigella flexneri.*

**Correct Answer:** (A) *Streptococcus pneumoniae.*

**Solution:**

**Step 1: Understanding the Concept:**
Protoplasts are bacterial or plant cells that have had their cell wall completely removed, usually by enzymatic treatment (like lysozyme) in an isotonic environment.
Spheroplasts, on the other hand, are cells with partially removed cell walls, typically derived from Gram-negative bacteria.

**Step 2: Detailed Explanation:**
1. **Gram-positive bacteria:** These have a thick peptidoglycan layer but no outer membrane. Treatment with lysozyme can completely digest the peptidoglycan, resulting in a naked cell membrane called a **protoplast**.
2. **Gram-negative bacteria:** These have an outer membrane in addition to a thin peptidoglycan layer. Lysozyme treatment often leaves some wall fragments or the outer membrane intact, resulting in a **spheroplast**.
3. **Analyzing the options:**
- *Streptococcus pneumoniae* is a **Gram-positive** bacterium. Thus, it can form true protoplasts.
- *Brucella abortus*, *Pasteurella multocida*, and *Shigella flexneri* are all **Gram-negative** bacteria and would form spheroplasts.

**Step 3: Final Answer:**
Protoplasts are generated from the Gram-positive organism *Streptococcus pneumoniae*.

Quick Tip

Isolate the Gram status:
Gram(+) $\rightarrow$ Protoplast (Total wall removal)
Gram(-) $\rightarrow$ Spheroplast (Partial wall removal)

---

**69. Which one of the following molecules is the master regulator of the planktonic-surface transition in *Pseudomonas aeruginosa* during biofilm formation?**

(A) Cyclic thiolactone
(B) Cyclic dimeric guanosine monophosphate
(C) Cyclic triadenylate
(D) Cyclohexamide

**Correct Answer:** (B) Cyclic dimeric guanosine monophosphate

**Solution:**

**Step 1: Understanding the Concept:**
The transition of bacteria from a free-swimming (planktonic) state to a sedentary, surface-attached community (biofilm) is highly regulated by intracellular signaling molecules.

**Step 2: Detailed Explanation:**
1. **c-di-GMP (Cyclic dimeric guanosine monophosphate):** This is a ubiquitous secondary messenger in bacteria.
High levels of c-di-GMP generally promote sessile lifestyles (biofilm formation, adhesin production) and inhibit motility.
2. In *Pseudomonas aeruginosa*, c-di-GMP levels control the switch from flagellar-mediated

swimming to surface attachment and the production of exopolysaccharides.
3. **Other options:**
- Cyclic thiolactone is involved in quorum sensing (e.g., in *Staphylococcus*).
- Cyclic triadenylate is often part of the prokaryotic antiviral (CBASS) immune system.
- Cyclohexamide is an inhibitor of eukaryotic protein synthesis.

**Step 3: Final Answer:**
The master regulator for the planktonic-to-surface switch is c-di-GMP, provided in option (B).

Quick Tip

Remember: High c-di-GMP = "Stick" (Biofilm); Low c-di-GMP = "Swim" (Motility). It is the central logic for bacterial lifestyle switches.

---

**70. Which one of the following is a protozoal disease?**

(A) Cholera
(B) Gonorrhea
(C) Kala-azar
(D) Syphilis

**Correct Answer:** (C) Kala-azar

**Solution:**

**Step 1: Understanding the Concept:**
Diseases are classified based on the type of infectious agent that causes them, such as bacteria, viruses, fungi, or protozoa (unicellular eukaryotes).

**Step 2: Detailed Explanation:**
1. **Cholera:** Caused by the bacterium *Vibrio cholerae*. (Bacterial)
2. **Gonorrhea:** Caused by the bacterium *Neisseria gonorrhoeae*. (Bacterial)
3. **Kala-azar (Visceral Leishmaniasis):** Caused by protozoan parasites of the genus *Leishmania* (e.g., *Leishmania donovani*). It is transmitted by the bite of infected sandflies. (Protozoal)
4. **Syphilis:** Caused by the bacterium *Treponema pallidum*. (Bacterial)

**Step 3: Final Answer:**
Kala-azar is the only protozoal disease in the list.

Quick Tip

Common protozoal diseases to remember: Malaria (*Plasmodium*), Kala-azar (*Leishmania*), Sleeping Sickness (*Trypanosoma*), and Amoebiasis (*Entamoeba*).

---

**71. Which one of the following drugs is a viral protease inhibitor?**

(A) Acyclovir
(B) Nevirapine
(C) Ritonavir
(D) Zidovudine

**Correct Answer:** (C) Ritonavir

**Solution:**

**Step 1: Understanding the Concept:**
Antiviral drugs, especially those used for HIV, are categorized by their mechanism of action (inhibiting specific steps in the viral life cycle).

**Step 2: Detailed Explanation:**
1. **Acyclovir:** A guanosine analog that inhibits viral DNA polymerase (primarily used for Herpes simplex).
2. **Nevirapine:** A Non-Nucleoside Reverse Transcriptase Inhibitor (NNRTI).
3. **Ritonavir:** A **Protease Inhibitor (PI)**. It binds to the viral protease, preventing the cleavage of polyprotein precursors into mature, functional viral proteins.
4. **Zidovudine (AZT):** A Nucleoside Reverse Transcriptase Inhibitor (NRTI).

**Step 3: Final Answer:**
Ritonavir is the protease inhibitor among the given options.

Quick Tip

Most protease inhibitors end with the suffix "-navir" (e.g., Ritonavir, Lopinavir, Indinavir). This makes them easy to identify in multiple-choice questions!

---

**72. In *Escherichia coli*, the minimum number of crossovers required between $F^-$ genome and the linear DNA transmitted by Hfr to form a viable recombinant is _____. (Answer in integer)**

**Correct Answer:** 2

**Solution:**

**Step 1: Understanding the Concept:**
In bacterial conjugation involving an Hfr (High Frequency of Recombination) donor and an $F^-$ recipient, a segment of linear donor DNA enters the recipient cell.

**Step 2: Key Formula or Approach:**
To maintain the circularity and integrity of the recipient's chromosome, a linear piece of DNA must integrate via a **double-crossover** event.

**Step 3: Detailed Explanation:**
1. The bacterial chromosome is circular.
2. If only one crossover occurs between a linear fragment and a circular chromosome, the circle is "broken" into a single long linear strand.
3. Linear genomic DNA is unstable in bacteria and is rapidly degraded by exonucleases.
4. Therefore, an even number of crossovers is required to exchange segments and keep the chromosome circular. The minimum even number is 2.

**Step 4: Final Answer:**
The minimum number of crossovers required is 2.

Quick Tip

Integration of a linear fragment into a circular chromosome **always** requires an even number of crossovers $(2, 4, \ldots)$ to produce a viable, circular product.

---

**73. The decimal reduction time of *Escherichia coli* at a particular temperature is one minute. Assuming no bacterial growth and constant death rate, the time required for one million bacteria to get reduced to one viable bacterium is _____ minutes. (Answer in integer)**

**Correct Answer:** 6

**Solution:**

**Step 1: Understanding the Concept:**
The decimal reduction time (D-value) is the time required, at a specific temperature, to kill 90% of the relevant microorganisms. This corresponds to a one-logarithm (1-$\log_{10}$) reduction in the population.

**Step 2: Key Formula or Approach:**
The total time required ($t$) is given by:

$$t = D \times n$$

where $D$ is the decimal reduction time and $n$ is the number of log cycles of reduction.

$$n = \log_{10}(N_0) - \log_{10}(N_t)$$

**Step 3: Detailed Explanation:**
1. **Initial population ($N_0$):** One million = $10^6$.
2. **Final population ($N_t$):** One = $10^0$.
3. **Calculate number of log cycles ($n$):**

$$n = \log_{10}(10^6) - \log_{10}(10^0) = 6 - 0 = 6$$

4. **Calculate time ($t$):**
Given $D = 1$ minute.

$$t = 1 \text{ minute} \times 6 = 6 \text{ minutes}$$

**Step 4: Final Answer:**
The time required is 6 minutes.

> Quick Tip
>
> Just count the zeros! To go from $1,000,000$ to 1, you have to cross 6 powers of 10. Multiply those 6 "steps" by the D-value to get the answer.

---

**74. Which one of the following options correctly matches the microbial names in Column I with their corresponding sources of epithet in Column II?**

| **Column I** | **Column II** |
|---|---|
| (P) *Klebsiella pneumoniae* | (i) causes stupor in mice |
| (Q) *Penicillium chrysogenum* | (ii) forms pus |
| (R) *Salmonella typhimurium* | (iii) the disease it causes |
| (S) *Streptococcus pyogenes* | (iv) produces a yellow pigment |

(A) P-i; Q-ii; R-iii; S-iv
(B) Q-i; R-ii; S-iii; P-iv
(C) R-i; S-ii; P-iii; Q-iv
(D) S-i; Q-ii; P-iii; R-iv

**Correct Answer:** (C) R-i; S-ii; P-iii; Q-iv

**Solution:**

**Step 1: Understanding the Concept:**
Biological nomenclature often uses epithets that describe the organism's morphology, metabolic products, habitat, or the disease they cause.

**Step 2: Detailed Explanation:**
1. **(P) *Klebsiella pneumoniae*:** The epithet "*pneumoniae*" refers directly to the **disease it causes** (pneumonia). Match: **P-iii**.
2. **(Q) *Penicillium chrysogenum*:** "*Chrysogenum*" comes from the Greek *chrysos* (gold) and refers to the **yellow pigment** it produces. Match: **Q-iv**.
3. **(R) *Salmonella typhimurium*:** "*Typhimurium*" implies a typhoid-like stupor (*typhos*) in mice (*mures*). Thus, it refers to **causes stupor in mice**. Match: **R-i**.
4. **(S) *Streptococcus pyogenes*:** "*Pyogenes*" is derived from *pyo* (pus) and *gen* (to form), meaning it **forms pus**. Match: **S-ii**.

**Step 3: Final Answer:**
Combining the matches: P-iii, Q-iv, R-i, S-ii. This corresponds to option (C).

Quick Tip

Break down the Latin/Greek roots:
*pneumonia* → lung disease
*chryso* → gold/yellow
*pyo* → pus
*typhus* → stupor

---

**75. Determine the correctness or otherwise of the following Assertion [a] and the Reason [r].**

**Assertion [a]: Silver and copper display bactericidal or antiseptic activity.**
**Reason [r]: Silver and copper effectively demonstrate oligodynamic action.**

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

**Solution:**

**Step 1: Understanding the Concept:**
Oligodynamic action refers to the inhibitory or lethal effect of very small amounts of heavy metals on bacteria.

**Step 2: Detailed Explanation:**
1. **Assertion [a]:** Metals like Silver (Ag) and Copper (Cu) have been known for centuries to prevent infection. They act as bactericidal agents by denaturing essential proteins and disrupting cell membranes. This is **True**.
2. **Reason [r]:** The term used for this antimicrobial effect exerted by tiny concentrations of heavy metal ions is **oligodynamic action**. This is **True**.
3. **Connection:** The assertion describes the observed biological phenomenon (antiseptic activity), and the reason explains the physiological mechanism/term for why it works at such low levels.

**Step 3: Final Answer:**
Both statements are true, and the Reason correctly explains the Assertion.

Quick Tip

Oligodynamic comes from *oligo* (small) and *dynamis* (power). Heavy metals like Hg, Ag, and Cu are toxic to microbes even at extremely low concentrations because they bind to sulfhydryl (-SH) groups in enzymes.

---

**76. When tryptophan level is low in *Escherichia coli*, the expression of tryptophan biosynthesis genes is turned on through an antiterminator stem-loop formation between**

(A) regions 1 and 2 of the leader sequence (*trpL*) of mRNA.
(B) regions 2 and 3 of the leader sequence (*trpL*) of mRNA.
(C) regions 2 and 4 of the leader sequence (*trpL*) of mRNA.
(D) regions 3 and 4 of the leader sequence (*trpL*) of mRNA.

**Correct Answer:** (B) regions 2 and 3 of the leader sequence (*trpL*) of mRNA.

**Solution:**

**Step 1: Understanding the Concept:**
Attenuation is a mechanism of transcriptional regulation in bacteria where the translation of a "leader peptide" determines whether transcription of the structural genes continues or is terminated prematurely.

**Step 2: Detailed Explanation:**
1. The *trp* operon leader mRNA has four regions (1, 2, 3, and 4) capable of forming base-paired stem-loops.
2. **Low Tryptophan Case:** The ribosome stalls at the Trp codons in **region 1** because it's waiting for Trp-tRNA. This leaves **region 2** free to pair with **region 3**.
3. The **2-3 stem-loop** is known as the **antiterminator** because it prevents region 3 from pairing with region 4.
4. Without the 3-4 terminator loop, RNA polymerase continues transcribing the operon.
5. **High Tryptophan Case:** The ribosome moves quickly through region 1, covering region 2, which allows **region 3 and 4** to pair and form the **terminator** loop, stopping transcription.

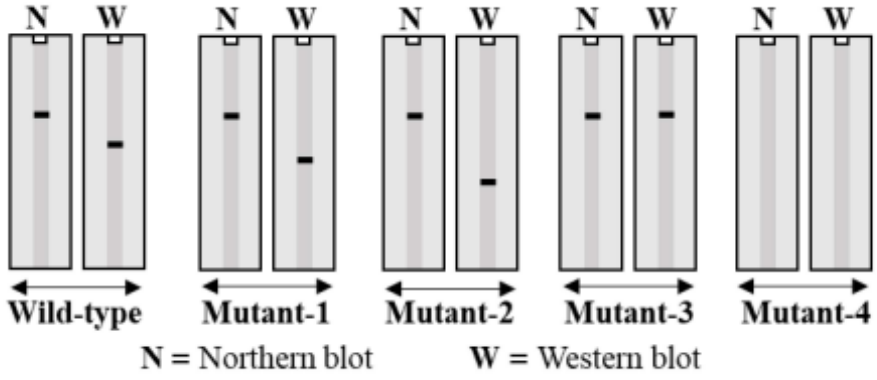
**Step 3: Final Answer:**
In low tryptophan conditions, the 2-3 stem-loop forms to allow expression.

Quick Tip

Remember:
Low Trp → 2:3 loop → GO
High Trp → 3:4 loop → STOP

---

**77. The effect of mutations in a gene at their transcriptional and translational levels were analyzed using Northern (N) and Western (W) blot techniques, respectively. The following figure shows the schematic representation of mRNA and protein expression profiles of the wild-type and its four different mutants. Which one of the following mutants contains mutation in the upstream regulatory region of the gene?**




(A) Mutant-1

(B) Mutant-2
(C) Mutant-3
(D) Mutant-4

**Correct Answer:** (D) Mutant-4

**Solution:**

**Step 1: Understanding the Concept:**
- **Northern Blot:** Detects and measures **mRNA** levels (Transcription).
- **Western Blot:** Detects and measures **protein** levels (Translation).
- The **upstream regulatory region** (Promoter) is responsible for initiating transcription.

**Step 2: Detailed Explanation:**
1. If a mutation occurs in the promoter/regulatory region, RNA polymerase cannot bind or initiate transcription correctly.
2. As a result, no mRNA is produced. This would result in an empty lane in the **Northern blot**.
3. Since there is no mRNA template, no protein can be translated. This would result in an empty lane in the **Western blot**.
4. **Analyzing the mutants based on general principles:**
- Mutant-1: Change in protein size, but mRNA is present. (Likely a frameshift/nonsense mutation within the ORF).
- Mutant-2: mRNA present, protein absent. (Likely a mutation in the translation initiation site or stability).
- Mutant-3: mRNA and protein both present. (Likely a silent or missense mutation).
- **Mutant-4:** No mRNA detected, no protein detected. This indicates a failure at the very first step—transcription.

**Step 3: Final Answer:**
Mutant-4 is the one with a mutation in the upstream regulatory region.

Quick Tip

"No mRNA = No Western". If the Northern blot is empty, the root cause is usually a promoter or transcriptional factor binding site mutation.

---

**78. Which one of the following leukocytes is the most abundant in a healthy human?**

(A) Basophils
(B) Eosinophils
(C) Monocytes
(D) Neutrophils

**Correct Answer:** (D) Neutrophils

**Solution:**

**Step 1: Understanding the Concept:**
Leukocytes (white blood cells) are classified into granulocytes and agranulocytes. Each type has a characteristic percentage in the blood differential count.

**Step 2: Detailed Explanation:**
The relative abundance of leukocytes in a healthy adult is typically:
1. **Neutrophils:** 50% to 70% (Most abundant)
2. **Lymphocytes:** 20% to 40%
3. **Monocytes:** 2% to 8%
4. **Eosinophils:** 1% to 4%
5. **Basophils:** 0.5% to 1% (Least abundant)

**Step 3: Final Answer:**
Neutrophils are the most abundant leukocytes.

Quick Tip

Use the mnemonic: "**N**ever **L**et **M**onkeys **E**at **B**ananas"
(**N**eutrophils, **L**ymphocytes, **M**onocytes, **E**osinophils, **B**asophils) to remember them in decreasing order of abundance.

---

**79. DNA amplification in the polymerase chain reaction is**

(A) linear.
(B) parabolic.
(C) sigmoidal.
(D) exponential.

**Correct Answer:** (D) exponential.

**Solution:**

**Step 1: Understanding the Concept:**
The Polymerase Chain Reaction (PCR) is a technique used to amplify a specific DNA sequence through repeated cycles of denaturation, annealing, and extension.

**Step 2: Key Formula or Approach:**
The number of DNA copies ($N$) after $n$ cycles is given by:

$$N = N_0 \times 2^n$$

where $N_0$ is the initial number of template molecules.

**Step 3: Detailed Explanation:**
1. In the first cycle, the target DNA is doubled (2 copies).
2. In the second cycle, those 2 copies serve as templates, resulting in 4 copies.
3. In the third cycle, it becomes 8, then 16, and so on.
4. This doubling in every cycle is the definition of **exponential growth**.
5. While factors like substrate depletion or enzyme degradation eventually cause the rate to plateau (making the overall curve sigmoidal in real-time PCR), the fundamental mathematical principle of the amplification process itself is exponential.

**Step 4: Final Answer:**
DNA amplification in PCR is exponential.

Quick Tip

PCR involves a $2^n$ factor. After 30 cycles, a single molecule can theoretically become $2^{30} \approx 10^9$ copies!

---

**80. In bacteriophage lambda ($\lambda$) life cycle, binding of Cro protein to $cI$ gene operator region**

(A) activates $cI$ gene expression.
(B) directs towards the lysogenic state.
(C) directs towards the lytic cycle.
(D) prevents $cI$ gene expression.

**Correct Answer:** (C) directs towards the lytic cycle.

**Solution:**

**Step 1: Understanding the Concept:**
The genetic switch in bacteriophage lambda is controlled by the balance between two repressor proteins: CI (the lambda repressor) and Cro (Control of Repressor and Other things).
The decision between the lytic and lysogenic cycles depends on which of these proteins occupies the operator regions ($O_R$ and $O_L$) first.

**Step 2: Detailed Explanation:**
1. **The CI Protein:** It promotes the lysogenic state by binding to $O_R1$ and $O_R2$ with high affinity, which represses the lytic promoter $P_R$ and activates its own promoter $P_{RM}$ to maintain high levels of CI.
2. **The Cro Protein:** It is the "lytic master" protein. It binds most strongly to the $O_R3$ site of the right operator.

3. **Binding at $O_R3$:** When Cro binds to $O_R3$, it physically blocks the promoter $P_{RM}$. Since $P_{RM}$ is the promoter responsible for $cI$ gene transcription during maintenance, Cro effectively prevents the synthesis of the CI repressor.
4. **Result:** Without the CI repressor, the lytic promoters ($P_L$ and $P_R$) remain active, leading to the expression of genes required for viral replication, head/tail assembly, and host cell lysis. Thus, binding of Cro to the operator region directly **directs the phage towards the lytic cycle**.

**Step 4: Final Answer:**
Binding of Cro represses $cI$ expression, thereby directing the phage into the lytic cycle.

Quick Tip

Remember: **CI = Lysogeny** (Stable) and **Cro = Lysis** (Host destruction). They act as a molecular toggle switch where each protein inhibits the synthesis of the other.

---

**81. Which of the following is/are ring(s) of bacterial flagellum?**

(A) C ring
(B) L ring
(C) P ring
(D) Z ring

**Correct Answer:** (A, B, C) C ring, L ring, and P ring

**Solution:**

**Step 1: Understanding the Concept:**
The bacterial flagellum is a complex motor-driven organelle. Its basal body consists of several rings that anchor the flagellum to the cell envelope and facilitate rotation.

**Step 2: Detailed Explanation:**
The structure of the basal body varies slightly between Gram-positive and Gram-negative bacteria. In Gram-negative bacteria (like *E. coli*), there are four main rings:
1. **L ring:** Associated with the outer **L**ipopolysaccharide membrane.
2. **P ring:** Associated with the **P**eptidoglycan layer.
3. **S-M ring:** Associated with the **S**upramembrane and cytoplasmic **M**embrane.
4. **C ring:** The **C**ytoplasmic ring (or rotor) located in the cytoplasm, which interacts with the stator (Mot proteins) to generate torque.
5. **Z ring:** This is NOT part of the flagellum. The Z-ring is a structure formed by the protein **FtsZ** at the mid-cell during bacterial cytokinesis (cell division).

**Step 4: Final Answer:**
Options (A), (B), and (C) are correct components of the flagellar basal body.

Quick Tip

Mnemonic for Flagellar Rings: **L-P-S-M-C**.
**L** (Lipid), **P** (Peptidoglycan), **S** (Space), **M** (Membrane), **C** (Cytoplasm). Gram-positive bacteria lack the L and P rings because they have no outer membrane.

---

**82. Which of the following bacteria is/are uncultivable?**

(A) *Borrelia burgdorferi*
(B) *Leptospira interrogans*
(C) *Mycobacterium leprae*
(D) *Treponema pallidum*

**Correct Answer:** (C, D) *Mycobacterium leprae* and *Treponema pallidum*

**Solution:**

**Step 1: Understanding the Concept:**
"Uncultivable" in microbiology usually refers to bacteria that cannot be grown in cell-free artificial laboratory media (like agar or broth). These organisms often require living hosts or specialized intracellular conditions for replication.

**Step 2: Detailed Explanation:**
1. ***Mycobacterium leprae*:** The causative agent of leprosy is an obligate intracellular parasite. To this day, it has not been successfully cultured in artificial media. It is typically grown in animal models like the nine-banded armadillo or mouse footpads.
2. ***Treponema pallidum*:** The causative agent of syphilis is also an obligate human pathogen. It is highly sensitive to oxygen and environment. It cannot be grown on standard agar or broth and is maintained in the laboratory through serial passage in rabbit testes.
3. ***Borrelia burgdorferi*:** While difficult to grow, it **can** be cultured in specialized, complex liquid media like BSK (Barbour-Stoenner-Kelly) medium.
4. ***Leptospira interrogans*:** It can be cultured in specialized media such as EMJH (Ellinghausen-McCullough-Johnson-Harris) medium.

**Step 4: Final Answer:**
*M. leprae* and *T. pallidum* are the classic examples of uncultivable bacterial pathogens.

Quick Tip

Always look for *M. leprae* and *T. pallidum* in "uncultivable" questions. They are the standard exceptions to Koch's postulates because they cannot be isolated in pure culture on artificial media.

---

**83. Which of the following antibiotic(s) inhibit(s) bacterial protein synthesis?**

(A) Erythromycin
(B) Tetracycline
(C) Bacitracin
(D) Vancomycin

**Correct Answer:** (A, B) Erythromycin and Tetracycline

**Solution:**

**Step 1: Understanding the Concept:**
Antibiotics are classified based on their mechanism of action. Key targets include cell wall synthesis, protein synthesis (translation), nucleic acid synthesis, and metabolic pathways.

**Step 2: Detailed Explanation:**
1. **Erythromycin:** This is a macrolide antibiotic. It binds to the **50S subunit** of the bacterial ribosome and inhibits translocation (the movement of tRNA from the A site to the P site). Thus, it inhibits protein synthesis.
2. **Tetracycline:** This binds to the **30S subunit** of the ribosome. It prevents the binding of aminoacyl-tRNA to the A site, thereby stopping the addition of new amino acids to the polypeptide chain. Thus, it inhibits protein synthesis.
3. **Bacitracin:** It inhibits **cell wall synthesis** by blocking the dephosphorylation of the lipid carrier bactoprenol, which is essential for transporting peptidoglycan precursors across the membrane.
4. **Vancomycin:** It inhibits **cell wall synthesis** by binding to the D-Ala-D-Ala terminus of the nascent peptidoglycan chain, preventing transpeptidation (cross-linking).

**Step 4: Final Answer:**
Options (A) and (B) are protein synthesis inhibitors.

Quick Tip

Protein synthesis inhibitors mnemonic:
**30S: A**minoglycosides, **T**etracyclines (**AT** 30).
**50S: C**hloramphenicol, **E**rythromycin (Macrolides), **L**incosamides (**CEL** at 50).

---

**84. Scientist(s) who contributed in disproving the theory of spontaneous generation is/are**

(A) Ferdinand Cohn.
(B) John Needham.
(C) John Tyndall.
(D) Louis Pasteur.

**Correct Answer:** (C, D) John Tyndall and Louis Pasteur

**Solution:**

**Step 1: Understanding the Concept:**
The theory of Spontaneous Generation (Abiogenesis) suggested that living organisms could arise from non-living matter. This was famously disproved in the 19th century through various rigorous experiments.

**Step 2: Detailed Explanation:**
1. **Louis Pasteur (1861):** He conducted the famous **swan-neck flask** experiment. He showed that boiled broth in a flask with a curved neck remained sterile because dust and microbes were trapped in the curve. When the flask was tilted, microbes entered, and the broth spoiled, proving that life comes from pre-existing life (Biogenesis).
2. **John Tyndall (1877):** He addressed the inconsistencies in Pasteur's results by discovering that some bacteria exist in heat-resistant forms (endospores). He developed the process of **Tyndallization** (fractional sterilization) and showed that dust-free air did not allow microbial growth, providing the final blow to spontaneous generation.
3. **Ferdinand Cohn:** He is credited with the discovery and classification of bacterial **endospores**, which helped Tyndall explain why some broths required multiple boilings, but he is not primarily cited as the person who "disproved" spontaneous generation.
4. **John Needham:** He actually **supported** the theory of spontaneous generation through flawed experiments with boiled mutton gravy.

**Step 4: Final Answer:**
Pasteur and Tyndall are the primary scientists responsible for disproving spontaneous generation.

Quick Tip

Spontaneous Generation Timeline:
1. Redi (Meat/Magots) - Disproved for macro-organisms.
2. Spallanzani (Sealed flasks) - Challenged it.
3. **Pasteur** (Swan-neck) - Disproved for microbes.
4. **Tyndall** (Endospores) - Final proof.

---

**85. A researcher sets up ten large outdoor tanks, each containing the same amount of algae and the same number of guppies (herbivorous fish). In five of these tanks, she also adds gourami fish, which are predators of guppies. Tanks were covered in mesh so no new species could enter. After 2 months, the researcher counted the number of guppies and gouramies, and measured the amount of algae. She found that the amount of algae was much higher in the tanks with gourami fish compared to those without gourami fish. Which one of the following processes best explains the differences in amounts of algae between these tanks?**

(A) Competition-colonisation trade-off
(B) Competitive exclusion principle
(C) Interference competition
(D) Trophic cascade

**Correct Answer:** (D) Trophic cascade

**Solution:**

**Step 1: Understanding the Concept:**
In ecology, a trophic cascade is an indirect interaction that can control entire ecosystems. It occurs when predators in a food web suppress the abundance or alter the behavior of their prey, thereby releasing the next lower trophic level from predation (or herbivory).

**Step 2: Detailed Explanation:**
1. **The Food Chain:** The system described is: **Gourami** (Predator) $\rightarrow$ **Guppy** (Herbivore) $\rightarrow$ **Algae** (Primary Producer).
2. **Experimental Observations:**
- **Without Gourami:** Guppy population is high $\rightarrow$ They eat lots of Algae $\rightarrow$ Algae levels are **Low**.
- **With Gourami:** Gouramis eat Guppies $\rightarrow$ Guppy population **Decreases** $\rightarrow$ Herbivory pressure on Algae is **Reduced** $\rightarrow$ Algae levels become **High**.
3. **Result:** The presence of the top predator (Gourami) has a positive indirect effect on the primary producer (Algae) by controlling the herbivore. This "top-down" control is the definition of a **trophic cascade**.

**Step 4: Final Answer:**
The observed increase in algae due to predator addition is explained by a trophic cascade.

Quick Tip

Trophic Cascade = "The enemy of my enemy is my friend."
Predator (+) $\rightarrow$ Herbivore (−) $\rightarrow$ Plant (+).
The effect ripples down the food chain through alternating positive and negative impacts.

---

**86. Immunoglobulins are classified into the following isotypes: IgG, IgM, IgA, IgD, IgE. What region of the immunoglobulin is used to determine this classification?**

(A) The constant region of the heavy chain only
(B) The constant region of the light chain only
(C) The variable region of both the heavy and light chains
(D) The constant region of both the heavy and light chains

**Correct Answer:** (A) The constant region of the heavy chain only

**Solution:**

**Step 1: Understanding the Concept:**
Immunoglobulins (antibodies) consist of two identical heavy chains and two identical light chains. Classification into isotypes (classes) is based on structural differences that determine the biological effector functions of the molecule.

**Step 2: Detailed Explanation:**
1. **Heavy Chains:** There are five types of heavy chains in mammals, designated by Greek letters: $\gamma$ (gamma), $\mu$ (mu), $\alpha$ (alpha), $\delta$ (delta), and $\epsilon$ (epsilon).
2. **Isotype Determination:** The specific type of **constant region (CH domains)** in the heavy chain determines the class of the antibody:
- $\gamma$ heavy chain $\rightarrow$ **IgG**
- $\mu$ heavy chain $\rightarrow$ **IgM**
- $\alpha$ heavy chain $\rightarrow$ **IgA**
- $\delta$ heavy chain $\rightarrow$ **IgD**
- $\epsilon$ heavy chain $\rightarrow$ **IgE**
3. **Light Chains:** Light chains only have two types ($\kappa$ and $\lambda$), and they do **not** determine the isotype.
4. **Variable Regions:** These determine the antigen-binding specificity (idiotype), not the class or isotype.

**Step 4: Final Answer:** Antibody classification is exclusively determined by the heavy chain constant region.

Quick Tip

Think of the **Constant Heavy** ($CH$) region as the "ID card" of the antibody. It tells the immune system what **class** it belongs to and what its **job** (function) is, while the variable region tells it **who** to attack (specificity).

---

**87. Correctly match the cell types in Column I to their primary function in Column II.**

| Column I | Column II |
|---|---|
| P) Melanocyte | 1) Muscle contraction |
| Q) Myocyte | 2) Pigment production |
| R) Granulosa | 3) Antibody production |
| S) B-cell | 4) Estrogen secretion |

(A) P−1; Q−3; R−2; S−4
(B) P−2; Q−1; R−4; S−3
(C) P−1; Q−2; R−3; S−4
(D) P−2; Q−3; R−4; S−1

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

**Solution:**

**Step 1: Understanding the Concept:**
Multicellular organisms have specialized cells adapted to perform specific physiological tasks. These are defined by the proteins they express.

**Step 2: Detailed Explanation:**
- **P) Melanocytes:** These are specialized cells in the skin, hair, and eyes that synthesize the pigment **melanin**. Therefore, their primary function is **pigment production** (2).
- **Q) Myocytes:** These are muscle cells. Their cytoplasm contains contractile proteins (actin and myosin) that allow for **muscle contraction** (1).
- **R) Granulosa cells:** These are the somatic cells of the ovarian follicle. They respond to FSH and produce **estrogen** (specifically estradiol) during the follicular phase. Therefore, their function is **estrogen secretion** (4).
- **S) B-cells (B lymphocytes):** These are key components of adaptive immunity. Upon activation and differentiation into plasma cells, they are responsible for **antibody production** (3).

**Step 4: Final Answer:**
The correct matching is P-2, Q-1, R-4, S-3, which corresponds to option (B).

Quick Tip

Match the most obvious ones first to eliminate options. **Melan**ocyte → **Melan**in (pigment) and **Myo**cyte → **Myo**sin (muscle). This usually narrows the answer down to one choice.

---

**88. Which one of the following groups includes at least one animal that is NOT an arthropod?**

(A) Group 1: crustaceans, scorpions, mites, insects
(B) Group 2: trilobites, horseshoe crabs, centipedes
(C) Group 3: millipedes, horseshoe crabs, sponges, earthworms
(D) Group 4: butterflies, moths, beetles

**Correct Answer:** (C) Group 3: millipedes, horseshoe crabs, sponges, earthworms

**Solution:**

**Step 1: Understanding the Concept:**
Phylum Arthropoda is the largest phylum in the animal kingdom. Its members are characterized by an exoskeleton made of chitin, a segmented body, and jointed appendages.

**Step 2: Detailed Explanation:**
1. **Phylum Arthropoda includes:** Insects (butterflies, beetles), Crustaceans (crabs, shrimp), Arachnids (scorpions, mites, spiders), Myriapods (centipedes, millipedes), and extinct Trilobites.
2. **Evaluating the Groups:**
- **Group 1:** All are arthropods.
- **Group 2:** All are arthropods (Horseshoe crabs are Chelicerates).
- **Group 3: Sponges** belong to Phylum **Porifera**. **Earthworms** belong to Phylum **Annelida**. Neither is an arthropod.
- **Group 4:** All are insects, which are arthropods.

**Step 4: Final Answer:**
Group 3 contains non-arthropod animals (sponges and earthworms).

Quick Tip

Remember: Earthworms are **segmented worms** (Annelida). They have a soft body and hydrostatic skeleton, unlike the hard chitinous exoskeleton of arthropods.

---

**89. Females of many insect species mate with multiple different males. Which of the following is/are an adaptive explanation(s) for multiple mating in insects?**

(A) Females obtain more resources by mating with multiple males
(B) Multiple mating increases the genetic variation among the offspring
(C) Multiple mating increases the probability of fertilization
(D) Multiple mating increases relatedness among the offspring

**Correct Answer:** (A, B, C)

**Solution:**

**Step 1: Understanding the Concept:**
Polyandry (females mating with multiple males) is common in many animal taxa. It provides both direct (material) and indirect (genetic) fitness benefits to the female.

**Step 2: Detailed Explanation:**
1. **Direct Benefits (A):** In many insects, males provide "nuptial gifts" (spermatophores containing nutrients). Mating with multiple males allows the female to accumulate more resources for egg production. Thus, (A) is correct.
2. **Genetic Benefits (B):** By mating with different males, a female produces a brood with

higher **genetic diversity** (different fathers). This can be a "bet-hedging" strategy in unpredictable environments. Thus, (B) is correct.
3. **Fertility Assurance (C):** Mating multiple times ensures that the female receives sufficient viable sperm to fertilize all her eggs, reducing the risk of "sperm depletion" from a single subfertile male. Thus, (C) is correct.
4. **Relatedness (D):** Multiple mating **decreases** the average relatedness among offspring (they become half-siblings instead of full-siblings). Therefore, (D) is **incorrect**.

**Step 4: Final Answer:**
Options (A), (B), and (C) provide adaptive evolutionary advantages for multiple mating.

Quick Tip

In evolutionary biology, "adaptive" means it increases **fitness**. Genetic diversity is almost always a positive adaptation in varying environments, while increased relatedness between siblings is generally **not** a direct benefit of multiple mating.

---

**90. Which one or more of the following terms describe(s) *Toxoplasma gondii*?**

(A) Virus
(B) Parasite
(C) Bacteria
(D) Fungus

**Correct Answer:** (B) Parasite

**Solution:**

**Step 1: Understanding the Concept:**
*Toxoplasma gondii* is a globally prevalent infectious agent. Classification depends on its cellular structure and lifestyle.

**Step 2: Detailed Explanation:**
1. *Toxoplasma gondii* is a unicellular, **eukaryotic** organism. It belongs to the Phylum **Apicomplexa**.
2. It is an **obligate intracellular parasite**. It requires a host (definitive hosts are felines, intermediate hosts include humans and other mammals) to complete its life cycle.
3. It is not a virus (it has complex cellular machinery and organelles like the apicoplast).
4. It is not a bacterium (it has a nucleus and membrane-bound organelles).
5. It is not a fungus (its genetics and structural features are distinct protozoal traits).

**Step 4: Final Answer:**
The most accurate descriptive term for *T. gondii* among the choices is **parasite**.

Quick Tip

*Toxoplasma gondii* is a **Protozoan Parasite**. Apicomplexans are famous for being parasites; other members include *Plasmodium* (Malaria) and *Cryptosporidium*.

---

**91. Which of the following statements is/are NOT correct about the technique used in molecular biology?**

(A) Southern blotting is used to detect specific DNA sequences
(B) Northern blotting is used to detect RNA expression levels
(C) Western blotting is used to detect proteins using antibodies
(D) ELISA is used to detect specific DNA sequences directly without antibodies

**Correct Answer:** (D) ELISA is used to detect specific DNA sequences directly without antibodies

**Solution:**

**Step 1: Understanding the Concept:**
Molecular biology utilizes various "blotting" and "assay" techniques to identify and quantify biological macromolecules (DNA, RNA, Proteins).

**Step 2: Detailed Explanation:**
1. **Southern Blot (A):** Uses DNA-DNA hybridization with a labeled probe to detect **specific DNA sequences**. This is **correct**.
2. **Northern Blot (B):** Uses DNA/RNA-RNA hybridization to detect specific **RNA** sequences and measure gene expression levels. This is **correct**.
3. **Western Blot (C):** Uses **specific antibodies** to identify and quantify **proteins** separated by electrophoresis. This is **correct**.
4. **ELISA (D):** Stands for **E**nzyme-**L**inked **I**mmuno**s**orbent **A**ssay. It is a plate-based assay used to detect **antigens or antibodies** in a sample. It relies **heavily on antibodies** and is NOT used to detect DNA sequences directly. To detect DNA, we use PCR, Southern blot, or Sequencing.

**Step 4: Final Answer:**
Statement (D) is incorrect.

Quick Tip

Mnemonic: **SNOW DROP**.
**S**outhern → **D**NA
**N**orthern → **R**NA
(O) → (O)
**W**estern → **P**rotein

**92. Assume that in the oxidative branch of the pentose phosphate pathway, each glucose-6-phosphate molecule generates the following products: 2 molecules of NADPH, 1 molecule of $CO_2$ and 1 molecule of ribulose-5-phosphate.**

**If 30 molecules of glucose-6-phosphate enter this pathway, and you randomly draw one molecule from the products of the pathway, the probability that this molecule is NADPH is _____ (round off to one decimal place).**

**Correct Answer:** 0.5

**Solution:**

**Step 1: Understanding the Concept:**
The oxidative phase of the Pentose Phosphate Pathway (PPP) is responsible for generating NADPH for biosyntheses. The stoichiometry of the reaction determines the total number of product molecules formed.

**Step 2: Key Formula or Approach:**
Probability of drawing a specific molecule ($P$) is:

$$P = \frac{\text{Number of specific molecules}}{\text{Total number of all product molecules}}$$

**Step 3: Detailed Explanation:**
1. **Product per molecule of Glucose-6-Phosphate (G6P):**
- NADPH: 2 molecules
- $CO_2$: 1 molecule
- Ribulose-5-phosphate: 1 molecule
- **Total products per G6P** $= 2 + 1 + 1 = 4$ molecules.

2. **Calculation for 30 molecules of G6P:**
- Total NADPH molecules $= 30 \times 2 = 60$.
- Total $CO_2$ molecules $= 30 \times 1 = 30$.
- Total Ribulose-5-phosphate molecules $= 30 \times 1 = 30$.
- **Grand total of all molecules in the product pool** $= 60 + 30 + 30 = 120$ molecules.

3. **Calculate Probability of drawing NADPH:**

$$P(\text{NADPH}) = \frac{60}{120} = 0.5$$

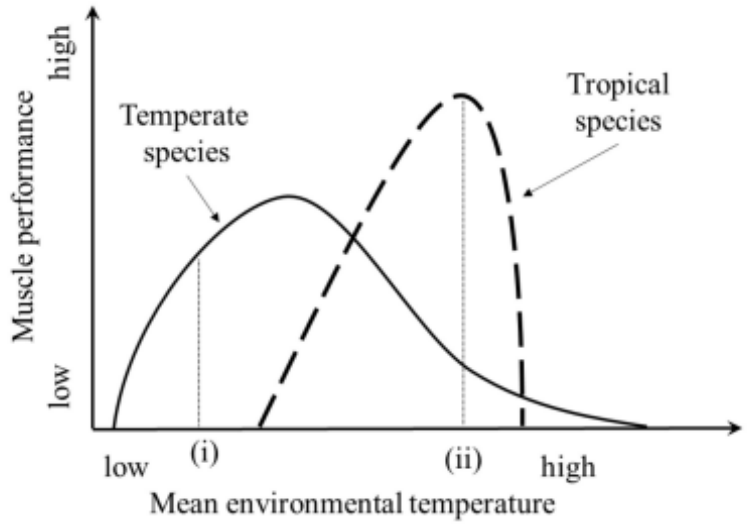
**Step 4: Final Answer:**
The probability is 0.5.

Quick Tip

Stoichiometry is constant. Since half of the product molecules produced per G6P are NADPH (2 out of 4), the probability of drawing one will always be 0.5, regardless of how many G6P molecules enter the pathway.

---

**93. Muscle performance is positively correlated with Darwinian fitness. The graph below describes the relationship between mean environmental temperature and muscle performance for two closely related lizard species, one living in temperate areas (solid line) and another living in tropical areas (dashed line). Current mean environmental temperatures are marked with vertical dotted lines at (i) for the temperate species and (ii) for the tropical species. If mean environmental temperatures at both locations increase at a steady rate over time, which one of the following is most likely to occur in the near future?**




(A) Temperate and tropical species will be negatively impacted to the same extent
(B) Temperate species may be positively impacted but tropical species will be negatively impacted
(C) Temperate species will be negatively impacted but tropical species will be positively impacted
(D) Neither temperate nor tropical species will be impacted

**Correct Answer:** (C) Temperate species will be negatively impacted but tropical species will be positively impacted

**Solution:**

**Step 1: Understanding the Concept:**
This question explores physiological adaptation to temperature. Performance curves (thermal performance breadths) typically show an optimum temperature where performance is maximized.

If the current environmental temperature is below the optimum, an increase in temperature improves performance.
If the current temperature is at or near the optimum, further increases push the organism into the stressful decline phase of the curve.

**Step 2: Detailed Explanation:**
1. **Temperate Species (Solid Line):** The current temperature (i) is located exactly at or very close to the peak of the performance curve for the temperate species.
As temperatures increase from (i), the lizard moves down the right side of its performance curve, leading to a decrease in muscle performance. This constitutes a negative impact.
2. **Tropical Species (Dashed Line):** The current temperature (ii) is located on the upward slope to the left of the peak for the tropical species.
As temperatures increase from (ii), the lizard moves towards its thermal optimum, leading to an increase in muscle performance. This constitutes a positive impact.

**Step 3: Final Answer:**
Based on the positioning of (i) and (ii) on the respective curves, temperate species will face a decline in fitness (negative impact), while tropical species will experience an increase in fitness (positive impact) as they approach their optimum.

Quick Tip

Always identify if the current environment is to the left (sub-optimal), center (optimal), or right (stressful) of the performance peak. Shifting to the right from the peak is always detrimental.

---

**94. In eukaryotic cells, a mutation reduces the enzymatic activity of pyruvate dehydrogenase by 90%, without affecting expression. Under aerobic conditions, which one of the following metabolic changes is most expected in cells with the mutation compared to cells without?**

(A) Mutated cells will accumulate pyruvate and increase lactate production, despite oxygen being available
(B) Mutated cells will have higher metabolic flux through Krebs cycle, resulting in higher NADH yield
(C) This mutation will have no effect on metabolism
(D) Mutated cells will have depleted levels of pyruvate and lactate, despite oxygen being available

**Correct Answer:** (A) Mutated cells will accumulate pyruvate and increase lactate production, despite oxygen being available

**Solution:**

**Step 1: Understanding the Concept:**
Pyruvate Dehydrogenase (PDH) is the key link between glycolysis and the Citric Acid (Krebs) Cycle. It converts pyruvate into acetyl-CoA within the mitochondria.

**Step 2: Detailed Explanation:**
1. In normal cells under aerobic conditions, pyruvate produced by glycolysis is transported into the mitochondria and converted to acetyl-CoA by PDH to enter the Krebs cycle.
2. In mutated cells where PDH activity is severely reduced (90% reduction), the rate of conversion of pyruvate to acetyl-CoA becomes a bottleneck.
3. Consequently, pyruvate accumulates in the cytosol. To regenerate the $NAD^+$ needed to keep glycolysis running, the cell diverts the excess pyruvate to lactate via the enzyme Lactate Dehydrogenase (LDH).
4. This phenomenon is similar to the Warburg effect or anaerobic fermentation, but here it occurs because of enzymatic deficiency rather than a lack of oxygen.

**Step 3: Final Answer:**
The lack of PDH activity forces the cell to use the lactic acid pathway even in the presence of oxygen, leading to pyruvate and lactate accumulation.

Quick Tip

When the "bridge" (PDH) between Glycolysis and the Krebs cycle is broken, the cell treats the situation like hypoxia because the Krebs cycle cannot be fueled efficiently.

---

**95. Which one of the following describes the role of enhancers in eukaryotic gene regulation?**

(A) Enhancers always lie immediately upstream of the promoter and function only in a fixed orientation
(B) Enhancers can act at variable distances from the promoters and may function upstream, downstream, or within introns of genes
(C) Enhancers directly bind to RNA polymerase II to initiate transcription
(D) Enhancers overlap with the RNA polymerase II binding site

**Correct Answer:** (B) Enhancers can act at variable distances from the promoters and may function upstream, downstream, or within introns of genes

**Solution:**

**Step 1: Understanding the Concept:**
Enhancers are cis-acting DNA sequences that increase the rate of transcription of a gene. They are a primary component of complex eukaryotic gene regulation.

**Step 2: Detailed Explanation:**
1. **Distance Independence:** Unlike promoters, which must be immediately upstream of the

transcription start site, enhancers can be located thousands of base pairs away from the gene they regulate.
2. **Position/Orientation Independence:** They can function effectively whether they are located 5' (upstream) or 3' (downstream) to the gene, or even within the introns of the gene itself. They also function regardless of their orientation ($5' \to 3'$ or $3' \to 5'$).
3. **Mechanism:** They bind specific transcription factors (activators) which then interact with the general transcription machinery at the promoter through DNA looping, often mediated by the Mediator complex. They do not directly bind RNA Pol II in the absence of other factors.

**Step 3: Final Answer:**
Option (B) correctly summarizes the flexible nature of enhancer positioning and function.

Quick Tip

Think of enhancers as "remote controls" for genes. They don't need to be right next to the "TV" (promoter) and work from any angle (orientation) as long as they can send a signal (looping).

---

**96. Retes are networks of outgoing arteries and returning veins that create a counter-current pattern. Retes in the flippers of seals that live in temperate areas function as**

(A) sensitivity enhancers to increase pain sensitivity in the flippers.
(B) metabolism blockers to prevent excess nutrients from being made in the flippers.
(C) heat blocks to prevent body heat from being lost to the flippers.
(D) pressure enhancers to spike blood pressure in the flippers.

**Correct Answer:** (C) heat blocks to prevent body heat from being lost to the flippers.

**Solution:**

**Step 1: Understanding the Concept:**
Counter-current heat exchange is a biological mechanism used by endotherms to conserve core body heat in cold environments. It involves the transfer of heat between blood vessels flowing in opposite directions.

**Step 2: Detailed Explanation:**
1. In marine mammals like seals, the flippers have a high surface-area-to-volume ratio, making them sites of high heat loss to the cold water.
2. To prevent this, arteries carrying warm blood from the core to the flippers are surrounded by a network of veins (the *rete mirabile*) carrying cold blood back from the flippers.
3. Heat is transferred from the warm arterial blood to the cool venous blood before it reaches the extremity.
4. This "pre-warms" the blood returning to the heart and "pre-cools" the blood going to the

flipper, effectively keeping the heat trapped in the body core.

**Step 3: Final Answer:**
The retes act as a thermal barrier or heat block to maintain core temperature.

> Quick Tip
>
> Counter-current exchange is a universal engineering principle in biology used for heat (seals, tuna), oxygen (fish gills), and concentration gradients (kidney loop of Henle).

---

**97. Researchers measure the activity of an enzyme in the presence of an inhibitor. They observe that**
• $V_{max}$ **of the enzyme remains unchanged at saturating substrate concentration**
• $K_m$ **increases compared to uninhibited enzyme**
**Which type of inhibition is most consistent with these observations?**

(A) Competitive inhibition
(B) Non-competitive inhibition
(C) Irreversible inhibition
(D) Substrate inhibition

**Correct Answer:** (A) Competitive inhibition

**Solution:**

**Step 1: Understanding the Concept:**
Enzyme inhibition patterns are identified by their effects on Michaelis-Menten kinetic parameters ($V_{max}$ and $K_m$).

**Step 2: Detailed Explanation:**
1. **Competitive Inhibition:** The inhibitor competes with the substrate for the active site. At very high (saturating) substrate concentrations, the substrate "out-competes" the inhibitor, allowing the enzyme to reach its original $V_{max}$. However, it takes more substrate to reach half-maximal velocity, so the $K_m$ **increases**.
2. **Non-competitive Inhibition:** The inhibitor binds to a site other than the active site. It reduces the overall turnover number of the enzyme regardless of substrate concentration, leading to a **decrease in** $V_{max}$, while $K_m$ **remains unchanged**.
3. **Uncompetitive Inhibition:** The inhibitor binds only to the enzyme-substrate (ES) complex, decreasing both $V_{max}$ and $K_m$.

**Step 3: Final Answer:**
The combination of unchanged $V_{max}$ and increased $K_m$ is the classic signature of competitive inhibition.

Quick Tip

Mnemonic: **C**ompetitive = **C**onstant $V_{max}$, **C**hanged $K_m$ (up).
**N**on-competitive = **N**ormal $K_m$, **N**ot-normal $V_{max}$ (down).

---

**98. Below are the numbers of individuals of migratory green warblers and the frequencies of three genotypes at a single locus for this species. F refers to the allele for faster migration and S to the allele for slower migration.**

| | **FF** | **FS** | **SS** | Total |
|---|---|---|---|---|
| Number of individuals | 35 | 20 | 10 | 65 |
| Genotype frequencies | 0.54 | 0.30 | 0.16 | 1 |

**What are the allele frequencies of F and S? (round off to 2 decimal places)**

(A) Allele frequency of F = 0.69 and allele frequency of S = 0.31
(B) Allele frequency of F = 0.59 and allele frequency of S = 0.41
(C) Allele frequency of F = 0.31 and allele frequency of S = 0.69
(D) Allele frequency of F = 0.50 and allele frequency of S = 0.50

**Correct Answer:** (A) Allele frequency of F = 0.69 and allele frequency of S = 0.31

**Solution:**

**Step 1: Understanding the Concept:**
Allele frequencies represent the proportion of a specific allele among all alleles for that locus in a population.

**Step 2: Key Formula or Approach:**
The frequency of an allele can be calculated from genotype frequencies $(D, H, R)$ as follows:

$$p = f(\text{Dominant Allele}) = D + \frac{1}{2}H$$

$$q = f(\text{Recessive Allele}) = R + \frac{1}{2}H$$

Alternatively, using raw counts ($N$ is total individuals):

$$p = \frac{2 \times (\text{number of homozygotes}) + (\text{number of heterozygotes})}{2 \times N}$$

**Step 3: Detailed Explanation:**
Total individuals $(N) = 65$. Total alleles $= 65 \times 2 = 130$.

1. **Calculation for F allele frequency ($p$):**
Using raw counts:

$$p = \frac{(2 \times 35) + 20}{130} = \frac{70 + 20}{130} = \frac{90}{130} \approx 0.6923$$

Using frequencies:

$$p = 0.54 + \frac{0.30}{2} = 0.54 + 0.15 = 0.69$$

2. **Calculation for S allele frequency ($q$):**

$$q = 1 - p = 1 - 0.69 = 0.31$$

Verify using raw counts:

$$q = \frac{(2 \times 10) + 20}{130} = \frac{20 + 20}{130} = \frac{40}{130} \approx 0.3077 \approx 0.31$$

**Step 4: Final Answer:**
The allele frequencies are F = 0.69 and S = 0.31.

> Quick Tip
>
> Allele frequency is always: "All of the homozygote frequency plus half of the heterozygote frequency." It's a quick calculation that works regardless of whether the population is in Hardy-Weinberg equilibrium.

---

**99. A drug was developed to inhibit histone acetyl transferase in eukaryotic cells. Cells treated with this drug have more compact chromatin and show reduction in transcription of several genes. Which of the following statements best explains why the drug has this effect?**

(A) Histone acetylation increases positive charge on histones, thereby tightening DNA binding and repressing transcription
(B) Histone H1 directly binds the nucleosome core and its acetylation directly causes nucleosome disassembly
(C) Histone acetylation neutralizes positive charge on histones, thereby loosening DNA-histone interactions and promoting transcription
(D) Euchromatin is normally condensed, so reduced acetylation of histones converts it into a transcriptionally active state

**Correct Answer:** (C) Histone acetylation neutralizes positive charge on histones, thereby loosening DNA-histone interactions and promoting transcription

**Solution:**

**Step 1: Understanding the Concept:**
Histone acetylation is a major epigenetic modification that regulates chromatin structure. DNA is negatively charged, while histones are rich in basic amino acids (Lysine, Arginine) that are positively charged.

**Step 2: Detailed Explanation:**
1. Histone Acetyl Transferases (HATs) add acetyl groups to the lysine residues on histone tails.
2. This modification **neutralizes** the positive charge on the lysines.
3. As the positive charge decreases, the electrostatic attraction between the histones and the negatively charged DNA phosphate backbone weakens.
4. This results in the "loosening" of the chromatin structure (conversion from heterochromatin to euchromatin), making the DNA more accessible to transcription factors and RNA polymerase.
5. **Effect of the drug:** By inhibiting HATs, the drug prevents this neutralization. Histones remain positively charged, DNA remains tightly bound (compact chromatin), and transcription is inhibited.

**Step 3: Final Answer:**
The drug works by preventing the neutralization of positive charges on histones, keeping chromatin in a repressed, compact state.

Quick Tip

Acetylation = **A**ctive transcription (loosens DNA).
Deacetylation/Methylation = **M**ute/Compact (tightens DNA).

---

**100. Two species of snakes, Species P and Species Q, have overlapping geographic distributions. Species P mainly eats rodents, whereas Species Q mainly eats invertebrates. Which one or more of the following terms describe(s) the process of speciation for these two species?**

(A) Sympatric speciation
(B) Parapatric speciation
(C) Allopatric speciation
(D) Niche differentiation

**Correct Answer:** (A) Sympatric speciation

**Solution:**

**Step 1: Understanding the Concept:**
Speciation is classified by the spatial relationship between the ancestral and diverging popula-

tions.

**Step 2: Detailed Explanation:**
1. **Allopatric:** Populations are separated by a physical geographic barrier.
2. **Parapatric:** Populations are in adjacent areas with a shared border; speciation occurs along an environmental gradient.
3. **Sympatric:** Speciation occurs **within the same geographic area** without physical separation. This often involves disruptive selection where different subgroups specialize in different ecological niches (e.g., different food sources).
4. **Analysis of the prompt:** The two species have "overlapping geographic distributions" (no barrier) and different food preferences (rodents vs. invertebrates). This implies that reproductive isolation evolved while they were living in the same place through **niche differentiation**. While niche differentiation is the *mechanism*, the resulting speciation type is **Sympatric**.

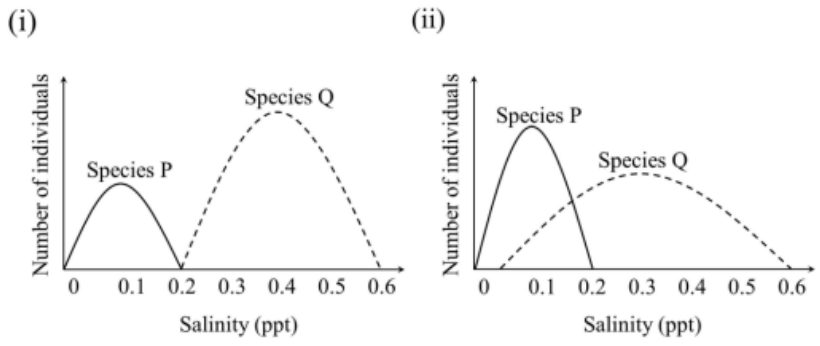
**Step 3: Final Answer:**
Because the populations are geographically overlapping, the speciation is sympatric.

Quick Tip

Remember: **Sym**patric = **S**ame place. **Allo**patric = **A**way from each other (barriers).

---

**101. In rivers that range in salinity (ppt) from low to high, researchers found that the aquatic snail species P (solid curve) and Q (dashed curve) were distributed according to the pattern illustrated in figure (i) when the species are together. The researchers then conducted a manipulative experiment in similar rivers with the same salinity range, where they removed either species P or Q. Figure (ii) illustrates the number of individuals of species P and Q when they were allowed to live alone. These snails have no other competitors or predators. Which one or more conclusions can be drawn from these two figures?**




(A) Fundamental niche of P is larger than fundamental niche of Q
(B) Fundamental niche of Q is larger than realized niche of Q
(C) Fundamental niche of P is larger than realized niche of P
(D) Fundamental and realized niches of P are the same

**Correct Answer:** (C) Fundamental niche of P is larger than realized niche of P

**Solution:**

**Step 1: Understanding the Concept:**
• **Fundamental Niche:** The full range of environmental conditions under which a species can survive and reproduce, observed when the species is **alone** (no competition).
• **Realized Niche:** The actual range of conditions occupied by a species when **interacting** with other species (competitors/predators).

**Step 2: Detailed Explanation:**
1. **Analyze Figure (ii) - Alone (Fundamental Niche):**
- Species P can live in salinities from roughly 0 to 0.3 ppt.
- Species Q can live in salinities from roughly 0.1 to 0.6 ppt.
- The fundamental niche of Q (0.5 ppt breadth) is **larger** than the fundamental niche of P (0.3 ppt breadth). Option (A) is false.
2. **Analyze Figure (i) - Together (Realized Niche):**
- Species P is restricted to 0 to 0.2 ppt.
- Species Q occupies 0.2 to 0.6 ppt.
3. **Comparison:**
- For P: Fundamental $(0 - 0.3)$ is larger than Realized $(0 - 0.2)$. Option **(C) is true**. Option (D) is false.
- For Q: Fundamental $(0.1 - 0.6)$ is larger than Realized $(0.2 - 0.6)$. Note that Q is excluded from the low salinity overlap by P. Thus, Option **(B) is also true**.

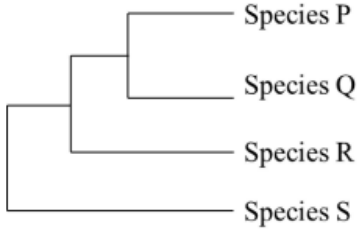
**Step 3: Final Answer:**
Both conclusions (B) and (C) are scientifically valid from the graphs. Usually, competitive exclusion causes the realized niche to be smaller than the fundamental niche.

Quick Tip

Fundamental Niche = "What a species CAN do" (Alone).
Realized Niche = "What a species DOES" (With company).
Competitive exclusion usually makes the Realized niche smaller.

---

**102. Which of the following statements is/are correct for the phylogenetic tree depicted below?**



(A) Species R and Species S are reciprocally monophyletic
(B) Species R is sister to a clade comprised of Species P and Q
(C) Species P and Species Q are reciprocally monophyletic
(D) Species P, Q, R and S share a common ancestor

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

**Solution:**

**Step 1: Understanding the Concept:**
Phylogenetic trees represent the evolutionary relationships among groups of organisms.
- **Sister Taxa:** Two lineages that diverged from the same immediate common ancestor.
- **Clade (Monophyletic group):** A group consisting of an ancestor and all its descendants.
- **Reciprocal Monophyly:** Two sister groups that are each monophyletic with respect to one another.

**Step 2: Detailed Explanation:**
1. **Structure of the tree:** P and Q share a common ancestor ($N_1$). R shares a common ancestor ($N_2$) with the (P,Q) clade. S shares a common ancestor ($N_3$, the root) with the (R,P,Q) clade.
2. **Evaluating (A):** R and S are not sister taxa. S is sister to the clade (R,P,Q). Thus, they are not reciprocally monophyletic in the standard sense.
3. **Evaluating (B):** Species R and the clade (P,Q) meet at node $N_2$. Therefore, R is indeed the sister group to the (P,Q) clade. **Correct**.
4. **Evaluating (C):** P and Q are sister taxa. In phylogenetic analysis, two sister taxa are considered reciprocally monophyletic. **Correct**.
5. **Evaluating (D):** All species on a single rooted tree are by definition descendants of the same root ancestor. **Correct**.

**Step 3: Final Answer:**
Statements (B), (C), and (D) are technically correct interpretations of the tree structure.

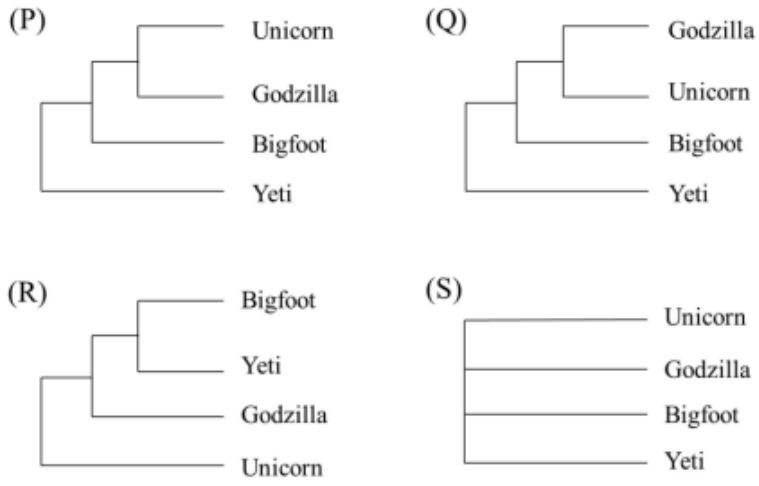
Quick Tip

To find "Sister" relationships, go back one node from the species. Everything coming out of that same node is the "Sister" group.

---

**103. In her exploration of the Western Ghats, Dora finds four new species of fungi. Below is the DNA sequence alignment for a single locus from these new species that she calls Yeti, Unicorn, Bigfoot and Godzilla. Using the principle of parsimony and the DNA sequence alignment information below, which one or more of the following tree topologies represent(s) the relationship between these species?**
**Yeti: ATGC**
**Unicorn: ATGT**

**Bigfoot: ATGA**
**Godzilla: ATGT**




(A) P
(B) Q
(C) R
(D) S

**Correct Answer:** (B) Q

**Solution:**

**Step 1: Understanding the Concept:**
The **Principle of Parsimony** states that the phylogenetic tree requiring the fewest evolutionary changes (mutations) is most likely the correct one.

**Step 2: Detailed Explanation:**
1. **Compare Sequences:**
- Yeti: ATGC
- Unicorn: ATGT
- Bigfoot: ATGA
- Godzilla: ATGT
2. **Observations:**
- Unicorn and Godzilla have **identical** sequences (ATGT). They must be sister taxa.
- Bigfoot differs from Unicorn/Godzilla by 1 nucleotide (position 4: A vs T).
- Yeti differs from Unicorn/Godzilla by 1 nucleotide (position 4: C vs T).
- Yeti and Bigfoot differ from each other by 1 nucleotide (position 4: C vs A).
3. **Evaluate Topologies:**
- **Topology Q:** Shows Godzilla and Unicorn as sister taxa (sharing the same branch). This is perfectly consistent with their identical sequences. Bigfoot and Yeti are then placed on separate lineages diverging from older nodes. This requires the fewest steps (zero steps to separate Unicorn from Godzilla).

**Step 3: Final Answer:**
Topology Q is the only one that places the identical taxa (Godzilla and Unicorn) as the closest relatives.

Quick Tip

Identical or near-identical sequences MUST be sister taxa in a parsimonious tree. Find the pair with the most similarities and look for them on the same "fork" in the options.

---

**104. Ergotism is caused by ingestion of grains infected with**

(A) *Clostridium perfringens*
(B) *Rhizopus stolonifer*
(C) *Lactococcus lactis*
(D) *Claviceps purpurea*

**Correct Answer:** (D) *Claviceps purpurea*

**Solution:**

**Step 1: Understanding the Concept:**
Ergotism (Saint Anthony's Fire) is a toxic condition resulting from consuming cereals (especially rye) infected with specific fungal alkaloids.

**Step 2: Detailed Explanation:**
1. ***Claviceps purpurea*** is an ascomycete fungus that infects the ovaries of developing kernels in cereal grasses. It replaces the grain with a dark, hard sclerotium (the ergot).
2. These sclerotia contain various **ergot alkaloids** (like ergotamine), which are derivatives of lysergic acid.
3. Ingestion causes severe symptoms: gangrene due to vasoconstriction or hallucinations/convulsions due to neurological effects.
4. **Other options:**
- *Clostridium*: Bacterium causing gangrene/food poisoning.
- *Rhizopus*: Common bread mold.
- *Lactococcus*: Probiotic used in cheese making.

**Step 3: Final Answer:**
The disease is specifically associated with *Claviceps purpurea*.

Quick Tip

Think: Ergot → Rye → *Claviceps*. It's also the historical source for the discovery of LSD (Lysergic acid diethylamide).

**105. Match the bacteria in Column I with their respective characteristic features in Column II.**

| Column I | Column II |
|---|---|
| (P) *E. coli* | (1) Gram-positive, round-shaped and non-spore formers |
| (Q) *B. subtilis* | (2) Gram-negative, rod-shaped and non-spore formers |
| (R) *S. aureus* | (3) Gram-positive, rod-shaped and spore formers |
| (S) *L. monocytogenes* | (4) Gram-positive, rod-shaped and non-spore formers |

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

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

**Solution:**

**Step 1: Understanding the Concept:**
Bacterial classification is based on Gram stain reaction (cell wall structure), morphology (shape), and physiological traits like endospore formation.

**Step 2: Detailed Explanation:**
- **P) *E. coli*:** It is the classic **Gram-negative, rod-shaped** enteric bacterium. It **does not** form spores. Match: **(2)**.
- **Q) *B. subtilis*:** It belongs to the genus *Bacillus*. These are **Gram-positive, rod-shaped** bacteria famous for producing highly resistant **endospores**. Match: **(3)**.
- **R) *S. aureus*:** *Staphylococcus* means "grapes" and "round." These are **Gram-positive, round-shaped (cocci)** clusters that are **non-spore** formers. Match: **(1)**.
- **S) *L. monocytogenes*:** It is a **Gram-positive, rod-shaped** bacterium that **does not** form spores (unlike *Bacillus* or *Clostridium*). Match: **(4)**.

**Step 3: Final Answer:**
The correct combination is P-2, Q-3, R-1, S-4.

Quick Tip

Remember: *Bacillus* and *Clostridium* are the only two major medically/economically important genera that form endospores. Both are Gram-positive rods.

**106. Carmine, a food colorant, is derived from**

(A) *Curcuma longa*
(B) *Dactylopius coccus*
(C) *Beta vulgaris*
(D) *Monascus purpureus*

**Correct Answer:** (B) *Dactylopius coccus*

**Solution:**

**Step 1: Understanding the Concept:**
Many food colorants are natural dyes extracted from plants, insects, or microbes.

**Step 2: Detailed Explanation:**
1. **Carmine (Cochineal extract):** It is a bright red pigment obtained from the **cochineal insect** (*Dactylopius coccus*). The insects are crushed, and the carminic acid is extracted.
2. **Other options:**
- *Curcuma longa*: Source of **Curcumin** (Yellow).
- *Beta vulgaris*: Source of **Beetroot Red** (Betanin).
- *Monascus purpureus*: A fungus that produces **Red Yeast Rice** pigment.

**Step 3: Final Answer:**
Carmine is specifically insect-derived from *Dactylopius coccus*.

Quick Tip

Carmine is one of the few food dyes that is not vegan, as it's made from crushed bugs!

---

**107. Which one of the following carbohydrates is NOT a storage polysaccharide?**

(A) Starch
(B) Glycogen
(C) Chitin
(D) Dextran

**Correct Answer:** (C) Chitin

**Solution:**

**Step 1: Understanding the Concept:**
Polysaccharides are classified based on their primary function: energy **storage** or **structural** support.

**Step 2: Detailed Explanation:**
1. **Starch:** Primary energy **storage** molecule in plants.
2. **Glycogen:** Primary energy **storage** molecule in animals and fungi.
3. **Dextran:** A complex, branched glucan often used as an energy **storage** reserve in certain bacteria and yeasts.
4. **Chitin:** It is a **structural** polysaccharide. It is a long-chain polymer of N-acetylglucosamine that provides structural integrity to the cell walls of fungi and the exoskeletons of arthropods. It is not broken down for energy metabolic fuel.

**Step 3: Final Answer:**
Chitin is structural, not for storage.

Quick Tip

Structural = Cellulose, Chitin, Peptidoglycan.
Storage = Starch, Glycogen, Inulin.

---

**108. Which one of the following statements is true for a high-pressure homogenizer?**

(A) Homogenization takes place only due to uniform mixing of solid and liquid
(B) Solid particles in the suspension are disintegrated due to the high shear rate exerted by the liquid
(C) High pressure steam is injected to dissolve the solids
(D) Solid particles in the suspension are compressed into a cake under high pressure

**Correct Answer:** (B) Solid particles in the suspension are disintegrated due to the high shear rate exerted by the liquid

**Solution:**

**Step 1: Understanding the Concept:**
High-pressure homogenization is a mechanical process used to reduce particle size or lyse cells by forcing a fluid through a narrow valve at very high pressures.

**Step 2: Detailed Explanation:**
1. The process works by converting potential energy (pressure) into kinetic energy as the fluid accelerates through the valve gap.
2. This creates **high shear forces**, **turbulence**, and **cavitation**.
3. The intense shear and impact against the valve surface physically tear apart or disintegrate the solid particles or microbial cells in the suspension.

**Step 3: Final Answer:**
Disintegration due to shear rate is the fundamental mechanism.

Quick Tip

Homogenizer mechanism = Shear + Cavitation + Impact.

---

**109. Coconut oil contains a small fraction of unsaturated fatty acids, but still has a low melting point due to the presence of**

(A) large amounts of long chain saturated fatty acids
(B) mostly medium chain saturated fatty acids such as lauric acid
(C) few hydrogen bonds per fatty acid chain
(D) higher cholesterol content

**Correct Answer:** (B) mostly medium chain saturated fatty acids such as lauric acid

**Solution:**

**Step 1: Understanding the Concept:**
The physical properties of oils (like melting point) are determined by the length of the fatty acid chains and the degree of unsaturation.

**Step 2: Detailed Explanation:**
1. Generally, saturated fats (like butter) are solid at room temperature because their straight chains pack tightly.
2. However, the melting point also **decreases as the chain length decreases**.
3. Coconut oil is unique because it is composed of over 90% saturated fats, but about 50% of that is **Lauric acid** (C12), which is a **medium-chain fatty acid** (MCFA).
4. Because these chains are relatively short compared to common animal fats (C16, C18), the intermolecular van der Waals forces are weaker, leading to a relatively low melting point ($\sim 24^\circ$C).

**Step 3: Final Answer:**
The presence of medium-chain saturated fatty acids explains its semi-solid/liquid behavior near room temperature.

Quick Tip

Shorter Chain = Lower Melting Point.
More Double Bonds = Lower Melting Point.

---

**110. Which of the following amines, produced as a result of protein degradation, is/are foul smelling?**

(A) Histamine
(B) Cadaverine
(C) Tyramine
(D) Putrescine

**Correct Answer:** (B, D) Cadaverine and Putrescine

**Solution:**

**Step 1: Understanding the Concept:**
Decarboxylation of amino acids by bacteria during the spoilage of protein-rich foods (meat, fish) produces biogenic amines.

**Step 2: Detailed Explanation:**
1. **Putrescine:** Produced from the decarboxylation of Ornithine/Arginine. It has a smell of decaying meat.
2. **Cadaverine:** Produced from the decarboxylation of **Lysine**. It is responsible for the characteristic odor of rotting flesh (as its name suggests).
3. **Histamine and Tyramine:** These are also produced during spoilage, but they are primarily known as **vasoactive** amines (allergens/migraine triggers) rather than being the dominant "foul" odors of decomposition.

**Step 3: Final Answer:**
Cadaverine and Putrescine are the primary foul-smelling ptomaines.

Quick Tip

Ptomaines = "Smell of death." Putrescine and Cadaverine are the standard indicators of meat spoilage.

---

**111. Water is flowing at 100 litres/min through a pipe with a diameter of 5 cm. Assume the coefficient of viscosity of water to be 0.001 Pa.s and the density to be** 1000 **kg/m$^3$. The Reynolds number for this flow is _____. (Round off to nearest integer)**

**Correct Answer:** 42441

**Solution:**

**Step 1: Understanding the Concept:**
The Reynolds number ($Re$) is a dimensionless value used in fluid mechanics to predict whether a flow will be laminar or turbulent.

**Step 2: Key Formula or Approach:**

$$Re = \frac{\rho v D}{\mu}$$

Where:
$\rho$ = density = 1000 kg/m$^3$
$v$ = velocity = $Q/A$
$D$ = diameter = 0.05 m
$\mu$ = viscosity = 0.001 Pa $\cdot$ s
$Q$ = flow rate
$A$ = cross-sectional area = $\pi \frac{D^2}{4}$

**Step 3: Detailed Explanation:** 1. **Convert Flow Rate ($Q$) to SI units:**

$$Q = 100 \text{ L/min} = \frac{100 \times 10^{-3} \text{ m}^3}{60 \text{ s}} \approx 0.001666 \text{ m}^3/\text{s}$$

2. **Calculate Velocity ($v$):**

$$A = \frac{\pi \times (0.05)^2}{4} = \frac{\pi \times 0.0025}{4} \approx 0.001963 \text{ m}^2$$

$$v = \frac{Q}{A} = \frac{0.001666}{0.001963} \approx 0.8488 \text{ m/s}$$

3. **Calculate Reynolds Number ($Re$):**

$$Re = \frac{1000 \times 0.8488 \times 0.05}{0.001} = 42.441 \times 1000 = 42441$$

Alternatively, using the substituted formula $Re = \frac{4\rho Q}{\pi D \mu}$:

$$Re = \frac{4 \times 1000 \times (0.1/60)}{\pi \times 0.05 \times 0.001} = \frac{6666.67}{0.15708} \approx 42441.3$$

**Step 4: Final Answer:**
Rounding to the nearest integer, we get 42441.

> **Quick Tip**
>
> Flow in a pipe is usually turbulent if $Re > 4000$. Here, 42441 is highly turbulent. Always be careful with unit conversions (L/min $\rightarrow$ m$^3$/s).

---

**112. Match the toxins in Column I with their respective sources in Column II.**

| Column I | Column II |
|---|---|
| P. Aflatoxin | 1. *Fusarium verticilloides* |
| Q. Nisin | 2. Enterohemorrhagic *E. coli* |
| R. Fumonisin | 3. *Lactococcus lactis* |
| S. Shiga-like toxin | 4. *Aspergillus flavus* |

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

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

**Solution:**

**Step 1: Understanding the Concept:**
The question asks to pair specific microbial metabolites (toxins and bacteriocins) with their respective producing organisms. These include mycotoxins produced by fungi and toxins/bacteriocins produced by bacteria.

**Step 2: Detailed Explanation:**

- **P. Aflatoxin:** These are potent hepatocarcinogenic mycotoxins produced primarily by certain molds of the genus *Aspergillus*, notably ***Aspergillus flavus*** and *Aspergillus parasiticus*. Thus, P matches with 4.

- **Q. Nisin:** Nisin is a polycyclic antibacterial peptide (bacteriocin) produced by the bacterium ***Lactococcus lactis*** that is used as a food preservative. Thus, Q matches with 3.

- **R. Fumonisin:** Fumonisins are a group of mycotoxins primarily produced by ***Fusarium verticillioides*** and *Fusarium proliferatum*, commonly found in corn. Thus, R matches with 1.

- **S. Shiga-like toxin:** These are toxins produced by **Enterohemorrhagic *Escherichia coli*** (EHEC), such as the O157:H7 strain, which are structurally and functionally similar to the Shiga toxin of *Shigella dysenteriae*. Thus, S matches with 2.

Combining these pairs gives: P-4, Q-3, R-1, S-2.

**Step 3: Final Answer:**
The correct matching sequence corresponds to option (C).

Quick Tip

Associate *Aspergillus* with Aflatoxin and *Fusarium* with Fumonisin. Nisin is the only bacteriocin here, produced by the common dairy starter *L. lactis*.

---

**113. Match the vitamins in Column I with their respective coenzyme forms listed in Column II.**

| Column I | Column II |
|---|---|
| P. Vitamin $B_1$ | 1. Tetrahydrofolate |
| Q. Vitamin $B_2$ | 2. Methylcobalamin |
| R. Pantothenic acid | 3. Thiamine pyrophosphate |
| S. Vitamin $B_{12}$ | 4. Flavin adenine dinucleotide |
| T. Folic acid | 5. Coenzyme A |

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

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

**Solution:**

**Step 1: Understanding the Concept:**
Most water-soluble B-vitamins act as precursors for essential coenzymes in metabolic pathways. This question requires matching the common vitamin name to its active biochemical form.

**Step 2: Detailed Explanation:**

- **P. Vitamin $B_1$ (Thiamine):** Its active coenzyme form is **Thiamine pyrophosphate (TPP)**, which is involved in decarboxylation reactions. (P-3).

- **Q. Vitamin $B_2$ (Riboflavin):** It is a precursor to **Flavin adenine dinucleotide (FAD)** and Flavin mononucleotide (FMN), which are key redox cofactors. (Q-4).

- **R. Pantothenic acid:** It is a vital component of **Coenzyme A (CoA)**, which is essential for fatty acid metabolism and the TCA cycle. (R-5).

- **S. Vitamin $B_{12}$ (Cobalamin):** One of its active coenzyme forms is **Methylcobalamin**, used in methionine synthesis. (S-2).

- **T. Folic acid:** Its active reduced form is **Tetrahydrofolate (THF)**, which serves as a carrier of one-carbon units. (T-1).

The complete set is P-3, Q-4, R-5, S-2, T-1.

**Step 3: Final Answer:**
This matching aligns perfectly with option (A).

> Quick Tip
>
> Remember the initials: **T**hiamine → **T**PP; **R**iboflavin → **F**AD/**F**MN; **P**antothenic → Co**A**.

---

**114. Which one of the following proteins brings about the coagulation of milk in the stomach of calves?**

(A) Rennin
(B) Alpha-lactalbumin
(C) Beta-lactoglobulin
(D) Lactoferrin

**Correct Answer:** (A) Rennin

**Solution:**

**Step 1: Understanding the Concept:**
Milk coagulation is the process of destabilizing casein micelles. In the stomachs of young ruminants, this is achieved enzymatically to slow down the passage of milk, allowing better digestion.

**Step 2: Detailed Explanation:**

- **Rennin (Chymosin):** This is an aspartic endopeptidase produced in the abomasum (fourth stomach) of calves. It specifically cleaves the $Phe_{105}$-$Met_{106}$ bond of $\kappa$-casein, which normally stabilizes the casein micelle. Removal of the hydrophilic macropeptide causes the remaining paracasein to precipitate in the presence of calcium ions, forming a curd.

- **Alpha-lactalbumin:** This is a major whey protein and a component of lactose synthase. It does not cause coagulation.

- **Beta-lactoglobulin:** This is the most abundant whey protein in bovine milk. It is sensitive to heat but does not cause enzymatic coagulation.

- **Lactoferrin:** This is an iron-binding glycoprotein with antimicrobial properties, not a coagulating enzyme.

**Step 3: Final Answer:**
The enzyme responsible for milk coagulation in calves is Rennin. Thus, option (A) is correct.

Quick Tip

Do not confuse **Rennin** (digestive enzyme) with **Renin** (kidney hormone involved in blood pressure regulation).

---

**115. Match the class of additives used for food preservation listed in Column I with their specific examples in Column II.**

| Column I | Column II |
|---|---|
| P. Antioxidants | 1. Rice bran wax |
| Q. Anti-foaming agent | 2. Tricalcium phosphate |
| R. Anti-caking agent | 3. Mineral oil |
| S. Glazing agent | 4. Butylated hydroxy anisole (BHA) |

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

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

**Solution:**

**Step 1: Understanding the Concept:**
Food additives are substances added to food to maintain or improve safety, freshness, taste, texture, or appearance. This question asks to match additive categories to specific chemical examples.

**Step 2: Detailed Explanation:**

- **P. Antioxidants:** These substances prevent or delay the oxidation of fats and oils. **Butylated hydroxy anisole (BHA)** is a widely used synthetic phenolic antioxidant. (P-4).

- **Q. Anti-foaming agent:** These reduce or prevent the formation of foam in food processing. **Mineral oil** and silicones are commonly used for this purpose in various industrial food applications. (Q-3).

- **R. Anti-caking agent:** These are added to powdered or granulated foods to prevent the formation of lumps. **Tricalcium phosphate** is a common example used in salt or powdered beverages. (R-2).

- **S. Glazing agent:** These provide a protective coating or a polished, shiny surface to food items like fruits or confectionery. **Rice bran wax** or carnauba wax are typical examples. (S-1).

The matches are P-4, Q-3, R-2, S-1.

**Step 3: Final Answer:**
The matching sequence corresponds to option (C).

Quick Tip

BHA, BHT, and TBHQ are the "big three" synthetic antioxidants to remember. Anti-caking agents are usually phosphates, silicates, or carbonates.

---

**116. Match the food items listed in Column I with their respective flavoring agents in Column II.**

| Column I | Column II |
|---|---|
| P. Cloves | 1. Diacetyl |
| Q. Butter | 2. Limonene |
| R. Orange | 3. Eugenol |
| S. Lemon | 4. Diallyl disulfide |
| T. Garlic | 5. Citral |

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

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

**Solution:**

**Step 1: Understanding the Concept:**
Natural flavors are composed of specific chemical compounds that give foods their characteristic aroma and taste. This question focuses on the primary volatile compounds associated with common foods.

**Step 2: Detailed Explanation:**

- **P. Cloves:** The principal flavoring component of clove oil is **Eugenol**, providing its spicy and warm aroma. (P-3).

- **Q. Butter: Diacetyl** (2,3-butanedione) is a byproduct of fermentation that gives butter its characteristic buttery flavor and aroma. (Q-1).

- **R. Orange: Limonene** is the major component of the oil extracted from citrus peels, particularly oranges. (R-2).

- **S. Lemon:** While limonene is present, **Citral** (a mixture of geranial and neral) is responsible for the distinct "lemon" scent. (S-5).

- **T. Garlic:** The characteristic pungent odor of garlic is due to organosulfur compounds, primarily **Diallyl disulfide**. (T-4).

The resulting sequence is P-3, Q-1, R-2, S-5, T-4.

**Step 3: Final Answer:**
This sequence matches option (D).

Quick Tip

Flavor chemistry often follows patterns: sulfur compounds in alliums (garlic/onion), terpenes in citrus (lemon/orange), and phenols in spices (cloves).

---

**117. Vegetable oils resist oxidation and maintain their quality for a long period due to the presence of**

(A) tocopherols
(B) hydrolytic enzyme such as lipases
(C) microorganisms such as molds and yeast
(D) carbohydrates

**Correct Answer:** (A) tocopherols

**Solution:**

**Step 1: Understanding the Concept:**
Oxidation is a primary cause of spoilage in oils, leading to rancidity. Resistance to oxidation is provided by antioxidants which scavenge free radicals.

**Step 2: Detailed Explanation:**

- **Tocopherols (Vitamin E):** These are natural fat-soluble antioxidants found in high concentrations in vegetable oils. They act by donating a hydrogen atom to lipid peroxy radicals, effectively terminating the chain reaction of lipid peroxidation.

- **Lipases:** These enzymes catalyze the hydrolysis of triglycerides into free fatty acids, which actually *promotes* hydrolytic rancidity and decreases oil quality.

- **Microorganisms:** Molds and yeasts can produce enzymes that degrade lipids or produce off-flavors, thereby *reducing* oil quality.

- **Carbohydrates:** These are generally not present in refined vegetable oils and do not contribute to oxidative stability.

**Step 3: Final Answer:**
Tocopherols are the natural compounds that protect vegetable oils from oxidative damage. Thus, option (A) is correct.

Quick Tip

Vegetable oils are often higher in natural antioxidants (tocopherols) than animal fats, which helps compensate for their higher level of polyunsaturation.

---

**118. For a given temperature difference between the top and bottom surfaces of a flat metal plate, Fourier's law of heat conduction implies that**

(A) temperature gradient increases with increase in heat transfer area
(B) heat flux is proportional to the thermal conductivity of the metal
(C) heat flux increases with increase in thickness of the metal plate
(D) temperature gradient decreases with increase in thickness of the metal plate

**Correct Answer:** (B) heat flux is proportional to the thermal conductivity of the metal

**Solution:**

**Step 1: Understanding the Concept:**
Fourier's law of heat conduction states that the rate of heat transfer through a material is proportional to the negative gradient in the temperature and to the area.

**Step 2: Key Formula or Approach:**
Fourier's Law in one dimension is:

$$Q = -kA\frac{dT}{dx}$$

Rearranging for heat flux ($q = Q/A$):

$$q = -k\frac{dT}{dx}$$

Where:
$Q$ is the heat transfer rate (W).
$q$ is the heat flux (W/m$^2$).
$k$ is the thermal conductivity (W/m·K).
$\frac{dT}{dx}$ is the temperature gradient (K/m).

**Step 3: Detailed Explanation:**

- **Option (A):** The temperature gradient ($dT/dx$) for a given temperature difference depends on thickness, not area.

- **Option (B):** From the equation $q = -k\frac{dT}{dx}$, it is evident that for a fixed temperature gradient, the heat flux ($q$) is directly proportional to the thermal conductivity ($k$). This is a fundamental implication of the law.

- **Option (C):** For a given $\Delta T$, heat flux $q = k\frac{\Delta T}{L}$. Thus, flux is *inversely* proportional to thickness ($L$).

- **Option (D):** The temperature gradient $dT/dx = \Delta T/L$. As thickness ($L$) increases, the magnitude of the gradient *decreases*. However, Option (B) is the more standard direct proportionality derived from the primary definition.

**Step 4: Final Answer:**
The most accurate statement based on Fourier's Law is that heat flux is proportional to thermal conductivity. Thus, option (B) is correct.

Quick Tip

Remember the analogy with Ohm's Law: Heat flow ≈ Current, Temperature difference ≈ Voltage, and Thermal Resistance ($L/kA$) ≈ Electrical Resistance.

**119. Xylooligosaccharides can be produced by**

(A) hydrolytic degradation of xylan by hydrochloric acid
(B) hydrolysis of starch
(C) enzymatic hydrolysis of lactose
(D) enzymatic hydrolysis of xylan containing lignocellulosic material

**Correct Answer:** (D) enzymatic hydrolysis of xylan containing lignocellulosic material

**Solution:**

**Step 1: Understanding the Concept:**
Xylooligosaccharides (XOS) are sugar oligomers made up of xylose units. They are considered functional food ingredients with prebiotic properties.

**Step 2: Detailed Explanation:**

- Xylan is a type of hemicellulose found in the cell walls of plants (lignocellulosic biomass).
- While acid hydrolysis (Option A) can break down xylan, it is difficult to control and often leads to the over-degradation of sugars into furfurals and high amounts of xylose monomer rather than oligomers.
- **Enzymatic hydrolysis** (Option D) using endo-1,4-$\beta$-xylanases is the preferred industrial method because it is highly specific and operates under mild conditions, yielding a high proportion of oligosaccharides from xylan-rich sources like corn cobs or wheat bran.
- Hydrolysis of starch (Option B) produces maltooligosaccharides, and hydrolysis of lactose (Option C) produces galactooligosaccharides.

**Step 3: Final Answer:**
Xylooligosaccharides are produced by the specific enzymatic breakdown of xylan found in lignocellulosic materials. Thus, option (D) is correct.

Quick Tip

Oligosaccharide names usually indicate their precursor: Xylo- from Xylan, Malto- from Starch (Amylose), Galacto- from Lactose.

---

**120. In a $\alpha$-helix, the R-groups on the amino acid residues**

(A) are found on the outside of the helix
(B) participate in the backbone H-bonding that stabilize the helix
(C) allow formation of right-handed helices
(D) allow formation of left-handed helices

**Correct Answer:** (A) are found on the outside of the helix

**Solution:**

**Step 1: Understanding the Concept:**
The $\alpha$-helix is a common secondary structure in proteins. Its geometry is defined by the tightly coiled peptide backbone and specific hydrogen bonding patterns.

**Step 2: Detailed Explanation:**

- In an $\alpha$-helix, the peptide backbone forms the inner core of the cylinder.
- To minimize steric hindrance (crowding) between the side chains of the amino acids, the **R-groups (side chains) project outward** from the helical axis into the surrounding environment.
- The helix is stabilized by hydrogen bonds between the N-H group of one amino acid residue and the C=O group of the residue four positions earlier $(i + 4)$ along the *backbone*, not involving the R-groups.
- While the chirality of L-amino acids predominantly favors right-handed helices, it is the spatial arrangement to avoid steric clash that dictates the R-groups' outward orientation.

**Step 3: Final Answer:**
In an $\alpha$-helix, the R-groups are oriented towards the exterior of the coiled structure. Thus, option (A) is correct.

Quick Tip

Imagine a spiral staircase: the backbone is the railing and steps, while the R-groups are like people standing on the steps pointing their arms outward away from the center.

---

**121. During constant pressure cake filtration, for an incompressible cake deposited uniformly over a constant filter surface area,**

(A) the cake resistance remains constant
(B) the cake resistance increases in proportion to the cake thickness

(C) the filtration rate remains constant
(D) the filtration rate decreases with time

**Correct Answer:** (D) the filtration rate decreases with time

**Solution:**

**Step 1: Understanding the Concept:**
Filtration rate is governed by the resistance offered by the filter medium and the accumulating cake. In constant pressure filtration, the driving force ($\Delta P$) is fixed.

**Step 2: Detailed Explanation:**

- As filtration proceeds, the thickness of the cake ($L$) increases as more solids are deposited.
- For an incompressible cake, the specific cake resistance ($\alpha$) is constant. However, the **total cake resistance** ($R_c = \alpha \rho_c V/A$) increases as the volume of filtrate ($V$) and the corresponding cake thickness increase.
- According to Darcy's Law for filtration:
$$\frac{dV}{dt} = \frac{A\Delta P}{\mu(R_c + R_m)}$$
- Since the driving force ($\Delta P$) and area ($A$) are constant, but the total resistance ($R_c$) keeps increasing as the cake grows, the **filtration rate ($dV/dt$) must decrease over time**.
- While Option (B) is physically true for an incompressible cake (Resistance $\propto$ thickness), Option (D) describes the fundamental kinetic observation of the process.

**Step 3: Final Answer:**
In constant pressure filtration, the rate of filtrate collection slows down as the cake layer thickens. Thus, option (D) is correct.

Quick Tip

Think of a vacuum cleaner bag: as it fills with dust (the "cake"), the air flow (the "filtration rate") noticeably drops even though the vacuum motor ("constant pressure") stays the same.

---

**122. Hot oil is being cooled in a countercurrent, double-pipe heat exchanger from 410 K to 340 K by chilled water entering at 290 K and exiting the exchanger at 330 K. The Log Mean Temperature Difference (LMTD) for this heat transfer is**

_____ **K. (Round off to one decimal place)**

**Correct Answer:** 63.8 K

**Solution:**

**Step 1: Understanding the Concept:**
The Log Mean Temperature Difference (LMTD) is used to determine the temperature driving force for heat transfer in flow systems, most notably in heat exchangers.

**Step 2: Key Formula or Approach:**
For a countercurrent heat exchanger:

$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$$

Where:
$\Delta T_1 = T_{h,in} - T_{c,out}$
$\Delta T_2 = T_{h,out} - T_{c,in}$

**Step 3: Detailed Explanation:**
1. **Identify the temperatures:**
Hot fluid inlet ($T_{h,in}$) = 410 K
Hot fluid outlet ($T_{h,out}$) = 340 K
Cold fluid inlet ($T_{c,in}$) = 290 K
Cold fluid outlet ($T_{c,out}$) = 330 K

2. **Calculate the temperature differences at the two ends:**

$$\Delta T_1 = 410 - 330 = 80 \text{ K}$$
$$\Delta T_2 = 340 - 290 = 50 \text{ K}$$

3. **Apply the LMTD formula:**

$$\text{LMTD} = \frac{80 - 50}{\ln(80/50)}$$
$$\text{LMTD} = \frac{30}{\ln(1.6)}$$

Using $\ln(1.6) \approx 0.4700$:

$$\text{LMTD} = \frac{30}{0.4700} \approx 63.8297 \text{ K}$$

**Step 4: Final Answer:**
Rounding to one decimal place, the LMTD is 63.8 K.

> Quick Tip
>
> In countercurrent flow, the temperature difference is more uniform throughout the exchanger compared to parallel flow, resulting in a higher LMTD and better efficiency.