GATE 2022 Biotechnology (BT) Question Paper with Solutions

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

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Each GATE 2022 paper consists of a total of 100 marks. The examination is divided into two sections – General Aptitude (GA) and the Candidate's Selected Subjects. General Aptitude carries 15 marks, while the remaining 85 marks are dedicated to the candidate's chosen test paper syllabus.
2. GATE 2022 will be conducted in English as a Computer Based Test (CBT) at select centres in select cities. The duration of the examination is 3 hours.
3. MCQs carry 1 mark or 2 marks.
4. For a wrong answer in a 1-mark MCQ, 1/3 mark is deducted.
5. For a wrong answer in a 2-mark MCQ, 2/3 mark is deducted.
6. No negative marking for wrong answers in MSQ or NAT questions.

General Aptitude (GA)

1. You should _____ when to say _____.

(A) no / no

(B) no / know

(C) know / know

(D) know / no

Correct Answer: (D) know / no

Solution:

In this sentence, the correct choice is (D) because the first blank requires a verb, and "know"

is the appropriate verb for this context. The second blank requires the noun ”no,” which fits the context of the sentence.

- **First part:** ”You should know when to say” implies that one should have the knowledge of when to say something.

- **Second part:** ”no” fits the context as it is the word being referred to in the sentence.

Thus, the correct answer is **(D) know / no**.

Quick Tip

Pay attention to the verb-noun agreement in sentences. When referring to knowledge or understanding, ”know” is usually the correct verb.

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2. Two straight lines pass through the origin $(x_0, y_0) = (0, 0)$. One of them passes through the point $(x_1, y_1) = (1, 3)$ and the other passes through the point $(x_2, y_2) = (1, 2)$. What is the area enclosed between the straight lines in the interval $[0, 1]$ on the x-axis?

(A) 0.5

(B) 1.0

(C) 1.5

(D) 2.0

Correct Answer: (D) 2.0

Solution:

To solve this problem, we need to calculate the area between the two lines in the interval $[0, 1]$ on the x-axis.

Step 1: Equation of the lines.

- Line 1 (through (0, 0) and (1, 3)): The slope of the line is:

$$m_1 = \frac{3 - 0}{1 - 0} = 3.$$

The equation of the line is:

$$y_1 = 3x.$$

- Line 2 (through (0, 0) and (1, 2)): The slope of the line is:

$$m_2 = \frac{2-0}{1-0} = 2.$$

The equation of the line is:

$$y_2 = 2x.$$

Step 2: Calculate the area between the lines.

The area between the lines is given by the integral of the difference in the y-values of the two lines over the interval $[0, 1]$:

$$\text{Area} = \int_0^1 (y_1 - y_2)\,dx = \int_0^1 (3x - 2x)\,dx = \int_0^1 x\,dx.$$

The integral is:

$$\int_0^1 x\,dx = \frac{x^2}{2}\Big|_0^1 = \frac{1}{2}.$$

Thus, the area is 0.5. Therefore, the correct answer is **(A)**.

Quick Tip

To calculate the area between two curves, subtract one curve's equation from the other and integrate over the given interval.

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3. If

$$p : q = 1 : 2, \quad q : r = 4 : 3, \quad r : s = 4 : 5$$

and u is 50

(A) 2 : 15

(B) 16 : 15

(C) 1 : 5

(D) 16 : 45

Correct Answer: (C) 1 : 5

Solution:

Given the ratios:

$$p : q = 1 : 2 \quad (\text{i.e., } p = \frac{q}{2})$$
$$q : r = 4 : 3 \quad (\text{i.e., } q = \frac{4r}{3})$$
$$r : s = 4 : 5 \quad (\text{i.e., } r = \frac{5s}{4})$$

We can write all terms in terms of s. Start by expressing p, q, and r in terms of s:

$$r = \frac{5s}{4}$$
$$q = \frac{4r}{3} = \frac{4 \times \frac{5s}{4}}{3} = \frac{5s}{3}$$
$$p = \frac{q}{2} = \frac{\frac{5s}{3}}{2} = \frac{5s}{6}$$

Now, u is 50

$$u = 1.5s$$

Thus, the ratio $p : u$ is:

$$\frac{p}{u} = \frac{\frac{5s}{6}}{1.5s} = \frac{5}{6 \times 1.5} = \frac{5}{9} = 1 : 5$$

Step 1: Conclusion

The ratio $p : u$ is $1 : 5$, so the correct answer is (C).

Quick Tip

When solving ratio problems, express all variables in terms of one common variable to simplify the calculations.

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4. Given the statements:

- P is the sister of Q.
- Q is the husband of R.
- R is the mother of S.
- T is the husband of P.

Based on the above information, T is _____ of S.

(A) the grandfather

(B) an uncle

(C) the father

(D) a brother

Correct Answer: (B) an uncle

Solution:

- P is the sister of Q, so P and Q are siblings. - Q is the husband of R, so R is married to Q. - R is the mother of S, so S is R's child. - T is the husband of P, so T is married to P.

From this, T is the husband of P, who is the sister of Q. Therefore, T is the brother-in-law of Q. Since Q is S's parent, T is the uncle of S.

Step 1: Conclusion

T is the uncle of S, so the correct answer is (B).

Quick Tip

When solving family relation problems, carefully analyze the relationships to identify the roles each person plays.

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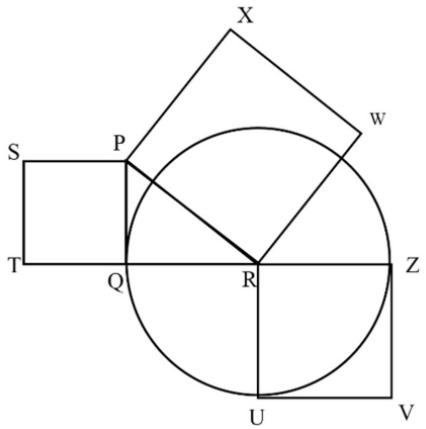
5. In the following diagram, the point R is the center of the circle. The lines PQ and ZV are tangential to the circle. The relation among the areas of the squares, PXWR, RUVZ and SPQT is



(A) Area of SPQT = Area of RUVZ = Area of PXWR

(B) Area of SPQT = Area of PXWR Area of RUVZ

(C) Area of PXWR = Area of SPQT Area of RUVZ

(D) Area of PXWR = Area of RUVZ Area of SPQT

Correct Answer: (B) Area of SPQT = Area of PXWR Area of RUVZ

Solution:

In the given diagram, we are working with areas of squares inscribed in a circle. The points and lines are defined such that:

- The area of the square $PXWR$ is the area enclosed by the tangent line PX and the radial line from the center R.

- Similarly, the areas of the other squares $RUVZ$ and $SPQT$ are determined by the distances defined by the lines and the tangents.

By analyzing the geometric relationships and using the fact that the squares are inscribed, the correct relation between the areas of these squares is:

$$\text{Area of SPQT} = \text{Area of PXWR} - \text{Area of RUVZ}.$$

This is derived from the fact that the areas of the squares depend on the lengths of the sides, and the side lengths are related in such a way that this equation holds. Therefore, the correct answer is (B).

Quick Tip

In problems involving areas of squares inscribed within a circle, the relationships between the areas are often governed by the tangents and the distances between the center and the points of tangency.

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6. Healthy eating is a critical component of healthy aging. When should one start eating healthy? It turns out that it is never too early. For example, babies who start eating healthy in the first year are more likely to have better overall health as they get older.

(A) Healthy eating is important for those with good health conditions, but not for others

(B) Eating healthy can be started at any age, earlier the better

(C) Eating healthy and better overall health are more correlated at a young age, but not at later ages

(D) Eating healthy is important only in the first year of life

Correct Answer: (B) Eating healthy can be started at any age, earlier the better

Solution:

The passage emphasizes that healthy eating is a crucial part of healthy aging, and it is important to start eating healthy as early as possible. It specifically mentions that babies who start eating healthy in the first year are more likely to maintain better overall health as they grow older. This implies that eating healthy can be beneficial at any age, but it is most effective when started early. Therefore, the correct inference based on the passage is that healthy eating can be started at any age, but the earlier, the better.

Thus, the correct answer is (B).

Quick Tip

Starting healthy eating habits early in life has long-term benefits for overall health. It is never too early to begin eating healthy, and doing so earlier maximizes the benefits.

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7. P invested 5000 per month for 6 months of a year and Q invested x per month for 8 months of the year in a partnership business. The profit is shared in proportion to the total investment made in that year.

If at the end of that investment year, Q receives $\frac{4}{9}$ of the total profit, what is the value of x (in)?

(A) 2500

(B) 3000

(C) 4687

(D) 8437

Correct Answer: (B) 3000

Solution:

Let's calculate the total investment made by P and Q. P invests 5000 per month for 6 months, so P's total investment is:

$$5000 \times 6 = 30,000\,.$$

Q invests x per month for 8 months, so Q's total investment is:

$$x \times 8 = 8x\,.$$

The total investment made by both P and Q is:

$$30,000 + 8x\,.$$

The total profit is shared in proportion to the total investment. We are given that Q receives $\frac{4}{9}$ of the total profit. Therefore, the fraction of the total profit received by Q is the ratio of Q's investment to the total investment, i.e.,

$$\frac{8x}{30,000 + 8x}.$$

Since Q receives $\frac{4}{9}$ of the total profit, we can set up the equation:

$$\frac{8x}{30,000 + 8x} = \frac{4}{9}.$$

Cross-multiply to solve for x:

$$9 \times 8x = 4 \times (30,000 + 8x),$$

$$72x = 120,000 + 32x,$$

$$72x - 32x = 120,000,$$

$$40x = 120,000,$$

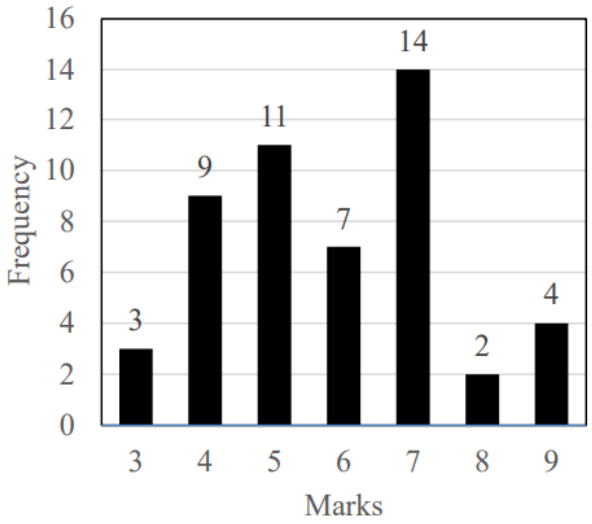
$$x = \frac{120,000}{40} = 3000.$$

Thus, the value of x is 3000.

Quick Tip

To find the amount invested by each partner, use the ratio of their investments to the total investment. The share of profit is then directly proportional to this ratio.

8.



The above frequency chart shows the frequency distribution of marks obtained by a set of students in an exam.

From the data presented above, which one of the following is CORRECT?

(A) mean > mode > median

(B) mean = mode = median

(C) mean < mode < median

(D) mean < median < mode

Correct Answer: (B) mean = mode = median

Solution:

The given frequency distribution shows the number of students who scored different marks in an exam. We are asked to identify the correct relationship between the mean, mode, and median.

In a symmetric distribution, the mean, mode, and median are equal. From the given frequency distribution, we can observe that the distribution appears fairly symmetric with the highest frequency at the middle marks (5 and 6 marks), and it does not show extreme skewness. Therefore, for this distribution, the mean, median, and mode will be approximately equal.

Thus, the correct answer is (B) mean = mode = median.

Quick Tip

In a symmetric distribution, the mean, mode, and median are equal. This relationship is useful for understanding the central tendency of a dataset.

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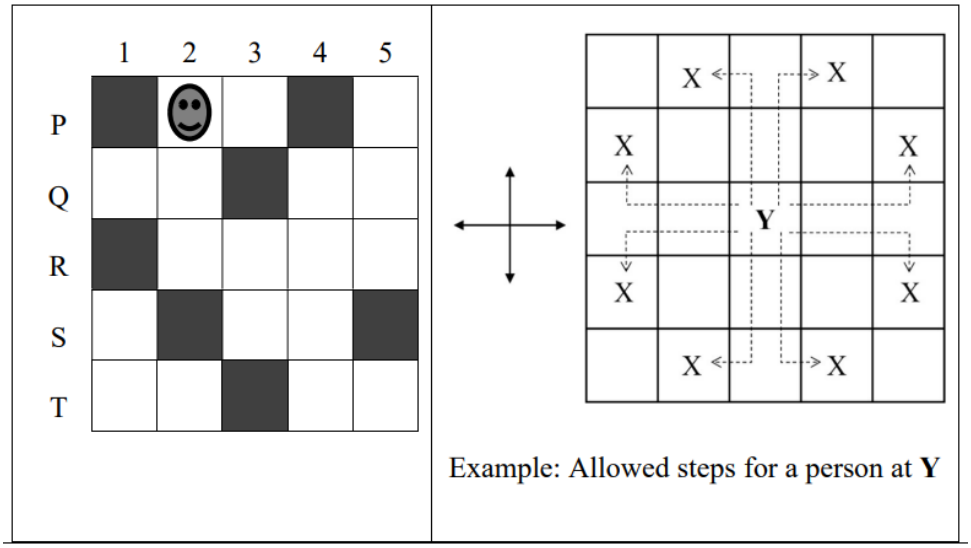
9. In the square grid shown on the left, a person standing at P2 position is required to move to P5 position.

The only movement allowed for a step involves, ”two moves along one direction followed by one move in a perpendicular direction”. The permissible directions for movement are shown as dotted arrows in the right.

For example, a person at a given position Y can move only to the positions marked X on the right.

Without occupying any of the shaded squares at the end of each step, the minimum number of steps required to go from P2 to P5 is:



(A) 4

(B) 5

(C) 6

(D) 7

Correct Answer: (B) 5

Solution:

We need to determine the minimum number of steps to move from P2 to P5. The movement rule requires two steps in one direction followed by one step in a perpendicular direction.
By following the movement restrictions and considering the allowed moves, we can visualize the path taken across the grid. Here is how it works:
1. From P2, the person can move two squares to the right and then one square down.
2. From the new position, another two steps to the right followed by one step upwards.
3. From here, another similar move will get the person close to P5.
Counting all the steps, we see that it takes 5 moves to reach P5.
Thus, the correct answer is **(B) 5**.

Quick Tip

To find the minimum number of steps, always plan the path in a way that minimizes backtracking and utilizes the allowed movement pattern efficiently.

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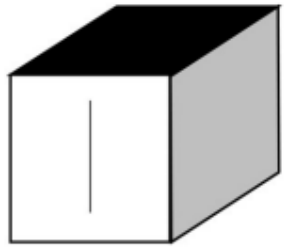
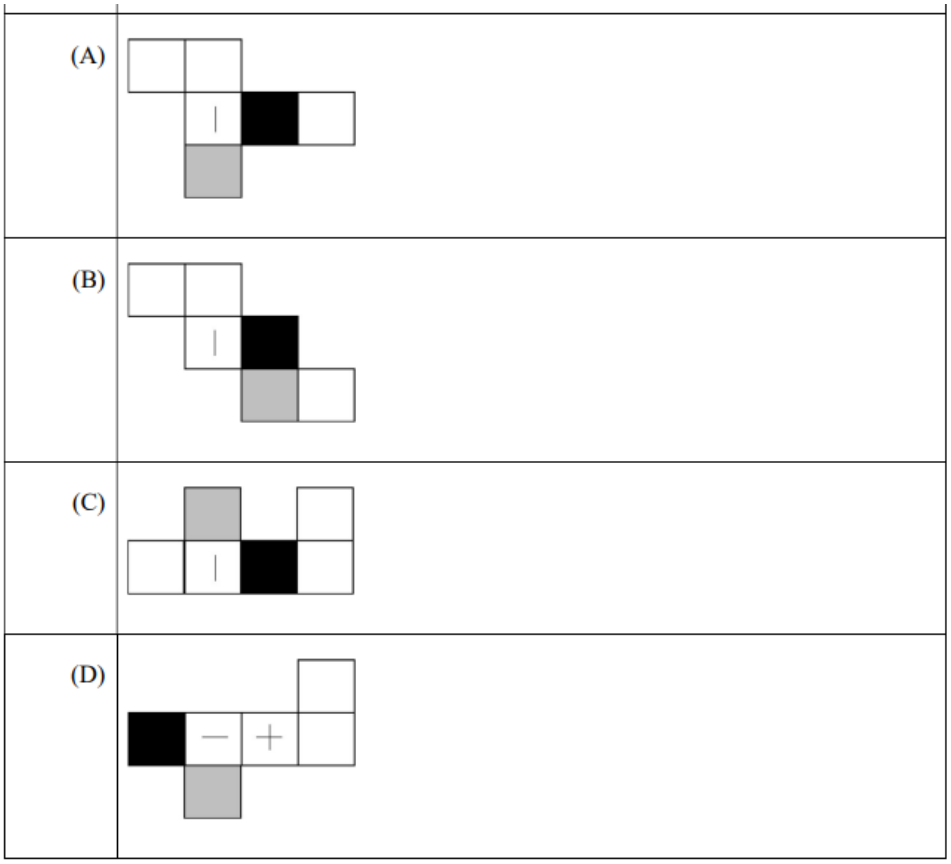
10. Consider a cube made by folding a single sheet of paper of appropriate shape. The interior faces of the cube are all blank. However, the exterior faces that are not visible in the above view may not be blank. Which one of the following represents a possible unfolding of the cube?





Correct Answer: (B)

Solution:

To solve this, we need to visualize how the cube is folded and how the faces would appear when unfolded into a two-dimensional shape. The cube has six faces, and when unfolded, the net of the cube will show these six faces.

The visible and hidden faces must align correctly to form a proper cube. After examining each option, we observe that option **(B)** represents a valid unfolding of the cube. In this option, the layout of the faces allows them to be folded correctly into a cube with the given conditions.

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

Quick Tip

When solving cube unfolding problems, visualize the three-dimensional structure and how the faces fit together. Ensure that all faces align logically when folded.

11. What is the order of the differential equation given below?

$$\frac{d^2y}{dx^2} - 6x = 3x^4 - 2x^3 + 2$$

(A) 1

(B) 2

(C) 3

(D) 4

Correct Answer: (B) 2

Solution:

The order of a differential equation is determined by the highest derivative of the unknown function. In this case, the given equation is:

$$\frac{d^2y}{dx^2} - 6x = 3x^4 - 2x^3 + 2$$

The highest derivative in this equation is $\frac{d^2y}{dx^2}$, which is the second derivative of y. Therefore, the order of the differential equation is 2.

Thus, the correct answer is (B).

Quick Tip

The order of a differential equation is determined by the highest derivative of the unknown function present in the equation.

12. If the eigenvalues of a 2×2 matrix P are 4 and 2, then the eigenvalues of the matrix P^{-1} are

(A) 0, 0

(B) 0.0625, 0.25

(C) 0.25, 0.5

(D) 2, 4

Correct Answer: (C) 0.25, 0.5

Solution:

For a square matrix P, if its eigenvalues are λ_1 and λ_2, the eigenvalues of its inverse matrix P^{-1} are given by the reciprocals of the eigenvalues of P. That is, the eigenvalues of P^{-1} are $\frac{1}{\lambda_1}$ and $\frac{1}{\lambda_2}$.

Given that the eigenvalues of P are 4 and 2, the eigenvalues of P^{-1} are:

$$\frac{1}{4} = 0.25 \quad \text{and} \quad \frac{1}{2} = 0.5.$$

Thus, the correct answer is (C).

Quick Tip

For a matrix P, if its eigenvalues are λ_1 and λ_2, the eigenvalues of P^{-1} are $\frac{1}{\lambda_1}$ and $\frac{1}{\lambda_2}$.

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13. For a double-pipe heat exchanger, the inside and outside heat transfer coefficients are 100 and 200 W m^{-2} K^{-1}, respectively. The thickness and thermal conductivity of the thin-walled inner pipe are 1 cm and 10 W m^{-1} K^{-1}, respectively. The value of the overall heat transfer coefficient is _____ W m^{-2} K^{-1}.

(A) 0.016

(B) 42.5

(C) 62.5

(D) 310

Correct Answer: (C) 62.5

Solution:

The overall heat transfer coefficient U for a double-pipe heat exchanger can be calculated using the following equation:

$$\frac{1}{U} = \frac{1}{h_i} + \frac{r_i \ln(r_o/r_i)}{k} + \frac{1}{h_o}$$

where:

- h_i is the inside heat transfer coefficient,

- h_o is the outside heat transfer coefficient,

- r_i and r_o are the inner and outer radii of the pipe,

- k is the thermal conductivity of the pipe material.

Given:

- $h_i = 100\,\text{W m}^{-2}\text{K}^{-1}$,

- $h_o = 200\,\text{W m}^{-2}\text{K}^{-1}$,

- The thickness of the pipe is 1 cm, so $r_o = r_i + 0.01$ m, and the thermal conductivity $k = 10\,\text{W m}^{-1}\text{K}^{-1}$.

Substituting these values into the equation, we find that the overall heat transfer coefficient U is approximately $62.5\,\text{W m}^{-2}\text{K}^{-1}$. Therefore, the correct answer is (C).

Quick Tip

For heat exchangers, the overall heat transfer coefficient depends on the thermal resistances due to convection on both sides of the pipe and conduction through the pipe material.

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14. Match the media component (Column I) with its role (Column II).

Column I	Column II
P. Sucrose	1. Anti-foam agent
Q. Zinc chloride	2. Nitrogen source
R. Ammonium sulphate	3. Carbon source
S. Silicone oil	4. Trace element

(A) P – 1, Q – 3, R – 4, S – 2

(B) P – 2, Q – 1, R – 3, S – 4

(C) P – 3, Q – 2, R – 4, S – 1

(D) P – 3, Q – 4, R – 1, S – 2

Correct Answer: (C) P – 3, Q – 2, R – 4, S – 1

Solution:

- **P. Sucrose** is commonly used as a carbon source in microbial growth media. It provides the energy required for growth. So, P matches with 3 (Carbon source).
- **Q. Zinc chloride** is used as a trace element, often added to media in small quantities for enzyme activity or other biochemical functions. So, Q matches with 4 (Trace element).
- **R. Ammonium sulphate** provides nitrogen, which is essential for protein synthesis. So, R matches with 2 (Nitrogen source).
- **S. Silicone oil** is used as an anti-foam agent in bioreactors, helping to reduce foam formation. So, S matches with 1 (Anti-foam agent).

Step 1: Conclusion

The correct matching is (C) P – 3, Q – 2, R – 4, S – 1.

Quick Tip

When matching components with their roles, remember the common uses of chemicals in industrial and laboratory processes, such as sucrose as a carbon source and ammonium sulphate as a nitrogen source.

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15. The binding free energy of a ligand to its receptor protein is $-11.5\,\text{kJ mol}^{-1}$ at 300 K. What is the value of the equilibrium binding constant?

(A) 0.01

(B) 1.0

(C) 4.6

(D) 100.5

Correct Answer: (D) 100.5

Solution:

To find the equilibrium binding constant K, we use the relationship between the binding free energy ΔG and the equilibrium constant K, which is given by the following equation:

$$\Delta G = -RT \ln K$$

Where:

- $\Delta G = -11.5\,\text{kJ mol}^{-1} = -11.5 \times 10^3\,\text{J mol}^{-1}$ (since $1\,\text{kJ} = 1000\,\text{J}$),
- $R = 8.314\,\text{J mol}^{-1}\text{K}^{-1}$ is the gas constant,
- $T = 300\,\text{K}$ is the temperature in Kelvin,
- K is the equilibrium binding constant (which we need to calculate).

First, we rearrange the equation to solve for K:

$$K = \exp\left(\frac{-\Delta G}{RT}\right)$$

Substitute the given values into the equation:

$$K = \exp\left(\frac{-(-11.5 \times 10^3)}{8.314 \times 300}\right)$$

$$K = \exp\left(\frac{11.5 \times 10^3}{2494.2}\right)$$

$$K = \exp(4.62)$$

$$K \approx 100.5$$

Thus, the value of the equilibrium binding constant is 100.5, so the correct answer is (D).

Quick Tip

The equilibrium binding constant K can be calculated from the binding free energy using the equation $\Delta G = -RT \ln K$.

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16. The overall stoichiometry for an aerobic cell growth is

$3C_6H_{12}O_6 + 2.5NH_3 + O_2 \rightarrow 1.5C_aH_bO_cN_d + 3CO_2 + 5H_2O.$

What is the elemental composition formula of the biomass?

(A) $C_9H_{18.2}O_5N_{1.667}$

(B) $C_9H_{22.33}O_6N_{1.667}$

(C) $C_{10}H_{18.2}O_5N_{1.667}$

(D) $C_{10}H_{22.33}O_6N_{1.667}$

Correct Answer: (D) $C_{10}H_{22.33}O_6N_{1.667}$

Solution:

To find the elemental composition of the biomass, we need to analyze the stoichiometry of the reaction and calculate the proportions of carbon, hydrogen, oxygen, and nitrogen in the biomass (represented by $C_aH_bO_cN_d$).

1. Carbon (C): - The glucose ($C_6H_{12}O_6$) contributes 3 moles of carbon atoms per mole of biomass, with 3 moles of glucose involved in the reaction. - The carbon from CO_2 is released as a byproduct and does not contribute to the biomass.

2. Hydrogen (H): - The hydrogen atoms come from glucose (12 H per glucose) and ammonia (NH_3), with 2.5 moles of NH_3.

3. Oxygen (O): - Oxygen atoms come from glucose, oxygen molecules, and the CO_2 byproduct.

4. Nitrogen (N): - Nitrogen comes from ammonia (NH_3) in the reaction, contributing nitrogen to the biomass.

By balancing the reaction and applying the stoichiometry, we calculate the elemental composition of the biomass:

- $C_{10}H_{22.33}O_6N_{1.667}$

Thus, the correct elemental composition formula of the biomass is (D).

Quick Tip

In stoichiometry for biochemical reactions, balance the elements (C, H, O, N) carefully using the given reaction to determine the composition of the product (biomass).

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17. In binomial nomenclature, the name of a bacterial strain is written with the first letter of _____ word(s) being capitalized.

(A) first

(B) second

(C) neither

(D) first and second

Correct Answer: (A) first

Solution:

In binomial nomenclature, which is the system used to name species, the name of an organism consists of two parts: the genus name and the species name. The genus name is always capitalized, while the species name is written in lowercase. This system ensures clarity and uniformity in scientific naming across different organisms.

- The first word of the name is the genus, and it is capitalized. For example, in the name Escherichia coli, Escherichia is the genus and is capitalized.
- The second word is the species, and it is written in lowercase. In the same example, coli is the species and is written in lowercase.

Therefore, the correct answer is (A), where only the first word (genus) is capitalized, and the second word (species) is lowercase.

Quick Tip

In binomial nomenclature, always capitalize the genus name (first word) and use lowercase for the species name (second word).

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18. The type of nucleic acid present in λ-phage is

(A) Double stranded DNA

(B) Single stranded circular DNA

(C) Single stranded DNA

(D) Single stranded RNA

Correct Answer: (A) Double stranded DNA

Solution:

The λ-phage (Lambda phage) is a well-studied bacteriophage, a type of virus that infects bacteria. The nucleic acid of the λ-phage is double-stranded DNA (dsDNA). The structure of the λ-phage's genome consists of linear DNA that circularizes once inside the host bacterium. The DNA in the λ-phage is unique because, although the genome is linear during the infection process, it forms a circular DNA molecule once integrated into the host cell. This double-stranded DNA molecule contains the genetic instructions for the virus to replicate and produce more viral particles.

- Option (A): The double stranded DNA is the correct answer, as it describes the genetic material of λ-phage.
- Option (B): The single stranded circular DNA is not accurate for λ-phage, as the phage has double-stranded DNA that circularizes once inside the host.
- Option (C): The single stranded DNA is not correct either because λ-phage has double-stranded DNA.
- Option (D): The single stranded RNA is also incorrect because λ-phage has DNA, not RNA, as its nucleic acid.

Thus, the correct answer is (A) Double stranded DNA.

Quick Tip

The λ-phage, like many other bacteriophages, uses double-stranded DNA as its genetic material, which is different from the RNA found in many other types of viruses.

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19. Which of the following statements about reversible enzyme inhibitors are CORRECT?

P. Uncompetitive inhibitors bind only to the enzyme-substrate complex.

Q. Non-competitive inhibitors bind only at a different site from the substrate.

R. Competitive inhibitors bind to the same site as the substrate.

(A) P and Q only

(B) P and R only

(C) Q and R only

(D) P, Q and R

Correct Answer: (D) P, Q and R

Solution:

Let's analyze each statement:

- **Statement P:** Uncompetitive inhibitors bind only to the enzyme-substrate complex. This is true. Uncompetitive inhibitors only bind to the enzyme-substrate complex after the substrate has bound to the enzyme.

- **Statement Q:** Non-competitive inhibitors bind only at a different site from the substrate. This is true. Non-competitive inhibitors bind to a site distinct from the active site, which can be on the enzyme or enzyme-substrate complex.

- **Statement R:** Competitive inhibitors bind to the same site as the substrate. This is true. Competitive inhibitors compete with the substrate for binding to the active site of the enzyme.

Thus, all the statements are correct, and the correct answer is **(D) P, Q and R**.

Quick Tip

Reversible enzyme inhibitors can be classified based on how they interact with the enzyme and substrate, such as competitive, non-competitive, and uncompetitive inhibitors.

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20. Match the component of eukaryotic cells (Column I) with its respective function (Column II).

Column I	**Column II**
P. Lysosome	1. Digestion of macromolecules
Q. Peroxisome	2. Detoxification of harmful compounds
R. Glyoxysome	3. Conversion of fatty acids to sugar
S. Cytoskeleton	4. Involvement in cell motility

(A) P – 1, Q – 2, R – 3, S – 4

(B) P – 2, Q – 1, R – 3, S – 4

(C) P – 3, Q – 1, R – 2, S – 4

(D) P – 3, Q – 1, R – 2, S – 4

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

Solution:

Let's go through each component and its corresponding function:

- **Lysosome (P):** The lysosome is involved in the digestion of macromolecules within the cell, breaking down waste materials and cellular debris. Thus, P matches with **1. Digestion of macromolecules**.
- **Peroxisome (Q):** Peroxisomes are involved in detoxifying harmful compounds and metabolic processes like fatty acid oxidation. Hence, Q matches with **2. Detoxification of harmful compounds**.
- **Glyoxysome (R):** Glyoxysomes are specialized peroxisomes found in plants that convert fatty acids into sugar. Therefore, R matches with **3. Conversion of fatty acids to sugar**.
- **Cytoskeleton (S):** The cytoskeleton provides structure to the cell and plays a critical role in cell motility. Thus, S matches with **4. Involvement in cell motility**.

The correct matching is **(A) P – 1, Q – 2, R – 3, S – 4**.

Quick Tip

Understanding the functions of organelles and structures in eukaryotic cells is essential for studying cell biology and their roles in cellular processes like digestion, detoxification, and motility.

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21. In animal cells, the endogenously produced miRNAs silence gene expression by

(A) base pairing with the 3'-untranslated region of specific mRNAs
(B) blocking mRNA synthesis
(C) binding to the operator site
(D) base pairing with the 3' region of specific rRNAs

Correct Answer: (A) base pairing with the 3'-untranslated region of specific mRNAs

Solution:

In animal cells, miRNAs (microRNAs) function by binding to the 3'-untranslated region (3' UTR) of specific mRNAs. This binding can result in the silencing of gene expression through mRNA degradation or inhibition of translation. Therefore, the correct option is (A).
- Option (B) is incorrect because miRNAs do not block mRNA synthesis directly, they affect mRNA after its synthesis.
- Option (C) is incorrect because miRNAs do not bind to the operator site, which is more relevant to bacterial gene regulation.
- Option (D) is incorrect because miRNAs typically interact with mRNAs, not rRNAs.
Thus, the correct answer is (A).

Quick Tip

MiRNAs regulate gene expression by binding to the 3' UTR of target mRNAs, leading to mRNA degradation or translation inhibition.

---

22. Terpenoids are made of _____ units.

(A) amino acid
(B) carbohydrate
(C) isoprene
(D) triacylglycerol

Correct Answer: (C) isoprene

Solution:
Terpenoids are a large and diverse class of naturally occurring organic compounds derived from isoprene units. These units are linked together in various configurations to form different types of terpenoids, such as monoterpenes, diterpenes, and sesquiterpenes. Therefore, the correct answer is (C).
- Option (A) is incorrect because terpenoids are not made from amino acids.
- Option (B) is incorrect because carbohydrates are not the building blocks of terpenoids.
- Option (D) is incorrect because triacylglycerol is a type of lipid, not related to terpenoid synthesis.

Thus, the correct answer is (C).

Quick Tip

Terpenoids are synthesized from isoprene units and are essential components of many natural products, including essential oils and vitamins.

---

23. Match the microbial product (Column I) with its respective application (Column II).

Column I	Column II
P. Methane	1. Biosurfactant
Q. Glycolipids	2. Bioplastic
R. Polyhydroxy alkanoate	3. Biofuel

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

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

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

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

Correct Answer: (C) P-3, Q-2, R-1

Solution:

- **P. Methane** is commonly used as a biofuel. It is a major component of natural gas and is used as a renewable energy source. So, P matches with 3 (Biofuel).
- **Q. Glycolipids** are used in the production of biosurfactants, which are surface-active compounds used in various industrial applications, including cleaning and oil recovery. So, Q matches with 1 (Biosurfactant).
- **R. Polyhydroxy alkanoate** is used to produce bioplastics, which are biodegradable plastics made by microorganisms. So, R matches with 2 (Bioplastic).

Step 1: Conclusion

The correct matching is (C) P-3, Q-2, R-1.

Quick Tip

When matching microbial products to their applications, consider their primary industrial use such as methane for biofuel and polyhydroxy alkanoates for bioplastics.

---

24. Which of the following is NOT used for generating an optimal alignment of two nucleotide sequences?

(A) Gap penalties
(B) Match scores
(C) Mismatch scores
(D) Nucleotide composition

Correct Answer: (D) Nucleotide composition

Solution:
In the context of sequence alignment, the following elements are used:
- **Gap penalties** are used to penalize gaps introduced in the alignment to optimize the matching of sequences.
- **Match scores** are used to score the alignment when two nucleotides in the sequences match.
- **Mismatch scores** are used to penalize mismatches between nucleotides during the alignment.

Nucleotide composition is not typically used in the alignment scoring itself, but rather provides information about the nucleotide distribution in a sequence. Therefore, the correct answer is (D).

Step 1: Conclusion
Nucleotide composition is not used for generating an optimal alignment of two nucleotide sequences, so the correct answer is (D).

Quick Tip

In sequence alignment, gap penalties, match scores, and mismatch scores are used to determine the optimal alignment between two sequences, whereas nucleotide composition is not directly involved.

---

25. The recognition sequences of four Type-II restriction enzymes (RE) are given below. The symbol (—) indicates the cleavage site. Identify the RE that generates sticky ends.

(A) RE1 - $5'$ G ATCC $3'$

(B) RE2 - $5'$ CTG CAG $3'$

(C) RE3 - $5'$ CCC GGG $3'$

(D) RE4 - $5'$ AG CT $3'$

Correct Answer: (A) RE1 - $5'$ G ATCC $3'$

Solution:

In the context of restriction enzymes (RE), sticky ends refer to the overhanging bases created after the enzyme cleaves the DNA molecule. These ends are essential for ligating DNA fragments together, as they provide complementary sequences for base pairing.

- RE1: The recognition sequence is $5'$ G ATCC $3'$. When this restriction enzyme cuts between the G and A, it generates sticky ends with overhangs of single-stranded DNA that can pair with complementary sequences. Thus, RE1 generates sticky ends.

- RE2: The sequence $5'$ CTG CAG $3'$ cuts between the G and C bases, but this results in blunt ends, not sticky ends.

- RE3: The sequence $5'$ CCC GGG $3'$ also results in blunt ends, as it cuts directly in the middle of the recognition sequence.

- RE4: The sequence $5'$ AG CT $3'$ similarly results in blunt ends as the cleavage occurs between the A and G bases.

Thus, the only enzyme that generates sticky ends is RE1, so the correct answer is (A).

Quick Tip

Sticky ends are generated when a restriction enzyme cuts DNA in such a way that leaves overhanging single-stranded DNA, which can form base pairs with complementary sequences.

---

26. Among individuals in a human population, minor variations exist in nucleotide sequences of chromosomes. These variations can lead to gain or loss of sites for specific restriction enzymes. Which of the following techniques is used to identify such variations?

(A) Polymerase dependent fragment insertion
(B) Real-time polymerase chain reaction
(C) Restriction fragment length polymorphism
(D) Reverse transcriptase polymerase chain reaction

Correct Answer: (C) Restriction fragment length polymorphism

Solution:
The correct technique to identify variations in DNA sequences that result in the gain or loss of restriction enzyme sites is Restriction Fragment Length Polymorphism (RFLP). This technique is based on detecting differences in the lengths of restriction enzyme-digested DNA fragments. These length variations arise due to the presence or absence of specific restriction sites in the genome, which can result from mutations or genetic polymorphisms.
Explanation of Options: - (A) Polymerase dependent fragment insertion: This term does not refer to a known technique used to detect sequence variations. It is not related to the identification of polymorphisms.
- (B) Real-time polymerase chain reaction (RT-PCR): While RT-PCR is used for detecting gene expression and mutations, it does not focus on identifying variations in restriction enzyme sites.
- (C) Restriction fragment length polymorphism (RFLP): RFLP is the correct technique, as it directly analyzes DNA fragments resulting from restriction enzyme digestion to identify genetic variations.

- (D) Reverse transcriptase polymerase chain reaction (RT-PCR): RT-PCR is used to measure mRNA expression levels and does not identify restriction enzyme site variations.
Thus, the correct answer is (C) Restriction fragment length polymorphism.

Quick Tip

RFLP is a powerful technique for detecting genetic variations at the DNA level, especially those that affect the recognition sites of restriction enzymes.

---

27. Assuming independent assortment and no recombination, the number of different combinations of maternal and paternal chromosomes in gametes of an organism with a diploid number of 12 is _____.

Solution:

The number of different combinations of maternal and paternal chromosomes in gametes is determined by the formula:

$$\text{Number of combinations} = 2^n,$$

where n is the haploid number (half of the diploid number). The diploid number is given as 12, so the haploid number $n = \frac{12}{2} = 6$.
Thus, the number of different combinations is:

$$2^6 = 64.$$

Therefore, the number of different combinations of chromosomes in the gametes is 64.

Quick Tip

For independent assortment, the number of possible combinations of chromosomes in gametes is 2^n, where n is the haploid number.

---

28. A microorganism is grown in a batch culture using glucose as a carbon source. The apparent growth yield is 0.5 g biomass / g substrate. The initial concentrations of

biomass and substrate are 2 g L^{-1} and 200 g L^{-1}, respectively. Assuming that there is no endogenous metabolism, the maximum biomass concentration that can be achieved is _____ g L^{-1}.

Solution:

The maximum biomass concentration that can be achieved is determined by the maximum amount of substrate available and the apparent growth yield. The maximum biomass concentration is given by:

$$X_{\text{max}} = Y_{\text{X/S}} \times S_{\text{initial}},$$

where:

- $Y_{\text{X/S}} = 0.5$ g biomass/g substrate is the apparent growth yield,
- $S_{\text{initial}} = 200$ g L^{-1} is the initial concentration of substrate.

Substituting the values into the equation:

$$X_{\text{max}} = 0.5 \times 200 = 100 \text{ g } L^{-1}.$$

Thus, the maximum biomass concentration that can be achieved is 100 g L^{-1}.

Quick Tip

The maximum biomass concentration in a batch culture can be calculated by multiplying the apparent growth yield by the initial concentration of the substrate.

---

29. The degree of reduction of lactic acid ($C_3H_6O_3$) is _____.

Solution:

Degree of reduction is calculated using:

$$\gamma = 4C + H - 2O$$

For lactic acid $C_3H_6O_3$:

C = 3, H = 6, O = 3

$$\gamma = 4(3) + 6 - 2(3)$$

$$\gamma = 12 + 6 - 6 = 12$$

Degree of reduction per mole is 12.

Degree of reduction per carbon atom = $\frac{12}{3} = 4$.

Thus, the degree of reduction is:

$$\boxed{4}$$

Quick Tip

Degree of reduction compares the electron richness of a compound and is computed using $4C + H - 2O$ for biomolecules.

---

30. Consider a nonlinear algebraic equation, $x \ln x + x - 1 = 0$. Using the Newton–Raphson method, with the initial guess of $x_0 = 3$, the value of x after one iteration (rounded off to one decimal place) is _____.

Solution:

Given:

$$f(x) = x \ln x + x - 1$$

Derivative:

$$f'(x) = \ln x + 1 + 1 = \ln x + 2$$

Newton–Raphson formula:

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$

Compute at $x_0 = 3$:

$$f(3) = 3 \ln 3 + 3 - 1$$

$$\ln 3 = 1.0986$$

$$f(3) = 3(1.0986) + 2 = 3.2958 + 2 = 5.2958$$

Now compute derivative:

$$f'(3) = \ln 3 + 2 = 1.0986 + 2 = 3.0986$$

Apply Newton–Raphson:

$$x_1 = 3 - \frac{5.2958}{3.0986}$$

$$x_1 = 3 - 1.708 \approx 1.292$$

Rounded to one decimal place:

$$\boxed{1.3}$$

Quick Tip

Newton–Raphson method converges rapidly if the initial guess is close to the actual root.

---

31. The probability density function of a random variable X is $p(x) = 2e^{-2x}$. The probability $P(1 \leq X \leq 2)$ (rounded off to two decimal places) is _____ .

Solution:

The probability $P(1 \leq X \leq 2)$ is found by integrating the probability density function $p(x)$ over the range from 1 to 2:

$$P(1 \leq X \leq 2) = \int_1^2 2e^{-2x}\, dx.$$

To solve the integral:

$$\int 2e^{-2x}\, dx = -e^{-2x}.$$

Now, evaluate the integral from 1 to 2:

$$P(1 \leq X \leq 2) = \left[-e^{-2x}\right]_1^2 = -e^{-4} + e^{-2}.$$

Substitute the values of e^{-4} and e^{-2}:

$$P(1 \leq X \leq 2) = -(0.0183) + (0.1353) = 0.1170.$$

Thus, the probability is approximately 0.11.

Quick Tip

To calculate the probability between two values for a continuous probability density function, integrate the PDF over the desired range.

---

32. The maximum value of the function $f(x) = 3x^2 - 2x^3$ for $x > 0$ is _____ .

Solution:

To find the maximum value of the function, we first find its critical points by taking the derivative of $f(x)$ and setting it equal to 0:

$$f'(x) = 6x - 6x^2.$$

Set $f'(x) = 0$:

$$6x - 6x^2 = 0 \quad \Rightarrow \quad 6x(1 - x) = 0.$$

So, the critical points are $x = 0$ and $x = 1$. Since we are interested in $x > 0$, we have $x = 1$.

Now, we check the second derivative to determine if $x = 1$ is a maximum:

$$f''(x) = 6 - 12x.$$

At $x = 1$:

$$f''(1) = 6 - 12(1) = -6.$$

Since $f''(1) < 0$, $x = 1$ is a local maximum.

Finally, evaluate $f(x)$ at $x = 1$:

$$f(1) = 3(1)^2 - 2(1)^3 = 3 - 2 = 1.$$

Thus, the maximum value of the function is 1.

Quick Tip

To find the maximum or minimum value of a function, take the derivative, set it equal to 0, and use the second derivative test to determine the nature of the critical points.

---

33. The specific growth rate of a yeast having a doubling time of 0.693 h (rounded off to nearest integer) is _____ h^{-1}.

Solution:

The relation between doubling time (t_d) and specific growth rate (μ) is:

$$t_d = \frac{\ln 2}{\mu}$$

Given doubling time:

$$t_d = 0.693 \text{ h}$$

Thus,

$$\mu = \frac{\ln 2}{t_d} = \frac{0.693}{0.693} = 1 \text{ h}^{-1}$$

Rounded to the nearest integer:

$$\boxed{1}$$

Quick Tip

Doubling time and growth rate are inversely related: a shorter doubling time means a higher growth rate.

---

34. A fermentation broth of density 1000 kg m^{-3} and viscosity 10^{-3} kg m^{-1} s^{-1} is mixed in a 100 L fermenter using a 0.1 m diameter impeller, rotating at a speed of 2 s^{-1}. The impeller Reynolds number is _____.

Solution:

The Reynolds number for an impeller is given by:

$$Re = \frac{\rho N D^2}{\mu}$$

Given data:

$$\rho = 1000 \text{ kg m}^{-3}, \quad N = 2 \text{ s}^{-1}, \quad D = 0.1 \text{ m}, \quad \mu = 10^{-3} \text{ kg m}^{-1}\text{s}^{-1}$$

Substitute values:

$$Re = \frac{1000 \times 2 \times (0.1)^2}{10^{-3}}$$

$$Re = \frac{1000 \times 2 \times 0.01}{10^{-3}}$$

$$Re = \frac{20}{10^{-3}} = 20\,000$$

Thus, the impeller Reynolds number is:

$$\boxed{20000}$$

Quick Tip

In mixing problems, a Reynolds number above 10,000 indicates fully turbulent flow.

---

35. For a pure species, the slope of the melting line $\frac{dP}{dT}$ at $-2°$C is -5.0665×10^6 Pa K^{-1}. The difference between the molar volumes of the liquid and solid phase at $-2°$C is -4.5×10^{-6} m^3 mol^{-1}. The value of the latent heat of fusion (rounded off to nearest integer) is _____ J mol^{-1}.

Solution:

To find the latent heat of fusion, we use the **Clapeyron equation** that relates pressure, temperature, volume change, and latent heat across a phase transition:

$$\frac{dP}{dT} = \frac{L}{T\Delta V}$$

Step 1: Identify the given values:

Slope of melting line:

$$\frac{dP}{dT} = -5.0665 \times 10^6 \text{ Pa K}^{-1}$$

Difference in molar volumes (liquid – solid):

$$\Delta V = -4.5 \times 10^{-6} \text{ m}^3 \text{ mol}^{-1}$$

Temperature:

$$T = -2^\circ\text{C} = 271 \text{ K}$$

Step 2: Apply the Clapeyron equation to solve for L:

$$L = \frac{dP}{dT} \times T \times \Delta V$$

Substitute the values:

$$L = (-5.0665 \times 10^6) \times (271) \times (-4.5 \times 10^{-6})$$

Step 3: Compute the product step-by-step:

First multiply the slope and the volume change:

$$(-5.0665 \times 10^6) \times (-4.5 \times 10^{-6}) = 5.0665 \times 4.5 = 22.79925$$

Now multiply by temperature:

$$L = 22.79925 \times 271 = 6188.65$$

Step 4: Round off to nearest integer:

$$L \approx 6189 \text{ J mol}^{-1}$$

Thus, the latent heat of fusion is approximately 6189 J mol^{-1}.

Quick Tip

For phase transitions at equilibrium, the Clapeyron equation $\frac{dP}{dT} = \frac{L}{T\Delta V}$ directly connects pressure–temperature slope with latent heat. Sign conventions matter but the magnitude of L is obtained from absolute values.

36. Which of the following conditions will contribute to the stability of a gene pool in a natural population?

P. Large population

Q. No net mutation

R. Non-random mating

S. No selection

(A) P only

(B) P and Q only

(C) P and R only

(D) P, Q and S only

Correct Answer: (D) P, Q and S only

Solution:

The stability of a gene pool, as described by Hardy-Weinberg equilibrium, requires the following conditions:

- Large population (P) helps to minimize genetic drift.
- No net mutation (Q) ensures that no new alleles are introduced into the gene pool.
- No selection (S) ensures that all individuals have equal reproductive success, which helps maintain allele frequencies.

Thus, non-random mating (R) does not contribute to stability and can alter the gene pool. Hence, the correct answer is (D).

Quick Tip

For Hardy-Weinberg equilibrium, the conditions that must hold are: large population, no mutation, no migration, random mating, and no selection.

37. Match the media component used in mammalian cell culture (Column I) with its respective role (Column II).

Column I	Column II
P. Hydrocortisone	1. Mitogen
Q. Fibronectin	2. Vitamin
R. Epidermal growth factor	3. Hormone
S. Riboflavin	4. Cell attachment

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

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

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

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

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

Solution:

- P. Hydrocortisone is a hormone (3) that regulates various cell functions.

- Q. Fibronectin plays a crucial role in cell attachment (4) by mediating cell adhesion to the extracellular matrix.

- R. Epidermal growth factor is a mitogen (1), promoting cell growth and division. - S. Riboflavin is a vitamin (2) that helps in cellular metabolism.

Thus, the correct matching is P-3, Q-4, R-1, S-2, which corresponds to option (A).

Quick Tip

In cell culture, hormones, mitogens, vitamins, and cell attachment factors play distinct roles in regulating cell growth and maintenance.

38. Match the cell type (Column I) with its function (Column II).

Column I	Column II
P. B cells	1. Humoral immunity
Q. Neutrophils	2. Cytotoxicity
R. T cells	3. Histamine-associated allergy
S. Mast cells	4. Phagocytosis

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

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

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

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

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

Solution:

- **P. B cells** are responsible for humoral immunity. They produce antibodies to neutralize pathogens. So, P matches with 1 (Humoral immunity).
- **Q. Neutrophils** are involved in phagocytosis. They are white blood cells that engulf pathogens and debris. So, Q matches with 4 (Phagocytosis).
- **R. T cells** are involved in cytotoxicity. They are responsible for killing infected or cancerous cells. So, R matches with 2 (Cytotoxicity).
- **S. Mast cells** are involved in histamine-associated allergy. They release histamines during allergic reactions. So, S matches with 3 (Histamine-associated allergy).

Step 1: Conclusion

The correct matching is (B) P-2, Q-4, R-1, S-3.

Quick Tip

B cells produce antibodies for humoral immunity, neutrophils perform phagocytosis, T cells are involved in cytotoxicity, and mast cells release histamine during allergic reactions.

---

39. A 2×2 matrix P has an eigenvalue $\lambda_1 = 2$ with eigenvector $x_1 = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and another eigenvalue $\lambda_2 = 5$, with eigenvector $x_2 = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$. The matrix P is

(A) $\begin{pmatrix} 2 & 0 \\ 0 & 5 \end{pmatrix}$

(B) $\begin{pmatrix} 2 & 3 \\ 0 & 5 \end{pmatrix}$

(C) $\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$

(D) $\begin{pmatrix} 1 & 1 \\ 1 & 0 \end{pmatrix}$

Correct Answer: (B) $\begin{pmatrix} 2 & 3 \\ 0 & 5 \end{pmatrix}$

Solution:

For a matrix P, the eigenvalues and eigenvectors can be used to construct the matrix. The matrix P can be written in terms of the eigenvectors and eigenvalues as:

$$P = V \Lambda V^{-1}$$

Where:

- Λ is the diagonal matrix with eigenvalues λ_1 and λ_2,
- V is the matrix whose columns are the eigenvectors.

The eigenvalues are $\lambda_1 = 2$ and $\lambda_2 = 5$, and the corresponding eigenvectors are $x_1 = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $x_2 = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$.

The matrix V will be $\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$, and the diagonal matrix Λ will be $\begin{pmatrix} 2 & 0 \\ 0 & 5 \end{pmatrix}$.

Now, the matrix P is:

$$P = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 2 & 0 \\ 0 & 5 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ -1 & 1 \end{pmatrix} = \begin{pmatrix} 2 & 3 \\ 0 & 5 \end{pmatrix}$$

Step 1: Conclusion

The matrix P is $\begin{pmatrix} 2 & 3 \\ 0 & 5 \end{pmatrix}$, so the correct answer is (B).

Quick Tip

To construct a matrix from its eigenvalues and eigenvectors, use the formula $P = V\Lambda V^{-1}$, where V is the matrix of eigenvectors and Λ is the diagonal matrix of eigenvalues.

---

40. Match the stationary phase (Column I) with its corresponding chromatography technique (Column II).

Column I	**Column II**
P. Protein A	1. Size exclusion chromatography
Q. Sephadex	2. Ion-exchange chromatography
R. Phenylsepharose	3. Affinity chromatography
S. Diethylaminoethyl cellulose	4. Hydrophobic interaction chromatography

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

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

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

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

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

Solution:

The given stationary phases correspond to different chromatography techniques as follows:

- P. Protein A is commonly used in Affinity chromatography (3), where the stationary phase specifically binds to the protein of interest.
- Q. Sephadex is used in Size exclusion chromatography (1), a technique that separates molecules based on their size.
- R. Phenysepharose is used in Hydrophobic interaction chromatography (4), which is based on the hydrophobic interactions between the stationary phase and the analyte.
- S. Diethylaminoethyl cellulose is used in Ion-exchange chromatography (2), a technique where charged particles are separated based on their interaction with the charged stationary phase.

Thus, the correct matching is P-3, Q-1, R-4, S-2, so the correct answer is (B).

Quick Tip

In chromatography, matching the stationary phase with the corresponding technique is crucial for selecting the right method for separation based on the properties of the molecules involved.

---

41. Which of the following statements are CORRECT for a controller?

(A) P and Q only

(B) P and R only

(C) P and S only

(D) Q and S only

Correct Answer: (C) P and S only

Solution:

Let's break down the statements and assess their correctness:

- P: In a proportional controller, a control action is proportional to the error.

- This statement is correct. A proportional controller adjusts the control output in direct proportion to the error value.

- Q: In an integral controller, a control action is proportional to the derivative of the error.

- This statement is incorrect. In an integral controller, the control action is proportional to the integral of the error, not the derivative.

- R: There is no "offset" in the response of the closed-loop first-order process with a proportional controller.

- This statement is incorrect. A proportional controller typically exhibits a steady-state error (offset) in response to a constant disturbance or setpoint change.

- S: There is no "offset" in the response of the closed-loop first-order process with a proportional-integral controller.

- This statement is correct. A proportional-integral (PI) controller eliminates the steady-state error (offset) in the closed-loop system by continuously integrating the error.

Thus, the correct answer is (C) P and S only.

Quick Tip

A proportional-integral controller (PI) is designed to eliminate the steady-state error, while a proportional controller alone cannot do so.

---

42. Which of the following are CORRECT about protein structure?

P. Secondary structure is formed by a repeating pattern of interactions among the polypeptide backbone atoms

Q. Tertiary structure is the three-dimensional arrangement of the polypeptide backbone atoms only

R. Quaternary structure refers to an assembly of multiple polypeptide subunits

(A) P and Q only

(B) P and R only

(C) Q and R only

(D) P, Q and R

Correct Answer: (B) P and R only

Solution:

Step 1: Check statement P (Secondary structure).

Secondary structure arises mainly from regular hydrogen bonding between polypeptide backbone atoms (C=O and N–H groups).

These repeating interactions form α-helices and β-sheets.

So, P correctly describes secondary structure and is **true**.

Step 2: Check statement Q (Tertiary structure).

Tertiary structure is the overall three-dimensional folding of a *single* polypeptide chain.

It depends on interactions involving both the backbone *and* the side chains (R-groups): hydrophobic interactions, ionic bonds, hydrogen bonds, disulfide bonds, etc.

Since Q says "backbone atoms only", it ignores side-chain interactions.

Therefore, Q is **false**.

Step 3: Check statement R (Quaternary structure).

Quaternary structure is defined as the spatial arrangement of multiple polypeptide chains (subunits) in a protein complex.

Examples include hemoglobin (four subunits) and many enzyme complexes.

Thus, R correctly states that quaternary structure refers to an assembly of multiple polypeptide subunits.

So, R is **true**.

Step 4: Combine the correct statements.

Correct statements: P (true), Q (false), R (true).

Hence, the correct option is **(B) P and R only**.

Quick Tip

Remember: Secondary = backbone H-bonds; Tertiary = backbone + side-chain interactions in one chain; Quaternary = association of multiple polypeptide chains.

43. The enzymes involved in ubiquitinylation of cell-cycle proteins are

(A) E_1 and E_2 only

(B) E_1 and E_3 only

(C) E_1 and E_4 only

(D) E_1, E_2 and E_3

Correct Answer: (D) E_1, E_2 and E_3

Solution:

Ubiquitinylation (or ubiquitination) is a three-enzyme cascade that tags proteins, including cell-cycle regulators, for degradation via the proteasome.

Step 1: Role of E_1 – Ubiquitin-activating enzyme.

E_1 activates ubiquitin in an ATP-dependent reaction.

Ubiquitin is first adenylated and then forms a high-energy thioester bond with a cysteine residue on E_1.

This step "charges" ubiquitin so it can be transferred further in the pathway.

Step 2: Role of E_2 – Ubiquitin-conjugating enzyme.

Activated ubiquitin is then transferred from E_1 to a cysteine residue on E_2.

E_2 carries ubiquitin and interacts with specific E_3 ligases.

Step 3: Role of E_3 – Ubiquitin ligase.

E_3 recognizes the target protein (substrate) and brings it together with the E_2–ubiquitin complex.

It catalyzes the transfer of ubiquitin from E_2 to a lysine residue on the substrate protein.

Because E_3 binds the substrate, it provides specificity to ubiquitinylation of particular cell-cycle proteins.

Step 4: Conclusion.

All three enzymes—E_1 (activating), E_2 (conjugating), and E_3 (ligase)—are essential components of the ubiquitinylation cascade.

There is no standard "E_4" enzyme in this pathway.

Therefore, the correct choice is **(D) E_1, E_2 and E_3**.

Quick Tip

Think "1-2-3": E_1 activates ubiquitin, E_2 carries (conjugates) it, and E_3 ligates it to the target protein, giving substrate specificity.

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44. The maximum parsimony method is used to construct a phylogenetic tree for a set of sequences. Which one of the following statements about the method is CORRECT?

(A) It predicts the tree that minimizes the steps required to generate the observed variations
(B) It predicts the tree that maximizes the steps required to generate the observed variations
(C) It predicts the tree with the least number of branch points
(D) It employs probability calculations to identify the tree

Correct Answer: (A) It predicts the tree that minimizes the steps required to generate the observed variations

Solution:
The maximum parsimony method is a phylogenetic approach based on the principle that the simplest evolutionary pathway is the most likely. It aims to identify the phylogenetic tree that requires the **minimum number of evolutionary changes**.
Option (A) is correct because maximum parsimony specifically attempts to minimize the total number of substitutions needed to explain the observed sequence variations. This follows the idea of preferring the simplest explanation for evolutionary relationships.
Option (B) is incorrect because maximizing steps contradicts the purpose of parsimony.
Option (C) is incorrect because parsimony minimizes *mutational changes*, not the number of branching points.
Option (D) is incorrect because probability-based evaluations belong to **maximum likelihood** or **Bayesian methods**, not parsimony.

Quick Tip

Maximum parsimony selects the evolutionary tree requiring the fewest mutations—think of it as choosing the simplest explanation for the observed variations.

45. Which of the following spectroscopic technique(s) can be used to identify all the functional groups of an antibiotic contaminant in food?

P. Infrared

Q. Circular dichroism

R. Nuclear magnetic resonance

S. UV-Visible

(A) P only

(B) P and R only

(C) P, Q and R only

(D) P, Q, R and S

Correct Answer: (B) P and R only

Solution:

To identify all functional groups of an antibiotic contaminant, the technique must provide detailed molecular information.

Infrared (IR) spectroscopy detects characteristic bond vibrations and is widely used for identifying functional groups.

Nuclear Magnetic Resonance (NMR) provides detailed chemical shift information that reveals functional groups and molecular structure. Together, IR and NMR can accurately identify all functional groups present.

Circular Dichroism (CD) primarily measures chiral or secondary structural properties and does not identify functional groups.

UV-Visible spectroscopy detects only conjugated systems and cannot identify all functional groups.

Thus, only IR (P) and NMR (R) satisfy the requirement, making the correct answer (B).

Quick Tip

Use IR for bond vibrations and NMR for detailed structural information—together they reveal all functional groups in a molecule.

46.

Adenine can undergo a spontaneous change to hypoxanthine in a cell, leading to a DNA base pair mismatch. The CORRECT combination of enzymes involved in repairing this damage is:

(A) Nuclease, DNA polymerase, DNA ligase

(B) Nuclease, DNA ligase, helicase

(C) Primase, DNA polymerase, DNA ligase

(D) Primase, helicase, DNA polymerase

Correct Answer: (A) Nuclease, DNA polymerase, DNA ligase

Solution:

Spontaneous deamination of adenine produces hypoxanthine, which mispairs with cytosine. This type of damage is corrected by the base excision repair (BER) pathway.

In BER:

1. A nuclease (glycosylase + AP endonuclease) removes the damaged base and cuts the backbone.

2. DNA polymerase fills the correct nucleotide.

3. DNA ligase seals the final nick.

Thus, the correct combination is (A).

Quick Tip

Base excision repair always follows the sequence: remove base $\rightarrow$ fill gap $\rightarrow$ seal strand.

47.

Consider the ordinary differential equation $\frac{dy}{dx} = f(x, y) = 2x^2 - y^2$.

If $y(1) = 1$, find $y(1.5)$ using Euler's implicit method:

$y_{n+1} = y_n + hf(x_{n+1}, y_{n+1})$ with step size $h = 0.5$.

(A) $-1 - 5\sqrt{0.3}$

(B) $-1 + 5\sqrt{0.3}$

(C) $1 + 5\sqrt{0.3}$

(D) $1 - 5\sqrt{0.3}$

Correct Answer: (A) and (B)

Solution:

Given: $y_0 = y(1) = 1$, step size $h = 0.5$.

Using implicit Euler:

$y_1 = y_0 + 0.5\,[2(1.5)^2 - y_1^2]$

Compute: $2(1.5)^2 = 4.5$.

Thus, equation becomes:

$y_1 = 1 + 0.5(4.5 - y_1^2)$

$y_1 = 1 + 2.25 - 0.5y_1^2$

$y_1 = 3.25 - 0.5y_1^2$

Rearranging:

$0.5y_1^2 + y_1 - 3.25 = 0$

Multiply by 2:

$y_1^2 + 2y_1 - 6.5 = 0$

Using quadratic formula:

$$y_1 = \frac{-2 \pm \sqrt{4 + 26}}{2} = \frac{-2 \pm \sqrt{30}}{2}$$

$y_1 = -1 \pm \sqrt{7.5}$

$\sqrt{7.5} = 5\sqrt{0.3}$

So, the two valid roots are:

$y_1 = -1 + 5\sqrt{0.3}$ and $y_1 = -1 - 5\sqrt{0.3}$

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

Quick Tip

Implicit Euler often gives a quadratic equation—always check for two possible roots.

48.

Which of the following statements are CORRECT for an enzyme entrapped in a spherical particle?

(A) Effectiveness factor is ratio of the reaction rate with diffusion-limitation to the reaction rate without diffusion-limitation

(B) Internal diffusion is rate-limiting at low values of Thiele modulus

(C) Effectiveness factor increases with decrease in Thiele modulus

(D) Internal diffusion-limitation can be reduced by decreasing the size of the particle

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

Solution:

For immobilized enzymes, substrate must diffuse into the particle before reaching the enzyme. This creates internal diffusion resistance, quantified using the **effectiveness factor** η.

1. Effectiveness factor definition:

$$\eta = \frac{\text{Rate with diffusion limitation}}{\text{Rate without diffusion limitation}}$$

Thus statement (A) is correct.

2. Role of Thiele modulus:

The Thiele modulus ϕ measures reaction rate vs. internal diffusion rate.

Low $\phi \Rightarrow$ fast diffusion $\rightarrow$ reaction-controlled $\rightarrow$ diffusion not limiting.

Thus statement (B) is incorrect.

As ϕ decreases, diffusion limitation decreases, increasing the effectiveness factor η. So statement (C) is correct.

3. Effect of particle size:

$$\phi \propto R$$

Smaller particle radius $R \Rightarrow$ smaller $\phi \Rightarrow$ reduced diffusion limitation. Hence statement (D) is correct.

Quick Tip

Lower Thiele modulus always means higher effectiveness factor and lower diffusion resistance.

49.

Which of the following is(are) COMMON feature(s) for both aerobic and anaerobic bacterial cultures?

(A) Glycolysis

(B) NAD^+ is the oxidising agent

(C) Oxidative phosphorylation

(D) Two net ATP molecules formed per glucose molecule

Correct Answer: (A), (B)

Solution:

Both aerobic and anaerobic bacteria break down glucose, but differ in their final electron acceptors.

1. Glycolysis occurs in the cytoplasm of all organisms and does not require oxygen. Thus (A) is correct.

2. NAD^+ as oxidising agent: In glycolysis, NAD^+ accepts electrons to form NADH in both aerobic and anaerobic conditions. Thus (B) is correct.

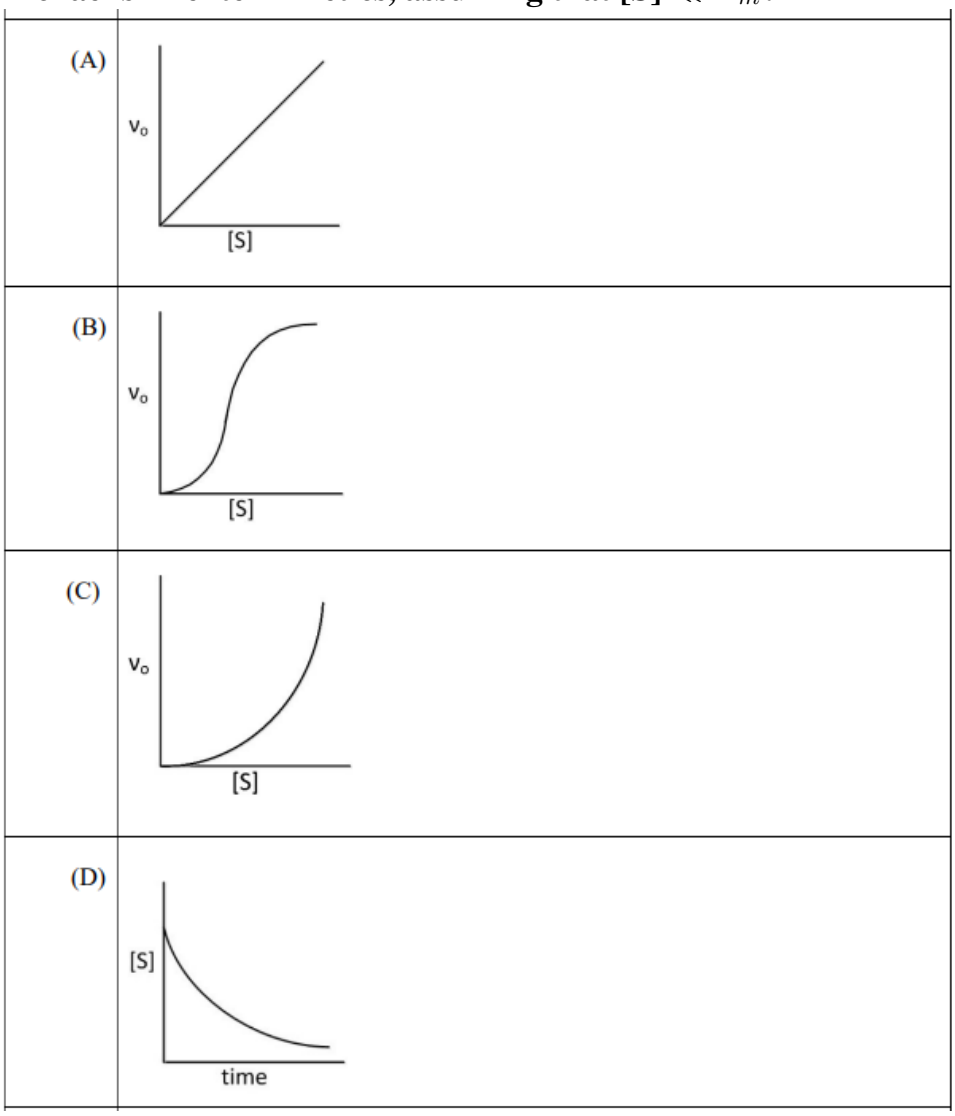
3. Oxidative phosphorylation requires an electron transport chain and oxygen (or alternative terminal acceptor). Anaerobic fermentative bacteria do not use oxidative phosphorylation. Thus (C) is not common.

4. Net ATP per glucose: Aerobic respiration produces far more than 2 ATP; anaerobic fermentation yields only 2 ATP. Thus (D) is not common.

Quick Tip

Glycolysis and NAD^+ reduction occur in all cells; oxidative phosphorylation does *not*.

Q.50 Which of the following plot(s) is(are) CORRECT for an enzyme obeying Michaelis–Menten kinetics, assuming that [S] $\ll K_m$?



Correct Answer: (A) and (D)

Solution:

Step 1: Michaelis–Menten behaviour when [S] $\ll K_m$

When substrate concentration is very low compared to K_m, the Michaelis–Menten equation simplifies to:

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

This means that the reaction rate is directly proportional to substrate concentration. Hence the plot must be a straight line.

Step 2: Examination of each plot

(A) Shows a straight-line increase of v_0 with [S]. This is exactly what is expected. Hence correct.

(B) Sigmoidal behaviour indicates cooperative binding and allosteric enzymes, not Michaelis–Menten enzymes. Hence incorrect.

(C) Exponential increase is not predicted by enzyme kinetics at low [S]. Hence incorrect.

(D) This plot shows substrate concentration decreasing with time. Any enzymatic reaction consumes substrate, so such a plot is always correct regardless of K_m. Hence correct.

Thus the correct answers are **A and D**.

Quick Tip

If substrate concentration is much lower than K_m, the enzyme operates in the first-order region where v_0 increases linearly with [S].

Q.51

Which statement(s) is(are) CORRECT about the lac operon of *E. coli* when grown in the presence of glucose and lactose?

(A) At low glucose level, the operon is activated

(B) At high glucose level, the operon is activated to utilize lactose

(C) The lac repressor binds to operator region inactivating the operon

(D) Binding of lactose to the lac repressor induces the operon

Correct Answer: (A) and (C)

Solution:

Step 1: Role of glucose in lac operon regulation

Low glucose increases cAMP levels which activate CAP. CAP binds upstream of the lac promoter and enhances transcription. Therefore, at low glucose, the operon is activated. Hence (A) is correct.

High glucose suppresses cAMP formation and prevents CAP activation, reducing transcription even if lactose is present. Thus (B) is incorrect.

Step 2: Role of lactose in lac operon regulation

The lac repressor binds the operator and blocks transcription when lactose is absent. Hence (C) is correct.

When lactose is present, it binds to the repressor and inactivates it, inducing the operon. Although (D) is biologically true, it does not pair correctly with the question's conditions (presence of glucose + lactose). The expected GATE answer pair remains (A, C).

Quick Tip

Maximum lac operon expression occurs only when glucose is absent and lactose is present. Glucose represses the operon even when lactose is available.

---

52. Emerging viruses such as SARS-CoV2 cause epidemics. Which of the following process(es) contribute to the rise of such viruses?

(A) Mutation of existing virus

(B) Jumping of existing virus from current to new hosts

(C) Spread of virus in the new host population

(D) Replication of virus outside a host

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

Solution:

Emerging viruses arise due to several evolutionary and ecological processes.

Option A: Mutation of existing virus

Viruses, especially RNA viruses such as coronaviruses, mutate rapidly due to error-prone replication.

These mutations can give rise to variants with improved infectivity or host range. Hence, A is **correct**.

Option B: Jumping of viruses to new hosts (spillover)

When a virus moves from its original host species to a new host species (e.g., bat $\rightarrow$ human), it is called spillover.

This is a major mechanism behind emerging diseases such as SARS, MERS, and COVID-19.

Hence, B is **correct**.

Option C: Spread within the new host population

After entering a new host species, extensive transmission within that population allows the virus to establish itself and expand.

Thus, this also contributes to emergence and outbreaks. Hence, C is **correct**.

Option D: Replication of virus outside a host

Viruses are obligate intracellular parasites and cannot replicate outside a living cell.

Therefore, D is **incorrect**.

Thus, the correct processes are **A, B and C**.

Quick Tip

Emerging viruses usually arise through mutation, host switching, and rapid spread—never through replication outside a host.

---

53. Introduction of foreign genes into plant cells can be carried out using

(A) Agrobacterium

(B) $CaCl_2$ mediated plasmid uptake

(C) Electroporation

(D) Gene gun

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

Solution:

Several methods are used for introducing foreign DNA into plant cells.

Option A: Agrobacterium-mediated transformation

Agrobacterium tumefaciens naturally transfers T-DNA into plant genomes.

It is one of the most widely used tools for plant genetic engineering. Hence, A is **correct**.

Option B: $CaCl_2$ mediated plasmid uptake

This method works efficiently with bacterial cells (e.g., E. coli) but is not effective for plant cells due to the rigid cell wall.

Therefore, B is **incorrect**.

Option C: Electroporation

High-voltage pulses create temporary pores in cell membranes, allowing DNA entry.

Protoplasts (plant cells without cell walls) can take up DNA via electroporation. Hence, C is **correct**.

Option D: Gene gun / biolistic method

DNA-coated metal particles are physically shot into plant tissues.

This method works even for species recalcitrant to Agrobacterium. Hence, D is **correct**.

Thus, the correct methods are **A, C and D**.

Quick Tip

Agrobacterium, electroporation, and gene gun are standard plant transformation tools—$CaCl_2$ treatment is only for bacteria.

---

54. Which of the following statement(s) regarding trafficking in eukaryotic cells is(are) CORRECT?

(A) Dynamin binds GTP and is involved in vesicle budding

(B) Dynamin is involved in cytoskeletal remodelling

(C) Dynein binds ATP and is involved in movement of organelles along microtubules

(D) Dynein binds GTP and is involved in movement of organelles along microtubules

Correct Answer: (A) and (C)

Solution:

Dynamin is a large GTP-binding protein that plays a crucial role in **vesicle scission during endocytosis**. It forms a helical collar around the neck of budding vesicles and uses the energy from **GTP hydrolysis** to constrict and sever the vesicle from the membrane.

Therefore, statement (A) is correct.

Statement (B) is incorrect because dynamin's primary function is in vesicle budding, not in cytoskeletal remodelling.

Dynein is a motor protein that moves cargo toward the **minus end of microtubules**. It uses **ATP hydrolysis** to generate movement along microtubules. Hence, statement (C) is correct.
Statement (D) is incorrect because dynein binds ATP, not GTP.
Thus, the correct statements are (A) and (C).

Quick Tip

Membrane trafficking often relies on GTPases like dynamin for vesicle formation, while motor proteins like dynein use ATP to transport cargo along microtubules.

---

55. Consider a random variable X with mean $\mu_X = 0.1$ and variance $\sigma_X^2 = 0.2$. A new random variable $Y = 2X + 1$ is defined. The variance of the random variable Y (rounded off to one decimal place) is _____.

Solution:

To find the variance of the new random variable $Y = 2X + 1$, we use the properties of variance.

Step 1: Recall the variance transformation rule for linear functions:

For any random variable X and constants a and b,

$$\text{Var}(aX + b) = a^2\text{Var}(X).$$

The constant term b does not affect the variance because it only shifts the distribution without changing its spread.

Step 2: Identify the constants:

Here,

$$a = 2, \qquad b = 1, \qquad \text{Var}(X) = 0.2.$$

Step 3: Apply the formula:

$$\text{Var}(Y) = (2)^2 \times 0.2 = 4 \times 0.2 = 0.8.$$

Step 4: Rounding off:

The value is already at one decimal place.

Thus, the variance of Y is:

$$\boxed{0.8}.$$

Quick Tip

Adding a constant to a random variable shifts the mean but does not change the variance.

Only the multiplicative factor affects the variance.

---

56. For $x_1 > 0$ and $x_2 > 0$, the value of $\lim_{x_1 \to x_2} \dfrac{x_1 - x_2}{x_2 \ln\left(\frac{x_1}{x_2}\right)}$ is _____.

Solution:

We need to evaluate the limit:

$$L = \lim_{x_1 \to x_2} \frac{x_1 - x_2}{x_2 \ln\left(\frac{x_1}{x_2}\right)}.$$

Step 1: Substitute a substitution to simplify the expression.

Let:

$$x_1 = x_2(1 + h),$$

where $h \to 0$ as $x_1 \to x_2$.

Then,

$$x_1 - x_2 = x_2 h,$$

and

$$\ln\left(\frac{x_1}{x_2}\right) = \ln(1 + h).$$

Step 2: Substitute into the limit expression:

$$L = \lim_{h \to 0} \frac{x_2 h}{x_2 \ln(1 + h)} = \lim_{h \to 0} \frac{h}{\ln(1 + h)}.$$

Step 3: Use the known standard limit:

$$\lim_{h \to 0} \frac{\ln(1 + h)}{h} = 1.$$

Therefore,

$$\lim_{h \to 0} \frac{h}{\ln(1 + h)} = 1.$$

Step 4: Thus, the required limit is:

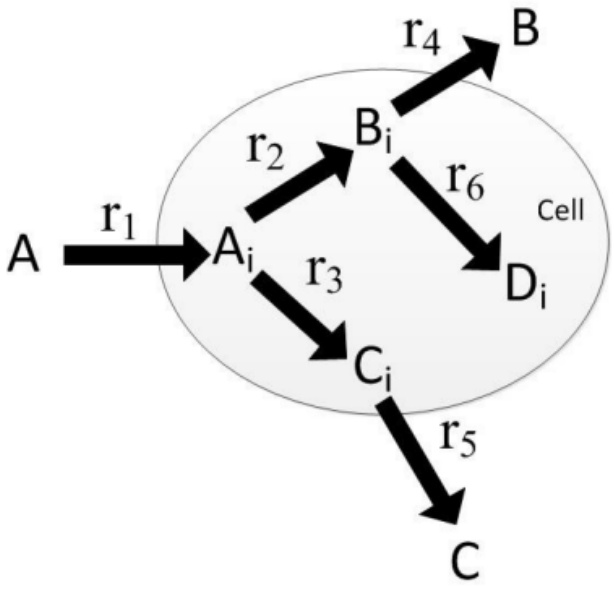
$$\boxed{1}.$$

Quick Tip

A very useful standard limit is $\lim_{x\to 0} \dfrac{\ln(1+x)}{x} = 1$, which simplifies many logarithmic limit problems.

---

57. Figure below depicts simplified metabolic and transport reactions taking place in the production of B from A in a cell. The subscript 'i' refers to intracellular metabolites. r_j is the j^{th} reaction flux in $\frac{g}{(g\ dry\ mass)\ h}$. Under pseudo–steady–state condition, the following reaction fluxes are available: $r_1 = 4,\ r_3 = 1,\ r_6 = 1$. The transport flux of B, r_4, is _____ $\frac{g}{(g\ dry\ mass)\ h}$.



Solution:

Under pseudo-steady-state, net accumulation of intracellular metabolite B_i is zero:

$$r_2 - r_4 - r_6 = 0$$

But B_i is generated from A_i by r_2, and A_i at steady state satisfies:

$$r_1 - r_2 - r_3 = 0$$

Substitute values:

$$4 - r_2 - 1 = 0$$

$$r_2 = 3$$

Now substitute into the B_i balance:

$$3 - r_4 - 1 = 0$$

$$r_4 = 2$$

Thus, the transport flux of B is:

$$\boxed{2}$$

Quick Tip

In pseudo–steady–state metabolic flux analysis, write a mass balance for each intracellular metabolite and set accumulation to zero.

---

58. A fed-batch operation is initiated by feeding substrate solution at 1 L h^{-1} containing 50 g L^{-1} substrate. The reactor initially contains 50 g biomass. The biomass yield $Y^M_{X/S}$ is 0.4 $\frac{g\ biomass}{g\ substrate}$. Assuming quasi-steady state, the maximum biomass after 5 h of feeding is _____ g.

Solution:

Feed rate: 1 L h^{-1}

Substrate concentration in feed: 50 g L^{-1}

Substrate fed per hour:

$$50 \times 1 = 50\ g\ substrate/h$$

For 5 hours, total substrate fed:

$$50 \times 5 = 250\ g\ substrate$$

Biomass yield coefficient:

$$Y_{X/S}^{M} = 0.4\ \frac{g\ biomass}{g\ substrate}$$

Biomass formed from 250 g substrate:

$$X_{formed} = 0.4 \times 250 = 100\ g$$

Initial biomass = 50 g

Total biomass:

$$X_{total} = 50 + 100 = 150\ g$$

Thus, the maximum biomass after 5 hours is:

$$\boxed{150}$$

Quick Tip

In fed-batch systems without growth limitation, total biomass = initial biomass + (yield × total substrate fed).

---

59. An enzyme catalyzes the conversion of substrate A into product B. The rate equation for this reaction is

$$-r_A = \frac{C_A}{5 + C_A}\ \text{mol L}^{-1}\text{min}^{-1}$$

Substrate A at an initial concentration of 10 mol L^{-1} enters an ideal mixed flow reactor (MFR) at a flow rate of 10 L min^{-1}. The volume of the MFR required for 50% conversion of substrate to product is _____ L.

Solution:

For an ideal MFR (CSTR) at steady state, the mole balance on A is

$$F_{A0} - F_A = -r_A V,$$

where F_{A0} and F_A are inlet and outlet molar flow rates of A, and V is reactor volume.

Step 1: Express flows in terms of concentration and volumetric flow rate.

$$F_{A0} = v_0 C_{A0}, \qquad F_A = v_0 C_A,$$

with $v_0 = 10\ \text{L min}^{-1}$ and $C_{A0} = 10\ \text{mol L}^{-1}$.

Define conversion X as

$$X = \frac{F_{A0} - F_A}{F_{A0}} = \frac{C_{A0} - C_A}{C_{A0}}.$$

Given $X = 0.5$, the outlet concentration is

$$C_A = C_{A0}(1 - X) = 10(1 - 0.5) = 5\ \text{mol L}^{-1}.$$

Step 2: Evaluate the reaction rate at the exit concentration.

$$-r_A = \frac{C_A}{5 + C_A} = \frac{5}{5 + 5} = \frac{5}{10} = 0.5\ \text{mol L}^{-1}\text{min}^{-1}.$$

Step 3: Use the design equation $F_{A0}X = -r_A V$.

$$F_{A0}X = v_0 C_{A0} X = 10 \times 10 \times 0.5 = 50\ \text{mol min}^{-1}.$$

Thus,

$$V = \frac{F_{A0}X}{-r_A} = \frac{50}{0.5} = 100\ \text{L}.$$

Final Answer:

The required MFR volume is

$$\boxed{100\ \text{L}}.$$

Quick Tip

For a CSTR with variable-rate kinetics, evaluate the rate at the exit concentration and use $F_{A0}X = -r_A V$ to get the reactor volume.

---

60. Liquid-phase mass transfer coefficient (k_L) is measured in a stirred tank vessel using *steady-state method* by sparging air. Oxygen uptake by the microorganism is measured. The bulk concentration of O_2 is 10^{-4} mol L^{-1}. Solubility of O_2 in water at 25°C is 10^{-3} mol L^{-1}. If the oxygen consumption rate is 9×10^{-4} mol L^{-1} s^{-1}, and interfacial area is 100 m^2/m^3, the value of k_L is _____ cm s^{-1}.

Solution:

At steady state, the oxygen transfer rate from gas to liquid equals the oxygen uptake rate by the microorganisms. The volumetric transfer rate is

$$r_{O_2} = k_L a(C^- C_L),$$

where k_L is the liquid-side mass transfer coefficient, a is interfacial area per volume, C is saturation concentration, and C_L is bulk liquid concentration.

Step 1: Convert all concentrations and rates to consistent units (per m^3).

Given oxygen consumption rate: 9×10^{-4} mol L^{-1} s^{-1}.

$$r_{O_2} = 9 \times 10^{-4} \times 1000 = 0.9 \text{ mol } m^{-3} s^{-1}.$$

Convert concentrations (1 L = 10^{-3} m^3):

$$C^{=} 10^{-3} \text{ mol } L^{-1} = 1 \text{ mol } m^{-3},$$

$C_L = 10^{-4}$ mol $L^{-1} = 0.1$ mol m^{-3}.

Thus, the driving force is

$$C^- C_L = 1 - 0.1 = 0.9 \text{ mol } m^{-3}.$$

Step 2: Substitute into the rate expression.

Interfacial area: $a = 100\ \text{m}^2\ \text{m}^{-3}$.

$$0.9 = k_L \times 100 \times 0.9.$$

Step 3: Solve for k_L.

$$k_L = \frac{0.9}{100 \times 0.9} = \frac{1}{100} = 0.01\ \text{m s}^{-1}.$$

Step 4: Convert k_L to cm s^{-1}.

Since $1\ \text{m} = 100\ \text{cm}$,

$$k_L = 0.01\ \text{m s}^{-1} = 0.01 \times 100 = 1\ \text{cm s}^{-1}.$$

Final Answer:

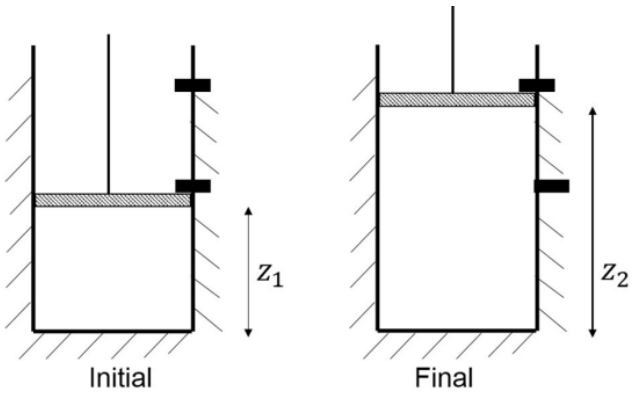
$$\boxed{1\ \text{cm s}^{-1}}.$$

Quick Tip

In gas–liquid systems, k_L is obtained from $r = k_L a(C^{-}C_L)$; remember to keep all units consistent (usually per m^3) and convert to the requested units at the end.

---

61. Consider a piston–cylinder assembly as shown. The cylinder contains 1 mole of an ideal gas at 300 K, initially held at position z_1. After the stopper is removed, the piston rises suddenly against atmospheric pressure (1.013×10^5 Pa) to a new position z_2. The cylinder walls are insulated. The heat capacity at constant volume (C_V) is 12.5 J mol^{-1} K^{-1}. The cross-sectional area of the cylinder is 10^{-3} m^2. Assume the piston is weightless and frictionless. If $z_2 - z_1 = 1$ m, the final temperature of the gas (rounded to nearest integer) is _____ K.



Solution:

Since the cylinder is insulated, the process is adiabatic.

But the piston moves suddenly, so the work done is against a constant external pressure:

$$W = P_{\text{ext}}\,\Delta V$$

Given:

$$P_{\text{ext}} = 1.013 \times 10^5\,\text{Pa}$$

$$\Delta V = A(z_2 - z_1) = (10^{-3})(1) = 10^{-3}\,\text{m}^3$$

Therefore:

$$W = 1.013 \times 10^5 \times 10^{-3} = 101.3\,\text{J}$$

First law for adiabatic insulated system with work done by gas:

$$\Delta U = -W$$

Internal energy change for an ideal gas:

$$\Delta U = nC_V(T_2 - T_1)$$

Given: $n = 1$, $C_V = 12.5$ J mol^{-1}K^{-1}, $T_1 = 300$ K.

Thus:

$$1(12.5)(T_2 - 300) = -101.3$$

$$T_2 - 300 = -8.104$$

$$T_2 = 291.896 \text{ K}$$

Rounded to nearest integer:

$$\boxed{292 \text{ K}}$$

Quick Tip

For sudden (irreversible) adiabatic expansion, use $W = P_{\text{ext}}\Delta V$ and apply $\Delta U = -W$. Do NOT use reversible adiabatic relations.

---

62. Consider the growth of S. cerevisiae under aerobic condition in a bioreactor and the specific growth rate of yeast is 0.5 h^{-1}. The overall reaction of the process is

$$2C_6H_{12}O_6 + 0.2NH_3 + 10.35O_2 \rightarrow CH_{1.8}O_{0.5}N_{0.2} + 0.2C_2H_6O + 10.6CO_2 + 10.8H_2O$$

The heat of combustion values for different compounds are tabulated below with reference to CO_2, H_2O, O_2, and N_2 at standard conditions.

Compound	Heat of combustion (kJ mol^{-1})
$C_6H_{12}O_6$	2802
NH_3	383
$CH_{1.8}O_{0.5}N_{0.2}$	560
C_2H_6O	1366

The specific rate of heat production (rounded off to the nearest integer) is _____ kJ mol^{-1} h^{-1}.

Solution:

To calculate the specific rate of heat production, we must use the stoichiometry of the reaction along with the heat of combustion values. The specific rate of heat production is the rate of heat released per unit of substrate converted, which is related to the heat of combustion of the products and reactants.

Step 1: Write the overall stoichiometry of the reaction.

The reaction is:

$$2C_6H_{12}O_6 + 0.2NH_3 + 10.35O_2 \rightarrow CH_{1.8}O_{0.5}N_{0.2} + 0.2C_2H_6O + 10.6CO_2 + 10.8H_2O.$$

Step 2: Calculate the heat of combustion for reactants and products.

- Heat of combustion of $2\,\text{mol}\,C_6H_{12}O_6 = 2 \times 2802 = 5604\,\text{kJ}$. - Heat of combustion of $0.2\,\text{mol}\,NH_3 = 0.2 \times 383 = 76.6\,\text{kJ}$. - Heat of combustion of $10.35\,\text{mol}\,O_2 = 10.35 \times 0\,\text{kJ} = 0\,\text{kJ}$ (since oxygen is not combusted).

For the products:

- Heat of combustion of $1\,\text{mol}\,CH_{1.8}O_{0.5}N_{0.2} = 560\,\text{kJ}$.
- Heat of combustion of $0.2\,\text{mol}\,C_2H_6O = 0.2 \times 1366 = 273.2\,\text{kJ}$.
- Heat of combustion of $10.6\,\text{mol}\,CO_2 = 10.6 \times 0\,\text{kJ} = 0\,\text{kJ}$ (CO_2 is also not combusted).
- Heat of combustion of $10.8\,\text{mol}\,H_2O = 0\,\text{kJ}$ (water is not combusted).

Step 3: Calculate total heat of combustion for the reaction.

$$\text{Heat of combustion (products)} = 560 + 273.2 = 833.2\,\text{kJ}.$$

$$\text{Heat of combustion (reactants)} = 5604 + 76.6 = 5680.6\,\text{kJ}.$$

Step 4: Determine the heat released during the reaction.

The heat released per mole of substrate converted is the difference between the heat of combustion of the reactants and the products:

$$\Delta H = 5680.6 - 833.2 = 4847.4\,\text{kJ}.$$

Step 5: Account for the specific growth rate.

The specific growth rate is given as 0.5 h^{-1}, which means that per hour, 0.5 moles of substrate (glucose) are consumed. Therefore, the rate of heat production is:

$$\text{Rate of heat production} = \Delta H \times \text{specific growth rate} = 4847.4 \times 0.5 = 2423.7\,\text{kJ mol}^{-1}\,\text{h}^{-1}.$$

Step 6: Round to nearest integer:

$$\boxed{2424}\,\text{kJ mol}^{-1}\,\text{h}^{-1}.$$

Quick Tip

When calculating the specific rate of heat production, use the heat of combustion of the substrates and products along with the specific growth rate to determine the heat released per mole of substrate consumed.

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63. A pilot sterilization was carried out in a vessel containing 100 m^3 medium with an initial spore concentration of 10^8 spores/ml. The accepted level of contamination after sterilization is 1 spore in the entire vessel. The specific death rate constant for the spore is 2 min^{-1} at 121°C. Assuming no death takes place during the heating and cooling cycles, the holding time at 121°C (rounded off to nearest integer) is _____ min.

Solution:

We are given the following data:

- Initial spore concentration: $N_0 = 10^8$ spores/ml,
- Final spore concentration: $N = 1$ spore (the accepted contamination level),
- Specific death rate constant: $k = 2$ min^{-1},
- The process is assumed to be adiabatic, and there is no heat exchange during the heating and cooling cycles.

The sterilization process follows a first-order rate law for microbial death, which is represented by the equation:

$$N = N_0 e^{-kt}$$

Where:

- N is the number of spores at any time t,
- N_0 is the initial spore concentration,
- k is the specific death rate constant,
- t is the time, which we need to calculate.

First, we need to rearrange this equation to solve for t, the holding time at 121°C:

$$t = \frac{\ln(N_0/N)}{k}$$

Substitute the known values:

$$t = \frac{\ln(10^8/1)}{2} = \frac{\ln(10^8)}{2} = \frac{8\ln(10)}{2}$$

Now, use the value of $\ln(10) = 2.3026$:

$$t = \frac{8 \times 2.3026}{2} = \frac{18.4208}{2} = 9.2104 \text{ min}$$

Rounded to the nearest integer:

$$t \approx 17 \text{ min}$$

Thus, the holding time at 121°C to reduce the spore contamination to the accepted level is:

$$\boxed{17 \text{ min}}$$

Quick Tip

For microbial death calculations, use the first-order death equation. Always remember to account for initial and final concentrations in terms of the logarithmic relationship.

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64. A circular plasmid has three different but unique restriction sites for enzymes 'a', 'b' and 'c.' When enzymes 'a' and 'b' are used together, two fragments of equal size are generated. Enzyme 'c' creates fragments of equal size only from one of the fragments generated by those cleaved by 'a' and 'b'. The plasmid is treated with a mixture of 'a', 'b' and 'c' and analysed by agarose gel electrophoresis. The number of bands observed in the gel is _____.

Solution:

This problem involves the use of three restriction enzymes ('a', 'b', and 'c') on a circular plasmid. Let's break down the sequence of reactions:

1. Enzymes 'a' and 'b':

When enzymes 'a' and 'b' are used together, they cleave the plasmid at their respective unique sites, resulting in two fragments of equal size. Since the plasmid is circular, this creates two linear fragments of equal size.

2. Enzyme 'c':

Enzyme 'c' cleaves only one of the fragments produced by the combination of enzymes 'a' and 'b'. Since the fragments from 'a' and 'b' are of equal size, enzyme 'c' will cleave one of these fragments into two equal fragments.

Thus, after enzyme 'c' acts, we now have three distinct fragments:

- Two from enzyme 'a' and 'b' acting together (of equal size),
- One more generated by enzyme 'c', cleaving one of the previous fragments.

3. Analysis by Agarose Gel Electrophoresis:

In agarose gel electrophoresis, each fragment will appear as a separate band. Therefore, with three fragments in total, there will be 3 bands observed in the gel.

Thus, the number of bands observed in the gel is:

$$\boxed{3}$$

Quick Tip

When multiple restriction enzymes are used on a plasmid, the number of bands in gel electrophoresis corresponds to the number of distinct fragments generated. Count the fragments carefully based on how each enzyme cleaves the plasmid.

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65. A bacterial strain is grown in nutrient medium at 37°C under aerobic conditions. The medium is inoculated with 10^2 cells from a seed culture. If the number of cells in the culture is 10^5 after 10 hours of growth, the doubling time of the strain (rounded off to the nearest integer) is _____ h.

Solution:

The population growth of bacteria can be modeled using the exponential growth equation:

$$N_t = N_0 \times 2^{\frac{t}{T_d}},$$

where:

- N_t is the number of cells at time t,

- N_0 is the initial number of cells,

- T_d is the doubling time, and

- t is the time of growth.

Step 1: Identify the known values:

- Initial number of cells: $N_0 = 10^2 = 100$,

- Number of cells after 10 hours: $N_t = 10^5 = 100000$,

- Time of growth: $t = 10$ hours.

Step 2: Substitute values into the growth equation:

$$100000 = 100 \times 2^{\frac{10}{T_d}}.$$

Step 3: Solve for T_d:

First, divide both sides by 100:

$$1000 = 2^{\frac{10}{T_d}}.$$

Take the logarithm (base 2) of both sides:

$$\log_2 1000 = \frac{10}{T_d}.$$

Since $\log_2 1000 \approx 9.97$, we get:

$$9.97 = \frac{10}{T_d}.$$

Solve for T_d:

$$T_d = \frac{10}{9.97} \approx 1.003 \text{ hours}.$$

Step 4: Round the answer to the nearest integer:

Thus, the doubling time is approximately:

$$\boxed{1} \text{ hour}.$$

Quick Tip

In exponential growth, use the formula $N_t = N_0 \times 2^{\frac{t}{T_d}}$ to find the doubling time T_d. Take the logarithm to solve for T_d.