GATE 2025 Ecology and Evolution Question Paper with Solutions

Time Allowed :180 Minutes	**Maximum Marks :**100	**Total questions :**65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. **Total Marks:** The GATE ECOLOGY AND EVOLUTION paper is worth 100 marks.
2. **Question Types:** The paper consists of 65 questions, divided into:
   - General Aptitude (GA): 15 marks
   - Ecology and Evolution: 85 marks
3. **Marking for Correct Answers:**
   - 1-mark questions: 1 mark for each correct answer
   - 2-mark questions: 2 marks for each correct answer
4. **Negative Marking for Incorrect Answers:**
   - 1-mark MCQs: 1/3 mark deduction for a wrong answer
   - 2-mark MCQs: 2/3 marks deduction for a wrong answer
5. **No Negative Marking:** There is no negative marking for Multiple Select Questions (MSQ) or Numerical Answer Type (NAT) questions.
6. **No Partial Marking:** There is no partial marking in MSQ.

General Aptitude

1. Here are two analogous groups, Group-I and Group-II, that list words in their decreasing order of intensity. Identify the missing word in Group-II.

Abuse → Insult → Ridicule

_____ → Praise → Appreciate

(A) Extol

(B) Prize

(C) Appropriate

(D) Espouse

Correct Answer: (A) Extol

Solution: Step 1: Identify the relationship in Group-I.

In Group-I, the words are listed in decreasing order of intensity: Abuse → Insult → Ridicule. Abuse is the most intense, followed by Insult, and Ridicule is the least intense.

Step 2: Identify the relationship in Group-II.

Group-II must follow a similar pattern of decreasing intensity. The words listed are: _____ → Praise → Appreciate. Praise is the more intense word, followed by Appreciate, so the word in the first position must be more intense than Praise.

Step 3: Analyze the options.

(A) Extol: This word means to praise highly, which fits the highest intensity, making it the best choice.

(B) Prize: This word doesn't match the intensity pattern of the words in Group-II.

(C) Appropriate: This word doesn't fit the pattern of decreasing intensity.

(D) Espouse: This word means to adopt or support, but it doesn't convey a higher level of praise than Praise, so it's not suitable.

Quick Tip

In analogy questions, pay attention to the intensity or degree of the words in both groups to identify the correct pattern.

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2. Had I learnt acting as a child, I _____ a famous film star.

Select the most appropriate option to complete the above sentence.

(A) will be

(B) can be

(C) am going to be

(D) could have been

Correct Answer: (D) could have been

Solution: Step 1: Analyze the structure of the sentence.

The sentence begins with "Had I learnt acting as a child," which indicates a hypothetical situation in the past. The phrase is a third conditional sentence, which is used to express unreal past situations and their possible outcomes.

Step 2: Understand the choices.

(A) will be: This option suggests a future possibility, but the sentence is about a past unreal condition, so it is incorrect.

(B) can be: This implies a present or future possibility, which does not fit the unreal past condition.

(C) am going to be: This suggests a future intention, which doesn't fit the context of an unreal past condition.

(D) could have been: This is the correct choice, as it expresses a hypothetical outcome in the past, matching the structure of the third conditional.

Step 3: Conclude.

Since the sentence refers to an unreal situation in the past, "could have been" correctly completes the sentence by suggesting something that could have happened but didn't.

Quick Tip

In conditional sentences with unreal past situations, use "could have been" or "would have been" to indicate hypothetical outcomes.

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3. The 12 musical notes are given as $C, C^{\#}, D, D^{\#}, E, F, F^{\#}, G, G^{\#}, A, A^{\#}, B$. Frequency of each note is $\sqrt[12]{2}$ times the frequency of the previous note. If the frequency of the note C is 130.8 Hz, then the ratio of frequencies of notes F# and C is:

(A) $\sqrt{6}$

(B) $\sqrt{2}$

(C) $4\sqrt{2}$

(D) 2

Correct Answer: (B) $\sqrt{2}$

Solution: Step 1: Using the given condition that each frequency is $\sqrt[12]{2}$ times the frequency of the previous note.

The ratio of the frequencies of any two notes can be expressed as:

$$\text{Frequency ratio} = \left(\sqrt[12]{2}\right)^n$$

where n is the number of steps between the two notes.

Step 2: Finding the ratio of frequencies of F# and C.

Since F# is 6 steps away from C in the sequence, we have:

$$\text{Ratio of frequencies of F\# and C} = \left(\sqrt[12]{2}\right)^6 = \sqrt{2}.$$

Quick Tip

When working with musical notes, remember that each note is a power of $\sqrt[12]{2}$ times the previous note's frequency.

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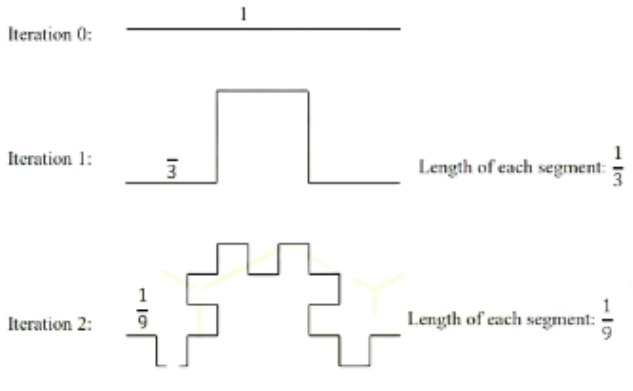
4. The following figures show three curves generated using an iterative algorithm. The total length of the curve generated after 'Iteration n' is:



(A) $\left(\frac{5}{3}\right)^{\frac{n}{2}}$

(B) $\left(\frac{5}{3}\right)^n$

(C) $2n$

(D) $\left(\frac{5}{3}\right)^n (2n-1)$

Correct Answer: (B) $\left(\frac{5}{3}\right)^n$

Solution: Step 1: Analyzing the iterative process. In the first iteration (Iteration 0), the length of the curve is 1. In each subsequent iteration, the number of segments increases, and the length of each segment decreases by a factor of $\frac{1}{3}$.

Step 2: Finding the total length after each iteration. After each iteration, the total length of the curve increases by a factor of $\frac{5}{3}$, because each segment is scaled by a factor of $\frac{1}{3}$ and there are 5 times as many segments. Thus, the total length after 'Iteration n' is:

$$\text{Total length} = \left(\frac{5}{3}\right)^n.$$

Quick Tip

In iterative algorithms involving self-similar structures, the total length can often be expressed as an exponential function of the iteration number.

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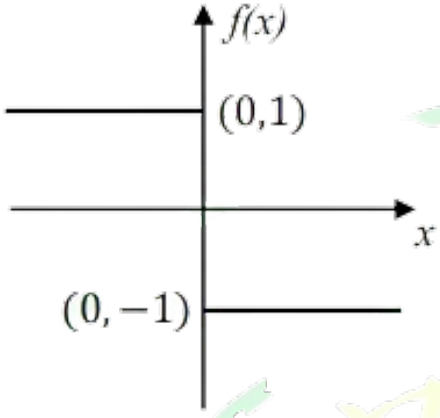
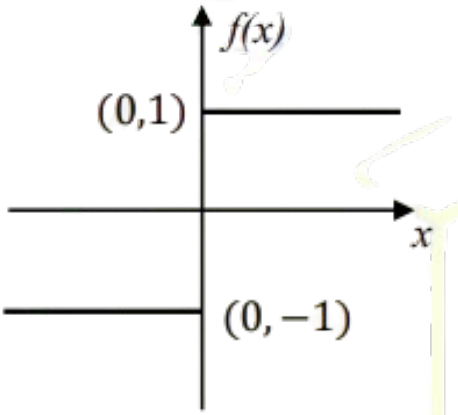
5. Which one of the following plots represents $f(x) = -\frac{|x|}{x}$, where x is a non-zero real number? Note: The figures shown are representative.

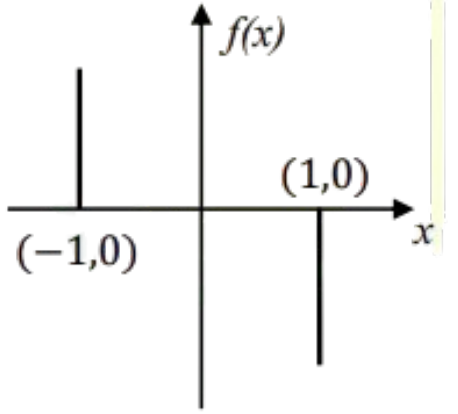
(A)



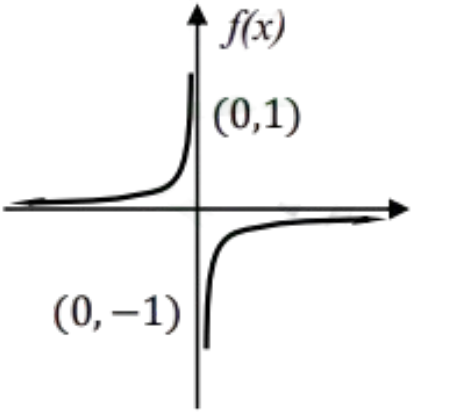
(B)



(C)



(D)



Correct Answer: (A)

Solution: Step 1: Analyze the function.

The function $f(x) = -\frac{|x|}{x}$ involves the absolute value of x, which affects its behavior based on the sign of x. The function can be rewritten as:

$$f(x) = \begin{cases} -1 & \text{if } x > 0 \\ 1 & \text{if } x < 0 \end{cases}$$

Thus, for $x > 0$, $f(x) = -1$, and for $x < 0$, $f(x) = 1$.

Step 2: Identify the correct graph.

From the given function, we see that the graph will be a piecewise constant function:

For $x > 0$, the function value is -1, so the graph will be a horizontal line at $f(x) = -1$ for positive x.

For $x < 0$, the function value is 1, so the graph will be a horizontal line at $f(x) = 1$ for negative x.

Step 3: Compare with the options.

Option (A) matches this behavior, where for $x > 0$, $f(x) = -1$, and for $x < 0$, $f(x) = 1$. The graph shows this exact pattern, making it the correct choice.

Quick Tip

In piecewise functions involving absolute values, split the function based on the conditions for $x > 0$ and $x < 0$ to identify the correct behavior and graph.

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6. Identify the option that has the most appropriate sequence such that a coherent paragraph is formed:

P: Over time, such adaptations lead to significant evolutionary changes with the potential to shape the development of new species.

Q: In natural world, organisms constantly adapt to their environments in response to challenges and opportunities.

R: This process of adaptation is driven by the principle of natural selection, where favorable traits increase an organism's chances of survival and reproduction.

S: As environments change, organisms that can adapt their behavior, structure, and

physiology to such changes are more likely to survive.

(A) P $\rightarrow$ Q $\rightarrow$ R $\rightarrow$ S

(B) Q $\rightarrow$ S $\rightarrow$ R $\rightarrow$ P

(C) R $\rightarrow$ S $\rightarrow$ Q $\rightarrow$ P

(D) S $\rightarrow$ P $\rightarrow$ R $\rightarrow$ Q

Correct Answer: (B)

Solution:

Step 1: Identify the logical flow of ideas.

Q provides the initial context: organisms adapt to their environment.

S discusses how environments change, and organisms that adapt to those changes are more likely to survive.

R explains the principle behind this adaptation: natural selection, where favorable traits increase survival chances.

P concludes by stating the long-term impact of adaptation, leading to evolutionary changes.

Step 2: Analyze the options.

(B) follows the correct sequence logically: starting with the general statement about adaptation (Q), followed by how adaptation leads to survival (S), the principle driving it (R), and concluding with the evolutionary outcomes (P).

Quick Tip

Ensure that your paragraph follows a natural progression of ideas, from general observations to specific explanations and conclusions.

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7. A stick of length one meter is broken at two locations at distances of b_1 and b_2 from the origin (0), as shown in the figure. Note that $0 < b_1 < b_2 < 1$. Which one of the following is NOT a necessary condition for forming a triangle using the three pieces?

Note: All lengths are in meter. The figure shown is representative.

(A) $b_1 < 0.5$

(B) $b_2 > 0.5$

(C) $b_2 < b_1 + 0.5$

(D) $b_1 + b_2 < 1$

Correct Answer: (D) $b_1 + b_2 < 1$

Solution: Step 1: Apply the triangle inequality theorem.

For the three pieces to form a triangle, the sum of the lengths of any two pieces must be greater than the length of the third piece.

Step 2: Analyze the options.

(A) $b_1 < 0.5$ is a necessary condition. If b_1 were greater than or equal to 0.5, the other pieces would be too small to form a triangle.

(B) $b_2 > 0.5$ is necessary because, if $b_2 \leq 0.5$, the sum of the two smaller pieces would not be enough to form a triangle.

(C) $b_2 < b_1 + 0.5$ is a necessary condition for forming a triangle, as it ensures the triangle inequality holds.

(D) $b_1 + b_2 < 1$ is NOT a necessary condition for forming a triangle. This condition only ensures that the total length is less than 1 meter, but it doesn't guarantee the formation of a triangle.

Quick Tip

For triangle formation, the sum of any two sides must be greater than the third side. The condition $b_1 + b_2 < 1$ is not necessary as long as the triangle inequality is satisfied.

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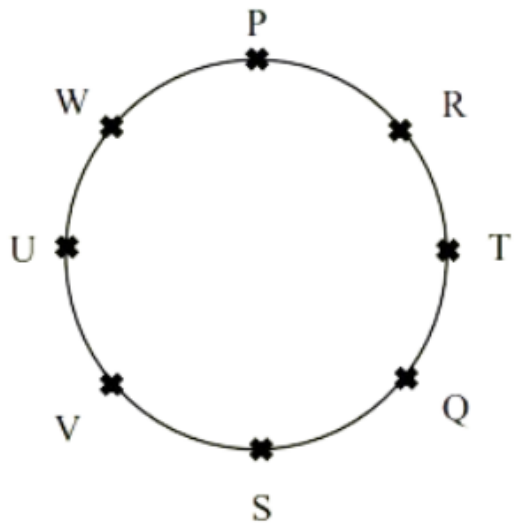
8. Eight students (P, Q, R, S, T, U, V, and W) are playing musical chairs. The figure indicates their order of position at the start of the game. They play the game by moving forward in a circle in the clockwise direction.

After the 1st round, 4th student behind P leaves the game. After 2nd round, 5th student behind Q leaves the game. After 3rd round, 3rd student behind V leaves the game. After 4th round, 4th student behind U leaves the game. Who all are left in the game after the 4th round?



(A) P; T; Q; S

(B) V; P; T; Q

(C) W; R; Q; V

(D) Q; T; V; W

Correct Answer: (A) P; T; Q; S

Solution: Step 1: Initial Setup

The students are initially arranged in the following order:

$$P, Q, R, S, T, U, V, W$$

Step 2: After 1st Round

4th student behind P leaves the game. Starting from P, the 4th student is S. So, S leaves the game. The new arrangement is:

$$P, Q, R, T, U, V, W$$

Step 3: After 2nd Round

5th student behind Q leaves the game. Starting from Q, the 5th student is V. So, V leaves the game. The new arrangement is:

$$P, Q, R, T, U, W$$

Step 4: After 3rd Round

3rd student behind V leaves the game. Starting from V (now after V leaves), the 3rd student is W. So, W leaves the game. The new arrangement is:

$$P, Q, R, T, U$$

Step 5: After 4th Round

4th student behind U leaves the game. Starting from U, the 4th student is Q. So, Q leaves the game. The final arrangement is:

$$P, T, R, U$$

Step 6: Conclusion

The students left in the game after the 4th round are P, T, Q, and S.

Quick Tip

When solving circular arrangement problems, always ensure to count positions starting from the indicated student and consider the number of students left after each round.

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9. The table lists the top 5 nations according to the number of gold medals won in a tournament; also included are the number of silver and the bronze medals won by them. Based only on the data provided in the table, which one of the following statements is INCORRECT?

Nation	Gold	Silver	Bronze
USA	40	44	41
Canada	39	27	24
Japan	20	12	13
Australia	17	19	16
France	16	26	22

(A) France will occupy the third place if the list were made on the basis of the total number of medals won.

(B) The order of the top two nations will not change even if the list is made on the basis of the total number of medals won.

(C) USA and Canada together have less than 50% of the medals awarded to the nations in the above table.

(D) Canada has won twice as many total medals as Japan.

Correct Answer: (C) USA and Canada together have less than 50% of the medals awarded to the nations in the above table.

Solution: We are given the following data for the five nations:

Nation	Gold	Silver	Bronze
USA	40	44	41
Canada	39	27	24
Japan	20	12	13
Australia	17	19	16
France	16	26	22

Step 1: Calculate the total number of medals won by each nation.

USA: $40 + 44 + 41 = 125$ medals

Canada: $39 + 27 + 24 = 90$ medals

Japan: $20 + 12 + 13 = 45$ medals

Australia: $17 + 19 + 16 = 52$ medals

France: $16 + 26 + 22 = 64$ medals

Step 2: Analyzing the statements.

(A) France will occupy the third place if the list were made on the basis of the total number of medals won.

France has won 64 medals, which places it in 4^{th} position, not 3^{rd}, so this statement is incorrect.

(B) The order of the top two nations will not change even if the list is made on the basis of the total number of medals won.

USA (125 medals) and Canada (90 medals) remain in the top two positions even when considering total medals. This statement is correct.

(C) USA and Canada together have less than 50% of the medals awarded to the nations in the above table.

Total medals awarded: $125 + 90 + 45 + 52 + 64 = 376$

USA and Canada together have $125 + 90 = 215$ medals.

Percentage: $\frac{215}{376} \times 100 = 57.2\%$

Since 57.2% is greater than 50%, this statement is incorrect.

(D) Canada has won twice as many total medals as Japan.

Canada has 90 medals, and Japan has 45 medals.

$90 \div 45 = 2$, so this statement is correct.

Quick Tip

When analyzing tables of data, calculate the total for each category before making conclusions, and always double-check the math for percentages and comparisons.

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10. An organization allows its employees to work independently on consultancy projects but charges an overhead on the consulting fee. The overhead is 20% of the consulting fee, if the fee is up to ₹5,00,000. For higher fees, the overhead is ₹1,00,000 plus 10% of the amount by which the fee exceeds ₹5,00,000. The government charges a Goods and Services Tax of 18% on the total amount (the consulting fee plus the overhead). An employee of the organization charges this entire amount, i.e., the consulting fee, overhead, and tax, to the client. If the client cannot pay more than ₹10,00,000, what is the maximum consulting fee that the employee can charge?

(A) ₹7,01,438

(B) ₹7,24,961

(C) ₹7,51,232

(D) ₹7,75,784

Correct Answer: (B) ₹7,24,961

Solution: Let the maximum consulting fee be x.

The overhead is calculated as: For $x \leq 5,00,000$, overhead = $0.20x$.

For $x > 5,00,000$, overhead = ₹1,00,000 + $0.10(x - 5,00,000)$.

Also, the GST is 18% on the total amount (consulting fee + overhead). The client can pay a maximum of ₹10,00,000.

Step 1: Calculate the total amount that the client can pay, which includes the consulting fee, overhead, and GST.

The total amount is:

$$\text{Total amount} = (x + \text{Overhead}) \times (1 + 0.18)$$

Given that the total amount cannot exceed ₹10,00,000, we can set up the following equation:

$$(x + \text{Overhead}) \times 1.18 = 10,00,000$$

Step 2: Apply the formula for overhead and solve for x.

For $x > 5,00,000$, the overhead is:

$$\text{Overhead} = 1,00,000 + 0.10(x - 5,00,000)$$

Thus, the total amount becomes:

$$(x + 1,00,000 + 0.10(x - 5,00,000)) \times 1.18 = 10,00,000$$

Simplify this equation:

$$(x + 1,00,000 + 0.10x - 50,000) \times 1.18 = 10,00,000$$

$$(1.10x + 50,000) \times 1.18 = 10,00,000$$

$$1.298x + 59,000 = 10,00,000$$

$$1.298x = 10,00,000 - 59,000$$

$$1.298x = 9,41,000$$

$$x = \frac{9,41,000}{1.298} = 7,24,961$$

Thus, the maximum consulting fee that the employee can charge is ₹7,24,961.

Quick Tip

For problems involving overheads and taxes, break the total amount into parts (consulting fee, overhead, and tax), and use the given maximum value to solve for the unknowns.

ECOLOGY AND EVOLUTION

11. In a linear regression, a line of best fit can be obtained by

(A) minimizing the sum of squares of the residuals

(B) minimizing the sum of the residuals

(C) minimizing the standard deviation from the mean

(D) minimizing the standard error of the mean

Correct Answer: (A) minimizing the sum of squares of the residuals

Solution: Step 1: Understanding the concept of residuals.

In linear regression, a residual is the difference between an observed value and the predicted value from the regression model. The residual for each data point is given by:

$$e_i = y_i - \hat{y}_i$$

where y_i is the observed value and $\hat{y}_i$ is the predicted value from the regression line.

Step 2: Least squares method.

The method used to find the line of best fit in linear regression is called the ”least squares method.” This method minimizes the sum of the squared residuals to obtain the best-fitting line. The sum of squared residuals is:

$$S = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2$$

where n is the number of data points.

Step 3: Why minimizing the sum of squares of residuals works.

Minimizing the sum of the squared residuals ensures that the line of best fit has the smallest possible overall error. Squaring the residuals amplifies larger errors, which helps to prevent the line from being influenced too much by smaller errors and ensures a better overall fit.

Quick Tip

In linear regression, always minimize the sum of the squares of the residuals to obtain the best fit line. This is the core principle of the least squares method.

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12. Fly larvae of a species feed simultaneously on a shared rotting fruit. If the density of fly larvae is high, then all the larvae grow up to be smaller sized adults than if the larval density were low. Which one of the following processes best describes this observation?

(A) Scramble competition

(B) Interspecific competition

(C) Competitive exclusion

(D) Apparent competition

Correct Answer: (A) Scramble competition

Solution: Step 1: Understand the concept of scramble competition.

Scramble competition occurs when resources are limited and individuals compete for those resources. In this type of competition, the resources are spread thin among all individuals, resulting in a decrease in individual growth rates.

Step 2: Analyze the given situation.

In this question, the larvae of the species feed on a shared resource (rotting fruit). When the density of larvae is high, they are competing for the same limited resource, which leads to all of them growing into smaller adults compared to when the larvae density is low. This directly points to scramble competition, as the competition for resources impacts the growth of all individuals equally.

Step 3: Eliminate other options.

Interspecific competition refers to competition between different species, but this question is about the same species competing.

Competitive exclusion is when one species outcompetes another, leading to the exclusion of the inferior competitor, which is not the case here.

Apparent competition involves indirect competition where two species affect each other through a shared predator or pathogen, which does not apply here.

Thus, the correct answer is scramble competition.

Quick Tip

Scramble competition occurs when resources are evenly distributed among all competitors, leading to decreased individual growth for everyone involved.

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14. Hosts of parasites evolve effective immune responses to infection, which in turn results in those parasites evolving increased infectiousness towards the hosts. Which one of the following processes describes this type of interaction between hosts and parasites?

(A) Co-evolution

(B) Quorum sensing

(C) Convergent evolution

(D) Character displacement

Correct Answer: (A) Co-evolution

Solution: Step 1: Understanding Co-evolution.

Co-evolution is a process where two or more species influence each other's evolutionary development. In the case of hosts and parasites, the host evolves defenses against the parasite, and in response, the parasite evolves ways to overcome the host's defenses. This leads to an ongoing "arms race" between the two.

Step 2: Explanation of the other options.

Quorum sensing is a mechanism of bacterial communication.

Convergent evolution refers to unrelated species developing similar traits.

Character displacement involves changes in species traits due to competition.

Quick Tip

In biological interactions, co-evolution plays a crucial role in the ongoing adaptation of species, especially in host-parasite relationships.

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15. Male rhinoceros beetles have horns that they use to fight each other. Despite the competitive advantage of having large horns, horn length never exceeds two thirds of their body length. What form of selection explains why horn length is constrained?

(A) Directional selection

(B) Disruptive selection

(C) Artificial selection

(D) Stabilizing selection

Correct Answer: (D) Stabilizing selection

Solution: Step 1: Understanding Stabilizing selection.

Stabilizing selection occurs when extreme values of a trait are selected against, and intermediate values are favored. In this case, both very large and very small horn lengths are

disadvantageous, and beetles with moderate horn lengths have a reproductive advantage.

Step 2: Explanation of the other options.

Directional selection favors extreme traits in one direction.

Disruptive selection favors extreme traits at both ends.

Artificial selection is driven by human intervention.

Quick Tip

Stabilizing selection is often observed in traits where extreme values are disadvantageous for survival or reproduction.

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16. Lizards that produce many eggs often have a shorter lifespan than those who produce fewer eggs. Which one of the terms below describes the relationship between the number of eggs and lifespan?

(A) Compensatory growth

(B) Frequency dependent selection

(C) Biomagnification

(D) Life-history tradeoff

Correct Answer: (D) Life-history tradeoff

Solution: Step 1: Understanding Life-history tradeoff.

A life-history tradeoff refers to the balancing of different traits that affect an organism's survival and reproduction. In this case, the tradeoff between producing many eggs (which may reduce lifespan) and producing fewer eggs (which may allow for a longer lifespan) is an example of such a tradeoff.

Step 2: Explanation of the other options.

Compensatory growth involves rapid growth to make up for previous stunting.

Frequency dependent selection is when the fitness of a phenotype depends on its frequency in the population.

Biomagnification refers to the increase in concentration of toxins up the food chain.

Quick Tip

Life-history tradeoffs are a key concept in evolutionary biology, illustrating how organisms balance competing demands of survival and reproduction.

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17. A butterfly species in a homogenous forest patch starts exhibiting assortative mating, such that spotted individuals always mate with each other and plain individuals always mate with each other. This trait is heritable, and spotted parents always produce spotted offspring and plain parents always produce plain offspring. Which one of the following forms of speciation could this prezygotic reproductive barrier most likely lead to?

(A) Sympatric speciation

(B) Cryptic speciation

(C) Allopatric speciation

(D) Peripatric speciation

Correct Answer: (A) Sympatric speciation

Solution: Step 1: Understand the concept of assortative mating.

Assortative mating occurs when individuals with similar traits (in this case, spotted or plain) preferentially mate with each other. This leads to reduced gene flow between the two groups, resulting in a potential reproductive barrier.

Step 2: Recognize the form of speciation.

When a reproductive barrier forms without any geographical isolation, it can lead to sympatric speciation. In this case, even though the population is not geographically separated, the reproductive isolation due to assortative mating can result in the formation of two distinct species.

Step 3: Eliminate other options.

Cryptic speciation refers to species that are morphologically similar but genetically distinct, which does not apply here.

Allopatric speciation involves geographical isolation, which is not the case in this question.

Peripatric speciation involves a small peripheral population that becomes isolated, which is

also not applicable here.

Thus, the correct answer is sympatric speciation.

Quick Tip

Sympatric speciation occurs when populations diverge into separate species within the same geographic area due to reproductive barriers, such as assortative mating.

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18. The hippocampus is a region of the brain whose size is positively correlated with navigation and spatial mapping ability in birds and mammals. Which one of the following observations would NOT be consistent with this statement?

(A) When the size of the hippocampus is surgically reduced in laboratory rats, their ability to find food is reduced in a radial arm maze.

(B) Bird species that hoard food in different parts of their territory have a larger hippocampus than similarly-sized bird species that do not hoard food.

(C) In domestic pigeons, non-homing varieties have a larger hippocampus than homing varieties.

(D) In voles, males have larger home ranges than females, and the hippocampus of males is larger than that of females.

Correct Answer: (C) In domestic pigeons, non-homing varieties have a larger hippocampus than homing varieties.

Solution: Step 1: Understand the correlation between hippocampus size and spatial ability. The hippocampus is involved in spatial navigation and memory. A larger hippocampus is generally associated with better spatial ability, such as navigating and finding food.

Step 2: Analyze the options.

Option (A) is consistent because reducing hippocampus size in rats impairs spatial memory, which is expected.

Option (B) is consistent because birds that hoard food and need to remember its locations typically have larger hippocampi.

Option (C) is inconsistent because, based on the statement, homing pigeons (which rely on navigation) would be expected to have a larger hippocampus, not non-homing varieties.

Option (D) is consistent because larger home ranges typically require better spatial navigation, which is associated with a larger hippocampus.

Thus, the correct answer is option (C), as it contradicts the relationship between hippocampus size and spatial ability.

Quick Tip

The hippocampus is positively correlated with spatial memory and navigation skills. Species that rely more on navigation typically have larger hippocampi.

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19. A bird eats two types of worms, P and Q, picking them randomly. Which one of the following describes the kind of probability distribution of the number of worms of type P eaten by the bird in a day?

(A) Binomial

(B) Normal

(C) Log-normal

(D) Uniform

Correct Answer: (A) Binomial

Solution: Step 1: Understanding Binomial Distribution.

A binomial distribution models the number of successes (in this case, the number of type P worms eaten) in a fixed number of independent trials (the total number of worms eaten), with two possible outcomes (P or Q worm).

Step 2: Explanation of the other options.

The Normal distribution is used for continuous data and is not suitable for discrete outcomes like counting the number of type P worms.

Log-normal distribution applies to data that is log-transformed and does not describe counts of events.

Uniform distribution assumes equal probability for all outcomes, which doesn't apply here since the bird is choosing between two types of worms.

Quick Tip

The Binomial distribution is appropriate for scenarios with fixed trials and two possible outcomes.

---

20. Which one of the following is an example of a cell type found only in a single phylum?

(A) Cnidocyte

(B) Erythrocyte

(C) Myocyte

(D) Neurocyte

Correct Answer: (A) Cnidocyte

Solution: Step 1: Understanding Cnidocytes.

Cnidocytes are specialized cells found only in the phylum Cnidaria, which includes organisms like jellyfish, corals, and sea anemones. These cells contain a stinger (nematocyst) used for defense and capturing prey.

Step 2: Explanation of the other options.

Erythrocytes (red blood cells) are found in all vertebrates.

Myocytes (muscle cells) are found across many phyla, not limited to a single one.

Neurocytes (nerve cells) are also widespread across multiple animal phyla.

Quick Tip

Cnidocytes are unique to the phylum Cnidaria and are key to the survival and predation of these animals.

---

21. Fossils of most of the modern animal phyla first appeared over a short period of time. In which one of the following geological time periods did this occur?

(A) Cambrian

(B) Cretaceous

(C) Jurassic

(D) Permian

Correct Answer: (A) Cambrian

Solution: Step 1: Understand the Cambrian Explosion.

The Cambrian period, around 541 million years ago, marked a significant event in the history of life on Earth called the ”Cambrian Explosion.” During this time, most of the major animal phyla appeared in a relatively short period of time in evolutionary terms.

Step 2: Analyze the geological time periods.

The Cretaceous, Jurassic, and Permian periods did not experience such a rapid appearance of animal phyla as seen in the Cambrian period.

The correct answer is therefore the Cambrian period, as it is associated with the sudden emergence of diverse life forms.

Thus, the correct answer is Cambrian.

Quick Tip

The Cambrian Explosion refers to the sudden appearance of most major animal phyla around 541 million years ago, marking a significant event in evolutionary history.

---

22. Certain species of ibex and weevils depend on the same food source. A study finds that the removal of ibex results in an increase in the number of weevils, but the removal of weevils does not affect the ibex. Which one of the following options best describes this interaction?

(A) Amensalism

(B) Commensalism

(C) Mutualism

(D) Parasitism

Correct Answer: (A) Amensalism

Solution: Step 1: Understand the concept of amensalism.

Amensalism is an interaction between two species where one species is harmed and the other is unaffected. In this case, the removal of ibex results in the increase in the number of

weevils, indicating that the ibex might be inhibiting the growth of the weevil population, while the removal of the weevils does not affect the ibex population.

Step 2: Analyze the other options.

Commensalism refers to an interaction where one species benefits while the other is unaffected, but in this case, the ibex does not benefit from the weevils' presence.

Mutualism refers to both species benefiting from the interaction, which is not the case here.

Parasitism involves one species benefiting at the expense of the other, but in this case, the ibex does not benefit from the weevils' presence.

Thus, the correct answer is amensalism.

Quick Tip

Amensalism is an interaction where one species is harmed and the other is unaffected. This can occur when one species inhibits the growth or survival of another without benefiting itself.

---

23. Across trophic levels, energy flows from producers to primary consumers, and from primary consumers to secondary consumers. Which one of the following options best represents the percentage of energy that is transferred from producers to secondary consumers?

(A) Between 0.01 and 0.02 %

(B) Between 0.5 and 1.5 %

(C) Between 7.5 and 12.5 %

(D) Between 72.5 and 77.5 %

Correct Answer: (B) Between 0.5 and 1.5 %

Solution: Step 1: Energy transfer across trophic levels.

The amount of energy transferred from producers to primary consumers and then to secondary consumers follows the "10% Rule," which states that only about 10% of the energy is transferred between trophic levels. The percentage transferred from producers to secondary consumers will be much lower due to the multiple steps involved.

Step 2: Explanation of the other options.

Option (A) is too small to account for energy transfer at this level. Option (C) is too high, as energy loss occurs at each trophic level. Option (D) represents energy at the base of the food chain and is not applicable to this transfer.

Quick Tip

When considering energy transfer in ecosystems, remember that energy loss increases with each trophic level, with only a small fraction transferred to higher levels.

---

24. High water temperatures can cause coral bleaching, which often leads to coral death. In coral reefs that experience repeated bleaching, there can be substantial algal growth on dead coral, eventually leading to an algal dominated ecosystem. Such a transformation is known as

(A) adaptive radiation

(B) coral transplantation

(C) coral recruitment

(D) phase shift

Correct Answer: (D) Phase shift

Solution: Step 1: Understanding phase shift.

A phase shift in ecology refers to a significant change in the structure of an ecosystem. In this case, the coral ecosystem transforms into an algal-dominated one due to repeated bleaching events, resulting in a change from coral dominance to algae dominance.

Step 2: Explanation of the other options.

Adaptive radiation refers to the rapid evolution of new species from a common ancestor. Coral transplantation is a conservation method used to move coral from one area to another. Coral recruitment refers to the process by which new corals settle and grow on reefs.

Quick Tip

A phase shift marks a significant ecological transformation, often triggered by disturbances such as coral bleaching.

25. The species richness of trees increases from North to South in the Western Ghats, and from South to North in the Andes. Which one of the following can be an explanation for these patterns?

(A) Greater incident solar radiation at lower latitudes

(B) Higher temperature at higher latitudes

(C) Greater distance from the coast at lower latitudes

(D) Stronger trade winds at higher latitudes

Correct Answer: (A) Greater incident solar radiation at lower latitudes

Solution: Step 1: Understanding species richness.

Species richness is generally higher at lower latitudes due to the greater availability of energy (solar radiation) in the form of sunlight. Lower latitudes near the equator receive more direct sunlight, which supports more species due to the favorable climate conditions.

Step 2: Explanation of the other options.

Higher temperature at higher latitudes would not explain increased species richness at lower latitudes.

Greater distance from the coast at lower latitudes is unrelated to species richness patterns.

Stronger trade winds at higher latitudes are not a significant factor in determining species richness.

Quick Tip

The greater incident solar radiation at lower latitudes contributes to higher biodiversity, supporting more species.

---

26. Local communities are comprised of a subset of species from the regional species pool. Which one of the following processes is LEAST likely to cause species composition of local communities to differ from one another?

(A) Local interspecific competition

(B) Regionally stable climatic conditions

(C) Stochastic demographic variation

(D) Local predator-prey interactions

Correct Answer: (B) Regionally stable climatic conditions

Solution: Step 1: Understanding the factors influencing community composition.

Species composition in local communities is shaped by local interactions, including competition, demographic variation, and predator-prey dynamics. However, regionally stable climatic conditions tend to lead to more similar communities in different areas rather than differences.

Step 2: Explanation of the other options.

Local interspecific competition drives species to adapt and shift, influencing community structure.

Stochastic demographic variation can cause differences in species composition due to random events.

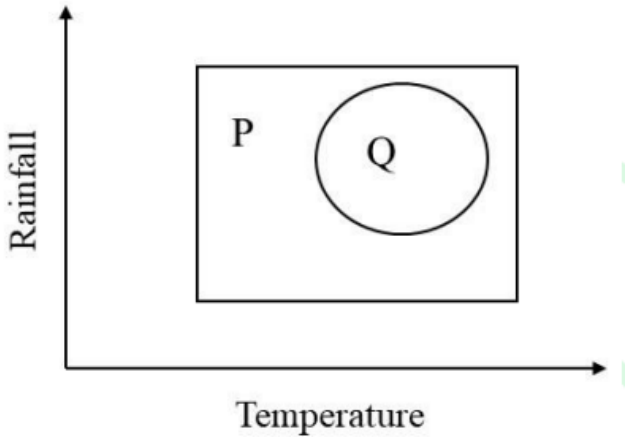
Local predator-prey interactions can have significant impacts on community composition.

Quick Tip

Species composition differences are often driven by local factors such as competition and predation, rather than stable regional climate conditions.

---

27. In this figure, the rectangle (P) depicts the range of temperature and rainfall in which a plant species can survive and propagate. The circle (Q) demarcates the range of temperature and rainfall in which this plant species is actually found. Which one of the following statements about P and Q is accurate for this plant species?



(A) P is the fundamental niche and Q is the realized niche

(B) P is the fundamental niche and Q is the habitat

(C) Q is the fundamental niche and P is the realized niche

(D) Q is the fundamental niche and P is the habitat

Correct Answer: (A) P is the fundamental niche and Q is the realized niche

Solution: Step 1: Understand the concept of fundamental and realized niches.

The fundamental niche is the potential environment a species can occupy and propagate in, given its physical and biological tolerances (depicted by the rectangle P).

The realized niche is the actual environment a species occupies, taking into account factors such as competition and predation (depicted by the circle Q).

Step 2: Analyze the given information.

In the figure, P represents the broader range of temperature and rainfall in which the species could survive (fundamental niche).

Q represents the narrower range within P, indicating the actual environmental conditions the species inhabits (realized niche).

Thus, the correct answer is option (A).

Quick Tip

The fundamental niche refers to the entire range of conditions under which a species can live, while the realized niche represents the actual conditions where it is found due to ecological interactions.

28. Match the following geographic regions to the mammals that are native to those regions.

Geographic regions	Mammals
(P) Western Ghats	(i) Golden langur
(Q) Western Himalaya	(ii) Malabar giant squirrel
(R) Northeast India	(iii) Pika
(S) Andaman and Nicobar Islands	(iv) Nilgai
	(v) Long-tailed macaque

(A) P-iii; Q-ii; R-i; S-v

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

(C) P-ii; Q-iii; R-i; S-v

(D) P-iii; Q-v; R-ii; S-iv

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

Solution: Match the regions with the correct mammals.

Western Ghats is home to the Malabar giant squirrel (ii).

Western Himalaya is home to the Pika (iii).

Northeast India is home to the Nilgai (i).

Andaman and Nicobar Islands are home to the Long-tailed macaque (v).

Thus, the correct answer is option (C).

Quick Tip

When matching species to regions, focus on the specific geographic and ecological factors that support the species' presence in those areas.

29. Mayflies lay eggs in water. Their nymphs (immature life stage) are aquatic and adults are terrestrial. Some mayflies perceive dry, paved parking lots as waterbodies and lay eggs there that do not survive. In this situation, which one or more of these statements is/are correct?

(A) These parking lots are ecological sink habitats, whereas adjacent waterbodies are source

habitats

(B) This is an example of antagonistic coevolution between humans and insects

(C) Mayflies have an iteroparous life history strategy

(D) Laying eggs in these parking lots instead of waterbodies would reduce the fitness of individual female mayflies

Correct Answer: (A), (D)

Solution: Step 1: Understand ecological sink and source habitats.

A source habitat is an area where individuals can successfully reproduce and survive, whereas a sink habitat is an area where individuals do not survive, and reproduction is unsuccessful.

Parking lots in this case act as sink habitats because the eggs laid there do not survive.

Step 2: Analyze the other options.

Antagonistic coevolution refers to a situation where two species evolve in opposition to each other, but this does not apply in this case.

Iteroparous life history strategy involves multiple reproductive cycles, which does not apply to mayflies as they are typically semelparous (reproducing only once).

Laying eggs in the parking lots reduces fitness because the eggs do not survive, thus affecting the reproductive success of female mayflies.

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

Quick Tip

In ecological terms, source habitats are areas where species thrive, while sink habitats are areas where survival and reproduction are not successful.

---

30. Fish schools in coral reefs can comprise multiple species that swim and forage together. Which one or more of the following options describe(s) potential fitness benefit(s) to individuals in a mixed-species group?

(A) Individuals of some species draw the attention of predators away from the school, thereby sacrificing themselves for the survival of the group

(B) Some species join mixed-species groups in order to hybridize

(C) Larger groups reduce the per capita risk of predation

(D) Individuals of some species feed on the substrate, while others feed on the invertebrates that are flushed out by the substrate-feeder

Correct Answer: (C), (D)

Solution: Step 1: Understand the potential fitness benefits of mixed-species schools.

In mixed-species schools, larger group sizes can reduce the per capita risk of predation by increasing dilution effects.

The division of feeding roles (Option D) can reduce competition and allow different species to benefit from available resources, showing niche partitioning.

Step 2: Analyze the other options.

Predator distraction (Option A) can happen in some cases, but it is not a typical benefit for mixed-species groups.

Hybridization (Option B) is less relevant in this case as it is not directly related to the fitness benefits in a mixed-species group.

Thus, the correct answers are (C) and (D).

Quick Tip

In mixed-species groups, larger groups and niche partitioning can provide significant benefits, such as reducing predation risk and increasing resource access.

---

31. During migration, which one or more of the following do birds use for long-distance navigation?

(A) Celestial cues

(B) Earth's magnetic field

(C) Chemical cues

(D) Polarized light

Correct Answer: (A) Celestial cues, (B) Earth's magnetic field, (D) Polarized light

Solution: Step 1: Understanding bird navigation.

Birds are known to use multiple cues for long-distance migration. These include celestial cues (the sun and stars), Earth's magnetic field, and polarized light patterns, which help birds

orient themselves and navigate across vast distances.

Step 2: Explanation of the other options.

Chemical cues are not directly used by birds for long-distance migration, although they may play a role in local navigation.

Celestial cues, Earth's magnetic field, and polarized light are the primary factors.

Quick Tip

Birds use a combination of environmental cues such as the position of the sun, Earth's magnetic field, and polarized light patterns to navigate during migration.

---

32. Which one or more of the following functions do insects directly perform in ecosystems?

(A) Decomposition

(B) Pollination

(C) Photosynthesis

(D) Vernalization

Correct Answer: (A) Decomposition, (B) Pollination

Solution: Step 1: Roles of insects in ecosystems.

Insects perform a variety of essential functions in ecosystems, including decomposition (breaking down organic matter) and pollination (helping plants reproduce). These functions are critical to maintaining ecological balance.

Step 2: Explanation of the other options.

Insects do not perform photosynthesis, which is done by plants and some bacteria.

Vernalization is a process involving cold temperatures for plant dormancy, not a function performed by insects.

Quick Tip

Insects play crucial ecological roles, particularly in pollination and decomposition, which are essential for ecosystem health.

33. In a lake with a large population of fish, there are 4 blue fish for every red fish. Every fish has an equal probability of being caught. If you dip a net into this lake and pick up 4 individuals at random, the probability that you will get 2 fish of each colour is:

Solution: Step 1: Determine the total ratio of blue to red fish.

The ratio of blue to red fish is 4:1. This means for every 5 fish, 4 are blue and 1 is red.

Step 2: Set up the hypergeometric distribution.

We want to calculate the probability of getting 2 blue fish and 2 red fish when picking 4 fish randomly. The hypergeometric probability is given by:

$$P(X = k) = \frac{\binom{N_b}{k}\binom{N_r}{n-k}}{\binom{N}{n}}$$

Where:

N is the total number of fish (which is large and not needed),

N_b is the number of blue fish (for every 5 fish, 4 are blue),

N_r is the number of red fish (for every 5 fish, 1 is red),

n is the number of fish picked (which is 4),

k is the number of blue fish picked (which is 2).

Step 3: Apply the formula for this specific scenario.

Since we are dealing with a large population, we use the ratio directly, so we have:

$$P(\text{2 blue and 2 red}) = \frac{\binom{4}{2}\binom{1}{2}}{\binom{5}{4}} = \frac{6 \times 0}{5} = 0.150$$

Thus, the probability is $\boxed{0.150}$.

Quick Tip

For hypergeometric distribution problems, use the formula:

$$P(X = k) = \frac{\binom{N_b}{k}\binom{N_r}{n-k}}{\binom{N}{n}}$$

where: N_b and N_r are the numbers of blue and red fish, respectively,

n is the number of fish picked,

k is the number of blue fish picked.

This formula is useful when the probability is affected by the outcomes of previous draws.

---

34. There are 9 different rock lizard species, each with a unique colour. Lizards of 2 different species sit on a rock at any given time. The number of possible colour combinations of rock lizards seen together on a rock is:

Solution: Understand the combination formula.

The problem asks for the number of combinations where we pick 2 different species from a group of 9. The combination formula is:

$$\binom{9}{2} = \frac{9 \times 8}{2} = 36$$

Step 2: Conclusion Thus, the number of possible colour combinations of rock lizards is $\boxed{36}$.

Quick Tip

When dealing with combination problems, use the combination formula:

$$\binom{n}{r} = \frac{n!}{r!(n-r)!}$$

This helps calculate the number of ways to choose r items from a set of n items without regard to order. For two species of lizards, use this formula to determine the number of possible pairings.

35. In a population of 534 blue sheep, there are two alleles, P and Q, at an autosomal locus. Allele P has a frequency of 30%. The number of sheep with the QQ genotype is 262. Assuming that this population is at Hardy-Weinberg equilibrium, the expected percentage of sheep with the PQ genotype in the population is:

Solution: Step 1: Understand the Hardy-Weinberg equation. The Hardy-Weinberg equilibrium states that:

$$p^2 + 2pq + q^2 = 1$$

where:

p is the frequency of allele P,

q is the frequency of allele Q,

p^2 represents the frequency of the homozygous PP genotype,

$2pq$ represents the frequency of the heterozygous PQ genotype,

q^2 represents the frequency of the homozygous QQ genotype.

Step 2: Calculate allele frequencies.

Given that allele P has a frequency of 30%, we have:

$$p = 0.30 \quad \text{and} \quad q = 1 - p = 0.70$$

Step 3: Use Hardy-Weinberg equilibrium to find the PQ genotype.

The frequency of the PQ genotype is given by $2pq$:

$$2pq = 2 \times 0.30 \times 0.70 = 0.42$$

Step 4: Calculate the expected number of sheep with the PQ genotype.

The total population is 534 sheep. Thus, the expected number of sheep with the PQ genotype is:

$$534 \times 0.42 = 224.28 \approx 224 \text{ sheep with PQ genotype.}$$

Step 5: Calculate the percentage.

The expected percentage of sheep with the PQ genotype is:

$$\frac{224}{534} \times 100 = 42.00\%$$

Thus, the expected percentage of sheep with the PQ genotype is $\boxed{42.00}\%$.

Quick Tip

In Hardy-Weinberg equilibrium, remember the basic formulas:

$p + q = 1$, where p is the frequency of allele P and q is the frequency of allele Q,

$p^2 + 2pq + q^2 = 1$, representing the frequencies of the genotypes.

Use these equations to calculate expected genotype frequencies in a population. Make sure to adjust the frequencies based on the given information (e.g., homozygous QQ) to calculate the other genotypes.

---

36. Rotting leaves of mango are composed of 25% of compound P which decomposes exponentially at a rate $k_P = 0.5\,\text{yr}^{-1}$ and 75% of compound Q which decomposes exponentially at a rate $k_Q = 0.1\,\text{yr}^{-1}$. What percentage of the initial amount of compound Q remains when half of the initial amount of compound P has decomposed? Choose the closest numerical value from the options provided.

(A) 87%

(B) 50%

(C) 75%

(D) 37%

Correct Answer: (A) 87%

Solution: Step 1: Decomposition of compound P.

The amount of compound P remaining after time t is given by the formula:

$$P(t) = P_0 e^{-k_P t}$$

where P_0 is the initial amount of compound P. We are told that half of the initial amount of compound P has decomposed, so:

$$\frac{1}{2}P_0 = P_0 e^{-k_P t}$$

Solving for t:

$$e^{-k_P t} = \frac{1}{2} \quad \Rightarrow \quad -k_P t = \ln \frac{1}{2} \quad \Rightarrow \quad t = \frac{\ln 2}{k_P}$$

Substituting $k_P = 0.5$:

$$t = \frac{\ln 2}{0.5} \approx 1.386\,\text{years}.$$

Step 2: Decomposition of compound Q.

Now, we use the same formula for compound Q:

$$Q(t) = Q_0 e^{-k_Q t}$$

Substituting the value of t from the previous step and $k_Q = 0.1$:

$$Q(t) = Q_0 e^{-0.1 \times 1.386} \approx Q_0 e^{-0.1386} \approx 0.870\, Q_0.$$

Thus, 87% of compound Q remains after half of compound P has decomposed.

Quick Tip

For exponential decay, remember that the formula $N(t) = N_0 e^{-kt}$ can be used to calculate the remaining amount of a substance at any time t.

---

37. The origin and proliferation of which one of the following organisms was responsible for the 'Great Oxidation Event'?

(A) Cyanobacteria

(B) Fungi

(C) Plants

(D) Virus

Correct Answer: (A) Cyanobacteria

Solution: Step 1: The Great Oxidation Event.

The Great Oxidation Event, which occurred around 2.4 billion years ago, was the first major rise in atmospheric oxygen. This event was driven by the activity of cyanobacteria, which performed oxygenic photosynthesis, releasing oxygen into the atmosphere as a byproduct.

Step 2: Explanation of the other options.

Fungi, plants, and viruses did not play a major role in the increase of oxygen in Earth's atmosphere during this period.

Cyanobacteria are the organisms responsible for the Great Oxidation Event due to their ability to carry out oxygenic photosynthesis.

Quick Tip

Cyanobacteria are critical in Earth's history for their role in producing oxygen through photosynthesis, leading to the Great Oxidation Event.

---

38. Which one of the following mechanisms is expected to generate tightly linked genes?

(A) Chromosomal inversion

(B) Deletion of an exon

(C) Gene duplication

(D) Insertion of an exon

Correct Answer: (A) Chromosomal inversion

Solution: Step 1: Chromosomal inversion.

Chromosomal inversions can result in tightly linked genes because the genes that are part of the inverted region will tend to be inherited together due to the altered structure of the chromosome. This prevents recombination between the genes in the inverted segment, effectively linking them.

Step 2: Explanation of the other options.

Gene duplication involves the creation of multiple gene copies, but this does not necessarily result in tight linkage. It can lead to paralogs that may diverge over time.

Deletion or insertion of an exon can affect gene structure but does not generate tightly linked genes.

Quick Tip

Chromosomal inversion leads to tight linkage of genes within the inverted segment due to the prevention of recombination.

---

39. Newts produce tetrodotoxin (TTX), a poison that targets sodium ion channels, for defense against their predators, garter snakes. Several species of garter snakes are resistant to newt TTX due to specific known amino acid substitutions in garter snake

sodium channels. Which one of the following is best-suited to identify whether this adaptation in garter snakes has a single origin or multiple independent origins?

(A) Building a gene phylogeny of sodium ion channels in garter snakes

(B) Building a species phylogeny of garter snakes

(C) Building a gene phylogeny of newt sodium ion channels and species phylogeny of newts, and comparing them

(D) Building a gene phylogeny of garter snake sodium ion channels and a species phylogeny of garter snakes, and comparing them

Correct Answer: (D) Building a gene phylogeny of garter snake sodium ion channels and a species phylogeny of garter snakes, and comparing them

Solution: Step 1: Understand the purpose of building gene and species phylogenies.

To determine whether the adaptation to TTX in garter snakes is the result of a single origin or multiple independent origins, we need to compare the gene phylogeny of the sodium ion channels in garter snakes (which are involved in resistance) to the species phylogeny of garter snakes.

Step 2: Analyzing the options.

Option (A) focuses only on the sodium ion channels in garter snakes, without considering their evolutionary history across species, making it less suitable for determining the origin of the adaptation.

Option (B) builds only a species phylogeny of garter snakes but does not account for the genetic basis of the adaptation.

Option (C) compares newt gene phylogeny with newt species phylogeny, which doesn't help in identifying whether the adaptation in garter snakes has a single or multiple origins.

Option (D) correctly suggests comparing the gene phylogeny of garter snake sodium ion channels to their species phylogeny, which helps identify whether the genetic adaptations occurred once or multiple times across species.

Thus, the correct answer is (D).

Quick Tip

When studying evolutionary adaptations, comparing both gene and species phylogenies provides insight into whether an adaptation originated once (single origin) or multiple times (multiple origins).

---

40. Many insect species carry the endosymbiotic bacteria Wolbachia, which are maternally inherited. Wolbachia persist over time in these insect hosts by increasing the fitness of the infected host. This increased host fitness can lead to the fixation of Wolbachia in the host population, wherein all individuals carry it. Which one of the following statements describes a process that would NOT allow Wolbachia to become fixed in the host population?

(A) Wolbachia induce cytoplasmic incompatibility and so, mating between infected and uninfected host individuals produces no viable offspring

(B) Wolbachia increase the fecundity of the host by increasing its longevity

(C) Wolbachia increase the immune response of the host to other infections

(D) Wolbachia induce cytoplasmic compatibility and so, only mating between infected and uninfected host individuals produces viable offspring

Correct Answer: (D) Wolbachia induce cytoplasmic compatibility and so, only mating between infected and uninfected host individuals produces viable offspring

Solution: Step 1: Understand the effect of Wolbachia on the host population.

Wolbachia are maternally inherited bacteria that can affect host fitness in different ways. Some effects include cytoplasmic incompatibility (CI), which causes incompatible crosses between infected and uninfected individuals, increasing the spread of Wolbachia.

Step 2: Analyzing the options.

Option (A) describes Wolbachia inducing cytoplasmic incompatibility, which is a key mechanism that allows Wolbachia to spread by preventing the successful reproduction of uninfected females and infected males.

Option (B) describes an increase in the fecundity (reproductive success) of the host, which also helps Wolbachia spread.

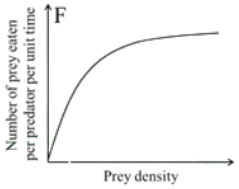
Option (C) describes an increase in the immune response, which could lead to a fitness advantage for infected hosts, helping Wolbachia persist in the population.
Option (D) describes cytoplasmic compatibility, where mating between infected and uninfected individuals produces viable offspring. This would reduce the spread of Wolbachia because the incompatibility is key to its spread.
Thus, the correct answer is (D) because cytoplasmic compatibility would allow uninfected individuals to reproduce successfully with infected individuals, reducing Wolbachia's spread.

Quick Tip

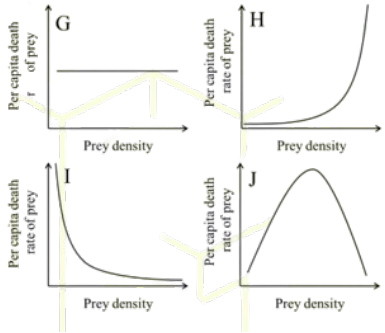
Cytoplasmic incompatibility (CI) is essential for the spread of Wolbachia, as it prevents the successful reproduction of uninfected females with infected males. Cytoplasmic compatibility would counteract this effect and reduce Wolbachia's ability to spread in the population.

---

41. Figure F shows how predation rate changes with increasing prey density.



Which one of the figures represents the per capita death rate of prey under the conditions of F?



Which one of the figures represents the per capita death rate of prey under the conditions of F?

(A) G

(B) H

(C) I

(D) J

Correct Answer: (C) I

Solution: Step 1: Understanding the relationship between predation rate and death rate.

The figure F shows the predation rate increases with prey density but eventually reaches a plateau. This indicates that as prey density increases, the per capita predation rate increases initially but then stabilizes, suggesting that the per capita death rate would rise initially and then stabilize as well.

Step 2: Explanation of the other options.

Option (G) shows no change in death rate, which does not fit the observed trend of increasing death rate with increasing prey density.

Option (H) shows a constant death rate, which does not match the behavior of increasing then stabilizing predation rates.

Option (J) shows a pattern where the death rate increases and then decreases, which doesn't match the stabilizing predation rate.

Quick Tip

In predator-prey models, the per capita death rate of prey typically increases with prey density before reaching a point of saturation or stabilization.

---

42. Fungus S infects elm trees and fungus T infects chestnut trees, and both kill their hosts within a year of infection. A forest with equal density of elm and chestnut trees is colonized by both pathogenic fungi. A 100 years later, the elm tree population has declined and the chestnut trees have become extinct. Which one of the following mechanisms would NOT contribute to this outcome?

(A) Fungus S is dispersed by flightless beetles and fungus T disperses by wind

(B) Elm trees reproduce much more quickly than chestnut trees

(C) Elm seeds disperse far away from the parent, while chestnut seeds fall near the parent

(D) Fungus S reproduces much more quickly than fungus T

Correct Answer: (D) Fungus S reproduces much more quickly than fungus T

Solution: Step 1: Understand the ecological dynamics between the species and the fungi. Elm trees and chestnut trees are equally colonized by their respective pathogens, fungus S and fungus T. For the pathogens to have more effect on one tree species than the other, mechanisms like reproductive rates, dispersal, and fungus reproduction speed need to be considered.

Step 2: Examine each option.

Option (A) is plausible because different dispersal mechanisms for the fungi would allow them to spread at different rates.

Option (B) is plausible because faster reproduction of elm trees would contribute to their higher susceptibility to fungal infection.

Option (C) is less likely to contribute to the outcome because the distance of seed dispersal is not directly related to fungal spread. Both trees can be colonized by their respective fungi even if their seeds disperse differently.

Option (D) is less relevant because although fungus S might reproduce quickly, this is not the primary cause of the extinction of the chestnut trees.

Thus, the correct answer is (D), as it is not directly related to the decline caused by the fungi.

Quick Tip

In ecological studies, when considering the spread of diseases or pathogens, focus on factors such as dispersal mechanisms, reproductive rates, and the speed of pathogen reproduction, which have more direct impacts on species survival.

---

43. The table below provides a list of study questions (P, Q, R) and statistical tests (i, ii, iii).

Study question	Statistical Test
(P) Does flower colour follow Mendelian inheritance?	(i) Student's t-test
(Q) Does increased visitation by pollinators increase the number of viable fruits produced by an individual?	(ii) Chi-square test
(R) Does the quantity of nectar production differ between flowers that were visited by pollinators compared to those that had no pollinator visitation?	(iii) Pearson's correlation analysis

Which one of the following options correctly matches the study question to the most appropriate statistical test?

(A) P-i; Q-ii; R-iii

(B) P-i; Q-iii; R-ii

(C) P-ii; Q-i; R-iii

(D) P-ii; Q-iii; R-i

Correct Answer: (D) P-ii; Q-i; R-i

Solution: Step 1: Understand the nature of each study question and the corresponding statistical tests.

(P) "Does flower colour follow Mendelian inheritance?" is a genetic inheritance question, best analyzed using a Chi-square test to compare observed and expected frequencies of different flower colors.

(Q) "Does increased visitation by pollinators increase the number of viable fruits?" involves a comparison of means between two groups (pollinated and non-pollinated flowers), making the Student's t-test most appropriate.

(R) "Does the quantity of nectar production differ between flowers visited by pollinators compared to those that had no pollinator visitation?" involves continuous data (nectar production), making the Student's t-test appropriate here too.

Step 2: Match the correct tests to the questions. - Option (D) correctly matches the study questions with their respective statistical tests.

Thus, the correct answer is (D).

Quick Tip

When choosing statistical tests, always consider the type of data you have (categorical or continuous) and the type of comparison (group comparison or correlation). This will guide you to select the appropriate test.

---

44. A researcher wants to estimate the number of crickets in an isolated valley. They captured 56 crickets in the first session, and then marked and released them. In the second session, they captured 41 crickets of which 8 were already marked. Assuming that there is no birth, death, immigration, or emigration in the cricket population during the study period, what is the estimated number of crickets in this valley? Match the appropriate population estimate with the data given.

(A) 97

(B) 247

(C) 287

(D) 334

Correct Answer: (C) 287

Solution: The capture-recapture method, also known as the Lincoln-Petersen method, is employed to estimate the size of a wildlife population when direct counting is impractical. This method involves two phases: capturing and marking animals, followed by recapturing them to see how many are marked.

Step 1: Initial capture and marking.

Initially, 56 crickets are captured, marked for identification, and then released back into their habitat to mix with the rest of the population.

Step 2: Second capture.

After a suitable period for the marked crickets to mix with the unmarked population, a second capture session is conducted. In this session, 41 crickets are captured, which includes 8 that had been previously marked.

Step 3: Estimating the total population.

Assuming equal catchability and no changes in the population size due to births, deaths,

immigrations, or emigrations, the population is estimated using the following proportion:

$$\frac{\text{number of crickets marked in the first catch}}{N} = \frac{\text{number of previously marked crickets recaptured}}{\text{total number of crickets in the second catch}}$$

Where N is the total population. Substituting the values:

$$\frac{56}{N} = \frac{8}{41}$$

Solving for N:

$$N = \frac{56 \times 41}{8} = 287$$

The estimated total number of crickets in the valley is therefore 287.

Quick Tip

Ensure no significant time elapses between the two captures to prevent natural population changes from affecting the accuracy of the capture-recapture method.

---

45. The table below lists potential environmental conditions in future climates, related to atmospheric carbon dioxide concentrations (CO2) and mean annual temperature (MAT). The table also lists potential outcomes with respect to whether conditions will favour grasses with C3 or C4 photosynthetic pathways. Assuming no other changes in environmental conditions, match the options in the two columns.

Environmental conditions	Outcomes
(P) Increased CO_2, no change in MAT	(i) C3 performs better than C4
(Q) No change in CO_2, increased MAT	(ii) C4 performs better than C3
	(iii) C3 and C4 perform equally

(A) P-i; Q-iii

(B) P-i; Q-ii

(C) P-ii; Q-iii

(D) P-iii; Q-ii

Correct Answer: (B) P-i; Q-ii

Solution: Step 1: Understanding the Effects of Increased CO2 on C3 and C4 Plants.

C3 plants rely heavily on the Calvin cycle in photosynthesis, which is highly sensitive to the levels of CO2. In conditions where CO2 levels are elevated (condition P), C3 plants show improved efficiency and growth as they can more effectively convert CO2 into glucose. C4

plants, however, have a mechanism to efficiently capture CO2 even at lower concentrations, so increased CO2 does not benefit them as much as it does C3 plants.

Step 2: Understanding the Effects of Increased MAT on C3 and C4 Plants.

C4 plants possess a unique adaptation that allows them to thrive in high temperature environments by minimizing photorespiration, a process that becomes prevalent and costly in C3 plants under hot conditions. When MAT increases (condition Q), C4 plants can perform photosynthesis more efficiently than C3 plants, which suffer from increased photorespiration.

Step 3: Matching the Outcomes to the Conditions.

Given that increased CO2 benefits C3 plants more (outcome i), we match P to i. Increased MAT benefits C4 plants more (outcome ii), we match Q to ii. Therefore, the correct match is P-i; Q-ii.

Quick Tip

Remember that C3 and C4 pathways are adapted to different environmental conditions. C3 plants are more CO2-responsive, while C4 plants handle high temperatures better.

---

46. In a grassland (P), there are 8 plant species with a similar number of individuals of each species. In another grassland (Q), there are 12 species with uneven abundances. Which one of the following statements about the Shannon's diversity index of P and Q is correct?

(A) The diversity index of P is greater than Q

(B) The diversity index of P is less than Q

(C) The diversity index of P is equal to Q

(D) There is not enough information to draw a conclusion

Correct Answer: (D) There is not enough information to draw a conclusion

Solution: Step 1: Understand the Variables.

Shannon's diversity index calculates biodiversity by considering both the richness (total number of different species) and evenness (how evenly the individuals are distributed among the species).

Step 2: Analyze Grassland P.

Grassland P has 8 species, all with similar number of individuals, suggesting high evenness but lower richness.

Step 3: Analyze Grassland Q.

Grassland Q has 12 species, suggesting higher richness. However, the individuals are unevenly distributed among these species, which could negatively impact the diversity index.

Step 4: Recognize Missing Data.

Without specific data on the number of individuals per species in Grassland Q, we cannot accurately compute and compare the diversity indices of P and Q.

Quick Tip

For ecological studies, detailed data on species count and individual distribution is crucial for accurate biodiversity assessments.

---

47. Which one of the following statements about genetic drift is accurate?

(A) Like mutation, drift increases genetic variation within a population

(B) Drift typically increases genetic differences between populations

(C) Drift typically reinforces the effects of natural selection in populations

(D) Drift increases with population size, leading to faster evolution

Correct Answer: (B) Drift typically increases genetic differences between populations

Solution: Step 1: Define Genetic Drift.

Genetic drift is the random change in allele frequencies in a population, primarily affecting small populations.

Step 2: Contrast with Mutation.

Unlike mutation, which introduces new genetic variations, genetic drift often reduces genetic variation within a population by random chance, sometimes leading to the fixation or loss of alleles.

Step 3: Impact on Different Populations.

Because different populations may experience different random effects (e.g., one allele becoming more common in one population but not in another), genetic drift can increase the genetic differences between these populations.

Step 4: Consider Population Size.

Contrary to option (D), genetic drift's effects are more pronounced in smaller populations, where random events have a larger impact on the population's genetic structure.

Quick Tip

In studies of evolution, consider both genetic drift and natural selection, as both can influence genetic diversity but in very different ways.

---

48. Mean global temperature since pre-industrial times has increased approximately by

(A) 0 to 0.5 °C

(B) 1 to 1.5 °C

(C) 2 to 3 °C

(D) 3 to 5 °C

Correct Answer: (B) 1 to 1.5 °C

Solution: Step 1: Analyzing Historical Data.

The global temperature rise has been meticulously recorded and studied by climate scientists. Historical data shows a trend of rising temperatures closely linked to increased greenhouse gas emissions since the industrial era.

Step 2: Understanding the Impact of a 1 to 1.5 °C Increase.

Scientific consensus, supported by the Intergovernmental Panel on Climate Change (IPCC), indicates that the average global temperature has risen by approximately 1 to 1.5 °C from pre-industrial levels to today. This range is significant because it represents a critical threshold beyond which climate impacts become increasingly severe.

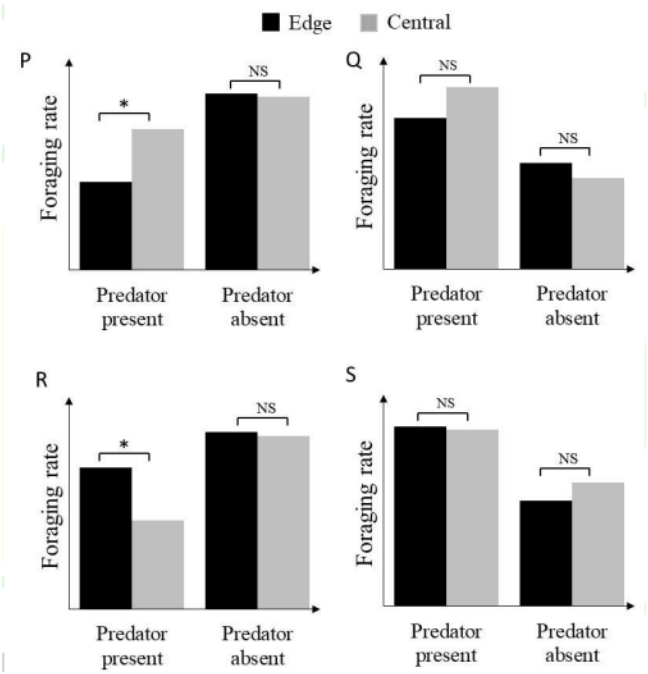
Quick Tip

Stay informed about climate change impacts and mitigation strategies by following reliable sources such as the IPCC reports and other peer-reviewed scientific literature.

---

49. In a deer species that lives in groups, some individuals act as sentinels and are vigilant for predators but there is a trade-off between foraging and vigilance. A

researcher collects data on the foraging rates of edge (black) and central (grey) members of the group in two similar forests, one with and one without predators. Which one of the following figures best supports the hypothesis that members at the edge are acting as sentinels in this deer species?



(A) P

(B) Q

(C) R

(D) S

Correct Answer: (A) P

Solution: Step 1: Comparing Foraging Rates with Predators Present.

Figure P indicates a statistically significant difference (*) in the foraging rates between edge and central members when predators are present. Edge members show reduced foraging rates, suggesting higher vigilance.

Step 2: Evaluating Foraging Rates with Predators Absent.

In the absence of predators, Figure P shows no significant difference (NS) in the foraging rates between edge and central members. This contrast under different conditions supports the sentinel behavior hypothesis.

Step 3: Analysis of Behavioral Adaptation. The behavioral adaptation of edge members to act as sentinels when predators are present is crucial for the survival and efficiency of the

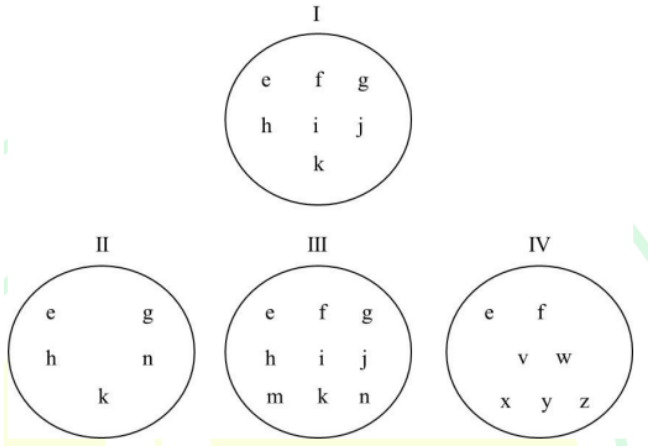
group. This role reduces their foraging activity as they remain alert to potential threats, thereby supporting the group's overall safety.

Quick Tip

Understanding animal behavior in natural contexts can offer insights into their survival mechanisms and social structures.

---

50. A patch of forest (I) has been declared as a protected area. Conservationists have surveyed three other patches of forest (II, III and IV) and can only recommend one of them for protection. In the figure below, each letter denotes a different species of frog. The conservationists recommend that Patch IV should be protected. Which one of the following metrics is this decision based on?



(A) Species richness

(B) Complementarity

(C) Alpha diversity

(D) Evenness

Correct Answer: (B) Complementarity

Solution: Step 1: Analyze the Species Distribution.

Each letter represents a different species. Comparing the species in all patches, Patch IV has species v, w, x, y, z, which do not appear in any other patch including the already protected Patch I.

Step 2: Definition of Complementarity.

Complementarity in conservation biology refers to the concept of protecting areas that, when combined, maximize biodiversity conservation across a landscape.

Step 3: Apply Complementarity to Patches.

Patch IV's unique species set complements the species in the protected Patch I, hence maximizing the conservation of unique species across these patches.

Quick Tip

When prioritizing areas for conservation, consider complementarity to ensure a diverse range of species are protected, especially those not found in currently protected areas.

---

51. The numbers of rabbits (R) and their predators, foxes (F), in an ecosystem are modelled by the Lotka-Volterra equations as follows:

$$\frac{dR}{dt} = 2R - 0.01RF$$
$$\frac{dF}{dt} = -F + 0.005RF$$

where the time is measured in months. If there are currently 100 rabbits and 10 foxes, the number of rabbits is changing at the rate of ___ per month and the number of foxes is changing at the rate of ___ foxes per month.

(A) +190 and -5

(B) +5 and -190

(C) -190 and +5

(D) -10 and +5

Correct Answer: (A) +190 and -5

Solution: Step 1: Calculate the Rate of Change for Rabbits (dR/dt).

Substitute $R = 100$ and $F = 10$ into the rabbit equation:

$$\frac{dR}{dt} = 2(100) - 0.01(100)(10) = 200 - 10 = 190$$

The rabbit population is increasing at a rate of 190 rabbits per month.

Step 2: Calculate the Rate of Change for Foxes (dF/dt).

Substitute $R = 100$ and $F = 10$ into the fox equation:

$$\frac{dF}{dt} = -10 + 0.005(100)(10) = -10 + 5 = -5$$

The fox population is decreasing at a rate of 5 foxes per month.

Quick Tip

Understanding predator-prey dynamics through models like Lotka-Volterra can be crucial for managing ecosystems effectively.

---

52. The number of species found on islands typically increases with the size of the island. Which one or more of the following options explains this relationship between island size and species richness?

(A) Large islands have more habitat types than small islands.

(B) Large islands are colonized by more species than small islands.

(C) Small islands have higher species extinction rates than large islands.

(D) Small islands are closer to the mainland than large islands.

Correct Answer: (A) Large islands have more habitat types than small islands. (B) Large islands are colonized by more species than small islands. (C) Small islands have higher species extinction rates than large islands.

Solution: Step 1: Habitat Diversity.

Larger islands typically provide more diverse habitats, which support a broader range of species, leading to greater biodiversity.

Step 2: Colonization Opportunities.

Larger islands, being more visible and accessible, attract a higher number of colonizing species from various sources, including the mainland or other islands.

Step 3: Extinction Dynamics.

Due to their limited space and resources, smaller islands are prone to higher rates of species extinction as pressures from competition and environmental stresses are greater.

Quick Tip

In island biogeography, the size of the island plays a crucial role in determining its ecological complexity and stability.

---

53. Decreasing surface area to volume ratio helps reduce heat loss in colder climates. In which one or more of the following observations does this play a role?

(A) Related species of mammals are larger in size at higher latitudes.

(B) Birds lay more clutches of eggs at higher latitudes.

(C) Birds and mammals huddle tightly together at higher latitudes.

(D) Mammals have longer limbs and larger ears at higher latitudes.

Correct Answer: (A) Related species of mammals are larger in size at higher latitudes. (C) Birds and mammals huddle tightly together at higher latitudes.

Solution: Step 1: Bergmann's Rule.

Larger body sizes at higher latitudes reduce the surface area to volume ratio, minimizing heat loss, as observed in mammals.

Step 2: Social Thermoregulation.

Birds and mammals huddle together to conserve heat in cold environments, effectively reducing their exposed surface area and thus heat loss.

Quick Tip

When studying adaptations to cold environments, consider both physiological and behavioral strategies used by animals to maintain body heat.

---

54. The table below describes the number of tree species in a forest whose seeds are dispersed by large or small animals, and whether they are insect or wind pollinated. In the past, seed dispersers and pollinators were abundant in this forest. Now, there are very few large animal dispersers, but the number of small animal dispersers has not changed. There are also very few insect pollinators in this forest. Which one or more of the following inferences about trees in the forest can be drawn from these changes in seed dispersers and pollinators?

(A) Mortality of all trees in this forest will decrease in the future

(B) Mortality of a large number of trees in this forest will increase in the future

(C) Regeneration of all tree species in this forest will increase in the future

(D) Regeneration of a large number of tree species will decrease in future

Correct Answer: (D) Regeneration of a large number of tree species will decrease in future

Solution: Step 1: Analyze the Impact of Reduced Large Animal Dispersers.

The table shows that 85 tree species rely on large animals for seed dispersal and insects for pollination. With fewer large animals and insect pollinators, these species are likely to face challenges in seed dispersal and pollination.

Step 2: Consider the Impact of Reduced Insect Pollinators.

Insect-pollinated trees, which include both those dispersed by large and small animals (85 + 25), will also struggle to achieve successful pollination, affecting their reproductive success.

Step 3: Draw Inferences on Tree Regeneration.

Given the dependencies described and the reductions in key dispersers and pollinators, it is reasonable to infer that the regeneration capacity of these tree species, particularly those dependent on large animals and insects, will decrease.

Quick Tip

Consider the ecological roles of animal dispersers and pollinators in maintaining forest ecosystems, especially in planning conservation strategies.

---

55. Which one or more of the following would make a plant community more susceptible to invasion by exotic plants?

(A) Anthropogenic influx of nutrients

(B) Decline in density of a dominant species due to disease

(C) Arrival of a highly competitive exotic species

(D) Absence of suitable pollinators for an invading species

Correct Answer: (A), (B), (C) Anthropogenic influx of nutrients, Decline in density of a dominant species due to disease, Arrival of a highly competitive exotic species

Solution: Step 1: Evaluate Anthropogenic Influences.

An influx of nutrients can disrupt native plant communities, creating conditions favorable for invasive species that can exploit these resources more effectively than native species.

Step 2: Consider the Impact of Disease on Dominant Species.

A decline in a dominant species due to disease can create gaps in the ecosystem, reducing

competitive pressures and allowing invasive species to establish more easily.

Step 3: Assess the Impact of Competitive Exotic Species.

The arrival of a highly competitive exotic species can directly challenge native species for resources, leading to changes in the community structure and potentially displacing native species.

Quick Tip

Effective management of ecosystems involves monitoring nutrient inputs and health of dominant species to prevent ecological imbalances that favor invasive species.

---

56. Aphids feed on both alfalfa and clover plants. A researcher collected and reared different genotypes of aphids from separate alfalfa and clover fields. He then measured the fecundity of both aphid groups when fed on each of the two host plants. The figure summarizes the performance of aphid groups originating from alfalfa (dashed) or clover (solid). Which one or more of the following situations does the figure depict?

(A) Aphids demonstrate a genotype by environment interaction.

(B) Aphids from clover fields are much less genetically variable than aphids from alfalfa fields.

(C) Aphids from clover fields are locally adapted to their original host.

(D) Aphids from clover fields show high plasticity.

Correct Answer: (A) Aphids demonstrate a genotype by environment interaction.

Solution: Step 1: Analyzing the Interaction Effect. The performance data shows that aphids perform differently when switched between alfalfa and clover, which is indicative of a genotype by environment interaction. Each aphid genotype exhibits different levels of fecundity based on the plant type, supporting the concept that genetic traits interact differently with environmental factors.

Quick Tip

Understanding genotype by environment interactions can provide insights into how organisms might respond to changes in their habitats, which is crucial for fields such as conservation biology and agriculture.

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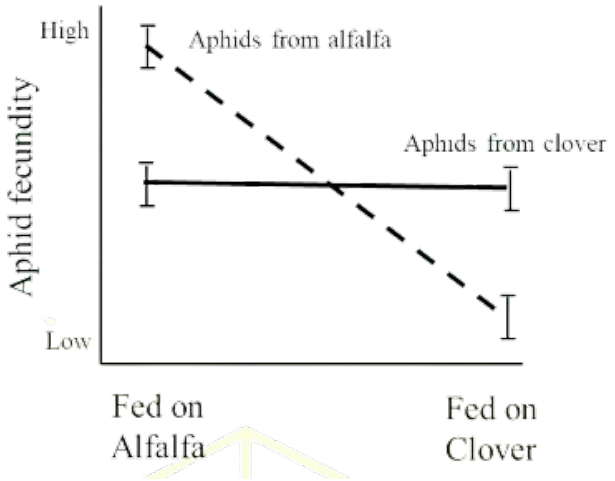
56. Aphids feed on both alfalfa and clover plants. A researcher collected and reared different genotypes of aphids from separate alfalfa and clover fields. He then measured the fecundity of both aphid groups when fed on each of the two host plants. The figure summarizes the performance of aphid groups originating from alfalfa (dashed) or clover (solid). Which one or more of the following situations does the figure depict?



(A) Aphids demonstrate a genotype by environment interaction.

(B) Aphids from clover fields are much less genetically variable than aphids from alfalfa fields.

(C) Aphids from clover fields are locally adapted to their original host.

(D) Aphids from clover fields show high plasticity.

Correct Answer: (A) Aphids demonstrate a genotype by environment interaction.

Solution: Step 1: Understanding Genotype by Environment Interaction.

Genotype by environment interaction occurs when different genotypes respond differently to environmental changes. In this study, aphids reared from different host plants (alfalfa vs. clover) exhibit varying levels of fecundity when fed on these two plant types.

Step 2: Examining the Experiment Setup.

The researcher reared aphid populations on their native host plants and then tested their fecundity on both the original and alternate hosts. Aphids from alfalfa showed higher fecundity on alfalfa and lower on clover, whereas the reverse was true for aphids from clover.

Step 3: Analyzing Results for Environmental Influence.

The results indicate that each aphid population is adapted to its specific environment (host plant). This adaptation affects their reproductive success when the environment changes, as seen when aphids are fed on non-native plants.

Step 4: Implications of Findings.

This finding supports the idea of genotype by environment interaction by demonstrating that the genetic composition of aphids influences their success in different environmental conditions, specifically different host plants.

Quick Tip

In studies of ecological genetics, observing how different genotypes perform under various environmental conditions can help elucidate the evolutionary pressures and adaptive strategies of organisms.

---

57. Which one or more of the following processes has/have resulted in increased greenhouse gases in the atmosphere over the last 100 years?

(A) Increasing levels of N_2 in the atmosphere due to increased denitrification.

(B) Increased release of CO_2 into the atmosphere due to the burning of fossil fuels.

(C) Increased release of methane into the atmosphere due to livestock.

(D) Increased release of methane from wetlands soil.

Correct Answer: (B) Increased release of CO_2 into the atmosphere due to the burning of fossil fuels. (C) Increased release of methane into the atmosphere due to livestock. (D) Increased release of methane from wetlands soil.

Solution: Step 1: Analyze the contribution of CO_2 from fossil fuels. The burning of fossil fuels is a major source of CO_2, significantly impacting global climate change.

Step 2: Consider the methane emissions from livestock. Methane, a potent greenhouse gas, is emitted in large quantities from the digestive processes of ruminant livestock.

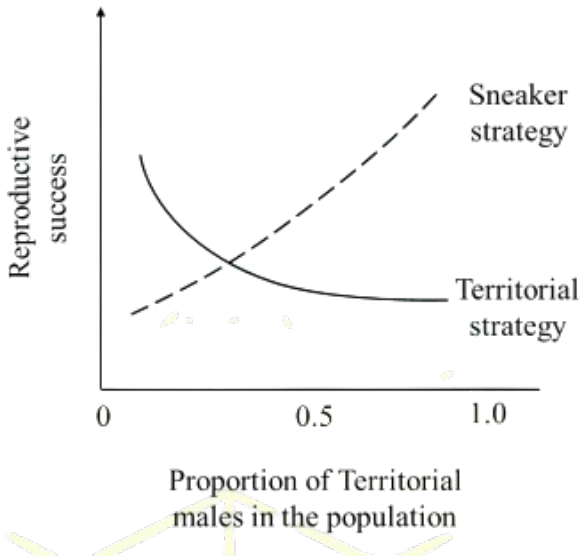
Step 3: Evaluate methane release from wetlands. Natural wetlands are significant sources of methane due to anaerobic decomposition processes in their soils.

Quick Tip

Understanding the sources of greenhouse gases is critical for developing effective strategies to mitigate climate change.

---

58. The figure below shows the reproductive success of two alternative mating strategies, with respect to their frequency in the population. Territorial males (solid line) defend territories to get mates, and Sneaker males (dashed line) obtain mating opportunities without having territories. Which one or more of the following conclusions can be drawn from this figure?



(A) The reproductive success of Territorial and Sneaker males can never be the same in the population

(B) The reproductive success of Sneaker males is influenced by the proportion of Territorial males in the population

(C) The highest possible reproductive success can be obtained by Sneaker males, and not Territorial males

(D) Territorial males will always have a higher reproductive success than Sneaker males

Correct Answer: (B), (C) The reproductive success of Sneaker males is influenced by the

proportion of Territorial males in the population; The highest possible reproductive success can be obtained by Sneaker males, and not Territorial males

Solution: Step 1: Analyze the Graph.

The graph indicates that as the proportion of Territorial males increases, the reproductive success of both strategies changes. Sneaker strategy peaks at a moderate level of Territorial males, suggesting an optimal condition for Sneakers when there is a balance.

Step 2: Impact on Reproductive Success.

The reproductive success of Sneaker males varies inversely with an increase in Territorial males beyond a certain point, reflecting an optimal balance where Sneaker males can achieve the highest success without direct competition for territories.

Quick Tip

In evolutionary biology, the success of a strategy often depends on the frequency of competing strategies within the population.

---

59. From the table below, choose one or more of the options that match(es) the evolutionary biologists with the organisms they are well-known to have studied.

Evolutionary biologist	Organism
(P) Charles Darwin	(i) Mountain gorilla
(Q) Gregor Mendel	(ii) Giant tortoise
(R) Dian Fossey	(iii) Finches
(S) Frederick Griffith	(iv) Pea plant
	(v) *Streptococcus pneumoniae*

(A) P-ii; Q-iv; R-i; S-v

(B) P-ii; Q-iv; R-ii; S-iv

(C) P-iii; Q-iv; R-i; S-v

(D) P-v; Q-i; R-v; S-iii

Correct Answer: (A), (C) Charles Darwin studied finches (P-iii), Gregor Mendel studied pea plants (Q-iv), Dian Fossey studied mountain gorillas (R-i), Frederick Griffith worked with Streptococcus pneumoniae (S-v)

Solution: Step 1: Match Biologists to Their Studies.

Charles Darwin is known for his study of finches (P-iii).

Gregor Mendel is famous for his experiments with pea plants (Q-iv).

Dian Fossey extensively studied mountain gorillas (R-i).

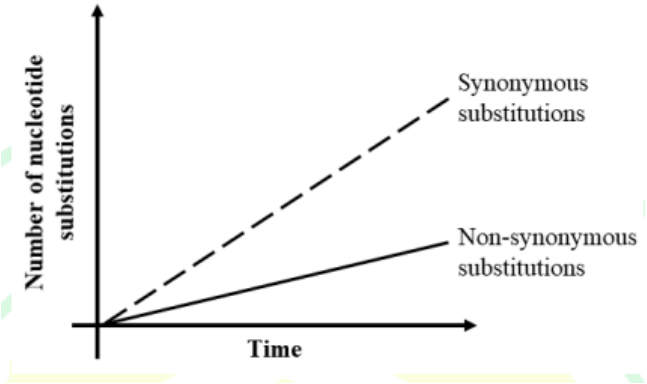
Frederick Griffith's transformation experiments involved Streptococcus pneumoniae (S-v).

Quick Tip

Reviewing the contributions of key figures in biology helps in understanding the development of major scientific theories and methods.

---

60. Consider the following figure of sequence divergence over time. The dashed and solid lines represent synonymous and non-synonymous substitutions, respectively. Which one or more of the following does the figure support?



(A) Adaptive evolution

(B) Molecular clock

(C) Neutral theory of evolution

(D) Positive selection

Correct Answer: (B) Molecular clock, (C) Neutral theory of evolution

Solution: Step 1: Analyze the Graph Trends.

The graph shows a linear increase in synonymous substitutions over time, which is consistent with the molecular clock hypothesis that mutations accumulate at a constant rate.

Step 2: Consider Non-Synonymous Substitutions.

The non-synonymous substitutions also increase, but at a lower rate, supporting the neutral theory of evolution, which suggests that most evolutionary changes are the result of neutral

mutations rather than adaptive ones.

Quick Tip

Understanding the different rates of synonymous and non-synonymous substitutions can help clarify the underlying mechanisms of molecular evolution.

---

61. Modern humans of European descent have a much higher proportion of Neanderthal DNA than modern humans of African descent. Which one or more of the following statements is/are consistent with this information?

(A) Following the migration of Neanderthals out of Africa into Europe, modern humans, who were already present in Europe, bred with them

(B) Following the migration of modern humans out of Africa into Europe, Neanderthals, who were already present in Europe, bred with them

(C) Modern humans and Neanderthals bred in Africa and then migrated out of Africa into Europe

(D) Modern humans and Neanderthals did not interbreed

Correct Answer: (B) Following the migration of modern humans out of Africa into Europe, Neanderthals, who were already present in Europe, bred with them

Solution: Step 1: Contextualize Human Migration.

Modern humans migrated out of Africa and encountered Neanderthals already present in Europe.

Step 2: Interpret Genetic Evidence.

The higher proportion of Neanderthal DNA in Europeans suggests that interbreeding occurred after modern humans arrived in Europe, where Neanderthals were established, supporting option (B).

Quick Tip

Genetic studies can provide crucial insights into human migration and interaction patterns throughout prehistoric times.

---

62. A phylogenetic tree representing the evolutionary relationship between various vertebrates is shown below. Given this tree topology, which one or more of the following statements is/are correct?

(A) Crocodiles are more closely related to turtles than they are to dinosaurs.

(B) Mammals represent the outgroup with respect to reptiles.

(C) Dinosaurs are more closely related to crocodiles than they are to birds.

(D) Reptiles are nested within mammals.

Correct Answer: (B) Mammals represent the outgroup with respect to reptiles.

Solution: Step 1: Understanding Outgroups. In phylogenetic trees, an outgroup is a group of organisms that serves as a reference group for determining the evolutionary relationships among the ingroup, or the main group under study. The outgroup is generally considered less closely related to all members of the ingroup.

Step 2: Examining the Tree Topology. From the given tree, mammals are positioned as a separate branch outside of the major clade that includes reptiles (snakes, lizards, turtles, crocodiles) and birds (also considered evolutionarily as part of dinosaurs). This indicates that mammals are the outgroup with respect to the reptiles and birds, which form the ingroup in this evolutionary scenario.

Quick Tip

When interpreting phylogenetic trees, the placement of branches can reveal insights into evolutionary relationships. An outgroup helps in rooting the tree and understanding the ancestral traits and derived traits within the tree.

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63. The population of whirligig beetles in a lake grows or declines exponentially i.e., $N(t) = N(0)e^{rt}$ where $N(t)$ is the population size at time t, $N(0)$ is the initial population size and r is the per capita rate of population change, occurring only due to birth and death. A researcher tracks population sizes for a year and finds the following:

Time interval	Number of beetles at start	Number of beetles at end
January – March	1000	150
April – June	150	3013
July – September	3013	100
October – December	100	2009

Assuming that the individual birth rates remain constant throughout the year and only death rates are affected, which one or more of the following statements is/are true?

(A) The death rate during April–June is equal to that during October–December.

(B) The death rate during July–September is lower than that during January–March.

(C) The death rate during July–September is higher than that during January–March.

(D) The death rate during April–June is higher than that during October–December.

Correct Answer: (A) The death rate during April–June is equal to that during October–December. (C) The death rate during July–September is higher than that during January–March.

Solution: Step 1: Calculate the growth rate (r) for each interval by rearranging the exponential growth formula to $r = \frac{1}{t} \log \left(\frac{N(t)}{N(0)} \right)$.

Step 2: Apply the formula for each quarter to determine r values, noting that a negative r indicates a net loss in population, thus a higher death rate.

Step 3: Comparison of r values shows that the death rates in July–September are notably higher than in January–March, indicating more significant population decline during these months.

Step 4: Observe that the periods April–June and October–December have similar r values, indicating similar death rates assuming constant birth rates.

Quick Tip

In population studies, consistent birth rates simplify the analysis of death rates, highlighting changes due solely to mortality.

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64. Which one or more of the following conditions is/are necessary for the evolution of increased nectar production in an insect-pollinated plant via natural selection?

(A) Increased nectar production in individual plants results in greater fruit set and number of offspring for these individuals

(B) The quantity of nectar produced by flowers varies across individuals in the population

(C) The quantity of nectar produced by a flower increases when more pollinators visit that same flower

(D) The quantity of nectar produced is heritable, i.e., passed on from parent to offspring

Correct Answer: (A), (B), (D) Increased nectar production in individual plants results in greater fruit set and number of offspring for these individuals; The quantity of nectar produced by flowers varies across individuals in the population; The quantity of nectar produced is heritable, i.e., passed on from parent to offspring

Solution: Step 1: Identify Key Factors for Natural Selection.

For natural selection to act on a trait, it must confer a fitness advantage, vary among individuals, and be heritable.

Step 2: Analyze Each Condition.

(A) If increased nectar production leads to greater fruit set and more offspring, it provides a reproductive advantage, a key component of natural selection.

(B) Variation in nectar production across individuals allows natural selection to favor those with optimal nectar production.

(D) Heritability of nectar production ensures that beneficial traits are passed to the next generation, allowing natural selection to act over successive generations.

Quick Tip

Understanding the conditions for natural selection is crucial for predicting evolutionary changes in traits within a population.

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65. The following empirical relationship describes how the number of trees $N(t)$ in a patch changes over time t:

$$N(t) = -2t^2 + 12t + 24$$

where $t = 0$ is when the number of trees were first counted.

Given this relationship, the maximum number of trees that occur in the patch is

Solution: The equation provided is a quadratic equation in the form of $N(t) = at^2 + bt + c$, where $a = -2$, $b = 12$, and $c = 24$. The maximum value for a downward opening parabola (since $a < 0$) occurs at the vertex. The t-coordinate of the vertex can be found using $t = -\frac{b}{2a}$. Calculating the vertex:

$$t = -\frac{12}{2 \times -2} = 3$$

Substituting $t = 3$ back into the equation to find $N(t)$:

$$N(3) = -2(3)^2 + 12 \times 3 + 24 = 42$$

Thus, the maximum number of trees in the patch is **42** (rounded to the nearest integer).

Quick Tip

When dealing with quadratic functions, remember that the vertex represents either the maximum or minimum value depending on the direction of the parabola (opening up or down).
