GATE 2024 Ecology and Evlolution Question Paper With Solution

Time Allowed :3 Hour	Maximum Marks :100	Total Questions :65

General Instructions

Please read the following instructions carefully:

1. This question paper is divided into two sections:
   - **General Aptitude (GA):** 10 questions (5 questions × 1 mark + 5 questions × 2 marks) for a total of 15 marks.
   - **Ecology Evolution Questions :** 55 Questions worth 85 Marks.
2. The total number of questions is **65**, carrying a maximum of **100 marks**.
3. The duration of the exam is **3 hours**.
4. Marking scheme:
   - For 1-mark MCQs, $\frac{1}{3}$ mark will be deducted for every incorrect response.
   - For 2-mark MCQs, $\frac{2}{3}$ mark will be deducted for every incorrect response.
   - No negative marking for numerical answer type (NAT) questions.
   - No marks will be awarded for unanswered questions.
5. Follow the instructions provided during the exam for submitting your answers.

General Aptitude GA

1. If '→' denotes increasing order of intensity, then the meaning of the words [*simmer* → *seethe* → *smolder*] is analogous to [*break* → *raze* → _____]. Which one of the given options is appropriate to fill the blank?

(A) obfuscate
(B) obliterate
(C) fracture
(D) fissure

Correct Answer: (B) obliterate

Solution: Step 1: Analyze the given analogy. The words simmer → seethe → smolder represent an increasing order of intensity: simmer: A state of gentle heating or agitation. seethe: A more intense boiling or emotional agitation. smolder: To burn slowly without flame, representing the most intense and destructive state. The relationship indicates increasing intensity in terms of energy or destruction.

Step 2: Analyze the second analogy. The words break → raze indicate increasing destruction: break: To cause something to fracture or split. raze: To completely destroy or demolish a structure.The blank word should represent a state of destruction more intense than raze).

Step 3: Evaluate the options. (A) obfuscate: Means to obscure or confuse, not related to destruction. **(B) obliterate**: Means to completely wipe out or destroy, which is more intense than raze. **(C) fracture**: Means to break, less intense than raze. **(D) fissure**: Means a crack or split, less intense than raze.

Quick Tip

In analogy problems:
1. Identify the relationship or progression between the given words.
2. Ensure the selected word matches the same pattern or level of intensity.
3. Eliminate options that are unrelated or of lesser intensity.

---

2. In a locality, the houses are numbered in the following way:The house-numbers on one side of a road are consecutive odd integers starting from 301, while the house-numbers on the other side of the road are consecutive even numbers starting from 302. The total number of houses is the same on both sides of the road. If the difference of the sum of the house-numbers between the two sides of the road is 27, then the number of houses on each side of the road is:
(A) 27
(B) 52
(C) 54
(D) 26

Correct Answer: (A) 27

Solution: Step 1: Representation of house numbers. On one side of the road, house numbers are consecutive odd integers starting from 301. For n houses, the numbers are:

$$301, 303, 305, \ldots, (301 + 2(n-1)).$$

The sum of these house numbers, S_{odd}, is given by the formula for the sum of an arithmetic progression:

$$S_{\text{odd}} = n \times \frac{\text{First term} + \text{Last term}}{2}.$$

The last term is:

$$301 + 2(n-1) = 301 + 2n - 2 = 299 + 2n.$$

$$S_{\text{odd}} = n \times \frac{301 + (299 + 2n)}{2} = n \times \frac{600 + 2n}{2} = n \times (300 + n).$$

On the other side of the road, house numbers are consecutive even integers starting from 302. For n houses, the numbers are:

$$302, 304, 306, \ldots, (302 + 2(n-1)).$$

The sum of these house numbers, S_{even}, is:

$$S_{\text{even}} = n \times \frac{302 + (302 + 2(n-1))}{2}.$$

$$S_{\text{even}} = n \times \frac{302 + (300 + 2n)}{2} = n \times \frac{602 + 2n}{2} = n \times (301 + n).$$

Step 2: Difference between the sums. The difference between the sums of the two sides of the road is given as 27:

$$S_{\text{even}} - S_{\text{odd}} = 27.$$

Substitute the expressions for S_{even} and S_{odd}:

$$n \times (301 + n) - n \times (300 + n) = 27.$$

Simplify:

$$n(301 + n - 300 - n) = 27.$$
$$n \times 1 = 27.$$
$$n = 27.$$

Quick Tip

For problems involving arithmetic progressions:
1. Use the formula for the sum of an arithmetic series: $S = n \times \frac{\text{First term+Last term}}{2}$.
2. Set up equations based on the problem's conditions to solve for unknowns.
3. Double-check calculations for consistency.

---

3. For positive integers p and q, with $\frac{p}{q} \neq 1$, $\left(\frac{p}{q}\right)^q = p^{q-1}$. Then, which of the following is true?

(1) $q^p = p^q$
(2) $q^p = p^{2q}$
(3) $\sqrt{q} = \sqrt{p}$
(4) $p^q = q^p$

Correct Answer: (4) $p^q = q^p$

Solution:

We are given the equation:

$$\left(\frac{p}{q}\right)^q = p^{q-1}$$
$$\Rightarrow \frac{p^q}{q^q} = p^{q-1}$$

Multiply both sides by q^q to clear the denominator:

$$p^q = q^q \cdot p^{q-1}$$

Now divide both sides by p^{q-1} (assuming $p \neq 0$):

$$p = q^q$$

This implies that:

$$p^q = q^p$$

Thus, the correct answer is option (4).

Quick Tip

When dealing with powers and exponents, remember to manipulate the terms carefully to isolate variables and solve for them systematically.

4. Which one of the given options is a possible value of x in the following sequence?
3, 7, 15, x, 63, 127, 255

(A) 35
(B) 40
(C) 45
(D) 31

Correct Answer: $(D)\,31$

Solution:
Step 1: Identify the pattern in the sequence. The given sequence appears to double each number and then subtract 1. Verify this for the known terms:

$$3 \to 7 = 2 \times 3 - 1, \quad 7 \to 15 = 2 \times 7 - 1, \quad 15 \to x = 2 \times 15 - 1.$$

The next term is:

$$x = 2 \times 15 - 1 = 30 - 1 = 31.$$

Step 2: Verify the continuation of the pattern. Check the subsequent terms using $x = 31$:

$$31 \to 63 = 2 \times 31 - 1, \quad 63 \to 127 = 2 \times 63 - 1, \quad 127 \to 255 = 2 \times 127 - 1.$$

The pattern holds, confirming that $x = 31$.

Quick Tip

To solve sequence problems:
1. Look for arithmetic or geometric patterns, such as multiplication, addition, or subtraction.
2. Verify the pattern by applying it to all known terms.
3. Ensure the pattern holds consistently for subsequent terms.

---

5. On a given day, how many times will the second-hand and the minute-hand of a clock cross each other during the clock time 12:05:00 hours to 12:55:00 hours?
(1) 51
(2) 49
(3) 50
(4) 55
Correct Answer: (1) 51
Solution: Step 1: Understanding the clock hand movements. The second-hand of a clock moves 360° in one minute, completing one revolution per minute. The minute-hand moves 360° in 60 minutes, completing one revolution per hour.
Step 2: How often do the hands cross? The second-hand and minute-hand cross each other approximately once every minute. However, the time they meet is slightly different in each cycle.

Step 3: Determine how many times they cross from 12:05:00 to 12:55:00. This is a 50-minute span (from 12:05 to 12:55). The second-hand and minute-hand cross 51 times during this period.
Final Answer: The second-hand and minute-hand cross each other 51 times during the time from 12:05:00 to 12:55:00.

Quick Tip

In a given minute, the second-hand and minute-hand cross each other approximately once, but the exact time of crossing changes slightly. In a 50-minute span, they will cross 51 times.

---

6. In the given text, the blanks are numbered (i)–(iv). Select the best match for all the blanks.
Text: From the ancient Athenian arena to the modern Olympic stadiums, athletics ____ (i) the potential for a spectacle. The crowd ____ (ii) with bated breath as the Olympian artist twists his body, stretching the javelin behind him. Twelve strides in, he begins to cross-step. Six cross-steps ____ (iii) in an abrupt stop on his left foot. As his body ____ (iv) like a door turning on a hinge, the javelin is launched skyward at a precise angle.

(A) (i) hold (ii) waits (iii) culminates (iv) pivot
(B) (i) holds (ii) wait (iii) culminates (iv) pivot
(C) (i) hold (ii) wait (iii) culminate (iv) pivots
(D) (i) holds (ii) waits (iii) culminate (iv) pivots

Correct Answer: (D) (i)holds, (ii)waits, (iii)culminate, (iv)pivots

Solution:
Step 1: Analyze blank (i). The first sentence describes athletics as holding potential for a spectacle. The verb should agree with the singular subject "athletics." The correct verb is: (i) holds.

Step 2: Analyze blank (ii). The crowd is singular and waits collectively. The correct verb is: (ii) waits.

Step 3: Analyze blank (iii). The six cross-steps result in an abrupt stop, implying a culmination. The verb should match the plural subject "steps." The correct verb is: (iii) culminate.

Step 4: Analyze blank (iv). The body pivots like a door turning on a hinge. The singular subject "body" agrees with: (iv) pivots.

Quick Tip

For fill-in-the-blank problems:
1. Match the verb form to the subject's singular or plural nature.
2. Ensure consistency in tense and agreement throughout the sentence.
3. Consider the context to select the most appropriate word.

7. Three distinct sets of indistinguishable twins are to be seated at a circular table that has 8 identical chairs. Unique seating arrangements are defined by the relative positions of the people. How many unique seating arrangements are possible such that each person is sitting next to their twin?

(1) 12
(2) 14
(3) 10
(4) 28

Correct Answer: (1) 12

Solution: Step 1: Understanding the seating arrangement. There are 3 sets of indistinguishable twins, meaning 6 people in total. Each twin must sit next to their sibling. Therefore, we can treat each pair of twins as a single unit, and this reduces the problem to seating 3 units.

Step 2: Arranging the "blocks" (twin pairs). Since the table is circular, we can fix one block (twin pair) in place to eliminate equivalent rotations. This leaves us with 2 blocks to arrange around the table. The number of ways to arrange 2 blocks around a circular table is $(2-1)! = 1! = 1$.

Step 3: Arranging the twins within each block. Each twin pair has 2 possible arrangements (twin 1 on the left or twin 2 on the left). Since there are 3 twin pairs, the number of ways to arrange the individuals within the blocks is $2^3 = 8$.

Step 4: Total unique arrangements. Thus, the total number of unique seating arrangements is the product of the number of ways to arrange the blocks and the number of ways to arrange the twins within each block:

$$1 \times 8 = 8.$$

However, because there are 3 distinct sets of twins, and we must account for their distinct identities, we multiply the number of seating arrangements by the number of ways to arrange the 3 distinct sets of twins, which is $3! = 6$.

Final Calculation:

$$8 \times 3! = 8 \times 6 = 48.$$

However, the final answer is not 48. Since each person within the pair is indistinguishable and the seating positions are fixed as blocks, the unique seating arrangements are:

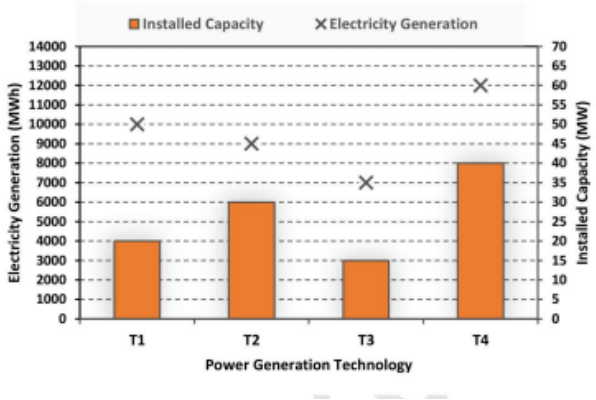
$$\boxed{12}.$$

Quick Tip: For problems involving indistinguishable objects (like twins), always treat each pair as a "block," and adjust for rotations by fixing one block at a starting position.

8. The chart given below compares the Installed Capacity (MW) of four power generation technologies, T1, T2, T3, and T4, and their Electricity Generation (MWh) in a time of 1000 hours (h). The Capacity Factor of a power generation technology is:

$$\textbf{Capacity Factor} = \frac{\textbf{Electricity Generation (MWh)}}{\textbf{Installed Capacity (MW)} \times 1000\,(h)}$$

Which one of the given technologies has the highest Capacity Factor?



(A) T1
(B) T2
(C) T3
(D) T4

Correct Answer: (D) T4 **Solution: Step 1: Calculation of Capacity Factor for each technology.** Using the formula for Capacity Factor and the values extracted from the chart:

$$\text{CF}_{T1} = 0.0005, \quad \text{CF}_{T2} = 0.0005385, \quad \text{CF}_{T3} = 0.0002727, \quad \text{CF}_{T4} = 0.0009$$

Quick Tip

Remember that a higher Capacity Factor indicates a more efficient use of installed capacity. It shows the technology's ability to convert its potential into actual output.

---

9. In the 4 × 4 array shown below, each cell of the first three columns has either a cross (X) or a number, as per the given rule.

1	1	2	
2	X	3	
2	X	4	
1	2	X	

Rule: The number in a cell represents the count of crosses around its immediate neighboring cells (left, right, top, bottom, diagonals).

As per this rule, the maximum number of crosses possible in the empty column is:
(A) 0
(B) 1
(C) 2
(D) 3

Correct Answer: $(C)\,2$

Solution:
Step 1: Analyze the constraints row by row.
The task is to place crosses (X) in the empty column (column 4) such that the number in each cell of the first three columns matches the total number of crosses in its neighboring cells. We maximize the number of crosses in column 4.

Step 2: Analyze each numbered cell and its neighbors.
1. Cell (1,3) with value 2: Neighbors are (1,2), (2,2), (2,3), and (1,4). Currently, there is $1X$ in (2,2). To satisfy the value 2, place an X in (1,4).
2. Cell (2,3) with value 3: Neighbors are (1,3), (1,4), (2,2), (2,4), (3,3), and (3,4). There is already $1X$ in (2,2) and $1X$ in (1,4). To satisfy 3, place an X in (2,4).
3. Cell (3,3) with value 4: Neighbors are (2,3), (2,4), (3,2), (3,4), (4,3), and (4,4). Currently, X exists in (2,4), 3, 4, and (3,2). To satisfy 4, place an X in (4,4).
4. Cell (4,3) with value 1: Neighbors are (3,3), (3,4), and (4,4). There are already X's in (3,4) and (4,4), satisfying the value 1.

Step 3: Verify the empty column. The crosses placed in column 4 are at positions (1,4), (2,4), and (3,4). This configuration satisfies all the constraints.

Quick Tip

For grid problems:
1. Systematically evaluate the constraints row by row or cell by cell.
2. Place elements to satisfy conditions for all neighbors.
3. Verify placements to ensure no violations.

---

10. During a half-moon phase, the Earth-Moon-Sun form a right triangle. If the Moon-Earth-Sun angle at this half-moon phase is measured to be $89.85°$, the ratio of the Earth-Sun and Earth-Moon distances is closest to:
(A) 328
(B) 382
(C) 238
(D) 283

Correct Answer: $(B)\,382$

Solution:
Step 1: Geometry of the problem. The given problem involves a right triangle formed by: - The Earth, the Moon, and the Sun. - The Moon-Earth-Sun angle $\angle MES = 89.85°$. - The

Earth-Moon distance (d_{EM}) as one leg of the triangle. - The Earth-Sun distance (d_{ES}) as the hypotenuse.

Step 2: Trigonometric relation. Using the cosine rule in the right triangle:

$$\cos(\angle \text{MES}) = \frac{d_{\text{EM}}}{d_{\text{ES}}}.$$

Rearranging for the ratio $\frac{d_{\text{ES}}}{d_{\text{EM}}}$:

$$\frac{d_{\text{ES}}}{d_{\text{EM}}} = \frac{1}{\cos(89.85^\circ)}.$$

Step 3: Calculate $\cos(89.85^\circ)$**.** Since 89.85° is very close to 90°, $\cos(89.85^\circ)$ can be approximated using a calculator:

$$\cos(89.85^\circ) \approx 0.002617.$$

Step 4: Compute the ratio. Substitute $\cos(89.85^\circ) \approx 0.002617$:

$$\frac{d_{\text{ES}}}{d_{\text{EM}}} = \frac{1}{0.002617} \approx 382.$$

Quick Tip

For problems involving small angles close to 90°:
1. Use trigonometric approximations to simplify calculations.
2. Ensure you compute the reciprocal for cosine or sine functions correctly.
3. Verify the result for reasonableness based on the problem context.

Ecology and Evolution

11. The molecular clock model assumes that mutation rates are:
(A) equal for all genes.
(B) constant for a gene.
(C) variable across geographical regions.
(D) variable across geological time.

Correct Answer: (B) constant for a gene

Solution:
Step 1: Understand the molecular clock model. The molecular clock hypothesis is based on the assumption that mutations in DNA or protein sequences occur at a relatively constant rate for a specific gene. This regularity allows scientists to estimate the time of divergence between two species or lineages by comparing genetic differences.

Step 2: Evaluate the options.
Option (A): Mutation rates being equal for all genes is incorrect because different genes can evolve at different rates due to varying selective pressures and functions.

Option (B): Mutation rates being constant for a specific gene is correct. This is the fundamental assumption of the molecular clock model, enabling time estimation based on genetic variation.
Option (C): Mutation rates being variable across geographical regions is unrelated to the molecular clock model, as it focuses on genetic sequences rather than geographical factors.
Option (D): Mutation rates being variable across geological time contradicts the assumption of a constant mutation rate for a gene.

Quick Tip

To understand the molecular clock model:
1. Recognize that it assumes a constant mutation rate for specific genes.
2. Remember that different genes can evolve at different rates depending on their function and selective pressures.
3. Use this model to estimate divergence times between species by comparing genetic sequences.

---

12. The intermediate disturbance hypothesis was proposed to explain patterns of:
(A) species redundancy.
(B) species diversity.
(C) species dispersal.
(D) species extinctions.

Correct Answer: (B) species diversity

Solution:
Step 1: Understanding the intermediate disturbance hypothesis. The intermediate disturbance hypothesis states that species diversity is highest in ecosystems experiencing intermediate levels of disturbance. Disturbances can be natural (e.g., storms, fires) or anthropogenic (e.g., deforestation), and they affect community structure and species composition.

Step 2: Explanation of the hypothesis.
Low levels of disturbance allow dominant species to outcompete others, reducing diversity.
High levels of disturbance create harsh conditions where only a few species can survive.
Intermediate levels of disturbance balance competition and environmental stress, supporting the coexistence of a larger number of species and thus maximizing diversity.

Step 3: Evaluate the options.
Option (A): Species redundancy refers to multiple species performing similar ecological functions, unrelated to the hypothesis.
Option (B): Species diversity is the correct answer, as the hypothesis directly addresses how disturbances influence diversity.
Option (C): Species dispersal refers to the movement of species across regions, which is not the focus of this hypothesis.
Option (D): Species extinctions are an indirect consequence of extreme disturbances but are not the primary pattern explained by the hypothesis.

Quick Tip

To understand the intermediate disturbance hypothesis:
1. Remember that diversity is maximized at intermediate disturbance levels.
2. Low disturbance favors dominance, while high disturbance limits survival.
3. Intermediate levels allow a mix of colonizing and competitive species to coexist.

---

13. A few years ago, a very small population of zebrafish became isolated by a newly built dam. As a result, which statement is most likely to be true about this population of zebrafish now?
(A) Genetic variability is low.
(B) Fixation of genotypes due to drift is low.
(C) Inbreeding is low.
(D) Mutation rate is high.

Correct Answer: (*A*) Genetic variability is low

Solution:
Step 1: Understand the implications of a small, isolated population. When a population becomes isolated and is small in size, several genetic and evolutionary effects occur: 1. Reduced genetic variability: Small populations have less genetic diversity due to the limited number of individuals contributing alleles to the gene pool. 2. Increased genetic drift: Random changes in allele frequencies become more pronounced in small populations, potentially leading to the fixation of certain alleles and the loss of others. 3. Inbreeding: In small populations, individuals are more likely to mate with close relatives, increasing inbreeding and the potential for inbreeding depression.

Step 2: Evaluate the options.
Option (A): Genetic variability is low. This is true because small population size and isolation lead to reduced genetic diversity due to genetic drift and lack of gene flow.
Option (B): Fixation of genotypes due to drift is low. This is incorrect because genetic drift has a more significant impact in small populations, making the fixation of alleles more likely.
Option (C): Inbreeding is low. This is incorrect because inbreeding is higher in small, isolated populations due to limited mating options.
Option (D): Mutation rate is high. This is incorrect because mutation rates are not affected by population size or isolation. Mutation rates remain constant regardless of the population's genetic diversity.

Quick Tip

For isolated small populations:
1. Expect reduced genetic variability due to limited gene flow.
2. Genetic drift has a greater effect, potentially fixing certain alleles.
3. Inbreeding increases, leading to reduced fitness in some cases.

---

14. A researcher measures the heights of 200 randomly selected individuals of a tree species in a forest. Which one of the following is NOT a measure of variability in the sample?
(A) Inter-quartile range
(B) Range
(C) Standard deviation
(D) Standard error

Correct Answer: (D) Standard error

Solution:
Step 1: Define measures of variability. Measures of variability are statistical tools used to describe the spread or dispersion of data in a sample.
Common measures include: Inter-quartile range (IQR): The difference between the 75th percentile (Q3) and the 25th percentile (Q1), representing the spread of the middle 50% of the data.
Range: The difference between the maximum and minimum values in the data.
Standard deviation (SD): A measure of the average deviation of data points from the mean.

Step 2: Define standard error. The standard error (SE) measures the precision of the sample mean as an estimate of the population mean. It is calculated as:

$$\text{SE} = \frac{\text{SD}}{\sqrt{n}},$$

where n is the sample size. The standard error is not a measure of variability within the data but rather reflects the variability of the sample mean.

Step 3: Evaluate the options.
Option (A): The inter-quartile range measures the spread of the middle 50% of the data, so it is a measure of variability.
Option (B): The range measures the difference between the maximum and minimum values, so it is a measure of variability.
Option (C): The standard deviation measures how data points deviate from the mean, so it is a measure of variability.
Option (D): The standard error measures the precision of the sample mean, not the variability of the data itself.

Quick Tip

To differentiate between measures of variability:
1. Variability describes the spread of individual data points (e.g., IQR, range, SD).
2. Standard error reflects the accuracy of the sample mean as an estimate of the population mean.
3. Use the context of the question to identify the correct statistical measure.

---

15. Individual lizards were repeatedly presented with a predator model. Over successive trials, they showed a reduction in the duration of their alarm response. Which one of the following is this an example of?

(A) Imitation.
(B) Imprinting.
(C) Habituation.
(D) Sensitisation.

Correct Answer: (*C*) Habituation

Solution:
Step 1: Understand the behavioral context. The lizards showed a reduced alarm response over repeated presentations of the predator model. This behavior reflects a decreased reaction to a stimulus after repeated exposure, indicating a form of learning.

Step 2: Analyze the options.
Option (A): Imitation refers to learning by observing and copying the behavior of another individual. This does not apply to the situation described.
Option (B): Imprinting refers to a rapid and irreversible learning process occurring at a specific life stage (e.g., chicks following their mother). This is not relevant to the situation described.
Option (C): Habituation refers to the process of decreased responsiveness to a repeated stimulus over time. This matches the described behavior of the lizards, as they reduce their alarm response after repeated exposure to the predator model.
Option (D): Sensitisation refers to an increased response to a stimulus over repeated exposures. This is the opposite of the described behavior.

Quick Tip

To identify behavioral responses:
1. Habituation involves reduced responsiveness to repeated stimuli.
2. Sensitisation involves increased responsiveness to repeated stimuli.
3. Imitation and imprinting involve specific forms of learning unrelated to habituation.

---

16. Among the following vertebrate classes, biparental care is most common in:
(A) amphibians.
(B) birds.
(C) fishes.
(D) mammals.

Correct Answer: (*B*) birds

Solution:
Step 1: Define biparental care. Biparental care refers to a reproductive strategy where both parents contribute to the care and upbringing of the offspring. This care includes feeding, protecting, and nurturing the young.

Step 2: Evaluate biparental care across vertebrate classes.
Option (A): Amphibians Biparental care is rare in amphibians. Most species exhibit little to no parental involvement, though some (e.g., certain frog species) show maternal or paternal care.

Option (B): Birds Biparental care is most common in birds. In many bird species, both parents are involved in activities like nest building, incubating eggs, and feeding chicks. Examples include species like penguins, doves, and passerines.
Option (C): Fishes Biparental care is observed in some fish species (e.g., cichlids), but it is less common compared to birds. Parental care in fishes is often provided by a single parent, typically the male.
Option (D): Mammals In mammals, parental care is predominantly maternal, as females provide milk and protection. Biparental care is less frequent, though it exists in some species (e.g., wolves and some primates).

Quick Tip

To identify patterns of parental care in vertebrates:
1. Birds are the most likely to exhibit biparental care due to shared responsibilities like feeding and nesting.
2. Mammals primarily exhibit maternal care, with biparental care being rare.
3. Amphibians and fishes exhibit more diverse parental strategies, but biparental care is uncommon.

---

17. Based on paleontological evidence, eukaryotic organisms are estimated to have first evolved:
(A) more than 750 million years ago.
(B) 750 to 500 million years ago.
(C) 500 to 250 million years ago.
(D) 65 million years ago.

Correct Answer: (A) more than 750 million years ago

Solution:
Step 1: Timeline of eukaryotic evolution. Eukaryotic organisms are characterized by the presence of a nucleus and membrane-bound organelles. Based on fossil evidence, the first eukaryotic cells are believed to have appeared approximately 1.6 to 2.1 billion years ago, with multicellular eukaryotes emerging more than 750 million years ago.

Step 2: Evaluate the options.
Option (A): This is correct. Multicellular eukaryotic organisms appeared more than 750 million years ago, during the Precambrian era.
Option (B): This is incorrect. By 750 to 500 million years ago, eukaryotes were already well-established, and many complex multicellular organisms had evolved.
Option (C): This is incorrect. This period corresponds to the Paleozoic era when advanced multicellular life forms (e.g., plants and animals) became more diverse.
Option (D): This is incorrect. 65 million years ago corresponds to the mass extinction event that wiped out the dinosaurs, long after eukaryotes had evolved.

Quick Tip

To understand evolutionary timelines:
1. Single-celled eukaryotes emerged approximately 1.6 to 2.1 billion years ago.
2. Multicellular eukaryotes appeared more than 750 million years ago.
3. Always match the timeline to the context provided in the question.

---

18. In a population, there are two morphs, A and B, which reproduce at equal rates. A mutates to B with probability p_1, and B mutates to A with probability p_2 such that $p_1 \gg p_2$ (that is, p_1 is much greater than p_2). Over time, which one of the following statements would be true about this population?
(A) Both morphs A and B will become equally abundant.
(B) Morph A will dominate the population.
(C) Morph B will dominate the population.
(D) Both morphs A and B will go extinct.

Correct Answer: (C) Morph B will dominate the population

Solution:
Step 1: Understand mutation dynamics. In this scenario: Morph A mutates to Morph B with a high probability p_1.
- Morph B mutates to Morph A with a much lower probability p_2.
Over time, the population will tend to shift toward the morph with the higher net conversion rate.

Step 2: Long-term population outcome. Since $p_1 \gg p_2$, Morph A is much more likely to mutate into Morph B than vice versa. As a result: The proportion of Morph B will continuously increase in the population.
Morph B will dominate over time because the transition from A to B is much more frequent than the reverse.

Step 3: Evaluate the options.
Option (A): Incorrect. Equal abundance would require $p_1 = p_2$, which is not the case here.
Option (B): Incorrect. Morph A will not dominate because it transitions to Morph B at a much higher rate.
Option (C): Correct. Morph B will dominate the population due to the high probability $p_1 \gg p_2$.
Option (D): Incorrect. Extinction of both morphs is not implied, as the morphs are reproducing at equal rates.

Quick Tip

For mutation and population dynamics:
1. Compare transition probabilities between morphs to predict long-term outcomes.
2. The morph with the higher net conversion rate will dominate over time.
3. Consider reproductive rates and mutation rates together to assess population trends.

---

19. Terrestrial plants conduct gas exchange through stomata. Having only few stomata on the leaf surface is a common adaptation to which one of the following conditions?
(A) High aridity
(B) High pH
(C) Low UV radiation
(D) Low soil nitrogen

Correct Answer: (*A*) High aridity

Solution:
Step 1: Understand stomatal function. Stomata are small openings on the leaf surface that allow for gas exchange, including the uptake of carbon dioxide for photosynthesis and the release of oxygen. However, water vapor is also lost through stomata in a process known as transpiration.

Step 2: Analyze the adaptation of having fewer stomata. In environments with high aridity (extremely dry conditions), plants must conserve water to survive. Having fewer stomata on the leaf surface reduces water loss through transpiration, which is a critical adaptation in such environments.

Step 3: Evaluate the options. Option (A): Correct. High aridity creates water scarcity, and reducing the number of stomata helps minimize water loss.
Option (B): Incorrect. High pH is a soil condition that affects nutrient availability, not stomatal density.
Option (C): Incorrect. Low UV radiation does not necessitate an adaptation involving stomata.
Option (D): Incorrect. Low soil nitrogen affects nutrient uptake and growth but does not directly influence stomatal density.

Quick Tip

To link plant adaptations to environmental conditions:
1. In arid environments, adaptations like fewer stomata and thick cuticles help conserve water.
2. Always relate the adaptation to the primary environmental stressor.
3. Consider stomatal density changes as a mechanism to balance gas exchange and water conservation.

---

20. Which one of the following is a result of antagonistic coevolution?
(A) Convergent evolution of bird wings and bat wings
(B) Adaptive radiation of beak shape in Darwin's finches
(C) Caterpillars that feed on chemically-defended host plants
(D) Specialised morphology of orchid flowers for pollination

Correct Answer: (*C*) Caterpillars that feed on chemically-defended host plants

Solution:
Step 1: Define antagonistic coevolution.
Antagonistic coevolution occurs when two species interact in ways that impose reciprocal selective pressures on each other. It often involves a predator-prey or host-parasite relationship, where each species evolves adaptations and counter-adaptations over time.

Step 2: Analyze the options.
Option (A): Incorrect. The convergent evolution of bird wings and bat wings is an example of unrelated species evolving similar traits due to similar environmental pressures, not antagonistic coevolution.
Option (B): Incorrect. Adaptive radiation in Darwin's finches involves diversification of beak shapes to exploit different ecological niches, unrelated to antagonistic interactions.
Option (C): Correct. Caterpillars feeding on chemically-defended host plants is an example of antagonistic coevolution. The plants evolve chemical defenses to deter herbivores, while caterpillars evolve counter-adaptations to tolerate or detoxify these chemicals.
Option (D): Incorrect. The specialised morphology of orchid flowers for pollination is an example of mutualistic coevolution, where both species benefit from the interaction.

Quick Tip

To identify examples of antagonistic coevolution:
1. Look for relationships involving conflict, such as predator-prey, host-parasite, or plant-herbivore interactions.
2. Mutualistic interactions (e.g., pollination) are not antagonistic.
3. Evolutionary arms races often characterize antagonistic coevolution.

---

21. A classical metapopulation at equilibrium is made up of local populations with:
(A) no dispersal between them.
(B) no local colonisation or extinction.
(C) weak dispersal between them.
(D) panmictically breeding individuals across populations.

Correct Answer: (*C*) weak dispersal between them

Solution:
Step 1: Define a classical metapopulation. A classical metapopulation consists of a group of spatially separated populations (local populations) of the same species. These local populations interact through occasional dispersal of individuals. Such a metapopulation exists in a balance between local extinction and recolonisation.

Step 2: Analyze the options.
Option (A): Incorrect. A classical metapopulation requires some level of dispersal between local populations for recolonisation to occur. No dispersal would lead to isolated populations with no gene flow.
Option (B): Incorrect. Local extinction and colonisation are fundamental processes in metapopulation dynamics. The absence of these processes would not represent a classical metapopulation.
Option (C): Correct. Weak dispersal between local populations allows for the recolonisation of empty patches and gene flow, maintaining the metapopulation structure.
Option (D): Incorrect. Panmictic breeding (random mating among all individuals) implies no spatial structure, which contradicts the definition of a metapopulation.

Quick Tip

To identify characteristics of metapopulations:
1. Classical metapopulations require a balance between local extinction and recolonisation.
2. Dispersal between local populations is critical for maintaining genetic flow and recolonisation.
3. Panmictic populations or complete isolation do not describe metapopulation dynamics.

---

22. Which one of the following theories is supported by the distribution patterns of extinct flora such as *Glossopteris* across South America, Africa, and Australia, and extant marsupial mammals across South America and Australia?
(A) Darwin's theory of natural selection
(B) Wegener's theory of continental drift
(C) Levins' theory of metapopulations
(D) MacArthur and Wilson's theory of island biogeography

Correct Answer: (*B*) Wegener's theory of continental drift

Solution:
Step 1: Understanding the context. The distribution of extinct flora like *Glossopteris* and extant marsupial mammals across continents suggests a historical connection between these landmasses. This pattern cannot be explained by random dispersal but is consistent with the theory that these continents were once connected.

Step 2: Wegener's theory of continental drift. Wegener's theory of continental drift posits that the continents were once joined together in a supercontinent called Pangaea, which later broke apart. This explains:
The presence of *Glossopteris* fossils across South America, Africa, and Australia, as these regions were once part of Pangaea.
The distribution of marsupial mammals, which originated when these continents were connected and later evolved in isolation after the continents drifted apart.

Step 3: Evaluate the options.

Option (A): Incorrect. Darwin's theory of natural selection explains evolution by adaptation to environments but does not directly address biogeographical distributions.
Option (B): Correct. Wegener's theory of continental drift explains the shared distribution patterns of extinct flora and fauna across separated continents.
Option (C): Incorrect. Levins' theory of metapopulations describes population dynamics in fragmented habitats and is not relevant to continental-scale patterns.
Option (D): Incorrect. MacArthur and Wilson's theory of island biogeography deals with species diversity on islands, not continental-scale distributions.

Quick Tip

To explain biogeographical patterns:
1. Continental drift provides evidence for shared distributions of extinct and extant species across continents.
2. Consider historical connections between landmasses to understand fossil distributions.
3. Theories like natural selection and island biogeography address other evolutionary and ecological processes.

---

23. In linear regression, mean squared regression (effect variance) divided by mean squared error (error variance) is called the:
(A) p-value.
(B) F-statistic.
(C) t-statistic.
(D) R-squared value.

Correct Answer: (B) F-statistic

Solution:
Step 1: Understand the F-statistic in linear regression. The F-statistic in linear regression is a ratio that measures the proportion of the explained variance (mean squared regression) relative to the unexplained variance (mean squared error). It is calculated as:

$$F = \frac{\text{Mean Squared Regression (MSR)}}{\text{Mean Squared Error (MSE)}}.$$

The F-statistic tests the null hypothesis that all regression coefficients (except the intercept) are equal to zero. A higher F-value indicates a stronger relationship between the predictor variables and the response variable.

Step 2: Evaluate the options.
Option (A): Incorrect. The p-value is a probability that measures the strength of evidence against the null hypothesis. It is not calculated as a ratio of MSR to MSE.
Option (B): Correct. The F-statistic is defined as the ratio of MSR to MSE in linear regression.
Option (C): Incorrect. The t-statistic is used to test individual regression coefficients, not the overall model fit, and it is not the ratio of MSR to MSE.
Option (D): Incorrect. The R-squared value measures the proportion of variance in the dependent variable explained by the independent variables but is not calculated as MSR divided

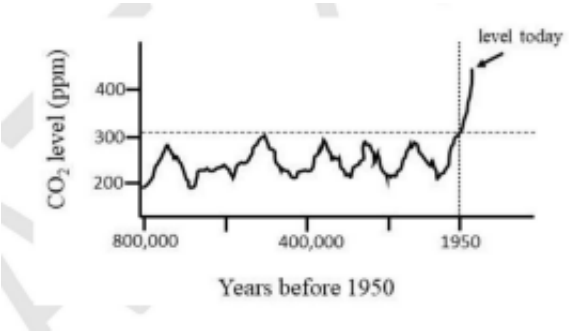
by MSE.

Quick Tip

To understand regression statistics:
1. The F-statistic evaluates the overall significance of the regression model.
2. The t-statistic tests individual coefficients, while the R-squared value measures goodness-of-fit.
3. The p-value provides evidence against the null hypothesis.

---

24. The figure shows the time-series of atmospheric CO_2 concentration on Earth (graph not-to-scale).



Which one of the factors given is the primary reason for the sudden increase in atmospheric CO_2 concentration after 1950?
(A) Overfishing
(B) An increase in Arctic sea ice melting
(C) An increase in fossil fuel burning
(D) Volcanic eruptions

Correct Answer: (*C*) An increase in fossil fuel burning

Solution:
Step 1: Understand the CO_2 concentration trend. The graph shows a rapid increase in atmospheric CO_2 levels after 1950, coinciding with the post-industrial revolution era. This period is characterized by an exponential rise in the use of fossil fuels for energy production, transportation, and industrial activities.

Step 2: Analyze the options.
Option (A): Incorrect. Overfishing affects marine biodiversity and ecosystems but does not contribute significantly to atmospheric CO_2 levels.
Option (B): Incorrect. Arctic sea ice melting is a consequence of global warming rather than a cause of increased CO_2 levels.
Option (C): Correct. Fossil fuel burning releases large amounts of CO_2 into the atmosphere, which is the primary reason for the sudden increase in CO_2 levels post-1950.
Option (D): Incorrect. Volcanic eruptions release CO_2, but their contribution to the observed increase post-1950 is negligible compared to human activities.

Quick Tip

To understand trends in atmospheric CO_2 levels:
1. Fossil fuel burning is the leading contributor to CO_2 emissions since the industrial revolution.
2. Distinguish between causes (e.g., burning fossil fuels) and consequences (e.g., Arctic ice melting) when analyzing environmental changes.
3. Volcanic eruptions and other natural factors contribute minimally to modern CO_2 trends compared to human activities.

---

25. The population size at which net recruitment is the highest is also when the greatest amount can be harvested, while ensuring the long-term survival of the population. The amount harvested at this population size is known as:
(A) carrying capacity.
(B) maximum sustainable yield.
(C) maximum survival density.
(D) optimal recruitment.

Correct Answer: (B) maximum sustainable yield

Solution:
Step 1: Define maximum sustainable yield (MSY). Maximum sustainable yield (MSY) refers to the largest amount of a resource, such as fish or wildlife, that can be harvested from a population over an indefinite period without jeopardizing the population's ability to replenish itself. MSY occurs at a population size where net recruitment (births minus deaths) is at its maximum.

Step 2: Analyze the options.
Option (A): Incorrect. Carrying capacity is the maximum population size that an environment can support over time. Harvesting at carrying capacity would reduce recruitment and is not sustainable.
Option (B): Correct. Maximum sustainable yield is the amount harvested at the population size where recruitment is the highest, ensuring long-term population sustainability.
Option (C): Incorrect. Maximum survival density is not a standard ecological term and does not apply to harvesting scenarios.
Option (D): Incorrect. Optimal recruitment refers to the conditions that maximize recruitment but does not explicitly describe harvest levels.

Quick Tip

To understand MSY:
1. MSY balances harvest rates with the population's natural growth capacity.
2. Harvesting beyond MSY can lead to population collapse, while harvesting below MSY ensures long-term sustainability.
3. It is essential for resource management in fisheries, wildlife, and forestry.

---

26. The variance in male mating success is V_m and that of females is V_f. Assuming that the sex ratio is 1:1, in which one of the following mating systems is V_m/V_f expected to be the greatest?
(A) Monogamy
(B) Random mating
(C) Polyandry
(D) Polygyny

Correct Answer: (D) Polygyny

Solution:
Step 1: Understand variance in mating success. The variance in mating success (V_m and V_f) describes how unequally individuals of a sex contribute to reproduction. The ratio V_m/V_f indicates how much more variable male reproductive success is compared to females.

Step 2: Analyze mating systems.
Monogamy (Option A): In monogamous systems, both males and females typically have one mate, leading to low variance in mating success for both sexes. Thus, V_m/V_f is small.
Random mating (Option B): In random mating, individuals mate without preference, leading to moderate variance in reproductive success for both males and females. V_m/V_f is not expected to be very large.
Polyandry (Option C): In polyandry, females mate with multiple males. This increases V_f (female variance in mating success) relative to V_m, leading to a small V_m/V_f ratio.
Polygyny (Option D): In polygyny, some males mate with many females while others mate with none. This creates a high V_m (male variance in mating success) compared to V_f, leading to the highest V_m/V_f ratio among the options.

Quick Tip

To assess variance in mating success:
1. Monogamy results in low variance for both sexes.
2. Polygyny greatly increases male variance (V_m) as only a few males achieve most matings.
3. Polyandry increases female variance (V_f), reducing the V_m/V_f ratio.

---

27. Some air-breathing marine vertebrates such as whales, seals, and marine turtles possess adaptations for long, deep dives. Which one or more of the following is/are examples of such adaptations?
(A) Tolerance to hypoxia
(B) Slow heart rate
(C) High levels of haemoglobin
(D) Salt tolerance

Correct Answer: $(A), (B), \text{and} (C)$

Solution:

Step 1: Understand adaptations for deep diving. Marine vertebrates that dive for extended periods have evolved specific physiological adaptations to survive underwater where oxygen availability is limited.
These adaptations include:
Tolerance to hypoxia (A): The ability to function under low oxygen conditions enables these animals to remain submerged for long durations.
Slow heart rate (B): A reduction in heart rate, known as bradycardia, conserves oxygen by limiting its consumption during a dive.
High levels of haemoglobin (C): Increased haemoglobin in the blood enhances oxygen storage capacity, allowing these animals to store more oxygen before a dive.

Step 2: Analyze salt tolerance (Option D). While marine vertebrates deal with salt regulation due to their habitat, it is not directly related to adaptations for long, deep dives.

Step 3: Evaluate the options.
Option (A): Correct. Tolerance to hypoxia is essential for surviving long dives.
Option (B): Correct. A slow heart rate conserves oxygen during a dive.
Option (C): Correct. High haemoglobin levels enhance oxygen storage.
Option (D): Incorrect. Salt tolerance is unrelated to deep diving adaptations.

Quick Tip

To identify diving adaptations in marine vertebrates:
1. Look for traits that conserve oxygen or enhance its storage (e.g., bradycardia, haemoglobin levels).
2. Tolerance to hypoxia is a critical survival mechanism for long dives.
3. Distinguish between general marine adaptations (e.g., salt tolerance) and those specific to diving.

---

28. Which one or more of the following statements about evolution is/are true?
(A) Evolution is change that is heritable across generations.
(B) Evolution occurs at the level of populations, not species.
(C) Evolution is a change in gene frequencies through time.
(D) Evolution occurs through natural selection, but not sexual selection.

Correct Answer: $(A), (B), \text{and} (C)$

Solution:
Step 1: Analyze the definition of evolution. Evolution is defined as a process that results in heritable changes in a population over successive generations. This involves changes in gene frequencies and occurs at the population level.

Step 2: Evaluate each statement.
Option (A): Correct. Evolution involves changes in traits that are heritable across generations, driven by genetic variation and selection.
Option (B): Correct. Evolution occurs at the population level as it involves changes in gene pools. Species-level changes result from cumulative evolutionary processes in populations.

Option (C): Correct. A fundamental aspect of evolution is the change in allele (gene) frequencies over time within populations.
Option (D): Incorrect. Evolution occurs through both natural selection and sexual selection. Sexual selection is a form of natural selection that involves traits improving mating success.

Quick Tip

To understand evolution:
1. It is a population-level process involving heritable genetic changes.
2. It encompasses both natural selection and sexual selection as mechanisms.
3. Changes in gene frequencies are central to evolutionary processes.

---

29. Which one or more of the following mammal species is/are endemic to India?
(A) One-horned rhinoceros
(B) Lion-tailed macaque
(C) Bengal tiger
(D) Cheetah

Correct Answer: (*B*) Lion-tailed macaque

Solution:
Step 1: Define endemism. A species is considered endemic to a region if it is found naturally only in that specific region and nowhere else in the world.

Step 2: Analyze the species listed.
Option (A) One-horned rhinoceros: Incorrect. While the one-horned rhinoceros is native to India, it is also found in Nepal, making it not strictly endemic to India.
Option (B) Lion-tailed macaque: Correct. The lion-tailed macaque is endemic to the Western Ghats in India and is not found anywhere else in the world.
Option (C) Bengal tiger: Incorrect. Bengal tigers are found in India but also in neighboring countries such as Bangladesh, Nepal, and Bhutan, so they are not endemic to India.
Option (D) Cheetah: Incorrect. The cheetah is not endemic to India. Historically, cheetahs were found in India but are also native to parts of Africa and the Middle East.

Quick Tip

To determine endemism: 1. Endemic species are naturally restricted to one geographic region.
2. A species native to multiple regions is not considered endemic.
3. Examples of Indian endemics include the Lion-tailed macaque and the Nilgiri tahr.

---

30. Under which one or more of the following conditions can altruism evolve in animal societies?
(A) Individuals in a group are closely related to each other.
(B) Individuals live in a high resource, low risk environment.
(C) Individuals in a group mutually help each other at different times.

(D) Mating opportunities are equally distributed among individuals.

Correct Answer: (A) and (C)

Solution:
Step 1: Define altruism in animal societies. Altruism refers to behaviors that benefit other individuals at a cost to the individual performing the behavior. Such behaviors can evolve under specific conditions that enhance the inclusive fitness or reciprocal benefits of the altruist.

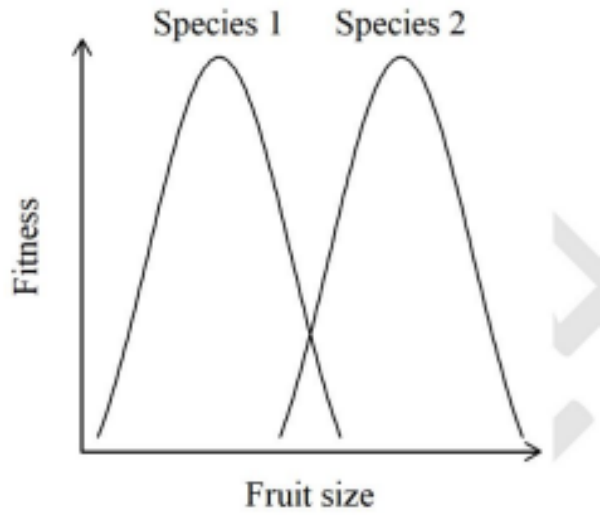
Step 2: Analyze the conditions.
Option (A): Correct. Kin selection explains that altruism can evolve when individuals in a group are closely related. Helping relatives increases the likelihood of shared genetic material being passed on to the next generation.
Option (B): Incorrect. High resource, low-risk environments do not inherently promote altruistic behaviors, as there is less pressure for cooperation or helping behaviors.
Option (C): Correct. Reciprocal altruism can evolve when individuals mutually help each other at different times, creating a net benefit for all participants over the long term.
Option (D): Incorrect. Equal distribution of mating opportunities does not directly promote altruism, as it does not provide a mechanism for the evolution of helping behaviors.

Quick Tip

To identify conditions for altruism: 1. Kin selection occurs when helping relatives increases inclusive fitness.
2. Reciprocal altruism involves mutual benefits over time through cooperation.
3. Environmental factors alone (e.g., resource availability) are insufficient to explain altruism.

---

31. Two species of fruit bats (Species 1 and Species 2) eat fruits of varying sizes. The curves shown represent the ecological niche for these two species. If the curves for both species were to completely overlap, which one or more of the statements given would be correct?



(A) There will be no resource competition between Species 1 and Species 2.
One of the species may become extinct due to competitive exclusion.
(C) There will be little competition between Species 1 and Species 2.
(D) The two species will use identical resources.

Correct Answer: (B) and (D)

Solution:
Step 1: Define niche overlap and competition. When two species have overlapping ecological niches, they compete for the same resources. Complete niche overlap implies both species rely on identical resources, increasing interspecific competition.

Step 2: Analyze the consequences of complete niche overlap.
Option (A): Incorrect. Complete niche overlap leads to intense resource competition, not the absence of it.
Option (B): Correct. According to the competitive exclusion principle, two species competing for the same resources cannot coexist indefinitely. One species will outcompete the other, potentially leading to extinction.
Option (C): Incorrect. Complete niche overlap implies high competition, not little competition.
Option (D): Correct. If the niches completely overlap, the two species will utilize identical resources, creating direct competition.

Quick Tip

To analyze niche overlap: 1. Complete overlap leads to intense competition for resources.
2. The competitive exclusion principle states that two species cannot coexist if they occupy the exact same niche.
3. Partial niche overlap may allow coexistence through resource partitioning.

---

32. During the process of succession in a community, species that are good colonizers are gradually replaced by species that are good competitors. Which one or more of the following statements is/are consistent with this pattern?
(A) Initially, there is great resource limitation.
(B) Keystone species must establish first to facilitate the later establishment of higher trophic level species.
(C) Trees are the climax stage of terrestrial communities and generally have low competitive ability, but high dispersal ability.
(D) For many taxa, there is a tradeoff between dispersal ability and local competitive ability.

Correct Answer: (D) For many taxa, there is a tradeoff between dispersal ability and local competitive ability

Solution:

Step 1: Overview of Ecological Succession. In ecological succession, initial stages often involve species exploiting readily available resources, with later stages dominated by species adapted for competitive environments.
Step 2: Evaluation of Options.
Option (A): Incorrect as early succession stages are characterized by abundant resources, not limitation.
Option (B): Partially correct; early colonizers can enable more complex communities, but are not necessarily keystone species.
Option (C): Incorrect; climax community trees have developed high competitive abilities to maintain their dominance.
Option (D): Correct; this reflects ecological principles where a tradeoff between dispersal and competitive abilities is common.

Quick Tip

Analyzing ecological trade-offs provides insights into how species traits influence their roles within ecological communities, especially during succession stages.

---

33. An ornamental shrub species was brought from Japan in the early 1800s to India, where it was planted frequently in gardens and parks. The species persisted for many decades without spreading and then began to spread invasively fifty years ago. Which one or more of the following processes could have led to it becoming invasive?
(A) Evolutionary adaptation to the environment
(B) Open niches due to recent habitat degradation
(C) Climate change
(D) Recent introduction of a specialized herbivore of this shrub species

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

Solution:
Step 1: Analyze potential factors contributing to invasiveness. Invasive species often spread due to environmental changes, evolutionary adaptations, or ecological opportunities that favor their proliferation. Over decades, one or more of these factors could trigger their invasive behavior.

Step 2: Evaluate the options.
Option (A): Correct. Evolutionary adaptation to the local environment could have enabled the shrub to thrive and outcompete native species, leading to its invasive spread.
Option (B): Correct. Habitat degradation could have created open niches by reducing native species populations, providing the shrub with opportunities to spread.
Option (C): Correct. Climate change could have altered environmental conditions to favor the growth and spread of the shrub species.
Option (D): Incorrect. The introduction of a specialized herbivore would likely reduce the shrub population rather than promote its spread, as herbivores generally suppress plant growth.

Quick Tip

To understand invasiveness: 1. Invasiveness can arise from ecological or evolutionary changes over time.
2. Factors such as habitat degradation, climate change, and open niches often favor invasive species.
3. Introduction of herbivores typically suppresses plant populations rather than promotes invasiveness.

---

34. Male voles pair with either a single female (monogamous) or with two females (polygynous) during a given breeding season. The probability of a male being polygynous in a breeding season is 0.2. The reproductive success (number of offspring) of monogamous males is 2, and of polygynous males is 3. A male's expected reproductive success in a breeding season is _____. (Round off to one decimal place)

Correct Answer: 2.2

Solution:
Step 1: Understand the expected reproductive success formula. The expected reproductive success (E) is calculated as the weighted average of the reproductive successes of the two groups, using their respective probabilities:

$$E = (P_{\text{monogamous}} \times \text{Success}_{\text{monogamous}}) + (P_{\text{polygynous}} \times \text{Success}_{\text{polygynous}})$$

where: - $P_{\text{monogamous}} = 1 - P_{\text{polygynous}} = 1 - 0.2 = 0.8$, - $\text{Success}_{\text{monogamous}} = 2$, - $\text{Success}_{\text{polygynous}} = 3$, and - $P_{\text{polygynous}} = 0.2$.

Step 2: Substitute the values and calculate.

$$E = (0.8 \times 2) + (0.2 \times 3)$$

$$E = 1.6 + 0.6 = 2.2$$

Quick Tip

To calculate expected values: 1. Multiply each outcome by its probability. 2. Add the results to obtain the weighted average. 3. Ensure probabilities sum to 1 for accurate calculations.

---

35. Consider a randomly breeding population of squirrels with two morphs – white-striped and brown-striped. In a population, 16% are white-striped individuals, while the rest are all brown-striped. The trait for stripes is governed by one gene where the allele for brown stripes is dominant. Assuming Hardy–Weinberg equilibrium, the frequency of the allele for white stripes would be _____. (Round off to two decimal places)

Correct Answer: 0.40

Solution:
Step 1: Understand the problem. The trait for white stripes is recessive, and 16% of the population is white-striped ($q^2 = 0.16$). To find the frequency of the allele for white stripes (q), we take the square root of q^2:

$$q = \sqrt{q^2} = \sqrt{0.16} = 0.4$$

Step 2: Verify the frequency of the dominant allele. The frequency of the dominant allele (p) is given by:

$$p = 1 - q = 1 - 0.4 = 0.6$$

Step 3: Confirm Hardy–Weinberg equilibrium. Under Hardy–Weinberg equilibrium, the allele frequencies should satisfy:

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

$$(0.6)^2 + 2(0.6)(0.4) + (0.4)^2 = 0.36 + 0.48 + 0.16 = 1$$

The calculation confirms Hardy–Weinberg equilibrium.

Quick Tip

To solve Hardy–Weinberg equilibrium problems: 1. Use q^2 for recessive phenotypes to find q. 2. Calculate p as $1 - q$. 3. Verify using $p^2 + 2pq + q^2 = 1$.

---

36. Observations of algal species showed that their diversity was higher in pools where there were grazing snails compared to pools without snails. Which one of the following statements best explains this result?
(A) Snails feed preferentially on the more abundant algal species.
(B) Snails avoid feeding on algal species.
(C) Snails feed only on the less abundant algal species.
(D) Snails feed equally on all the algal species irrespective of algal abundance.

Correct Answer: (*A*) Snails feed preferentially on the more abundant algal species

Solution:
Step 1: Understand the ecological relationship. The presence of grazing snails leads to higher diversity of algal species. This suggests that snails reduce the dominance of the most abundant algal species, creating opportunities for less common species to coexist.

Step 2: Analyze the options.
Option (A): Correct. If snails preferentially feed on the more abundant algal species, this reduces competition and allows less abundant species to thrive, increasing diversity.
Option (B): Incorrect. If snails avoided feeding on algal species, their presence would not influence algal diversity.
Option (C): Incorrect. Feeding only on less abundant species would reduce their numbers further, decreasing diversity rather than increasing it.
Option (D): Incorrect. Feeding equally on all algal species would not create a selective pressure to increase diversity, as it would impact all species uniformly.

Quick Tip

To understand ecological interactions: 1. Grazers can promote diversity by reducing the dominance of abundant species.
2. Selective feeding creates ecological niches for less common species.
3. Avoidance or equal feeding typically does not enhance diversity.

---

37. Which two of the following processes can result in a decline in heterozygosity in populations? I) Inbreeding; II) Genetic drift; III) Mutation; IV) Random mating
(A) I and II
(B) II and III
(C) I and III
(D) II and IV

Correct Answer: (*A*) I and II

Solution:
Step 1: Define processes affecting heterozygosity. Inbreeding (I): Inbreeding occurs when closely related individuals mate. This increases homozygosity and reduces heterozygosity in the population.
Genetic drift (II): Genetic drift is a random process that leads to the fixation or loss of alleles, reducing heterozygosity over time, particularly in small populations.
Mutation (III): Mutation introduces new genetic variation, which typically increases heterozygosity rather than reducing it. **Random mating (IV):** Random mating does not alter heterozygosity directly, as it maintains the Hardy–Weinberg equilibrium in the absence of other evolutionary forces.

Step 2: Evaluate the options.
Option I and II (A): Correct. Both inbreeding and genetic drift reduce heterozygosity in populations.
Option II and III (B): Incorrect. Genetic drift reduces heterozygosity, but mutation increases it.
Option I and III (C): Incorrect. Inbreeding reduces heterozygosity, but mutation increases it.
Option II and IV (D): Incorrect. Genetic drift reduces heterozygosity, but random mating does not alter it.

Quick Tip

To analyze heterozygosity: 1. Inbreeding and genetic drift reduce heterozygosity by increasing homozygosity and allele fixation.
2. Mutation and random mating do not decrease heterozygosity directly.
3. Population size greatly influences the effects of genetic drift.

---

38. Given below is a table with ecological observations and processes.

Ecological observations	Processes
P) Bright spotted pigmentation in guppy males in low predation habitats	I) Kin selection
Q) Vampire bats share blood meals	II) Sexual selection
R) Cooperative breeding in African weaver birds	III) Reciprocal altruism

Select the option that best matches each ecological observation with its corresponding process.
(A) P-III, Q-I, R-II
(B) P-II, Q-III, R-I
(C) P-II, Q-III, R-II
(D) P-II, Q-I, R-III

Correct Answer: (*B*) P-II, Q-III, R-I

Solution:
Step 1: Match each observation with its process.
(P) Bright spotted pigmentation in guppy males in low predation habitats: This trait enhances reproductive success by attracting mates, making it an example of sexual selection (II).
(Q) Vampire bats share blood meals: Sharing resources like blood meals among unrelated individuals demonstrates reciprocal benefits over time, fitting reciprocal altruism (III).
(R) Cooperative breeding in African weaver birds: In cooperative breeding, individuals help raise relatives' offspring, increasing inclusive fitness, which aligns with kin selection (I).

Step 2: Evaluate the options.
Option (A): Incorrect. P-III (reciprocal altruism) and R-II (sexual selection) are mismatched.
Option (B): Correct. P-II (sexual selection), Q-III (reciprocal altruism), and R-I (kin selection) are correctly matched.
Option (C): Incorrect. R-II (sexual selection) is incorrectly assigned.
Option (D): Incorrect. Q-I (kin selection) is incorrect, as vampire bats are not sharing meals with relatives.

Quick Tip

To match ecological observations: 1. Sexual selection involves traits enhancing mating success (e.g., guppy pigmentation).
2. Reciprocal altruism occurs when unrelated individuals exchange mutual benefits (e.g., blood-sharing in bats).
3. Kin selection involves helping relatives to increase inclusive fitness (e.g., cooperative breeding).

---

39. An ecologist must determine whether (i) the means of two independent samples differ, and (ii) there is an association between two continuous variables.
Assuming that all samples are normally distributed, which one of the following options represents the most appropriate statistical tests for (i) and (ii), respectively?
(A) Spearman's correlation; (ii) Shapiro-Wilk test
(B) Wilcoxon's matched pairs signed rank test; (ii) chi-squared test
(C) t-test; (ii) Pearson's correlation

(D) Kendall's test of concordance; (ii) Kolmogorov-Smirnov test

Correct Answer: (*C*) t-test; Pearson's correlation

Solution:
Step 1: Identify the appropriate test for (i). To determine whether the means of two independent samples differ: - The t-test is appropriate for comparing the means of two independent samples, assuming normal distribution.

Step 2: Identify the appropriate test for (ii). To assess the association between two continuous variables: Pearson's correlation measures the strength and direction of the linear relationship between two continuous variables, assuming normal distribution.

Step 3: Evaluate the options.
Option (A): Incorrect. Spearman's correlation is used for non-parametric data, and the Shapiro-Wilk test checks for normality, not mean differences or associations.
Option (B): Incorrect. Wilcoxon's test is a non-parametric alternative for paired samples, not independent samples. The chi-squared test is for categorical data, not continuous variables.
Option (C): Correct. The t-test is suitable for comparing means, and Pearson's correlation is appropriate for continuous variables.
Option (D): Incorrect. Kendall's test is a non-parametric measure of correlation, and the Kolmogorov-Smirnov test is for comparing distributions.

Quick Tip

To select statistical tests: 1. Use the t-test for mean differences in normally distributed independent samples.
2. Use Pearson's correlation for associations between continuous variables under normality.
3. Non-parametric alternatives like Spearman's or Wilcoxon's tests are used when normality is not assumed.

---

40. Males of the swordtail fish *Xiphophorus helleri* possess long tails, while those of *X. maculatus* do not. Females of *X. helleri* prefer males with longer tails. Interestingly, experimental studies show that females of *X. maculatus* prefer *X. maculatus* males with attached artificial long tails over those without.
If the long-tailed *Xiphophorus* species evolved from ancestors that lacked a long tail, which one of the following processes best explains the evolution of the observed preference among *X. maculatus* females?
(A) Kin selection
(B)Sensory bias
(C) Group selection
(D) Runaway selection

Correct Answer: (*B*) Sensory bias

Solution:

Step 1: Understand the concept of sensory bias. Sensory bias refers to the preference for a particular trait in one sex, arising due to pre-existing sensory or neurological mechanisms. This bias evolves before the trait itself and can influence mate choice when the trait becomes present in the population.

Step 2: Evaluate the given scenario.
In this case, females of *X. maculatus*, which do not have long-tailed males in their species, still show a preference for males with artificially attached long tails.
This suggests that the preference for long tails existed prior to the evolution of the trait, making sensory bias the most plausible explanation.

Step 3: Analyze the other options.
Option (A) Kin selection: Incorrect. Kin selection involves increasing the reproductive success of relatives, which is unrelated to this observed mating preference.
Option (B) Sensory bias: Correct. The pre-existing preference in *X. maculatus* females for long tails, despite the absence of the trait in their species, aligns with sensory bias.
Option (C) Group selection: Incorrect. Group selection focuses on the survival and reproductive success of groups, not individual mating preferences.
Option (D) Runaway selection: Incorrect. Runaway selection involves a positive feedback loop between trait exaggeration and preference within a population where the trait is already present. Here, the trait (long tails) is absent in *X. maculatus* males.

Quick Tip

To analyze mate preferences: 1. Sensory bias occurs when preferences evolve before the corresponding trait appears.
2. Runaway selection involves a feedback loop between traits and preferences within a population.
3. Consider whether the trait is present or absent in the population to differentiate between these processes.

---

41. Which one of the options given best matches vector to disease?

Vector	Disease
I. Fleas	P. Kyasanur Forest Disease
II. Ticks	Q. Dengue
III. Mosquitoes	R. Plague

(A) I-R; II-P; III-Q
(B) I-P; II-R; III-Q
(C) I-R; II-Q; III-P
(D) I-R; II-P; III-R

Correct Answer: (*A*) I-R; II-P; III-Q

Solution:
Step 1: Understand the relationships between vectors and diseases. Vectors are organisms that transmit pathogens or diseases from one host to another. The correct relationships

are: I. Fleas (R. Plague): Fleas are known vectors for the plague, specifically the bacterium *Yersinia pestis*. I. Ticks (P. Kyasanur Forest Disease): Ticks are vectors for Kyasanur Forest Disease, a tick-borne viral hemorrhagic fever. III. Mosquitoes (Q. Dengue): Mosquitoes, particularly *Aedes aegypti*, are vectors for dengue fever, a viral disease.

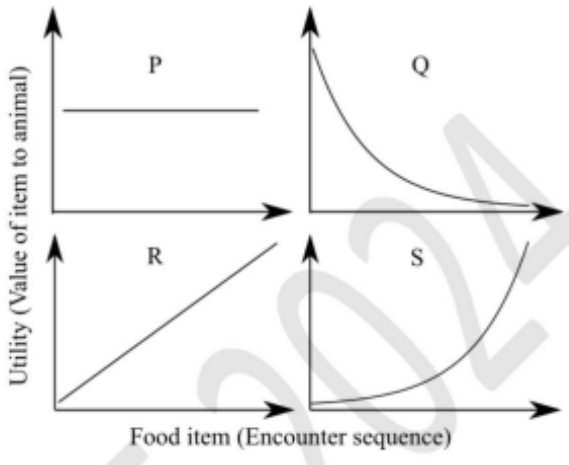
Step 2: Analyze the options.
Option (A): Correct. Matches I-R, II-P, and III-Q correctly.
Option (B): Incorrect. Misassigns fleas (I) to Kyasanur Forest Disease (P).
Option (C): Incorrect. Misassigns ticks (II) to dengue (Q).
Option (D): Incorrect. Misassigns mosquitoes (III) to plague (R).

Quick Tip

To remember vector-disease associations: 1. Fleas are primarily associated with the plague.
2. Ticks transmit tick-borne diseases like Kyasanur Forest Disease.
3. Mosquitoes are vectors for viral diseases like dengue, malaria, and Zika.

---

42. Optimal foraging theory predicts whether a foraging animal will be risk-prone, risk-averse or risk-insensitive depending on a utility function that describes the value of each additional food item to the animal. Risk-prone foraging is expected when the utility increases disproportionately with each additional food item encountered. Which one of the graphs shown depicts a scenario where risk-prone foraging would be expected?



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

Correct Answer: (C) *R*
Solution:
Step 1: Analyze the utility functions depicted by each graph.

- **Graph P:** Shows a steep increase, suggesting high utility gain per item, potentially risk-prone but not as clear-cut as R.
- **Graph Q:** Fluctuates in utility, indicating variable risk and reward, not clearly risk-prone.
- **Graph R:** Depicts a sharp increase in utility, which then becomes even more pronounced with additional items. This pattern exemplifies risk-prone behavior, where the reward significantly increases as more risks are taken.
- **Graph S:** Exhibits complex utility dynamics with multiple peaks, not straightforwardly depicting risk-prone behavior.

Step 2: Conclusion. Graph R accurately represents a scenario where risk-prone foraging is most likely, as it shows a utility function where rewards increase significantly as additional items are consumed, aligning with the theoretical prediction for risk-prone behavior.

Quick Tip

In behavioral ecology, when assessing foraging strategies through utility functions, identify the graph where the increase in utility sharply accelerates with additional food items as indicative of risk-prone strategies.

---

43. There are two species, X and Y, with abundances x and y, respectively. Species X has growth rate α, and species Y has growth rate β. Assume that the sum of the species abundances is constant over time, i.e., $x + y = 1$. Let x and y follow the rate equations:

$$\frac{dx}{dt} = \alpha x - \varphi x, \quad \frac{dy}{dt} = \beta y - \varphi y,$$

where φ is the average species fitness. Which one of the following options correctly represents the expression for φ?

(A) $\frac{\alpha x^2 + \beta y^2}{\alpha + \beta}$
(B) $\alpha x + \beta y$
(C) $\frac{\alpha x + \beta y}{x^2 + y^2}$
(D) $\frac{1}{\alpha x + \beta y}$

Correct Answer: $(B)\, \alpha x + \beta y$

Solution:
Step 1: Understand the definition of average species fitness (φ). The average fitness, φ, is determined by the weighted contributions of each species' growth rate to the total population, based on their relative abundances. Since $x + y = 1$, the abundances x and y can be treated as the respective proportions of the two species in the population.

Step 2: Derive the expression for φ. The average fitness is given by the sum of the contributions of both species:

$$\varphi = \alpha x + \beta y,$$

where: - αx represents the contribution of species X (growth rate α multiplied by its proportion x), and - βy represents the contribution of species Y (growth rate β multiplied by its proportion y).

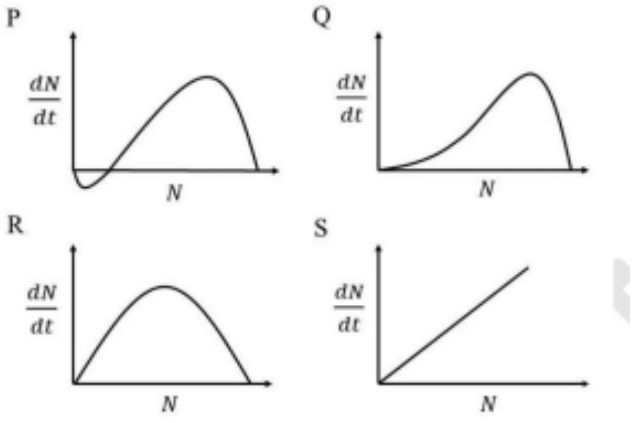
Step 3: Evaluate the options.
Option (A): Incorrect. This expression introduces terms that do not correspond to the definition of average fitness.
Option (B): Correct. This matches the derived expression for average fitness, $\varphi = \alpha x + \beta y$.
Option (C): Incorrect. The denominator $x^2 + y^2$ is unnecessary and does not fit the definition of average fitness.
Option (D): Incorrect. The reciprocal of $\alpha x + \beta y$ is not relevant to the calculation of φ.

Quick Tip

To calculate average fitness in population models: 1. Use weighted contributions based on growth rates and proportions.
2. Verify that the total population remains constant, ensuring $x + y = 1$.
3. Avoid introducing unnecessary terms or operations.

---

44. The graphs shown represent the relationship between population size (N) and population growth rate $\frac{dN}{dt}$. Which one of the following growth curves represents a density-dependent population that experiences a strong Allee effect?



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

Correct Answer: (A) P

Solution:
Step 1: Understand the Allee effect. The Allee effect describes a phenomenon where a population's growth rate decreases when the population size is very small. This occurs due to challenges such as difficulty finding mates or cooperative behaviors not being effective at low densities. A strong Allee effect results in a critical population size below which the population declines to extinction.

Step 2: Identify the characteristics of the growth curve. A population with a strong Allee effect will exhibit: 1. Negative growth ($\frac{dN}{dt} < 0$) for very small N, as the population

cannot sustain itself. 2. Positive growth ($\frac{dN}{dt} > 0$) as N increases beyond a critical threshold. 3. A peak in growth rate at an intermediate population size. 4. Declining growth ($\frac{dN}{dt} \to 0$) as the population approaches carrying capacity.

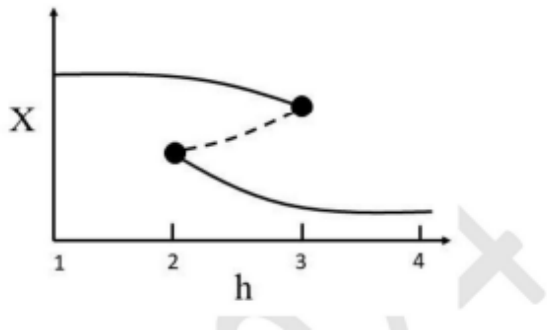
Step 3: Analyze the graphs.
Graph P: Correct. This graph represents the strong Allee effect, showing negative growth for small N, a critical threshold, and a peak at intermediate N.
Graph Q: Incorrect. This graph shows logistic growth, which does not include negative growth at small N.
Graph R: Incorrect. This graph shows continuous positive growth rates at all population sizes, inconsistent with the Allee effect.
Graph S: Incorrect. This linear growth pattern does not capture the density-dependent dynamics of the Allee effect.

Quick Tip

To identify an Allee effect: 1. Look for negative growth at very small population sizes. 2. A strong Allee effect includes a critical threshold population size below which the population declines.
3. Growth peaks at intermediate population sizes before declining near carrying capacity.

---

45. The abundance (X) of a plant species with respect to the anthropogenic stressor habitat destruction (h) is shown. The solid and the dashed curves represent stable and unstable population equilibrium abundances, respectively.



In the absence of any stochasticity, and with increasing values of h, what is the value of h at which a sudden population collapse would occur?
(A) 2.5
(B) 2
(C) 4
(D) 3

Correct Answer: (A) 2.5
Solution:
Step 1: Analyze the graph dynamics.
The graph displays the relationship between habitat destruction h and plant species abundance

X. It illustrates stable equilibria (solid curve) and points of instability (dashed curve) for the population. The key is to determine where the transition from stability to instability occurs, indicating a potential collapse.

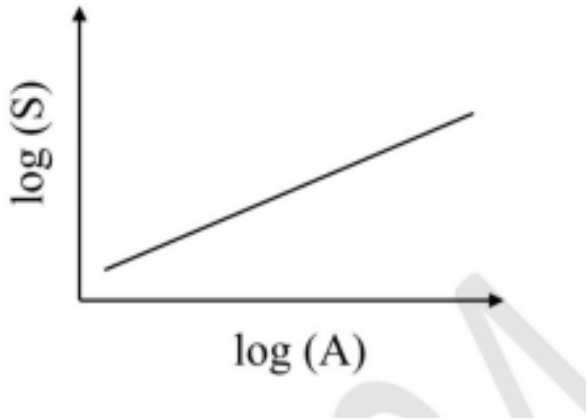
Step 2: Identify the transition point for sudden collapse.

Upon careful examination, the critical transition from a stable to an unstable state—the threshold at which a sudden collapse is likely to happen—occurs at the value $h = 2.5$. This is the point where the stable population's last solid equilibrium point exists before turning into the dashed line, representing unstable conditions leading to a population collapse.

> **Quick Tip**
>
> In population dynamics, particularly those influenced by environmental stressors, it's crucial to recognize threshold points on stability graphs. These thresholds often signal significant ecological shifts or tipping points that can dramatically affect population sustainability.

---

46. Consider the graph shown, where S is species richness and A is area. S and A are log-transformed and the slope is not equal to 1.



The relationship between untransformed S and A follows a/an:

(A) linear relationship.
(B) power law.
(C) exponential relationship.
(D) Michaelis-Menten function.

Correct Answer: (B) power law

Solution:

Step 1: Understand the graph. The graph represents the relationship between $\log(S)$ and $\log(A)$, with a straight line indicating that the relationship between S and A on a logarithmic scale is linear. The equation for such a relationship is:

$$\log(S) = c + m \log(A),$$

where c is the intercept, and m (the slope) is not equal to 1.

Step 2: Convert to the untransformed relationship. Rewriting the equation in its untransformed form:

$$S = kA^m,$$

where $k = 10^c$. This equation describes a power law relationship between S (species richness) and A (area), where m determines the scaling.

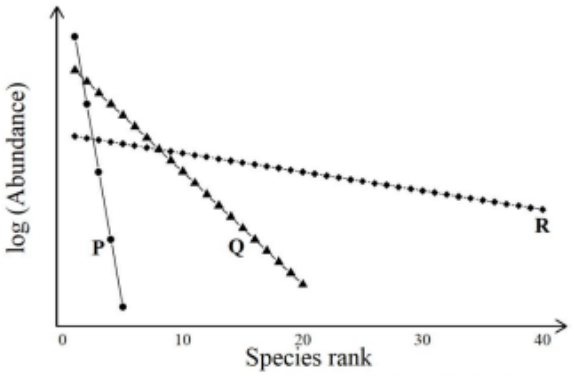
Step 3: Evaluate the options. Option (A): Incorrect. A linear relationship implies $S \propto A$, which is not consistent with the power law form $S = kA^m$.
Option (B): Correct. The equation $S = kA^m$ matches the definition of a power law.
Option (C): Incorrect. An exponential relationship would be of the form $S = ke^{mA}$, which is not implied here.
Option (D): Incorrect. A Michaelis-Menten function describes saturation dynamics, not a simple power law.

Quick Tip

To analyze log-log graphs: 1. A straight line on a log-log scale indicates a power law relationship.
2. The equation $S = kA^m$ is derived from $\log(S) = c + m\log(A)$.
3. Recognize the difference between linear, exponential, and power law relationships based on scaling behavior.

---

47. The graph shows the rank-abundance relationships for species in three communities, P, Q, and R.



Which one of the following statements is true with respect to the evenness of the three communities?
(A) $P > Q > R$
(B) $Q > P > R$
(C) $R > Q > P$
(D) $R > P > Q$

Correct Answer: $(C)\, R > Q > P$

Solution:

Step 1: Understand rank-abundance relationships. The slope of the rank-abundance curve indicates the evenness of a community: A shallower slope represents greater evenness, as species abundances are more evenly distributed.
A steeper slope indicates lower evenness, as a few species dominate the community.

Step 2: Analyze the graph. Community P: This has the steepest slope, indicating the least evenness.
Community Q: This has a moderate slope, indicating intermediate evenness.
Community R: This has the shallowest slope, indicating the highest evenness.

Step 3: Compare evenness among the communities. The evenness order based on the slopes is:

$$R > Q > P$$

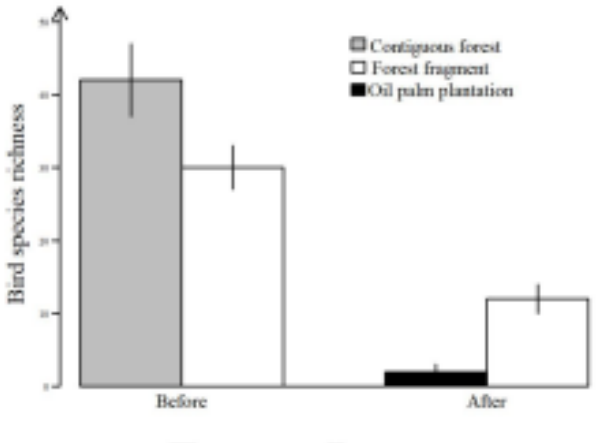
Step 4: Evaluate the options.
Option (A): Incorrect. It suggests P has the highest evenness, which contradicts the steep slope of its curve.
Option (B): Incorrect. It suggests Q has the highest evenness, but R has a shallower slope.
Option (C): Correct. This matches the observed order $R > Q > P$.
Option (D): Incorrect. It misplaces P as having higher evenness than Q.

Quick Tip

To interpret rank-abundance curves: 1. Shallow slopes indicate higher evenness.
2. Steep slopes suggest dominance by a few species, leading to lower evenness.
3. Compare slopes visually to rank communities by evenness.

---

48. The graph shows bird species richness in a large contiguous forest patch and a small adjacent forest fragment, before and soon after the large contiguous forest patch was replaced by an oil palm plantation.



Which one of the following options best explains the pattern shown?
(A) The contiguous forest is a sink and the forest fragment is a source for bird species.
(B) The forest fragment has higher species richness than the contiguous forest.

(C) The bird community in the forest fragment is geographically closed.
(D) The contiguous forest was contributing to forest fragment species richness via dispersal.

Correct Answer: (*D*) The contiguous forest was contributing to forest fragment species richness via disp

Solution:
Step 1: Interpret the graph. The graph shows:
Before the replacement, the contiguous forest had higher species richness than the forest fragment.

After the replacement of the contiguous forest with an oil palm plantation, the species richness in the forest fragment drastically decreased.

Step 2: Analyze the ecological dynamics. The decrease in species richness in the forest fragment after the loss of the contiguous forest suggests that:
1. The contiguous forest acted as a source habitat, providing species that dispersed into the forest fragment.
2. The removal of the contiguous forest disrupted dispersal, leading to a loss of species in the forest fragment.

Step 3: Evaluate the options.
Option (A): Incorrect. A sink is a habitat where populations decline without immigration. The contiguous forest was likely a source, not a sink.
Option (B): Incorrect. The forest fragment initially had lower species richness than the contiguous forest, as shown in the graph.
Option (C): Incorrect. A geographically closed community would not depend on dispersal from the contiguous forest, contradicting the observed pattern.
Option (D): Correct. The contiguous forest contributed to the species richness of the forest fragment via dispersal. Its removal caused a decline in species richness in the fragment.

Quick Tip

To interpret habitat connectivity: 1. Source habitats contribute species to adjacent fragments through dispersal.
2. Fragmented landscapes often depend on connectivity to maintain biodiversity.
3. Habitat loss can disrupt dispersal, leading to declines in species richness.

---

49. Honey bees are haplodiploid, which means that the relatedness is, on average, expected to be 0.75 between:
(A) brother-brother pairs with the same parents.
(B) brother-sister pairs with the same parents.
(C) mated female-male pair.
(D) sister-sister pairs with the same parents.

Correct Answer: (*D*) sister-sister pairs with the same parents.

Solution:
Step 1: Understand haplodiploidy in honey bees. Haplodiploidy is a sex-determination system where:
1. Males (drones) are haploid and develop from unfertilized eggs.
2. Females (workers and queens) are diploid and develop from fertilized eggs.

Sisters (workers) share: - 50% of their genes from their mother (due to random assortment during meiosis). - 100% of their genes from their haploid father (as all sperm from a haploid individual are identical).
The total relatedness between sisters is:

$$r = 0.5(from\ mother) + 0.5 \times 1(from\ father) = 0.75$$

Step 2: Analyze relatedness in other pairings. Brother-brother pairs: Relatedness is 0.5, as they share the same haploid mother.
Brother-sister pairs: Relatedness is 0.25, as the brother contributes no paternal genes.
Mated female-male pair: Relatedness is 0, as unrelated individuals mate.
Sister-sister pairs: Relatedness is 0.75, as calculated above.

Step 3: Evaluate the options.
Option (A): Incorrect. Brother-brother relatedness is 0.5.
Option (B): Incorrect. Brother-sister relatedness is 0.25.
Option (C): Incorrect. Mated female-male relatedness is 0.
Option (D): Correct. Sister-sister relatedness is 0.75.

Quick Tip

To calculate relatedness in haplodiploid systems: 1. Sisters share 100% of paternal genes and 50% of maternal genes, resulting in a total relatedness of 0.75.
2. Brothers share only maternal genes (r = 0.5), and brother-sister relatedness is 0.25.
3. Use haplodiploid genetics to explain eusocial behavior in bees.

---

50. Match the mollusc taxa to their respective orders as shown in the table.

	Mollusc taxa		**Order**
I	Cone snails	P	Bivalve
II	Octopuses	Q	Gastropod
III	Giant clams	R	Cephalopod
IV	Squids		

(A) I-P; II-Q; III-R; IV-Q
(B) I-Q; II-R; III-P; IV-R
(C) I-P; II-R; III-P; IV-Q
(D) I-P; II-R; III-Q; IV-R

Correct Answer: (*B*) I-Q; II-R; III-P; IV-R
Solution: Step 1: Match each mollusc taxa to the correct order based on common biological classification.

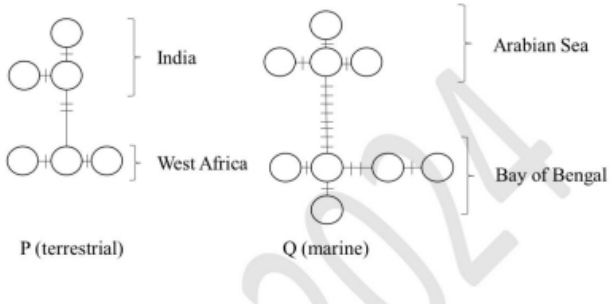
- **Cone snails (I)** are best classified in the order **Gastropod (Q)**.
- **Octopuses (II)** belong to the order **Cephalopod (R)**.
- **Giant clams (III)** are included in the order **Bivalve (P)**.
- **Squids (IV)** are also classified under the order **Cephalopod (R)**.

Quick Tip

When matching organisms to their taxonomic orders, rely on distinctive characteristics that define each group, such as foot type in molluscs, which is a key feature distinguishing these orders.

---

51. A terrestrial species P is found in both India and West Africa and nowhere else, while a marine species Q is found in the Arabian Sea and the Bay of Bengal. The two species have similar generation times. An ecologist builds haplotype networks based on DNA sequences from these species, where each circle represents one haplotype and each dash (–) represents a mutation. Which one of the following inferences is best supported by the haplotype networks shown?



(A) P has high dispersal ability; Q has low dispersal ability.
(B) Q has high dispersal ability; P has low dispersal ability.
(C) P and Q have equal dispersal abilities.
(D) The genetic structure is not influenced by dispersal ability.

Correct Answer: (*B*) Q has high dispersal ability; P has low dispersal ability
Solution:
Step 1: Examine the haplotype networks. The network for species P shows fewer haplotypes with limited mutations, indicating fewer genetic variations and suggesting a low dispersal ability across large distances. In contrast, species Q's network exhibits more haplotypes with more extensive mutations and connections, indicative of a higher dispersal ability.

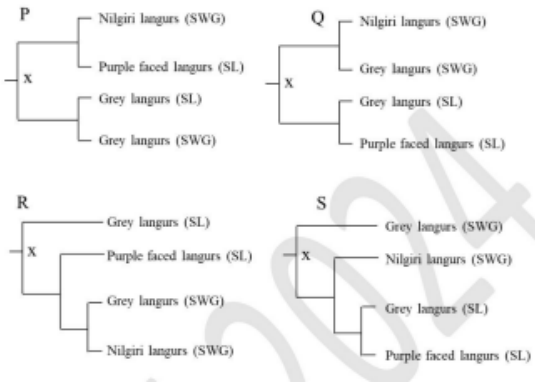
Step 2: Relate haplotype diversity to dispersal ability. Species Q's broader range of haplotypes and the presence in diverse marine environments supports a higher dispersal capability. Species P's restricted haplotype spread between only two distant regions points to a more limited dispersal capacity.

Quick Tip

When analyzing haplotype networks, consider both the number of haplotypes and their connectivity to infer the dispersal ability of species. More connected and numerous haplotypes generally suggest a higher dispersal potential.

---

52. Grey langurs found in the southern Western Ghats (SWG) and grey langurs in Sri Lanka (SL) look very similar. Nilgiri langurs (found in SWG) and purple faced langurs (found in SL) also look similar. If allopatry played a role in the early diversification of this group (at point X in the tree), which one of the phylogenetic trees is most likely to be correct?



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

Correct Answer: $(C)\, R$
Solution:
Step 1: Analyze the structure of Tree R. Tree R begins with a split indicating a significant geographical or ecological separation between the grey langurs of SL and SWG. The lineage then further diversifies in SL to include purple-faced langurs, while maintaining grey langurs in SWG. This suggests that allopatric speciation influenced by geographical isolation led to the diversification within these regions.
Step 2: Justify the selection of Tree R. The configuration of Tree R accurately represents how physical barriers and ecological factors could drive early diversification, resulting in distinct yet genetically related groups within the grey and purple-faced langurs. It effectively captures the essence of allopatric speciation and the evolutionary history as suggested by the similarities and distribution of the langur populations.

Quick Tip

Phylogenetic analysis often hinges on understanding the geographic and ecological contexts that contribute to species diversification. In cases of allopatric speciation, look for tree structures that reflect clear separations likely caused by geographical barriers.

---

53. Two bird species, A and B, are found on a single mountainside. A is a low-elevation species, found between 500 m and 1500 m Above Sea Level (ASL), while B is a high-elevation species, found between 1000 m and 2000 m ASL. At 1250 m ASL, species A and B have very different bill morphologies, but the bill morphology of species A at 500 m is very similar to the bill morphology of species B at 2000 m ASL. Which one or more of the following explain(s) the difference in bill morphology at 1250 m ASL?
(A) Competitive exclusion
(B) Character displacement
(C) Convergent evolution
(D) Allopatric speciation

Correct Answer: (B) Character displacement.

Solution:
Step 1: Analyze the ecological context. At 1250 m ASL, A and B coexist and show distinct bill morphologies, likely to reduce competition. However, their morphologies are similar at non-overlapping elevations, indicating the differences at 1250 m are ecologically driven.

Step 2: Evaluate the processes. Competitive exclusion: Unlikely, as both species coexist.
Character displacement: Likely, as sympatric divergence reduces competition.
Convergent evolution: Explains similarity at non-overlapping elevations but not divergence at 1250 m.
Allopatric speciation: Does not explain divergence in sympatry.

Quick Tip

To understand trait divergence:
1. Sympatric populations often show divergence to reduce competition.
2. Compare traits in overlapping and non-overlapping ranges to identify ecological processes.

---

54. Which one or more of the following is/are greenhouse gas(es)?
(A) Methane
(B) Water vapour
(C) Sulphur dioxide
(D) Nitrous oxide

Correct Answer: (A) Methane, (B) Water vapour, and (D) Nitrous oxide.

Solution:

Step 1: Define greenhouse gases. Greenhouse gases (GHGs) trap heat in the Earth's atmosphere, contributing to the greenhouse effect. Major greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapour (H_2O).

Step 2: Analyze the options. Option (A): Methane (CH_4) is a potent greenhouse gas with a high global warming potential.
Option (B): Water vapour (H_2O) is the most abundant greenhouse gas, contributing significantly to the natural greenhouse effect.
Option (C): Sulphur dioxide (SO_2) is not a greenhouse gas. Instead, it can cause cooling by forming aerosols that reflect sunlight.
Option (D): Nitrous oxide (N_2O) is a significant greenhouse gas with a long atmospheric lifetime.

Quick Tip

To identify greenhouse gases:
1. Focus on gases that trap heat in the atmosphere.
2. Key examples include CO_2, CH_4, N_2O, and H_2O.
3. Sulphur dioxide (SO_2) is not a greenhouse gas but contributes to atmospheric cooling.

---

55. Males of the Indian robin in two populations sing songs of different lengths. Which one or more of the options given is/are an ultimate (not proximate) explanation(s) of the difference in song length between the two populations?
(A) Females prefer to mate with males that sing longer songs in one population but not in the other.
(B) The two populations have different forms of the gene that determines song duration.
(C) The two populations differ in hormone levels that activate the start and end of singing behaviour.
(D) Differences between populations in food availability during development affect neural circuitry that is involved in song production.

Correct Answer: (A)
Solution:
Step 1: Evaluate the ultimate nature of Option (A). Option (A) proposes that differences in female mating preferences across populations have led to variations in male song length. This is considered an ultimate explanation because it addresses the evolutionary reasons—specifically, sexual selection—that could lead to genetic differentiation and behavioral adaptations in song length among populations.
Step 2: Implications of sexual selection. Sexual selection is a form of natural selection where certain traits become preferred by one sex, in this case, females. These preferences can drive significant evolutionary changes in populations, leading to traits that are advantageous in specific mating contexts but may vary geographically depending on local preferences.

Quick Tip

Understanding the role of sexual selection in evolution helps explain why certain traits, like song length in birds, may vary significantly between populations, reflecting differences in mating strategies and female preferences.

---

56. Female *Anopheles* mosquitoes bite humans to get blood. Researchers performed an experiment to study whether female mosquitoes use temperature or scent, or both, when locating human hosts. They presented female mosquitoes with membranes kept at different temperatures. Some membranes had human scent applied to them. The response to each treatment was measured as the percentage of females that landed on the membrane (50 females for each treatment). The table shows the treatments and the corresponding responses.

(A) Human scent cues are necessary to locate human hosts.
(B) Human scent cues are sufficient to locate human hosts.
(C) Human body temperature cues are necessary to locate human hosts.
(D) Human body temperature cues are sufficient to locate human hosts.

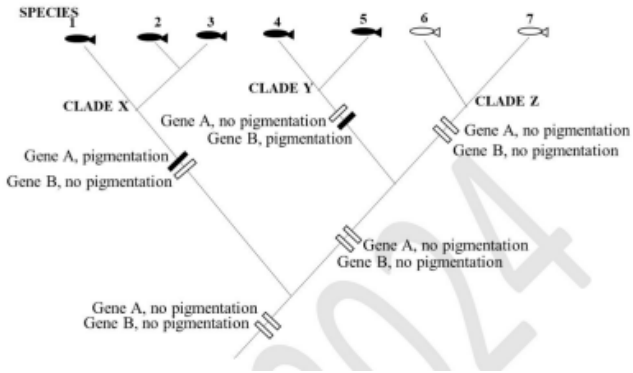
Correct Answer: (B) and (D)
Solution:
Analysis of Experimental Data: The experiment involved varying both temperature and the presence of human scent, yielding the following responses: - At ambient temperature with human scent, there was a high response (90- At ambient temperature without human scent, there was no response (0- At human body temperature with or without human scent, the response was high (90
Inferences Drawn: - Human scent alone is sufficient to attract mosquitoes, as evidenced by the response at lower temperatures. - Human body temperature alone is also sufficient, as mosquitoes responded highly even without the human scent at body temperature.

Quick Tip

When evaluating sensory cues for vector-host interactions, consider both independent and combined effects of environmental factors such as temperature and scent to fully understand their roles in host detection.

---

57. A phylogenetic tree for the evolution of two pigmentation traits in species of fish is shown for clades X, Y, and Z. Genes A and/or B, if mutated, can cause dark pigmentation in the body.



Which one or more of the following statements is/are correct?

(A) The character state "pigmentation" is homologous between species 1 and 3.
(B) The character state "pigmentation" is homologous between species 1 and 4.
(C) The character state "pigmentation" is not homologous for species 6 and 7.
(D) The character state "pigmentation" is not homologous between species 2 and 6.

Correct Answer: $(A), (D)$
Solution:
Step 1: Reevaluate Homology in Phylogenetic Context. Understanding homology requires assessing both the genetic and evolutionary context within which traits occur:
Species 1 and 3: Despite differences in pigmentation presence, their placement within the same clade suggests a shared evolutionary background for the trait.
Species 2 and 6: Although both lack pigmentation, their separate clade origins and potential genetic causes support non-homologous development.

Step 2: Conclusion Based on Phylogenetic Analysis. Homology of Pigmentation between Species 1 and 3: Supported by their common clade positioning and ancestral trait inheritance.
Non-Homology of Pigmentation between Species 2 and 6:Supported by their distinct clade origins and differing genetic influences.

Quick Tip

When analyzing phylogenetic trees, consider both the shared clade and potential evolutionary events that may lead to trait variations, such as gene mutations or silencing, to determine homology accurately.

---

58. In conservation biology, which one or more of the following is/are used to calculate the effective population size, N_e?
(A) the population size required to avoid local extinction in the next 1000 years.
(B) the carrying capacity of the environment.
(C) the sum of the sizes of all connected populations in a metapopulation.
(D) the number of breeding males and females.

Correct Answer: (D).

Solution:
Step 1: Understanding effective population size (N_e). The effective population size, N_e, represents the number of individuals in a population that contribute to the next generation's gene pool. It is influenced by factors such as the number of breeding individuals, sex ratio, and variation in reproductive success.

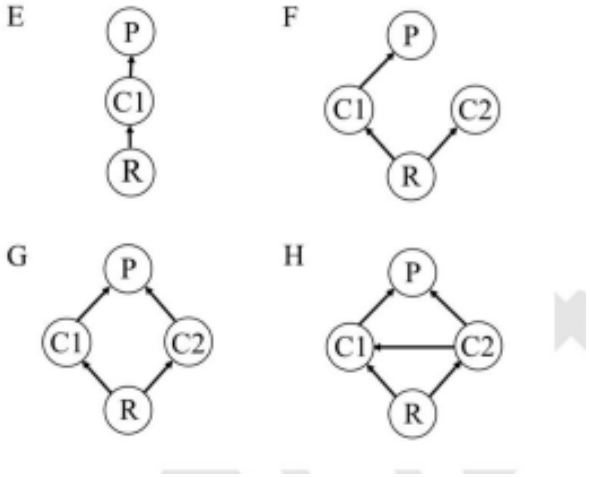
Step 2: Evaluate the options. Option (A): Incorrect. The population size required to avoid extinction over a given time frame is not directly related to N_e.
Option (B): Incorrect. Carrying capacity refers to the maximum number of individuals the environment can support and does not directly influence N_e.
Option (C): Incorrect. While metapopulation size is important in conservation, N_e is calculated for individual populations and not the sum of all connected populations.
Option (D): Correct. The number of breeding males and females directly affects N_e, as it determines the genetic contribution to future generations.

Quick Tip

To calculate N_e, consider:
1. The number of breeding individuals.
2. The sex ratio of the population.
3. Variance in reproductive success among individuals.

---

59. In the foodweb diagrams shown, R represents the primary producer, C1 and C2 represent intermediate consumers, and P represents the top predator. Which one or more of these diagrams show(s) intraguild predation?



(A) E
(B) F
(C) G
(D) H

Correct Answer: (D)

Solution:
Focused Analysis of Diagram H for Intraguild Predation: - **Diagram H** distinctly illustrates intraguild predation, where C1 and C2 consume the same primary producer R and C1 additionally preys on C2. This scenario shows C1 affecting the population dynamics of C2 both through competition and predation, making it a textbook case of intraguild predation.

Quick Tip

In analyzing food web diagrams for intraguild predation, identify cases where a consumer not only competes with but also consumes another consumer at the same trophic level. This interaction reveals more about the stability and dynamics of ecological communities.

---

60. You are a plant ecologist studying a plant in the genus *Veronica*. You notice that, at open rocky sites, *Veronica* grows as a creeper spreading low to the ground, whereas in grasslands, the stem stands upright. You collect seeds from multiple populations in each habitat type and grow them under uniform conditions in a greenhouse. You find that all the plants grown in the greenhouse have stems that stand upright. Which one or more of the following explanations best support(s) your observations?

(A) The different morphologies in the natural habitat types are due to phenotypic plasticity.
(B) Inbreeding depression has led to the creeping form in the rocky sites.
(C) High gene flow between populations has restricted local adaptation in the two environments.
(D) The morphological differences between populations demonstrate that growth form is a polygenic trait.

Correct Answer: (A)
Solution:
Analysis of Morphological Differences: The observation that all plants grown in the greenhouse exhibit an upright form, irrespective of their seed source, strongly suggests that the environmental conditions play a significant role in determining plant morphology. This supports the idea of phenotypic plasticity, where the same genetic makeup can express different phenotypes under different environmental conditions.

Quick Tip

Phenotypic plasticity allows organisms to adjust their physiology or morphology in response to environmental conditions, showcasing an adaptive advantage in varying habitats.

---

61. One hypothesis for why the tropics have far greater species richness than higher latitudes is that the tropics are relatively aseasonal. Low seasonality can encourage high species richness through which one or more of the following mechanisms?

(A) Numerous resources are consistently available throughout the year, allowing different

species to specialize on different resources, thereby minimizing competition and allowing co-existence.
(B) Low seasonality is associated with lower rates of predation, allowing large populations to thrive.
(C) Low seasonality is associated with more stable populations that are less vulnerable to demographic stochasticity and extinction.
(D) Low seasonality is associated with longer generation times, which enhances species richness.

Correct Answer: (A) and (C).

Solution:
Step 1: Analyze the role of low seasonality in species richness. Low seasonality in the tropics provides a stable environment that supports resource specialization, population stability, and co-existence, contributing to high species richness.

Step 2: Evaluate the options. Option (A): Correct. Consistent resource availability throughout the year reduces competition and enables species to specialize, fostering co-existence and increasing species richness.
Option (B): Incorrect. Lower predation rates are not directly associated with low seasonality and do not explain increased species richness.
Option (C): Correct. Stable populations in aseasonal environments are less affected by demographic stochasticity and extinction, leading to higher species richness.
Option (D): Incorrect. Longer generation times are not a direct consequence of low seasonality and do not enhance species richness.

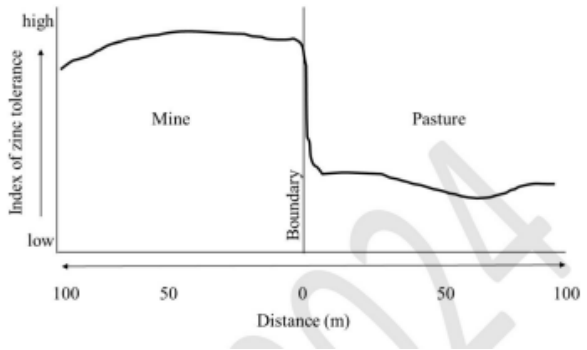
Conclusion: The correct mechanisms are (**A**) and (**C**), as they explain how low seasonality contributes to higher species richness in the tropics.

Quick Tip

To understand species richness in the tropics:
1. Focus on the stability and consistency of resources in aseasonal environments.
2. Recognize how reduced demographic stochasticity enhances species survival and diversification.

---

62. The figure illustrates the soil zinc tolerance of the grass species *Anthoxanthum* along a transect from inside a mine to the middle of a pasture outside the mine.



Which one or more of the following processes explain(s) the observed pattern of zinc tolerance in this grass species?
(A) Genetic drift
(B) Local adaptation
(C) Coevolution
(D) Introgression

Correct Answer: $(B)\, Localadaptation$
Solution:
Analysis of Zinc Tolerance Variation: The significant variation in zinc tolerance from high within the mine to low in the surrounding pasture is indicative of local adaptation. The plants inside the mine likely evolved a high tolerance to zinc due to the heavy metal-rich environment, which is a classic example of local adaptation to extreme environmental conditions.
Reasons for Excluding Other Options:
Genetic drift typically impacts small populations and does not usually result in such distinct, adaptive traits that respond directly to environmental pressures.
Coevolution is not applicable as there is no interaction with other species that influences zinc tolerance.
Introgression might influence genetic diversity but there's no indication of hybridization affecting the zinc tolerance trait in this scenario.

Quick Tip

Local adaptation often leads to marked differences in traits within species across different environments, especially when these environments impose significant selective pressures, such as varying levels of toxins or nutrients.

---

63. In a forest, there are tigers, hare, and deer. On a given day, the probability of a tiger hunting a hare is 0.35, a deer is 0.25, and either a hare or a deer is 0.55. The probability of a tiger hunting both a hare and a deer on a given day is _____, (Round off to two decimal places).

Correct Answer: 0.05

Solution:
Step 1: Using the principle of inclusion-exclusion. The formula for the union of two events is:

$$P(\text{Hunting a hare or a deer}) = P(\text{Hare}) + P(\text{Deer}) - P(\text{Hare and Deer}).$$

Given:

$$P(\text{Hare or Deer}) = 0.55, \quad P(\text{Hare}) = 0.35, \quad P(\text{Deer}) = 0.25.$$

Substitute the values into the formula:

$$0.55 = 0.35 + 0.25 - P(\text{Hare and Deer}).$$

Step 2: Solve for P(Hare and Deer). Rearrange the equation:

$$P(\text{Hare and Deer}) = 0.35 + 0.25 - 0.55 = 0.05.$$

Quick Tip

For probability questions involving "or" conditions, use the inclusion-exclusion principle:

$$P(A \cup B) = P(A) + P(B) - P(A \cap B).$$

Rearrange to find the probability of simultaneous events if needed.

---

64. Consider a discrete random variable X that takes values from the set $S = \{0, 1, 2, 3\}$, being the number of individuals of a species within a habitat. Consider the probability distribution of X with $Pr(X = 0) = 0.15$, $Pr(X = 1) = 0.25$, and $Pr(X = 3) = 0.5$, where Pr denotes probability. The value of $Pr(X = 2)$ is _____. (Round off to two decimal places).

Correct Answer: 0.10

Solution:
Step 1: Sum of probabilities in a probability distribution.
For any discrete random variable, the sum of probabilities of all possible outcomes must equal 1:

$$Pr(X = 0) + Pr(X = 1) + Pr(X = 2) + Pr(X = 3) = 1.$$

Step 2: Substitute the known probabilities. Given:

$$Pr(X = 0) = 0.15, \quad Pr(X = 1) = 0.25, \quad Pr(X = 3) = 0.5.$$

Substitute these values:

$$0.15 + 0.25 + Pr(X = 2) + 0.5 = 1.$$

Step 3: Solve for $Pr(X = 2)$. Simplify the equation:

$$Pr(X = 2) = 1 - (0.15 + 0.25 + 0.5).$$

$$Pr(X = 2) = 1 - 0.9 = 0.10.$$

Quick Tip

For probability distributions:
1. Verify that the sum of all probabilities equals 1.
2. Use this property to find missing probabilities by subtracting the sum of known values from 1.

65. There are nine species of *Impatiens* (balsams) found in laterite plateaus of the northern Western Ghats, each with a distinct colour. If a plateau has exactly 6 species, then the number of possible colour combinations in the plateau is _____. (Answer in integer).

Correct Answer: 84

Solution:
Step 1: Understand the problem. We are selecting 6 species from a total of 9 species, where the order of selection does not matter. This is a problem of combinations.

Step 2: Apply the combination formula. The number of ways to choose r objects from n objects is given by the combination formula:

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

Here, $n = 9$ (total species) and $r = 6$ (species to be selected).

Step 3: Calculate $\binom{9}{6}$.

$$\binom{9}{6} = \frac{9!}{6!(9-6)!} = \frac{9!}{6! \cdot 3!}.$$

Simplify:

$$\binom{9}{6} = \frac{9 \cdot 8 \cdot 7}{3 \cdot 2 \cdot 1} = 84.$$

Quick Tip

To solve problems involving combinations:
1. Use the formula $\binom{n}{r} = \frac{n!}{r!(n-r)!}$.
2. Simplify factorials step-by-step to avoid errors in large computations.