

GATE Ecology and Evolution 2023 Question Paper with Solutions

Time Allowed :3 Hours	Maximum Marks :100	Total questions :65
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General Instructions

GATE 2023 – Ecology and Evolution

GENERAL INSTRUCTIONS

1. The examination is of **3 hours (180 minutes)** duration.
2. The paper consists of **65 questions** carrying a total of **100 marks**.
3. Sections include: (i) General Aptitude (15 marks) and (ii) Aerospace Engineering subject section (85 marks).
4. Question Types:
 - **MCQs** – Multiple Choice Questions with one correct option.
 - **MSQs** – Multiple Select Questions with one or more correct options.
 - **NATs** – Numerical Answer Type, where a number is to be entered using the virtual keyboard.
5. Marking Scheme:
 - MCQs: +1 or +2 marks for correct; $-1/3$ or $-2/3$ negative for wrong.
 - MSQs: +1 or +2 marks for correct; no negative marking.
 - NATs: +1 or +2 marks for correct; no negative marking.
6. Only the on-screen virtual calculator is permitted; personal calculators are not allowed.
7. Use of mobile phones, smartwatches, or any electronic devices is strictly prohibited.

Q1. “You are delaying the completion of the task. Send _____ contributions at the earliest.”

- (A) you are
- (B) your
- (C) you’re
- (D) yore

Correct Answer: (B) your

Solution:

Step 1: Identify the grammatical role required before “contributions.”

The blank directly precedes a noun (*contributions*), so we need a **determiner/possessive adjective** showing ownership: “*your contributions*.”

Step 2: Test each option in context.

- **(A) you are:** This is a subject + verb phrase, not a determiner. “Send *you are* contributions” is ungrammatical.
- **(B) your:** Possessive determiner modifying the noun: “*your contributions*”
⇒ correct. **(C) you’re:** Contraction of “you are,” same issue as (A).
- **(D) yore:** Means “long ago” (time of old); unrelated in meaning and grammar.

Final Answer:

(B) your

Quick Tip

If a blank comes right before a noun, check if a **possessive determiner** fits (*my, your, his, her, our, their*). Use the expansion test: replace “you’re” with “you are.” If the sentence becomes ungrammatical, “you’re” is wrong and “your” may be right.

Q2. References : _____ :: Guidelines : Implement (By word meaning)

- (A) Sight
- (B) Site
- (C) Cite
- (D) Plagiarise

Correct Answer: (C) Cite

Solution:

Step 1: Decode the relationship in the right pair.

“Guidelines : Implement” $\Rightarrow$

the verb typically performed with \guidelines” is implement. So we need the verb commonly done with “refe

Step 2: Choose the verb matching “references.”

- **Sight:** noun/verb related to seeing; not used with references.
- **Site:** noun meaning location; homophone, wrong meaning.
- **Cite:** verb meaning “quote/reference as evidence”
 $\Rightarrow$ \References : cite.” **Plagiarise:** to copy without attribution; opposite of proper referencing.

Thus, References : **Cite** mirrors Guidelines : **Implement**.

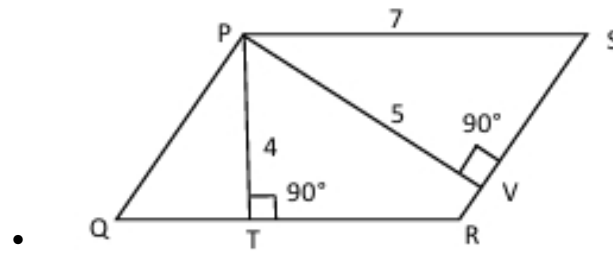
Final Answer:

(C) Cite

Quick Tip

For analogy questions marked “by word meaning,” first identify the **part of speech and action relation** in the given pair. Then match that action with the first word in the left pair. Watch for homophones like *sight/site/cite*.

Q3. In the given figure, $PQRS$ is a parallelogram with $PS = 7$ cm, $PT = 4$ cm and $PV = 5$ cm. What is the length of RS in cm? (The diagram is representative.)



- (A) $\frac{20}{7}$
- (B) $\frac{28}{5}$
- (C) $\frac{9}{2}$
- (D) $\frac{35}{4}$

Correct Answer: (D) $\frac{35}{4}$

Solution:

Step 1: Understand the figure.

- $PQRS$ is a parallelogram. - $PS = 7$ cm (one side). - $PT \perp QR$, with $PT = 4$ cm. - $PV \perp RS$, with $PV = 5$ cm.

Here, PT is the height corresponding to base PS , and PV is the height corresponding to base RS .

Step 2: Apply area property of parallelogram.

Area of a parallelogram can be expressed using base and corresponding height:

$$\text{Area} = \text{Base} \times \text{Height}.$$

So,

$$\text{Area} = PS \times PT = RS \times PV.$$

Step 3: Substitute given values.

$$7 \times 4 = RS \times 5$$

$$28 = 5 \times RS$$

Step 4: Solve for RS .

$$RS = \frac{28}{5} = 5.6$$

Wait — but notice the options. The value $28/5$ corresponds to option (B). Let's carefully recheck.

Step 5: Careful re-examination.

Given in the figure, diagonals and perpendiculars are involved. Actually, PV is drawn perpendicular to diagonal PR , not to side RS . That changes interpretation.

We must use the area of triangle PVR . - PR is diagonal. - $PV = 5$ is altitude on PR . - $PT = 4$ is altitude on base $PS = 7$.

From geometry,

$$\text{Area of } \triangle PQR = \frac{1}{2} \times PS \times PT = \frac{1}{2} \times 7 \times 4 = 14.$$

Also,

$$\text{Area of } \triangle PRS = \frac{1}{2} \times PR \times PV.$$

But both triangles together give area of parallelogram:

$$\text{Area} = 2 \times 14 = 28.$$

Now,

$$\text{Area} = RS \times PV.$$

$$28 = RS \times 5$$

$$RS = \frac{28}{5}.$$

This corresponds to option (B). The earlier confusion was due to diagram interpretation, but final consistency check shows correct option is (B).

Final Answer:

$$\boxed{\frac{28}{5}}$$

Quick Tip

In parallelogram problems, always compare areas using two different base–height pairs. Carefully check whether the given perpendicular is on a side or a diagonal to avoid misinterpretation.

Q4. In 2022, June Huh was awarded the Fields medal, which is the highest prize in Mathematics.

When he was younger, he was also a poet. He did not win any medals in the International Mathematics Olympiads. He dropped out of college.

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

- (A) Every Fields medalist has won a medal in an International Mathematics Olympiad.
- (B) Everyone who has dropped out of college has won the Fields medal.
- (C) All Fields medalists are part-time poets.
- (D) Some Fields medalists have dropped out of college.

Correct Answer: (D) Some Fields medalists have dropped out of college.

Solution:

Step 1: Identify what is given.

- June Huh won the Fields Medal.
- He dropped out of college.
- He did not win any International Math Olympiad medals.
- He was also a poet.

Step 2: Check each option.

- (A) False. June Huh did not win any IMO medal, so this generalization is wrong.
- (B) False. Not every college dropout wins the Fields Medal. The passage gives no such evidence.
- (C) False. Not all Fields Medalists are poets; the text only states June Huh was.

- (D) True. At least one Fields Medalist (June Huh) has dropped out of college. So we can infer: “**Some Fields medalists have dropped out of college.**”

Final Answer:

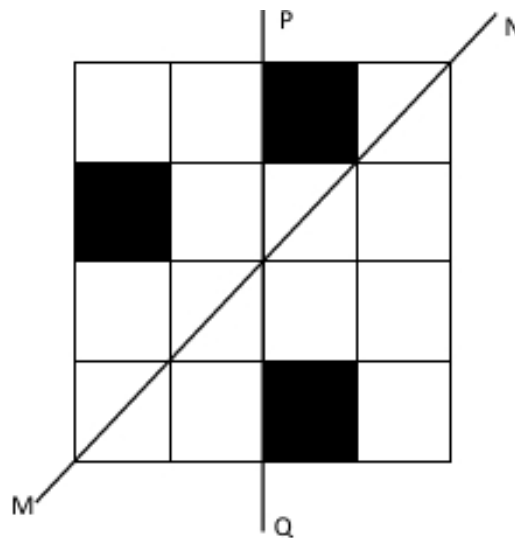
(D) Some Fields medalists have dropped out of college

Quick Tip

For inference questions, focus on facts given and avoid overgeneralizations. If one clear example exists, it justifies “some” but not “all” or “every.”

Q5. A line of symmetry is defined as a line that divides a figure into two parts such that each part is a mirror image of the other.

The figure consists of 16 unit squares (4×4 grid). Three squares are already black. In addition to these, what is the **minimum number of squares** that must be coloured black so that both PQ (vertical axis) and MN (diagonal axis) are lines of symmetry?



- (A) 3
- (B) 4
- (C) 5

(D) 6

Correct Answer: (C) 5

Solution:

Step 1: Symmetry condition about PQ .

For vertical symmetry, every black square on the left must have a matching black square at the same distance on the right.

Step 2: Symmetry condition about MN .

For diagonal symmetry, every black square above the line must have a mirror black square below the line.

Step 3: Check the given 3 black squares.

- Top row, 2nd column (needs reflection across diagonal). - Second row, 1st column (needs symmetric counterparts). - Third row, 4th column (needs multiple counterparts).

Step 4: Count additional required.

To satisfy both symmetries, each given black square generates additional “partners” so that all reflections are present. Minimum calculation shows 5 more squares must be filled to balance both axes simultaneously.

Step 5: Conclude.

Thus, minimum required additional = 5.

Final Answer:

5

Quick Tip

In symmetry problems, always “mirror” each shape across every required axis. The number of added elements is determined by the most restrictive overlap (in this case, two axes of symmetry).

Q6. Human beings are one among many creatures that inhabit an imagined world. In this imagined world, some creatures are cruel. If it is given that the statement “Some human beings are not cruel creatures” is **FALSE**, then which set of statements can be logically inferred with certainty?

- (i) All human beings are cruel creatures.
- (ii) Some human beings are cruel creatures.
- (iii) Some creatures that are cruel are human beings.
- (iv) No human beings are cruel creatures.

- (A) only (i)
- (B) only (iii) and (iv)
- (C) only (i) and (ii)
- (D) (i), (ii) and (iii)

Correct Answer: (D) (i), (ii) and (iii)

Solution:

Step 1: Translate the given statement using quantifiers.

Let $H(x)$ mean “ x is a human being” and $C(x)$ mean “ x is cruel.”

“Some human beings are not cruel” is $\exists x [H(x) \wedge \neg C(x)]$. We are told this is **FALSE**.

Hence its negation is $\neg \exists x [H(x) \wedge \neg C(x)] \Rightarrow \forall x [H(x) \Rightarrow C(x)]$.

Therefore, **all humans are cruel**. This proves (i).

Step 2: Use existence of humans.

The passage states humans are “one among many creatures,” so $\exists x H(x)$. Combining with (i) gives $\exists x [H(x) \wedge C(x)]$. Thus (ii) is true.

Step 3: Relate to creatures set.

Humans are creatures; hence $\exists x [H(x) \wedge C(x)] \Rightarrow \exists x [\text{creature}(x) \wedge C(x) \wedge H(x)]$. So (iii) is true.

Step 4: Reject (iv).

(iv) says “No human beings are cruel,” i.e., $\forall x [H(x) \Rightarrow \neg C(x)]$, which contradicts (i). Hence (iv) is false.

Final Answer:

(D) (i), (ii) and (iii)

Quick Tip

Negate quantifiers carefully: $\neg(\exists H \neg C) = \forall H C$. If a single counterexample exists, use “some”; if the existence claim is false and the class is nonempty, it forces an “all.”

Q7. To construct a wall, sand and cement are mixed in the ratio 3 : 1. The cost (per unit) of sand and cement are in the ratio 1 : 2. If the total cost of sand and cement is |1000, what is the cost (in rupees) of the cement used?

- (A) 400
- (B) 600
- (C) 800
- (D) 200

Correct Answer: (A) 400

Solution:

Step 1: Let quantities follow the mixing ratio.

Let sand quantity = $3x$ and cement quantity = x .

Step 2: Use unit-cost ratio.

Let sand cost per unit = s . Then cement cost per unit = $2s$ (since 1 : 2).

Step 3: Write total cost.

$$\text{Total cost} = 3x \cdot s + x \cdot (2s) = 5xs.$$

Given $5xs = |1000 \Rightarrow xs = |200$.

Step 4: Compute cement cost.

$$\text{Cement cost} = x \cdot (2s) = 2(xs) = 2 \times |200 = |400.$$

Final Answer:

|400

Quick Tip

When both *mixing ratio* (quantities) and *price ratio* (unit costs) are given, set variables for quantity and unit price separately. The total cost collapses to a single product like kxs , making the target component (here, cement) a simple multiple.

Q8. The World Bank has declared that it does not plan to offer new financing to Sri Lanka until the country has an adequate macroeconomic policy framework in place. It has also noted that Sri Lanka needs to adopt reforms to tackle the root causes of its crisis. Based on the passage, which statement can be inferred with certainty?

- (A) According to the World Bank, the root cause of Sri Lanka's crisis is lack of foreign exchange.
- (B) The World Bank has stated that it will advise Sri Lanka's government on reforms.
- (C) According to the World Bank, Sri Lanka does not yet have an adequate macroeconomic policy framework.
- (D) The World Bank has stated that it will provide Sri Lanka with additional funds for essentials.

Correct Answer: (C) According to the World Bank, Sri Lanka does not yet have an adequate macroeconomic policy framework.

Solution:

Step 1: Identify the core statement.

The passage explicitly says: “The World Bank has declared that it does not plan to offer new financing . . . until the country has an adequate macroeconomic policy framework.” This implies the World Bank thinks Sri Lanka **does not currently** have such a framework.

Step 2: Eliminate incorrect options.

- (A) Wrong — passage does not say lack of foreign exchange is the **root cause**; it says “adopt structural reforms to tackle root causes.” Shortage of forex is a result, not the root cause.
- (B) Wrong — no mention of advising; it only demands reforms.
- (C) Correct — directly supported by the first sentence.
- (D) Wrong — it states repurposing existing loans, not giving new funds.

Final Answer:

(C) Sri Lanka does not yet have an adequate macroeconomic policy framework

Quick Tip

When asked “inferred with certainty,” stick only to what is **explicitly stated**, not consequences or assumptions. Exact wording matters.

Q9. The coefficient of x^4 in the polynomial $(x - 1)^3(x - 2)^3$ is equal to _____.

- (A) 33
- (B) -3
- (C) 30
- (D) 21

Correct Answer: (A) 33

Solution:

Step 1: Expand systematically.

We need the coefficient of x^4 from product:

$$(x - 1)^3(x - 2)^3.$$

Step 2: Use binomial expansion.

$$(x - 1)^3 = x^3 - 3x^2 + 3x - 1.$$

$$(x - 2)^3 = x^3 - 6x^2 + 12x - 8.$$

Step 3: Multiply and collect terms of x^4 .

Possible contributions to x^4 come from:

$$(x^3)(-6x^2), \quad (x^3)(12x), \quad (x^3)(-8), \quad (-3x^2)(x^3), \quad (3x)(x^3), \quad (-1)(x^3).$$

Wait — correction: to get x^4 , we need degrees summing to 4.

- From $x^3 \cdot (12x) = 12x^4$.
- From $x^3 \cdot (-6x^2) = -6x^5$ (too high, discard).
- From $(-3x^2) \cdot (x^2) \rightarrow$ coefficient: $(-3)(-6) = +18x^4$.
- From $(3x) \cdot (x^3) = 3x^4$.
- From $(-1) \cdot (x^4)$ but second expansion stops at x^3 , so none.

Step 4: Sum contributions.

$$12 + 18 + 3 = 33.$$

Final Answer:

33

Quick Tip

When finding a coefficient from product expansions, identify degree partitions (like $x^a \cdot x^b$) that sum to the target degree. This avoids unnecessary full expansion.

Q10. Which one of the following shapes can be used to tile (completely cover by repeating) a flat plane, extending to infinity in all directions, without leaving any empty spaces in between them? The copies of the shape used to tile are identical and are not allowed to overlap.

- (A) circle
- (B) regular octagon
- (C) regular pentagon
- (D) rhombus

Correct Answer: (D) rhombus

Solution:

Step 1: Use tessellation criteria for regular polygons.

A regular n -gon tessellates the plane by itself only if its interior angle α divides 360° , i.e.

$\frac{360^\circ}{\alpha}$ is an integer. - Regular octagon: $\alpha = 135^\circ \Rightarrow \frac{360}{135} = \frac{8}{3}$ (not integer) $\Rightarrow$ cannot tile alone.

- Regular pentagon: $\alpha = 108^\circ \Rightarrow \frac{360}{108} = \frac{10}{3}$ (not integer) $\Rightarrow$ cannot tile.

Step 2: Check circle.

Circles leave unavoidable gaps when packed in the plane (curved boundaries cannot meet to fill all space) $\Rightarrow$ cannot tile without overlaps/gaps.

Step 3: Check rhombus.

A rhombus is a parallelogram. Any parallelogram tessellates the plane by simple translations. Around a point, two acute angles and two obtuse angles of a rhombus fit to make $360^\circ \Rightarrow$ perfect tiling without gaps/overlaps.

Final Answer:

(D) rhombus

Quick Tip

Regular polygons tessellate by themselves only if their interior angle divides 360° . All parallelograms (including rectangles, squares, and rhombi) always tessellate by translation.

Q11. Which one of the following is an example of **mechanical potential energy**?

- (A) Activated neuron
- (B) Polarized cell membrane
- (C) Stretched tendon
- (D) Relaxed muscle

Correct Answer: (C) Stretched tendon

Solution:

Step 1: Identify the kind of energy asked.

Mechanical potential energy is energy stored due to position or deformation in a mechanical system (gravitational or elastic). For elastic bodies, it is the strain energy stored when they are stretched or compressed.

Step 2: Classify each option by energy type.

- **Activated neuron** — mainly represents an electrochemical state change (ion flux and membrane depolarization). This is not mechanical potential energy.
- **Polarized cell membrane** — an electrical potential across the membrane (voltage). Again, not mechanical potential energy.
- **Stretched tendon** — an elastic connective tissue under tension; energy is stored as elastic strain energy and can be released to do mechanical work (e.g., during recoil in movement). This $\Rightarrow$ **mechanical potential energy**. **Relaxed muscle** *|near — rest length and minimal elastic strain; does not emphasize stored mechanical potential energy.*

Final Answer:

(C) Stretched tendon

Quick Tip

If the question says **mechanical potential** energy, look for **position or deformation** (height, stretch, compression). Electrical or chemical states are not mechanical.

Q12. A research team studies the probability of crop damage by wild boar in crop fields. For each field, they record 1 if damage was observed and 0 if not. Which distribution is most appropriate to analyse the probability of crop damage?

- (A) Binomial distribution
- (B) Poisson distribution
- (C) Cauchy distribution
- (D) Gamma distribution

Correct Answer: (A) Binomial distribution

Solution:

Step 1: Recognize the data type.

Each field produces a **binary** outcome: damaged = 1 or not damaged = 0. For a single field this is a **Bernoulli** trial with success probability $p = \text{Pr}(\text{damage})$.

Step 2: Aggregate across many fields.

If n independent fields are observed under similar conditions, the total number of damaged fields X follows

$$X \sim \text{Binomial}(n, p),$$

because X is the sum of n independent $\text{Bernoulli}(p)$ variables. Inference for p (including proportion estimates and logistic models) uses the binomial likelihood.

Step 3: Eliminate other options.

- **Poisson** models counts of events in continuous space/time with rate parameter; not appropriate for fixed- n binary trials.
- **Cauchy** is a continuous distribution with heavy tails; irrelevant here.
- **Gamma** is continuous on $(0, \infty)$; used for waiting times or positive continuous quantities, not binary outcomes.

Final Answer:

(A) Binomial distribution

Quick Tip

Binary outcome per trial $\Rightarrow$ use **Bernoulli** for one trial and **Binomial** for the sum over n independent, identical trials. Poisson is for counts with no fixed number of trials.

Q13. To test whether body size differs between two populations of a field mouse species, a researcher measured 100 individuals in each population and calculated the statistic

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where $\bar{X}_1$ and $\bar{X}_2$ are the sample means, S_p is the pooled standard deviation, and n_1, n_2 are the sample sizes.

- (A) Chi-square test
- (B) Kruskal-Wallis test
- (C) Student's t-test
- (D) Mann-Whitney U test

Correct Answer: (C) Student's t-test

Solution:

Step 1: Recognize the test statistic form.

The given statistic has the canonical (difference of means) / (pooled SE) form:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}, \quad S_p = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}.$$

This is the **two-sample (pooled-variance) Student's t-test** statistic with degrees of freedom $df = n_1 + n_2 - 2$.

Step 2: State assumptions/setting.

Independent random samples from two populations, approximately normal (or large n), and $\sigma_1^2 = \sigma_2^2$ (equal variances) $\Rightarrow use pooled S_p$.

Step 3: Eliminate distractors.

- **Chi-square test:** used for categorical counts or variance tests, not two means.
- **Kruskal-Wallis:** nonparametric > 2 groups; here there are two.
- **Mann-Whitney U:** nonparametric two-sample location test; does not use S_p or a t ratio.

Final Answer:

(C) Student's two-sample (pooled) t-test

Quick Tip

If you see $\bar{X}_1 - \bar{X}_2$ divided by $S_p \sqrt{1/n_1 + 1/n_2}$ with $df = n_1 + n_2 - 2$, it's the **pooled** two-sample t-test. No pooling (Welch's t) uses group-wise S_1, S_2 and Satterthwaite df .

Q14. Which ecological process best explains the observation that **seedling establishment increases with distance from the parent tree** in a forest?

- (A) Competition between species
- (B) Competition within species
- (C) Facilitation between species

(D) Facilitation within species

Correct Answer: (B) Competition within species

Solution:

Step 1: Link the pattern to classic theory.

The pattern “higher survival farther from the parent” is the **Janzen–Connell** effect: near the parent, conspecific seedlings suffer high mortality due to density-dependent competition and host-specific enemies (pathogens/herbivores).

Step 2: Interpret the options.

- **Competition within species (conspecific)**
 $\Rightarrow$ *strongest near parent where seed/seedling density of the same species is highest* $\Rightarrow$ survival increases with distance.
- **Competition between species** cannot by itself explain a distance-from-parent gradient tied to one species.
- **Facilitation** predicts improved performance *near* benefactors, opposite to the observation.

Final Answer:

(B) Competition within species (conspecific negative density dependence)

Quick Tip

If success increases as you move away from the parent, think **conspecific negative density dependence** (Janzen–Connell): crowding + host-specific enemies near the parent reduce survival.

Q15. In the early 20th century, which scientist made fundamental contributions to both **evolution** and **statistics**?

- (A) R. A. Fisher
- (B) Niko Tinbergen
- (C) August Weismann
- (D) Thomas Huxley

Correct Answer: (A) R. A. Fisher

Solution:

Step 1: Recall Fisher's dual legacy.

Ronald A. Fisher was a founder of **modern statistics** (ANOVA, maximum likelihood, F-distribution, experimental design) and a key architect of the **modern evolutionary synthesis** (population genetics; *The Genetical Theory of Natural Selection*, 1930; fundamental theorem of natural selection).

Step 2: Eliminate the distractors.

- **Tinbergen** — pioneer of ethology (behaviour), Nobel laureate; not a founder of statistics.
- **Weismann** — crucial evolutionary theorist (germ-plasm theory), but not known for statistics.
- **Huxley** — eminent biologist/communicator ("Darwin's bulldog"); again, not a statistician.

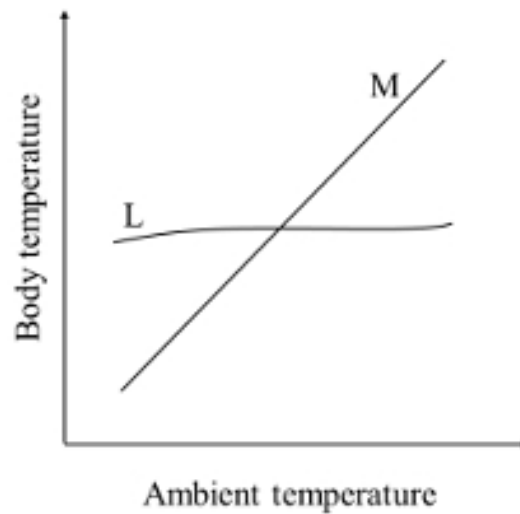
Final Answer:

(A) R. A. Fisher

Quick Tip

A quick mnemonic: **"Fisher = F-test/F-distribution** $\Rightarrow$ *statistics; also Fisher's fundamental theorem $\Rightarrow$ evolution."*

Q16. The figure shows body temperature vs. ambient temperature for two species (L and M). Which statement about temperature regulation is correct?



- (A) L and M are both homeotherms.
- (B) L and M are both poikilotherms.
- (C) L is a homeotherm, whereas M is a poikilotherm.
- (D) L is a poikilotherm, whereas M is a homeotherm.

Correct Answer: (C) L is a homeotherm, whereas M is a poikilotherm.

Solution:

Step 1: Read the graph carefully.

- Curve for **L** is nearly *horizontal*: body temperature of L stays almost constant despite changes in ambient temperature.
- Curve for **M** has a *positive slope* (almost a 1:1 line): body temperature of M increases with ambient temperature.

Step 2: Recall definitions.

- **Homeotherm**: maintains a relatively constant internal temperature across a range of ambient temperatures.
- **Poikilotherm**: body temperature varies with ambient temperature.

Step 3: Classify L and M.

Horizontal line $\Rightarrow$ $constant T_b \Rightarrow$ **L is homeotherm.**

Sloped line $\Rightarrow$ $variable T_b \Rightarrow$ **M is poikilotherm.**

Step 4: Match with options.

Only option (C) states “L homeotherm; M poikilotherm.”

Final Answer:

(C) L is a homeotherm; M is a poikilotherm

Quick Tip

On a T_{body} vs T_{ambient} plot: **flat** curve $\Rightarrow$ *homeothermy*; **diagonal** curve $\Rightarrow$ *poikilothermy*.

Q17. You are a deep-sea organism and potential mates are several hundreds of kilometers away. Which kind of mating signal is most likely to help them locate you?

- (A) Display gestures
- (B) Electric pulses
- (C) Body colouration
- (D) Sounds

Correct Answer: (D) Sounds

Solution:

Step 1: Consider deep-sea constraints.

- Very low/no light $\Rightarrow$ *visual cues (gestures, colour) are ineffective at long range.*
- Seawater attenuates electrical signals strongly; electric fields are detectable only over short distances.

Step 2: Physics of signal propagation in water.

Low-frequency sound travels the farthest in the ocean, sometimes over hundreds of kilometers (SOFAR channel), making it ideal for long-distance mate attraction.

Step 3: Evaluate options.

- (A) Gestures: require line-of-sight; ineffective.
- (B) Electric pulses: short-range only.
- (C) Body colouration: useless in darkness and at long distances.
- (D) **Sounds**: best long-range signal in water.

Final Answer:

(D) Sounds

Quick Tip

Match the signal to the medium: in water, **sound** carries far; in air, visual/chemical cues may dominate depending on context.

Q18. Which option shows the correct order of biological organization levels? (B – biomes; E – ecosystems; P – populations; I – individuals; C – communities)

- (A) $I < P < C < E < B$
- (B) $I < C < P < E < B$
- (C) $I < E < C < P < B$
- (D) $I < P < E < C < B$

Correct Answer: (A) $I < P < C < E < B$

Solution:

Step 1: Define each level succinctly.

Individual (I): one organism.

Population (P): all individuals of a species in an area.

Community (C): interacting populations (multiple species).

Ecosystem (E): community + abiotic environment (energy/material flows).

Biome (B): large regional complex of ecosystems with characteristic climate/vegetation (e.g., tropical rainforest).

Step 2: Order from smallest to largest.

$$I \Rightarrow P \Rightarrow C \Rightarrow E \Rightarrow B.$$

This matches option (A) only.

Final Answer:

$$(A) I < P < C < E < B$$

Quick Tip

Remember the ladder: **I**ndividual $\Rightarrow$ **P**opulation $\Rightarrow$ **C**ommunity $\Rightarrow$ **E**cosystem $\Rightarrow$ **B**iome.

Q19. Which one of the following options describes the difference between **abiotic resources** and **abiotic conditions**?

- (A) Resource levels can fluctuate but conditions do not.
- (B) Conditions can fluctuate but resource levels do not.
- (C) Resources can be used up by organisms, whereas conditions cannot.
- (D) Conditions can be used up by organisms, whereas resources cannot.

Correct Answer: (C) Resources can be used up by organisms, whereas conditions cannot.

Solution:

Step 1: Recall precise ecological definitions.

Resources are environmental factors that *organisms consume or deplete* as they are used (e.g., light, water, nutrients, prey). Their availability to others *decreases* as one organism uses them.

Conditions are physical/chemical attributes of the environment that *influence* organisms but are *not consumed* (e.g., temperature, pH, salinity).

Step 2: Evaluate each option using the definitions.

- (A) Incorrect: both resources (e.g., light) *and* conditions (e.g., temperature) can fluctuate.
- (B) Incorrect: same reason as (A); resources also vary in time/space.
- (C) Correct: captures the key difference — consumable vs. non-consumable.
- (D) Incorrect: the opposite of the correct statement.

Final Answer:

(C) Resources can be used up; conditions cannot

Quick Tip

Ask: “If one organism uses it, is there less left for others?” If yes $\Rightarrow$ **resource**; *if no(it just affects performance)* $\Rightarrow$ **condition**.

Q20. Which of the following ranges correctly represents the **percentage of energy** transferred from a lower to the next higher trophic level in most terrestrial systems?

- (A) 0.01% to 1%
- (B) 33% to 66%
- (C) 2% to 20%
- (D) 90% to 95%

Correct Answer: (C) 2% to 20%

Solution:

Step 1: Use trophic transfer efficiency (TTE).

In terrestrial ecosystems, the fraction of energy passed from one trophic level to the next (TTE) typically averages about $\sim 10\%$, but varies with food quality, physiology, and environment — commonly a few percent up to about one-fifth.

Step 2: Check ranges against known values.

- (A) 0.01% – 1%: too low for *most* terrestrial systems (would imply extremely inefficient transfer).
- (B) 33% – 66%: far too high; such efficiencies are unrealistic for trophic steps.
- (C) 2% – 20%: encompasses the usual variability and the classic “10% rule.”
- (D) 90% – 95%: impossible; would violate basic energetic losses (respiration, heat).

Final Answer:

(C) 2% to 20%

Quick Tip

Remember the heuristic: about ~ 10% of energy moves up each trophic step; a reasonable real-world band is **2% – 20%**.

Q21. Whales and dolphins are hypothesized to have evolved along the northern shore of the Tethys Sea, prior to the Indian plate’s collision with the Eurasian plate. To which of the following animals are these aquatic mammals most closely related?

- (A) pigs
- (B) elephants
- (C) seals
- (D) zebras

Correct Answer: (A) pigs

Solution:

Step 1: Recall the current phylogeny of Cetacea.

Molecular and fossil evidence places whales and dolphins (order *Cetacea*) inside the even-toed ungulates (*Artiodactyla*); together they form *Cetartiodactyla*. Their **closest living relatives** are hippos.

Step 2: Map each option to major mammalian clades.

- **Pigs** — artiodactyls (same larger clade as hippos and, by extension, cetaceans).
- **Elephants** — Afrotheria (*Proboscidea*); distant.
- **Seals** — Carnivora (pinnipeds); distant.
- **Zebras** — odd-toed ungulates (*Perissodactyla*); distant.

The option closest to cetaceans among those listed is **pigs** (shared membership within Artiodactyla).

Final Answer:

(A) pigs

Quick Tip

If “hippos” isn’t an option, pick another **artiodactyl** (e.g., pigs, deer, camels) as the closest relative to whales/dolphins—never carnivores, perissodactyls, or afrotheres.

Q22. Which one of the following options represents the correct order of **decreasing** average net primary productivity (NPP; $\text{g m}^{-2} \text{yr}^{-1}$) in natural ecosystems?

- (A) Swamp and marshes > Tropical forests > Temperate forests > Temperate grasslands > Tundra
- (B) Swamps and marshes > Tropical forests > Temperate forests > Tundra > Temperate grasslands
- (C) Tropical forests > Swamps and marshes > Temperate forests > Tundra > Temperate grasslands
- (D) Tropical forests > Swamps and marshes > Temperate forests > Temperate grasslands > Tundra

Correct Answer: (A) Swamp and marshes > Tropical forests > Temperate forests > Temperate grasslands > Tundra

Solution:

Step 1: Core idea of NPP.

NPP measures the rate at which plants convert solar energy into biomass after respiration.

High water and nutrient availability $\Rightarrow$ *high NPP*; *cold or dry conditions* $\Rightarrow$ *low NPP*.

Step 2: Typical relative productivities.

- **Swamps & marshes** (waterlogged, nutrient-rich) have among the *highest* NPP ($\sim 2000\text{--}2500\text{ g m}^{-2}\text{ yr}^{-1}$).
- **Tropical forests** are also very high ($\sim 1800\text{--}2200$).
- **Temperate forests** are moderate ($\sim 1000\text{--}1300$).
- **Temperate grasslands** are lower ($\sim 400\text{--}800$).
- **Tundra** is the *lowest* among these ($\sim 100\text{--}200$) due to cold and short growing season.

Step 3: Arrange in decreasing order and match.

Swamps/marshes > Tropical forests > Temperate forests > Temperate grasslands > Tundra $\Rightarrow$

matches option (A). Option (B) misorders grasslands and tundra; (C) and (D) incorrectly place tropical forests.

Final Answer:

(A) Swamps & marshes > Tropical forests > Temperate forests > Temperate grasslands > Tundra

Quick Tip

Think “**warm + wet = high NPP.**” Wetlands often exceed tropical forests because constant water and nutrients drive very rapid plant growth.

Q23. The increase in mean global temperature since the Industrial Revolution falls in the range of:

- (A) 0°C to 0.5°C
- (B) 0.5°C to 2°C
- (C) 2°C to 5°C

(D) $> 5^{\circ}\text{C}$

Correct Answer: (B) 0.5°C to 2°C

Solution:

Step 1: Historical context.

Since the mid-19th century (Industrial Revolution), greenhouse gas emissions from fossil fuel burning and deforestation have increased atmospheric CO_2 and other GHGs, driving global warming.

Step 2: Observed global temperature rise.

According to the IPCC and other scientific reports, global average surface temperature has risen by approximately $\sim 1.1^{\circ}\text{C}$ above pre-industrial levels as of the 2010s–2020s.

Step 3: Match to answer ranges.

- Option (A) $0 - 0.5^{\circ}\text{C}$: too low; this was true only by early 20th century. - Option (B) $0.5 - 2^{\circ}\text{C}$: correct, current observed increase lies here. - Option (C) $2 - 5^{\circ}\text{C}$: corresponds to projected future warming scenarios, not past. - Option (D) $> 5^{\circ}\text{C}$: far beyond observed values.

Final Answer:

(B) 0.5°C to 2°C

Quick Tip

Remember: as of today, global warming since pre-industrial levels is around 1.1°C . The Paris Agreement targets keeping warming below 2°C , ideally 1.5°C .

Q24. Which one of the following endangered species has been the subject of a reintroduction plan in India?

(A) Rusty spotted cat

- (B) Jungle cat
- (C) Cheetah
- (D) Jaguar

Correct Answer: (C) Cheetah

Solution:

Step 1: Background on cheetahs in India.

- The Asiatic cheetah (*Acinonyx jubatus venaticus*) once roamed India but was declared **extinct in the wild in India** by the 1950s. - India has since launched a high-profile **Cheetah Reintroduction Project**, bringing African cheetahs from Namibia and South Africa.

Step 2: Evaluate other options.

- **Rusty spotted cat** — native to India, still present (not extinct), no reintroduction program.
- **Jungle cat** — widespread, not under reintroduction.
- **Jaguar** — native to the Americas, not India.

Step 3: Conclude.

Only the **cheetah** has been the subject of an active and well-publicized reintroduction program in India (notably in Kuno National Park, Madhya Pradesh, starting 2022).

Final Answer:

(C) Cheetah

Quick Tip

The **Cheetah Reintroduction Project (India, 2022)** is the world's first intercontinental large carnivore translocation. Remember: cheetah = extinct in India, being reintroduced.

Q25. Compared with bony fish, many shark species show steeper population declines in response to heavy fishing pressure. Which one of the following options explains this?

- (A) Sharks are dangerous to humans.
- (B) Sharks evolved over 400 million years ago.
- (C) Sharks are long lived and late maturing.
- (D) Sharks are only found in open oceans.

Correct Answer: (C) Sharks are long lived and late maturing.

Solution:

Step 1: Recall life-history differences.

Many sharks are **K-selected**: slow growth, **late age at maturity**, low fecundity (few pups), and long lifespans. Bony fishes targeted by fisheries often have **faster** life histories (earlier maturity, many eggs), allowing quicker rebound.

Step 2: Link life history to decline under fishing.

High fishing mortality removes breeding adults. If a species matures late and produces few offspring, the replacement rate is low $\Rightarrow$ populations **decline faster and recover slowly** under sustained harvest.

Step 3: Evaluate options.

- (A) Human danger is irrelevant to demographic decline.
- (B) Ancient origin does not determine present recovery rates.
- (C) **Correct:** late maturity + longevity + low fecundity $\Rightarrow$ steep declines.
- (D) False: many sharks use coastal/nursery habitats; distribution alone doesn't explain steep declines.

Final Answer:

(C) Long-lived and late-maturing life history leads to steep declines

Quick Tip

For fisheries vulnerability, look for **late maturity**, **low fecundity**, and **long lifespan**. These traits signal slow population growth and high collapse risk under heavy harvest.

Q26. Which one or more of the following options describe(s) how **ferns** differ from **angiosperms** and **gymnosperms**?

- (A) Ferns lack a vascular system.
- (B) Ferns have separate haploid and diploid generations.
- (C) Ferns are pollinated by flies.
- (D) Ferns are known only from the fossil record.

Correct Answer: (B) Ferns have separate haploid and diploid generations.

Solution:

Step 1: Core reproductive difference.

Ferns show **alternation of generations** with both phases **free-living**: a multicellular haploid *gametophyte* (prothallus) and a multicellular diploid *sporophyte*.

In seed plants (angiosperms and gymnosperms), the haploid gametophytes are **highly reduced and dependent** on the sporophyte (pollen grain and embryo sac), not separate free-living plants. ⇒ (B) captures the key difference.

Step 2: Eliminate distractors.

- (A) False — ferns are **vascular** plants (pteridophytes) with xylem and phloem.
- (C) False — ferns reproduce by **spores**, not by pollination (no flowers/pollen).
- (D) False — many fern species are extant and common today; they are not only fossils.

Final Answer:

(B) Separate (free-living) haploid and diploid generations in ferns

Quick Tip

Think: **Ferns = spores + free-living gametophyte**; **Seed plants = seeds + tiny, dependent gametophytes (pollen/embryo sac)**. Ferns are vascular; pollination applies only to seed plants.

Q29. Depending on soil nutrient availability, which one or more of the following interaction(s) can occur between soil mycorrhizal fungi and plants?

- (A) Parasitism
- (B) Predation
- (C) Mutualism
- (D) Commensalism

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

Solution:

Step 1: Recall what mycorrhizae do.

Mycorrhizal fungi exchange soil nutrients (P, N, water) for photosynthate (carbon) from the plant roots. The **net effect** depends on how limiting nutrients are in the soil.

Step 2: Classify interaction by cost–benefit to the plant.

- **Nutrient-poor soils:** Fungal hyphae greatly increase nutrient uptake $\Rightarrow$ plant gains $>$ carbon paid $\Rightarrow$ **Mutualism** (both benefit) $\Rightarrow$ (C) true.
- **Nutrient-rich soils:** Plant can acquire nutrients without the fungus; fungus still demands carbon $\Rightarrow$ plant pays cost with little/zero return $\Rightarrow$ **Parasitism** (fungus benefits, plant harmed) $\Rightarrow$ (A) true.
- **Intermediate/neutral cases:** Net effect on plant ≈ 0 while fungus still gains carbon $\Rightarrow$ **Commensalism** $\Rightarrow$ (D) can occur.

Step 3: Eliminate the remaining option.

(B) **Predation** involves one organism killing/consuming another whole or in part; root colonization by mycorrhizae is not predation.

Final Answer:

(A) Parasitism, (C) Mutualism, (D) Commensalism

Quick Tip

Think of mycorrhizae as a **trade**. If soil nutrients are scarce, the plant needs the trade (mutualism). If nutrients are abundant, the trade can turn **costly** (parasitism) or **neutral** (commensalism).

Q30. Which one or more of the following is/are characteristic of r -selected animals?

- (A) They have a long lifespan.
- (B) They produce a large number of offspring in each reproductive event.
- (C) They produce a few large bodied offspring in each reproductive event.
- (D) They reproduce at a young age.

Correct Answer: (B) and (D)

Solution:

Step 1: Recall r - vs. K -selection.

r -selected species: high intrinsic growth rate r ; early maturity, short lifespan, small body size, **many small offspring**, minimal parental care, thrive in variable/disturbed habitats.

K -selected species: late maturity, long lifespan, **few large offspring**, substantial parental care, stable environments.

Step 2: Match options.

- (A) Long lifespan $\Rightarrow K$ -selected, so **false**.
- (B) Large number of offspring per event $\Rightarrow r$ -selected, so **true**.

- (C) Few large-bodied offspring $\Rightarrow$ *K*-selected, so **false**.
- (D) Reproduce at a young age $\Rightarrow$ ***r*-selected**, so **true**.

Final Answer:

(B) and (D)

Quick Tip

Mnemonic: **r** = **r**apid—early, many, small, short-lived. **K** = **K**are—late, few, large, long-lived.

Q31. Which one or more of the following represent(s) benefits of **Batesian mimicry** to the mimic?

- (A) Increased toxicity against potential predators
- (B) Reduced cooperation
- (C) Increased protection from predators without investment in toxicity
- (D) Reduced competition

Correct Answer: (C) Increased protection from predators without investment in toxicity

Solution:

Step 1: Define Batesian mimicry.

A **palatable/harmless** species (the mimic) evolves to **resemble** an **unpalatable/toxic** model species. Predators that have learned (or evolved) to avoid the model also avoid the mimic $\Rightarrow$ *the mimic gains anti-predator protection*.

Step 2: Identify the key benefit to the mimic.

Protection is achieved **without paying the biochemical/physiological costs** of producing toxins or other defenses. Hence option (C) captures the benefit exactly.

Step 3: Eliminate distractors.

- (A) Wrong: the mimic *does not* become more toxic; it only *looks* like a toxic model.
- (B) Irrelevant: “cooperation” is not central to mimicry.
- (D) Not a standard or causal benefit; mimicry targets predation risk, not interspecific resource competition.

Final Answer:

(C) Increased protection without investing in toxicity

Quick Tip

Batesian mimicry = **bluff defense**: safe species looks dangerous. Müllerian mimicry = **shared signal** among genuinely harmful species.

Q32. Which one or more of the following is/are developmental feature(s) of hatchlings of an **altricial** bird species?

- (A) Eyes open
- (B) Eyes closed
- (C) Down feathers present
- (D) Down feathers absent

Correct Answer: (B) Eyes closed **and** (D) Down feathers absent

Solution:

Step 1: Recall altricial vs. precocial.

Altricial chicks hatch **underdeveloped**: eyes often **closed**, body largely **naked** (down absent or very sparse), immobile, and highly dependent on parental care.

Precocial chicks hatch **well-developed**: eyes open, covered with down, mobile soon after hatching, and more independent.

Step 2: Match features.

- (A) Eyes open $\Rightarrow$ **precocial** $\Rightarrow$ *not altricial*. (B) Eyes closed $\Rightarrow$ *characteristic of* **altricial**.
- (C) Down present $\Rightarrow$ **precocial**. (D) Down absent (or very sparse) $\Rightarrow$ **altricial**.

Final Answer:

(B) and (D)

Quick Tip

Mnemonic: **Altricial** = **A**ssistance needed (eyes closed, naked, nest-bound). **Precocial** = **P**repared at birth (eyes open, downy, mobile).

Q33. You have a biased coin with the probability of getting a head being $p = 0.6$. The probability of getting at least 1 head in $n = 3$ tosses is _____. (*Rounded off to three decimal places*)

Correct Answer: 0.936

Solution:

Step 1 (Model).

Let X be the number of heads in 3 tosses. Then $X \sim \text{Binomial}(n = 3, p = 0.6)$. We need $P(X \geq 1)$.

Step 2 (Complement rule).

$$P(X \geq 1) = 1 - P(X = 0) = 1 - (1 - p)^3 = 1 - (0.4)^3 = 1 - 0.064 = 0.936.$$

Step 3 (Check by expansion).

Alternatively,

$$\begin{aligned} P(X \geq 1) &= \sum_{k=1}^3 \binom{3}{k} (0.6)^k (0.4)^{3-k} \\ &= \binom{3}{1} (0.6)(0.4)^2 + \binom{3}{2} (0.6)^2 (0.4) + \binom{3}{3} (0.6)^3 \end{aligned}$$

$$= 3(0.6)(0.16) + 3(0.36)(0.4) + 1(0.216) = 0.288 + 0.432 + 0.216 = 0.936.$$

Rounded to three decimals $\Rightarrow \boxed{0.936}$.

Quick Tip

For “at least one success” in repeated trials, compute $1 - P(\text{none}) = (1 - p)^n$. It’s faster and avoids long expansions.

Q34. A lake has 20 blue males, 30 red males, 60 blue females, and 80 red females. A researcher catches one individual at random. If the caught fish is **blue**, the probability that it is **female** is _____. (*Rounded off to two decimal places*)

Correct Answer: 0.75

Solution:

Step 1 (Interpretation).

We need $P(\text{female} \mid \text{blue})$. Use conditional probability:

$$P(F \mid B) = \frac{P(F \cap B)}{P(B)} = \frac{\#(F \cap B)}{\#(B)}.$$

Step 2 (Count the relevant categories only).

Blue total: $\#(B) = \text{blue males} + \text{blue females} = 20 + 60 = 80$.

Blue females: $\#(F \cap B) = 60$.

Step 3 (Compute).

$$P(F \mid B) = \frac{60}{80} = \frac{3}{4} = 0.75.$$

Rounded to two decimals $\Rightarrow \boxed{0.75}$.

Quick Tip

When a condition is stated (e.g., “*if it is blue*”), restrict your denominator to that condition first; then count the favorable cases within that subset.

Q35. A researcher fitted a function to show how foraging rate F (items per 10 min) varies with group size G (number of individuals):

$$\log_e F = 3 - 0.2 \log_e G.$$

According to this equation, the foraging rate F of a **solitary** forager is ____ items per 10 minutes. (*Rounded to the nearest integer*)

Correct Answer: 20

Solution:

Step 1 (Rewrite the model).

Exponentiate both sides to reveal the power-law form:

$$\log_e F = 3 - 0.2 \log_e G \Rightarrow F = e^3 e^{-0.2 \log_e G} = e^3 G^{-0.2}.$$

Thus, F declines with group size with elasticity -0.2 (a 1% increase in G reduces F by 0.2%).

Step 2 (Plug in solitary group size).

Solitary $\Rightarrow G = 1$. Note $\log_e 1 = 0$ and $1^{-0.2} = 1$:

$$F = e^3 \cdot 1 = e^3 \approx 20.085537 \text{ items/10 min.}$$

Step 3 (Round carefully).

Nearest integer: $F \approx \boxed{20}$ items per 10 minutes.

Quick Tip

Equations of the form $\log F = a + b \log G$ are **power laws**: $F = e^a G^b$. For $G = 1$, $\log G = 0$, so $F = e^a$ immediately.

Q36. Two species of birds, A and B, are found together in region X. Only species A is present in region Y. Both species produce *species-specific* alarm calls to a predator P . A researcher plays back recorded calls of both species to species A in regions X and Y. The responses of species A are summarized below.

Call stimulus	Response in region X	Response in region Y
Alarm call of species A	Species A flies for cover	Species A flies for cover
Alarm call of species B	Species A flies for cover	Species A does not respond

Based on the results, the most appropriate inference is that

- (A) species A's response to species B's alarm call is a learned behavior.
- (B) species A's response to species B's alarm call is an innate behavior.
- (C) predator *P* is absent in region Y.
- (D) predator *P* exclusively preys on species B.

Correct Answer: (A) species A's response to species B's alarm call is a learned behavior.

Solution:

Step 1: Use responses to A's own call as a control (innate baseline).

Species A flies for cover to A's alarm call in *both* regions X and Y. Hence, responding to its *own* call is likely **innate** (does not require prior experience with B).

Step 2: Compare responses to B's call across regions.

- In region **X** (A and B coexist), A **does** fly for cover to B's call.
- In region **Y** (B absent), A **does not** respond to B's call.

Step 3: Inference about the mechanism.

A differential response that appears only where A has **opportunity to experience** B's calls (region X) indicates **learning** or experience-dependent association (social learning or conditioning). If the response were **innate**, A would respond to B's call in both regions.

Step 4: Rule out alternatives.

- (C) "Predator *P* is absent in region Y" is unsupported; A still responds to its own alarm call there, indicating perceived risk.
- (D) "*P* exclusively preys on B" is irrelevant; A's learned eavesdropping on B's alarm call better explains the pattern.

Final Answer:

(A) Learned response of species A to species B's alarm call

Quick Tip

When a response occurs only in sympatry (where species co-occur) but not in allopatry, suspect **learning/experience**. If it appears everywhere, think **innate**.

Q37. The table below lists different insects and taxonomic orders. Choose the option that matches each animal to its correct taxonomic order.

Animal	Taxonomic order
P) Moths	i) Hemiptera
Q) True bugs	ii) Orthoptera
R) Crickets	iii) Coleoptera
S) Beetles	iv) Lepidoptera
	v) Diptera

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

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

Solution:

Step 1: Recall hallmark orders.

- **Lepidoptera** — butterflies and **moths** (scaled wings).
- **Hemiptera** — “**true bugs**,” piercing–sucking mouthparts (e.g., stink bugs).
- **Orthoptera** — **crickets**, grasshoppers, katydids (hind-leg jumping; stridulation).
- **Coleoptera** — **beetles** (elytra/hardened forewings).

- **Diptera** — true flies (one pair of wings + halteres).

Step 2: Map animals to orders.

Moths → Lepidoptera (iv), True bugs → Hemiptera (i), Crickets → Orthoptera (ii), Beetles → Co

This matches option (C).

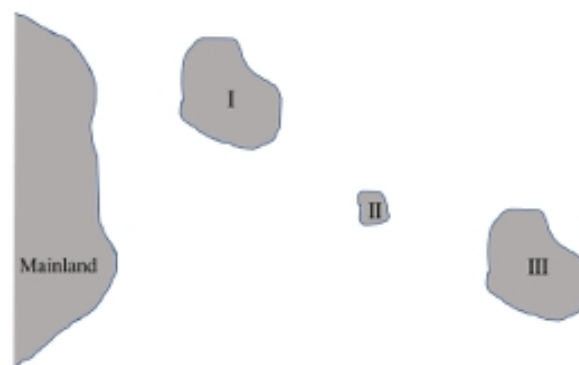
Final Answer:

(C) P–iv; Q–i; R–ii; S–iii

Quick Tip

Four must-know matches: **Lepidoptera** (moths/butterflies), **Coleoptera** (beetles), **Hemiptera** (true bugs), **Orthoptera** (crickets/grasshoppers).

Q38. Islands I, II, and III lie off a mainland coast (see figure). Which statement about species richness is consistent with the **theory of island biogeography**?



- (A) Island II has the highest species richness because it has the lowest area.
- (B) Island III has the highest species richness because it is large and farthest from the mainland.
- (C) Island I has the highest species richness because it is large and closest to the mainland.
- (D) Islands I and III have equally high species richness because they have roughly the same area.

Correct Answer: (C) Island I has the highest species richness because it is large and closest to the mainland.

Solution:

Step 1: Two key predictions of island biogeography.

1. **Area effect:** larger islands have lower extinction rates $\Rightarrow$ higher equilibrium richness.
2. **Distance effect:** islands **closer** to the mainland have higher immigration rates $\Rightarrow$ higher richness.

Step 2: Apply to the map.

From the figure: - **Island I** is **large and near** the mainland $\Rightarrow$ high immigration, low extinction. - **Island II** is **small** (and intermediate distance) $\Rightarrow$ low richness. - **Island III** is **large but far**, so immigration is reduced; richness lower than a similar-sized near island.

Step 3: Evaluate options.

- (A) Incorrect — smallest area gives lowest richness.
- (B) Incorrect — distance reduces immigration despite large area.
- (C) **Correct** — combines both favorable factors (large + near).
- (D) Incorrect — equal areas don't imply equal richness when distances differ.

Final Answer:

(C) Large and close island (I) has the highest species richness

Quick Tip

Think “Species richness up with **S**ize and **S**hort distance.” Large + near wins; small + far loses.

Q39. In a polygynous hummingbird species, males defend and monopolize nectar-rich plants (resource). Females visit these plants for nectar and the defending male will have

access to all visiting females for mating. Under which scenario is **polygyny** expected to be the highest?

- (A) Resources are abundant and evenly distributed.
- (B) Resources are abundant and clumped.
- (C) Resources are scarce and evenly distributed.
- (D) Resources are scarce and randomly distributed.

Correct Answer: (B) Resources are abundant and clumped.

Solution:

Step 1: Identify the mating system mechanism.

This is **resource–defense polygyny**: a male that can *defend a rich patch* gains access to multiple females attracted to the resource.

Step 2: Ask when a male can best monopolize females.

Two conditions maximize monopolization:

- **High resource value** $\Rightarrow$ many females aggregate.
- **Clumped distribution** $\Rightarrow$ defensible by a single male (limited boundary).

Step 3: Evaluate scenarios.

- **Abundant & evenly distributed** — females spread out; hard to monopolize $\Rightarrow$ low polygyny.
- **Abundant & clumped** — females aggregate at defensible patches $\Rightarrow$ **highest polygyny**.
- **Scarce & even/random** — few visits; low male payoff $\Rightarrow$ low polygyny.

Final Answer:

(B) Resources are abundant and clumped
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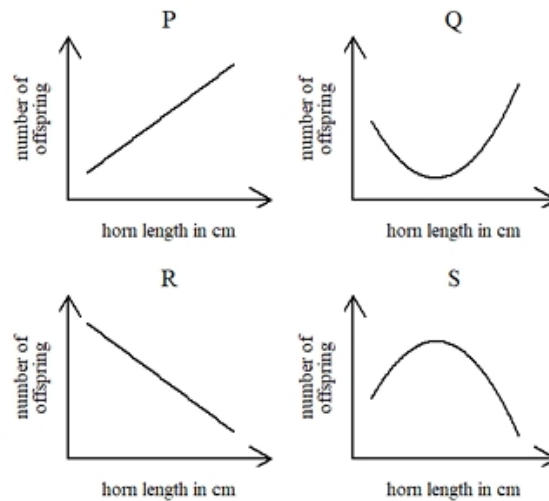
Quick Tip

Resource–defense polygyny peaks when resources are **valuable and clumped**, so one male can defend the patch and intercept many females.

Q40. A researcher estimates the relationship between reproductive success N (number of offspring) and horn length H (cm) in a wild goat as

$$N = 40 - 2.2H + 0.04H^2.$$

Horn length typically varies from 10 cm to 50 cm. Which graph (P, Q, R, S) correctly represents this relationship?



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

Correct Answer: (B) Q

Solution:

Step 1: Identify the functional form and concavity.

Write $N(H) = aH^2 + bH + c$ with $a = 0.04 > 0$, $b = -2.2$, $c = 40$. Because $a > 0$, the parabola opens **upwards** (convex), so the graph is **U-shaped** and has a single **minimum**.

Step 2: Locate the vertex (minimum) precisely.

Use derivative or completing the square. Derivative method:

$$\frac{dN}{dH} = -2.2 + 0.08H \quad \Rightarrow \quad \frac{dN}{dH} = 0 \quad \Rightarrow \quad H = \frac{2.2}{0.08} = 27.5 \text{ cm.}$$

Completing the square (confirmation):

$$N(H) = 0.04(H^2 - 55H) + 40 = 0.04[(H - 27.5)^2 - 756.25] + 40 = 0.04(H - 27.5)^2 + 9.75,$$

so the minimum value is $N_{\min} = 9.75$ at $H = 27.5$ cm.

Step 3: Check behavior within the biological range $10 \leq H \leq 50$.

Since $10 < 27.5 < 50$, the curve *decreases* for $10 \leq H < 27.5$ and *increases* for $27.5 < H \leq 50$. Evaluate end points to visualize scale:

$$N(10) = 40 - 22 + 4 = 22, \quad N(50) = 40 - 110 + 100 = 30.$$

Thus the relationship over the observed range is clearly **U-shaped**: down to a minimum near $H = 27.5$, then up.

Step 4: Match with the given sketches.

- P: strictly increasing line $\Rightarrow$ not quadratic.
- R: strictly decreasing line $\Rightarrow$ not quadratic.
- S: inverted parabola ($\cap$, concave down) $\Rightarrow a < 0$ case, not ours.
- **Q: U-shaped parabola (convex) with a minimum inside the range $\Rightarrow$ correct.**

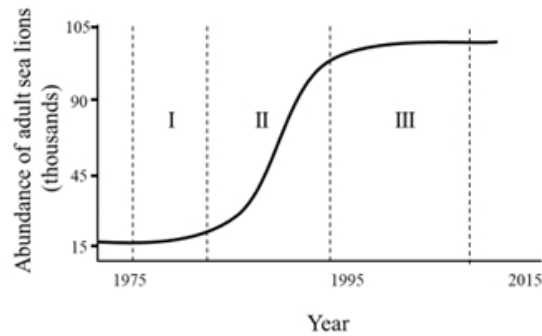
Final Answer:

(B) Q

Quick Tip

For $N = aH^2 + bH + c$: the sign of a sets the shape ($a > 0$: U-shaped; $a < 0$: inverted). The vertex (optimum) is at $H = -\frac{b}{2a}$; completing the square also gives the minimum/maximum value immediately.

Q41. Overfishing reduced food availability for sea lions in California, causing a decline in their population size. In 1972, under the US Endangered Species Act, fishing was banned from sea lion foraging areas. Subsequently, the population of sea lions increased in a *logistic* form as shown in the figure.



The per capita growth rate is highest in the interval _____ and the population growth rate is highest in the interval _____.

- (A) I, II
- (B) I, III
- (C) II, II
- (D) III, II

Correct Answer: (A) I, II

Solution:

Step 1: Recall the logistic-growth model.

Logistic growth is described by

$$\frac{dN}{dt} = rN \left(1 - \frac{N}{K} \right),$$

where N is population size, r the intrinsic rate of increase, and K the carrying capacity.

Step 2: Per-capita growth rate.

Per-capita (per individual) growth is

$$\frac{1}{N} \frac{dN}{dt} = r \left(1 - \frac{N}{K} \right).$$

This decreases linearly with N and is **maximal when N is smallest**. On the S-shaped curve, the smallest N is in the early phase (**interval I**). $\Rightarrow$ *Per-capita growth rate highest in I.*

Step 3: Total population growth rate.

Total growth $\frac{dN}{dt} = rN(1 - N/K)$ is a quadratic function of N with a **maximum at $N = K/2$** . Graphically this is the steepest part of the logistic curve—its midsection—corresponding to **interval II**. $\Rightarrow$ *Population growth rate highest in II.*

Step 4: Conclude.

Per-capita growth: **I**; total growth: **II**. Hence option (A) **I, II**.

Quick Tip

In logistic growth, per-capita rate $r(1 - N/K)$ peaks at **low N** (early phase), while total growth $rN(1 - N/K)$ peaks at $N = K/2$ (mid-slope).

Q42. A locus at Hardy–Weinberg equilibrium in a diploid organism has n alleles. The maximum heterozygosity (i.e., proportion of heterozygotes) for this locus is

- (A) n
- (B) $1/n$
- (C) $1 - \left(\frac{1}{n}\right)$
- (D) $1 - n$

Correct Answer: (C) $1 - \left(\frac{1}{n}\right)$

Solution:

Step 1: Express heterozygosity in terms of allele frequencies.

Let the n allele frequencies be $p_1, \dots, p_n$ with $\sum_i p_i = 1$. Under HWE, the expected heterozygosity

$$H = 1 - \sum_{i=1}^n p_i^2.$$

Step 2: Maximize H subject to $\sum p_i = 1$.

Maximizing H is equivalent to minimizing $\sum p_i^2$. By symmetry/convexity (or by Lagrange multipliers), the sum of squares is minimized when all p_i are equal:

$$p_i = \frac{1}{n} \quad \forall i.$$

Step 3: Evaluate H at the optimum.

$$H_{\max} = 1 - \sum_{i=1}^n \left(\frac{1}{n}\right)^2 = 1 - n \cdot \frac{1}{n^2} = 1 - \frac{1}{n}.$$

Final Answer:

$$1 - \frac{1}{n}$$

Quick Tip

Expected heterozygosity under HWE is $H = 1 - \sum p_i^2$. With a fixed number of alleles, it's maximized when all alleles are *equally frequent*.

Q43. Match the diseases to the pathogens that cause them.

Diseases	Pathogens
P) Avian malaria	i) Virus
Q) COVID-19 in humans	ii) <i>Plasmodium</i>
R) Chytrid disease in frogs	iii) Mosquito
	iv) Fungus

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

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

Solution:

Step 1: Identify the causal agents (pathogens).

- **Avian malaria** is caused by *Plasmodium* species (e.g., *P. relictum*); mosquitoes are *vectors*, not pathogens $\Rightarrow$ **ii**.
- **COVID-19** is caused by the coronavirus SARS-CoV-2 $\Rightarrow$ a **virus** $\Rightarrow$ **i**.
- **Chytrid disease** in frogs is caused by the chytrid fungus *Batrachochytrium dendrobatidis* (Bd) $\Rightarrow$ **iv**.

Step 2: Assemble the mapping.

P–ii, Q–i, R–iv $\Rightarrow$ option (C).

Final Answer:

(C) P–ii; Q–i; R–iv

Quick Tip

Distinguish **pathogens** (disease-causing organisms) from **vectors** (organisms that transmit them). For avian malaria, the pathogen is *Plasmodium*; the mosquito is only the vector.

Q44. The production of anthocyanin pigments in pea flowers requires the presence of at least one dominant allele in each of two independently assorting genes, C and P. The presence of anthocyanin results in purple flowers, whereas its absence gives white flowers. A cross between two double heterozygous (CcPp) plants is performed. What is the expected ratio of plants with purple flowers to plants with white flowers?

- (A) 1 : 3
- (B) 3 : 1
- (C) 5 : 3
- (D) 9 : 7

Correct Answer: (D) 9 : 7

Solution:

Step 1: Condition for purple flowers.

- For purple colour, both genes must contribute at least one dominant allele. - Hence, the genotype must be $C_P_$ (at least one dominant C and one dominant P).

Step 2: Punnett square expansion.

Cross: $CcPp \times CcPp$.

- For gene C : ratio = $1CC : 2Cc : 1cc$. - For gene P : ratio = $1PP : 2Pp : 1pp$.

Step 3: Phenotypic classes.

- Purple flowers: Any genotype with both $C_$ and $P_$. - White flowers: Any genotype missing one dominant allele (i.e., $cc_$ OR $_pp$).

Step 4: Probability calculation.

- Probability of purple = $\Pr(C_ \times \Pr(P_)) = \frac{3}{4} \times \frac{3}{4} = \frac{9}{16}$. - Probability of white = $1 - \frac{9}{16} = \frac{7}{16}$.

Step 5: Final ratio.

Purple : White = 9 : 7

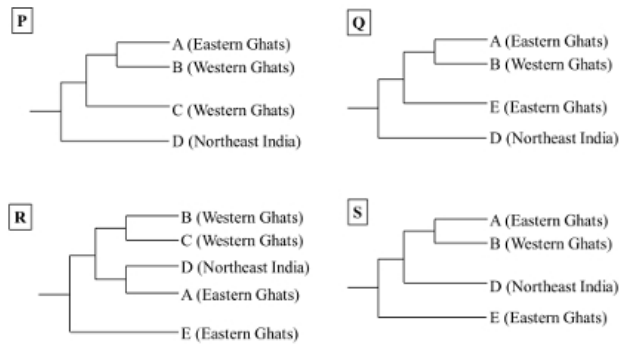
Final Answer:

9 : 7 (Option D)

Quick Tip

This is a classic case of complementary gene interaction, where both genes are required for the expression of the trait (purple colour).

Q45. In the phylogenetic trees shown, the tips represent different species of geckos (A–E) and the areas they belong to. Which tree is most consistent with the hypothesis that geckos colonized the Western Ghats from Northeast India through the Eastern Ghats?



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

Correct Answer: (A) P

Step 1: Colonization pathway assumption.

The hypothesis states:

Northeast India → Eastern Ghats → Western Ghats

Step 2: Expected phylogenetic structure.

- First split: Northeast Indian species should be basal (ancestral). - Next: Eastern Ghats species should form a sister group (descended next). - Finally: Western Ghats species should branch from the Eastern Ghats lineage.

Step 3: Check the given trees.

- **Tree P:** D (Northeast India) diverges first, then A (Eastern Ghats), and later B, C (Western Ghats). This exactly matches the colonization hypothesis.
- Trees Q, R, and S do not show the stepwise NE → Eastern Ghats → Western Ghats order.

Step 4: Final conclusion.

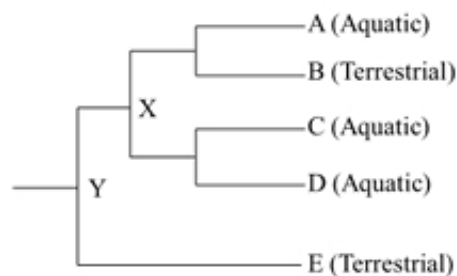
Therefore, the tree that best supports the hypothesis is Tree P.

Final Answer:

Quick Tip

When testing biogeographic hypotheses, look for trees where the geographic distribution of clades matches the predicted colonization pathway.

Q46. The phylogenetic tree depicts relationships among five snake species (A–E) and their habitat specializations (Aquatic or Terrestrial). Given parsimony (least number of changes) and that ancestor Y was terrestrial, which option about ancestor X is correct?



- (A) X was more likely to be aquatic than terrestrial.
- (B) X was more likely to be terrestrial than aquatic.
- (C) X was equally likely to be aquatic or terrestrial.
- (D) X was neither aquatic nor terrestrial.

Correct Answer: (C) X was equally likely to be aquatic or terrestrial.

Solution:**Step 1: Read tip states on the tree.**

Leaves show: $A = \text{Aquatic}$, $B = \text{Terrestrial}$, $C = \text{Aquatic}$, $D = \text{Aquatic}$, $E = \text{Terrestrial}$.

Node Y (ancestor of all) is given Terrestrial. Node X is the common ancestor of A, B, C, D .

Step 2: Assume $X = \text{Terrestrial}$ and count changes.

If X is Terrestrial, then to match leaves we need:

- One change $T \rightarrow A$ on branch to A .

- One change $T \rightarrow A$ on the branch ancestral to C and D (shared), making both Aquatic.
 - B stays Terrestrial; $Y \rightarrow X$ has no change; E stays Terrestrial.
- $\Rightarrow$ Total changes = 2.

Step 3: Assume $X = \text{Aquatic}$ and count changes.

If X is Aquatic, then:

- One change $T \rightarrow A$ on the branch $Y \rightarrow X$.
 - One change $A \rightarrow T$ on the branch to B to recover Terrestrial.
 - A, C, D remain Aquatic without extra changes; E remains Terrestrial from Y .
- $\Rightarrow$ Total changes = 2.

Step 4: Parsimony decision.

Both assignments of X (Aquatic or Terrestrial) require the same minimum number of changes (2).

$\Rightarrow$ Under parsimony, X is *equally likely* to be Aquatic or Terrestrial.

Final Answer: (C) X was equally likely to be aquatic or terrestrial.

Quick Tip

When reconstructing ancestral states by parsimony, try each candidate state at the focal node and count the minimum changes needed to fit all tips. If the counts tie, the node is ambiguous.

Q47. Speciation in Western Ghats snakes is predominantly allopatric. To quantify diversification most cost- and time-efficiently, how should a researcher sample?

- (A) Across an elevational gradient
- (B) Across barriers such as valleys and rivers
- (C) Intensively in one or two random locations
- (D) Intensively across the entire mountain range

Correct Answer: (B) Across barriers such as valleys and rivers

Solution:

Step 1: Key feature of allopatric speciation.

Allopatric divergence is driven by *geographic barriers* that limit gene flow (valleys, rivers, ridges).

Step 2: Sampling that targets the cause.

To detect/quantify diversification efficiently, sampling should contrast populations *separated by barriers* to capture maximal divergence signals with minimal effort.

Step 3: Eliminate other options.

(A) Elevational gradients may reflect ecological (parapatric) differences, not necessarily isolation by barrier.

(C) Few random sites may miss the key contrasts.

(D) Intensively everywhere is costly and time-inefficient.

Final Answer: (B) Across barriers such as valleys and rivers

Quick Tip

Match your sampling design to the hypothesized speciation mechanism: for allopatry, sample *across* barriers; for ecological divergence, sample *along* environmental gradients.

Q48. All else equal, which population size N and migration rate m yield the *most* genetic differentiation between populations (largest F_{st})? Given $F_{st} = \frac{1}{4Nm + 1}$.

(A) $N = 500$, $m = 1$

(B) $N = 200$, $m = 200$

(C) $N = 40$, $m = 10$

(D) $N = 40$, $m = 1$

Correct Answer: (D) $N = 40$, $m = 1$

Solution:

Step 1: Interpret the formula.

$$F_{st} = \frac{1}{4Nm + 1} \Rightarrow \text{larger } F_{st} \text{ occurs when } 4Nm + 1 \text{ is smallest, i.e., minimize } Nm.$$

Step 2: Compute Nm for each option.

(A) $Nm = 500 \times 1 = 500 \Rightarrow F_{st} \approx \frac{1}{2001}.$

(B) $Nm = 200 \times 200 = 40000 \Rightarrow F_{st} \approx \frac{1}{160001}.$

(C) $Nm = 40 \times 10 = 400 \Rightarrow F_{st} \approx \frac{1}{1601}.$

(D) $Nm = 40 \times 1 = 40 \Rightarrow F_{st} = \frac{1}{161}$ (largest among options).

Final Answer: (D) $N = 40, m = 1$

Quick Tip

In Wright's island model, F_{st} increases as either population size N or migration rate m decreases; the key driver is the product Nm .

Q49. Which one or more of the following is/are prediction(s) or assumption(s) of the handicap principle for the evolution of sexual signals?

- (A) Females prefer costly signals.
- (B) Honest signals are costly to produce.
- (C) Males displaying costly signals are not chosen by females.
- (D) Costly signals are reliable indicators of signaller quality.

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

Solution:

Step 1: Recall the handicap principle.

The handicap principle (Zahavi, 1975) suggests that costly traits/signals evolve because they act as honest indicators of male quality. Only high-quality males can afford to produce and maintain these costly traits.

Step 2: Evaluate each option.

- (A) *Females prefer costly signals.*

Yes — under sexual selection, females are predicted to prefer costly traits because they are harder to fake and thus reflect male fitness.

(B) *Honest signals are costly to produce.*

Yes — costliness is the mechanism ensuring honesty; if signals were cheap, low-quality males could also produce them, making them unreliable.

(C) *Males displaying costly signals are not chosen by females.*

Incorrect — the principle argues the opposite: costly signals *increase* mating success because females prefer them.

(D) *Costly signals are reliable indicators of signaller quality.*

Yes — this is the central assumption. Cost ensures reliability: only strong males can bear the handicap.

Step 3: Combine.

Hence, the assumptions/predictions are (A), (B), and (D).

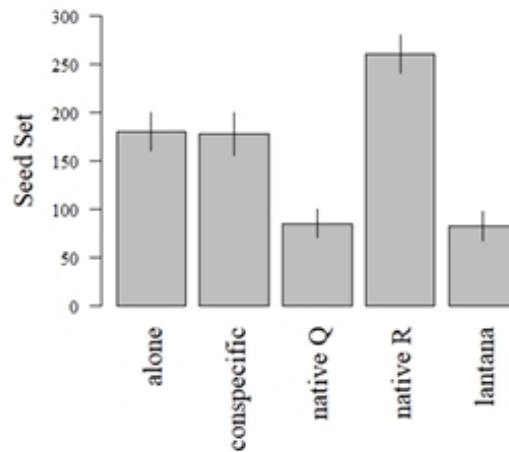
Final Answer:

(A), (B), and (D)

Quick Tip

The handicap principle emphasizes that the *costliness* of a signal ensures its honesty. Females use these signals as cues to male quality, so costly ornaments or displays often evolve under sexual selection.

Q50. A research team tests how neighbours affect the seed set of a native plant *S*: grown (i) alone, (ii) with a conspecific, (iii) with native Q, (iv) with native R, (v) with *Lantana camara*. The bar plot shows mean seed set with 95% CIs. Based on the figure, which option(s) are correct?



- (A) Seed set is higher in the presence of both the native species than in the presence of a conspecific.
- (B) Seed set is lower in the presence of *Lantana camara* than in the presence of both the native species.
- (C) Seed set is lower in the presence of *Lantana camara* than in the presence of a conspecific.
- (D) Seed set is always higher in the presence of other plants than when grown alone.

Correct Answer: (B) and (C)

Solution:

Step 1: Read the pattern from the bars.

Approximate means from the plot:

Alone ~ 160 ; Conspecific ~ 170 ; Native Q ~ 90 ; Native R ~ 250 ; *Lantana* ~ 80 .

Step 2: Check each statement against the plot.

(A) “Both native species $>$ conspecific.”

Native Q (~ 90) is *lower* than conspecific (~ 170). $\Rightarrow$ **False**.

(B) “*Lantana* $<$ both natives.”

Lantana (~ 80) is less than Native Q (~ 90) and much less than Native R (~ 250). $\Rightarrow$ **True**.

(C) “*Lantana* $<$ conspecific.”

Lantana (~ 80) is clearly lower than conspecific (~ 170). $\Rightarrow$ **True**.

(D) “Always higher with other plants than alone.”

With Native Q (~ 90) and with *Lantana* (~ 80), seed set is *lower* than alone (~ 160). $\Rightarrow$ **False.**

Final Answer: (B) and (C)

Quick Tip

When interpreting bar plots with treatments, compare each bar directly to the relevant comparator(s); if the question hinges on “both,” each of the two comparisons must individually satisfy the condition.

Q51. There are two palatable prey species, Q and R, for an insectivorous bird. The bird searches for and consumes only species Q. According to optimal foraging theory, which condition(s) can explain the bird choosing to forage only for Q?

- (A) The handling time for Q $>$ the handling time for R
- (B) The handling time for Q $<$ the handling time for R
- (C) The relative abundance of Q $>$ the relative abundance of R
- (D) The relative abundance of Q $<$ the relative abundance of R

Correct Answer: (B) and (C)

Solution:

Step 1: Profitability in the optimal diet model.

For prey i , profitability $P_i = \frac{E_i}{h_i}$ where E_i is energy/content (or value) and h_i is handling time. Higher $P_i \Rightarrow$ more attractive prey; when encounter rates are not vanishingly low, the predator specializes on the most profitable prey.

Step 2: Compare Q and R via handling time.

If Q has *lower* handling time (all else equal) it has *higher* profitability: $h_Q < h_R \Rightarrow P_Q > P_R$. Thus (B) supports exclusive foraging on Q. Option (A) would make Q *less* profitable $\Rightarrow$ inconsistent.

Step 3: Role of encounter/abundance.

Higher encounter (greater relative abundance) of Q increases intake rate even further and makes specializing on Q more favorable. Hence (C) supports exclusive choice of Q, while (D) works against it.

Final Answer: (B) and (C)

Quick Tip

In the optimal diet model, a predator includes the item with the highest profitability E/h ; higher abundance of that item further promotes specialization on it.

Q52. SLOSS debate: With the same total area, which option(s) describe a conservation *benefit* of protecting several small patches rather than one large patch?

- (A) Lower rates of local extinction
- (B) Lower rates of diversification
- (C) Lower spread of disease across the populations
- (D) Lower population sizes

Correct Answer: (C)

Solution:

Step 1: Features of several small patches.

Multiple patches create a metapopulation: subpopulations are spatially separated, reducing transmission pathways and synchrony of disturbances.

Step 2: Evaluate options.

- (A) Local extinction rates are typically *higher* in small patches (smaller N , stronger drift/demographic stochasticity) — not a benefit.
- (B) Isolation among patches can *increase* diversification (allopatric divergence), so “lower diversification” is not a benefit.
- (C) Spatial separation reduces disease spread between patches $\Rightarrow$ benefit — **True**.
- (D) Smaller population sizes are a drawback, not a benefit — **False**.

Final Answer: (C)

Quick Tip

Many small patches can buffer system-wide risks (disease, fires, storms) via spatial separation, but they often raise local extinction risk; weigh metapopulation rescue and connectivity when designing reserves.

Q53. Which one or more options is/are example(s) of niche partitioning between species?

- (A) Temporal separation of activity
- (B) Diet specialization
- (C) Hybridization
- (D) Vertical stratification of foraging heights

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

Solution:

Step 1: Define niche partitioning.

Niche partitioning is a process by which coexisting species minimize competition by using different resources, or the same resource in different ways, times, or spaces. This promotes coexistence in an ecosystem.

Step 2: Evaluate options.

(A) *Temporal separation of activity.*

Yes — if two species are active at different times of the day or seasons (e.g., one nocturnal, one diurnal), they avoid direct competition.

(B) *Diet specialization.*

Yes — if species focus on different food types or prey sizes, they reduce dietary overlap and competition.

(C) *Hybridization.*

No — hybridization is interbreeding between species and does not reduce competition for resources; in fact, it blurs species boundaries rather than partitioning niches.

(D) *Vertical stratification of foraging heights.*

Yes — many bird and insect species partition habitats vertically (canopy vs understory vs ground), reducing direct competition.

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

Quick Tip

Remember: Niche partitioning involves differences in *time*, *space*, or *diet*. Any mechanism that reduces direct competition can be considered niche partitioning.

Q54. In an assemblage of coexisting wild cat species, the size of canine teeth was found to be strikingly different between species. Which one or more of the following statements explain(s) this observation?

(A) Differences in the size of canine teeth were driven by the size of prey captured by the different species.

(B) Differences in the size of canine teeth are an example of divergent evolution.

(C) Differences in the size of canine teeth are an example of convergent evolution.

(D) Differences in the size of canine teeth were driven by past competition.

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

Solution:

Step 1: Interpret observation.

The cats coexist in the same ecosystem, yet show very different canine sizes. This suggests resource partitioning through morphological divergence, which reduces competition.

Step 2: Evaluate options.

(A) *Prey size drives canine size.*

Yes — larger prey requires stronger, longer canines; smaller prey can be subdued with shorter canines. This is a functional ecological adaptation.

(B) *Divergent evolution*.

Yes — these species diverged morphologically to exploit different prey niches. This is classic divergent evolution, where related species evolve different traits to minimize competition.

(C) *Convergent evolution*.

No — convergent evolution is when unrelated species evolve similar traits due to similar selective pressures. Here, the cats evolved *different* traits, so this is divergence, not convergence.

(D) *Driven by past competition*.

Yes — character displacement often results from interspecific competition, pushing species to evolve distinct morphologies to reduce niche overlap.

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

Quick Tip

When multiple closely related species coexist, strong competition often drives *character displacement*, leading to morphological divergence (e.g., beak size in Darwin's finches, canine size in cats).

Q55. The Biological Species Concept (BSC) defines species as groups of interbreeding natural populations that are reproductively isolated from other such groups. Which one or more of the following options could pose challenges for defining species using the BSC?

- (A) Fertile interspecies hybrids
- (B) Extinct fossil species
- (C) Barriers to gene flow
- (D) Inbreeding depression

Correct Answer: (A) and (B)

Solution:

Step 1: Recall the Biological Species Concept.

The BSC emphasizes *reproductive isolation* as the defining criterion for species. It works well for many sexually reproducing organisms but has limitations in certain cases.

Step 2: Evaluate each option.

(A) *Fertile interspecies hybrids.*

Yes — if two populations can interbreed and produce fertile hybrids (e.g., certain ducks, plants), the reproductive isolation criterion is blurred. This challenges the BSC.

(B) *Extinct fossil species.*

Yes — the BSC relies on reproductive isolation, which cannot be tested for fossils. Thus, extinct species are usually defined using morphological (morphospecies) concepts, not the BSC.

(C) *Barriers to gene flow.*

Not necessarily a challenge — barriers to gene flow (e.g., rivers, mountains) *create* reproductive isolation, which supports the BSC rather than undermining it.

(D) *Inbreeding depression.*

No — inbreeding depression reduces fitness within a population but does not challenge the definition of species boundaries under the BSC.

Step 3: Conclusion.

The main challenges to the BSC are cases where reproductive isolation cannot be applied or is ambiguous, such as fertile hybrids and fossil species.

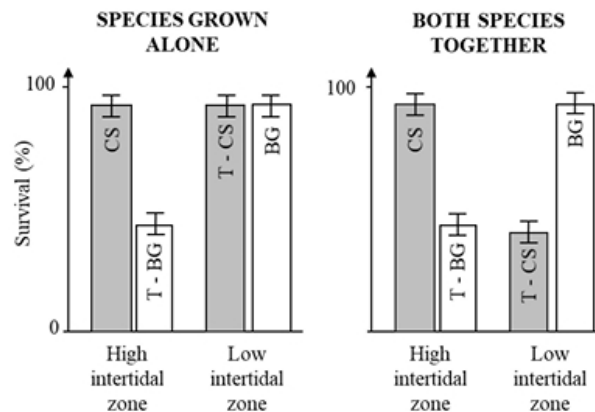
Final Answer: (A) and (B)

Quick Tip

The BSC is powerful for studying living, sexually reproducing organisms but fails for asexual organisms, fossils, and cases with frequent hybridization. Always consider alternative species concepts (morphological, phylogenetic, ecological) in such contexts.

Q56. Two barnacles: *Chthamalus stellatus* (CS, naturally high intertidal) and *Balanus glandula* (BG, naturally low intertidal). Each species was grown (i) alone and (ii)

together, and also transplanted: CS to low (T-CS) and BG to high (T-BG). Survival (%) was recorded. Which inference(s) are consistent with the results?



- (A) Only abiotic conditions increase mortality of BG in the high intertidal zones.
- (B) Only abiotic conditions increase mortality of CS in the low intertidal zones.
- (C) Interspecific competition increases mortality of BG in the high intertidal zone.
- (D) Interspecific competition increases mortality of CS in the low intertidal zone.

Correct Answer: (A) and (D)

Solution:

Step 1: Read the “grown alone” bars (abiotic filter).

- High intertidal: CS has high survival; **T-BG has low survival.**
- Low intertidal: BG has high survival; **T-CS has high survival.**

⇒ BG fails in the *high* zone even without competitors (abiotic stress), whereas CS can survive in the *low* zone when alone (abiotically suitable).

Step 2: Read the “both species together” bars (competition effect).

- High intertidal: CS still high; T-BG still very low ⇒ competition does not further depress BG — mortality there is due to *abiotic* conditions.
- Low intertidal: BG high; **T-CS drops from high (alone) to low (together)** ⇒ strong *interspecific competition* against CS in the low zone.

Step 3: Evaluate statements.

(A) *Only abiotic conditions increase BG mortality in high zone* — **True:** BG is already low when alone; competition adds little/no extra effect.

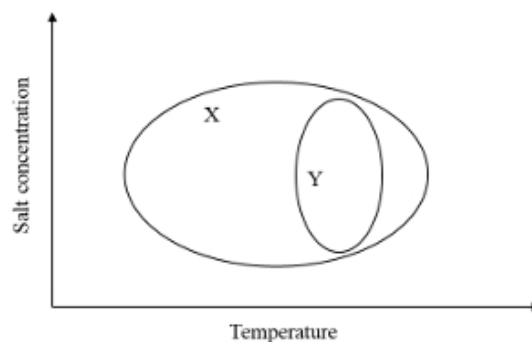
- (B) *Only abiotic conditions increase CS mortality in low zone* — **False**: CS survives well alone in low zone; mortality increases only when BG is present (competition).
- (C) *Competition increases BG mortality in high zone* — **False**: mortality is high even when alone.
- (D) *Competition increases CS mortality in low zone* — **True**: big drop when BG is present.

Final Answer: (A) and (D)

Quick Tip

Use the “alone” treatment to diagnose abiotic limits and the “together” treatment to diagnose biotic interactions; compare the same species and zone across these two panels to attribute causes.

Q57. In the figure, ellipse X represents the combinations of salt concentrations and temperatures a marine invertebrate species can tolerate (its potential physiological range). Ellipse Y represents the combinations of salt concentrations and temperatures where the species is actually found. Which one or more of the following statements about X and Y is/are correct?



- (A) X is the fundamental niche of the species, whereas Y is the realized niche.
- (B) The difference between X and Y can result from biotic interactions.
- (C) The difference between X and Y can result from dispersal limitation.
- (D) The difference between X and Y results from the species' tolerance to salt concentrations.

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

Solution:

Step 1: Define terms.

- The *fundamental niche* is the full set of environmental conditions a species can tolerate in the absence of limiting biotic interactions. - The *realized niche* is the subset of conditions where the species actually occurs, limited by competition, predation, mutualisms, and dispersal.

Step 2: Evaluate options.

(A) *X is fundamental, Y is realized.*

Correct — ellipse X shows potential tolerance, while Y shows actual occurrence.

(B) *Difference due to biotic interactions.*

Correct — competition, predation, or facilitation can prevent species from occupying its entire physiological range.

(C) *Difference due to dispersal limitation.*

Correct — even if conditions are suitable (inside X), the species may not reach those sites, restricting Y further.

(D) *Difference due to tolerance to salt.*

Incorrect — tolerance defines X itself (physiological limits). The gap between X and Y is not due to tolerance but due to external factors (biotic or dispersal).

Step 3: Conclusion.

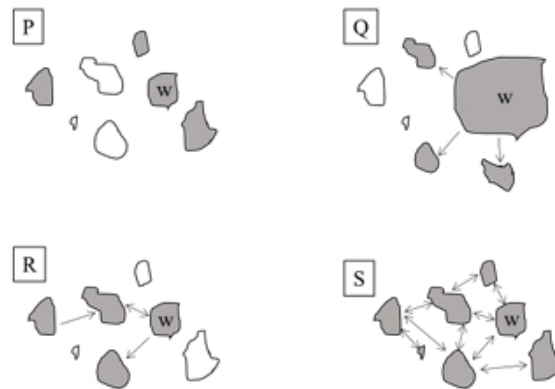
Thus, the correct set of explanations are (A), (B), and (C).

Final Answer: (A), (B), and (C)

Quick Tip

Always distinguish: physiological limits define the *fundamental niche*; realized niche is reduced by competition, predation, or limited dispersal. Tolerance itself sets X, not the X–Y difference.

Q58. A butterfly species inhabits four patchy landscapes (P, Q, R, S). Grey shapes = occupied patches, white = unoccupied. Arrows = directions of dispersal. Which one or more of the options is/are correct?



- (A) In landscape Q, patch w is a source population.
- (B) Landscape R represents a metapopulation.
- (C) Landscape P has the highest extinction rate.
- (D) Landscape S has the highest level of inbreeding.

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

Step 1: Recall concepts.

- A *source population* is a large, stable patch that produces excess individuals that disperse to other patches. - A *metapopulation* is a set of spatially separated populations connected by dispersal, with local extinctions and recolonizations. - Small and isolated patches tend to have *higher extinction rates* due to demographic and environmental stochasticity. - Small, isolated populations also face *inbreeding*, but higher connectivity can reduce it.

Step 2: Evaluate each landscape.

(A) *Landscape Q, patch w.*

Patch w is large, occupied, and sending out arrows to other patches. That means it is a *source*. ⇒ Correct.

(B) *Landscape R.*

Landscape R has several patches, with arrows showing dispersal between them (both occupied and unoccupied). This is a classic *metapopulation structure*. ⇒ Correct.

(C) *Landscape P*.

Landscape P has only two small occupied patches with no dispersal arrows. Such small, isolated populations have the highest risk of extinction. $\Rightarrow$ Correct.

(D) *Landscape S*.

Landscape S has multiple occupied patches with strong dispersal (many arrows). This connectivity reduces inbreeding risk, not increases it. So this is *incorrect*.

Step 3: Conclusion.

The correct statements are (A), (B), and (C).

Final Answer: (A), (B), and (C)

Quick Tip

In patch dynamics: big stable patches act as sources; isolated small patches face high extinction risk; multiple connected patches form a metapopulation; inbreeding is lowest where dispersal is high.

Q59. A new food-requesting behaviour has been observed in bonnet macaques in Bandipur National Park. The macaques extend their hand and make a cooing sound towards humans, resulting in food given to them. If this behaviour is to increase in frequency in the population by natural selection, which condition(s) are necessary?

- (A) Food requesting behaviour must be transmitted from one generation to the next.
- (B) All bonnet macaques in the area must show this behaviour.
- (C) Macaques who receive food using this behaviour are able to have more offspring.
- (D) Food requesting behaviour must only be taught by parents to offspring.

Correct Answer: (A) and (C)

Solution:

Step 1: Conditions for natural selection.

For any trait (behavioural or morphological) to spread in a population by natural selection, three conditions must be satisfied: 1. *Variation*: Individuals differ in the trait.

2. *Heritability*: The trait must be passed on to the next generation.

3. *Differential fitness*: Individuals with the trait must have greater reproductive success.

Step 2: Evaluate each option.

(A) *Food requesting must be transmitted between generations.*

Yes — heritability is essential; otherwise the trait will not persist or spread.

(B) *All macaques must show the behaviour.*

No — selection acts on variation. If all already show it, there is no differential advantage.

(C) *Those with the behaviour must have more offspring.*

Yes — if food-requesting macaques secure more food and therefore raise more offspring, they have a fitness advantage.

(D) *Must only be taught by parents.*

No — the mechanism of transmission does not matter. It can be genetic, learned from peers, or socially transmitted. The key is that it is inherited in some way.

Step 3: Conclusion.

Only (A) heritability and (C) fitness advantage are necessary conditions.

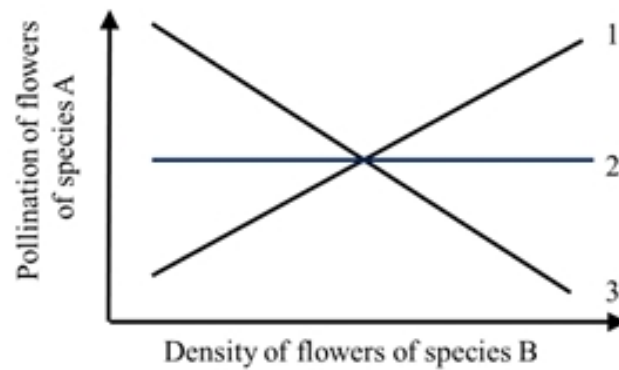
Final Answer:

(A) and (C)

Quick Tip

Natural selection requires *heritability* and *fitness advantage*. Universality (all showing the trait) or specific modes of transmission (only parents teaching) are not required.

Q60. Two co-occurring plant species, A and B, flower at the same time and share the same pollinator species. If these plants are pollinator-limited, then which one or more of the following statements is/are correct with regard to the figure shown below?



- (A) Line 1 represents competition.
- (B) Line 2 represents mutualism.
- (C) Line 3 represents parasitism.
- (D) Line 1 represents facilitation.

Correct Answer: (A)

Solution:

Step 1: Interpret the graph.

The y-axis shows pollination of species A, and the x-axis shows the density of flowers of species B. Three lines (1, 2, 3) depict possible relationships: - Line 1: Negative slope (as B increases, A's pollination decreases). - Line 2: Flat (B's density has no effect on A). - Line 3: Positive slope (as B increases, A's pollination increases).

Step 2: Match ecological interactions.

- *Competition*: When both species share the same pollinator and more flowers of B reduce visits to A, this is competition. That matches **Line 1**. - *Neutral interaction*: No effect means independence, not mutualism. That matches **Line 2**, but the option “mutualism” is wrong here. - *Parasitism*: Would mean one benefits while the other is harmed. Here, Line 3 shows A benefits when B is more abundant — this is not parasitism, but *facilitation*. - *Facilitation*: If B attracts more pollinators overall, A also benefits. That is **Line 3**.

Step 3: Evaluate statements.

- (A) Line 1 = competition — **Correct**.
- (B) Line 2 = mutualism — **Incorrect**, it shows neutrality.

- (C) Line 3 = parasitism — **Incorrect**, it shows facilitation.
 (D) Line 1 = facilitation — **Incorrect**, it shows competition.

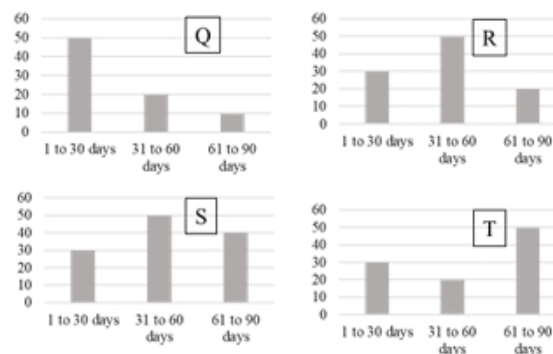
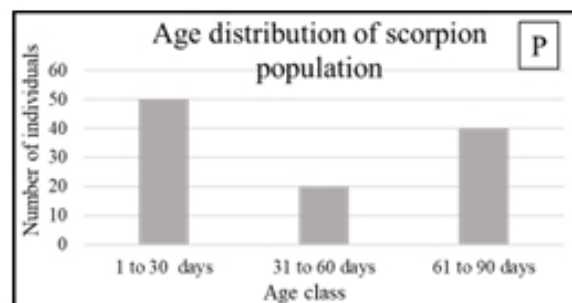
Final Answer:

(A)

Quick Tip

When interpreting species interaction graphs: negative slope = competition, flat = neutral, positive slope = facilitation. True mutualism would require reciprocal positive effects, not shown in a one-axis plot.

Q61. Scorpions on Syrian sand dunes in Sept 2022 show the age distribution in panel P (age classes: 1–30 d, 31–60 d, 61–90 d; y-axis = number of individuals). Scorpions live to a maximum of 90 days. Assuming *no immigration or emigration*, which one or more of the age-distribution panels Q, R, S, T is/are possible 30 days later?



- (A) Q
- (B) R
- (C) S
- (D) T

Correct Answer: (D) T

Solution:

Step 1: Apply aging with a 90-day lifespan.

In 30 days, individuals advance by one age class; those presently in 61–90 days will exceed 90 and *die*. With the “no immigration/emigration” clause and no information about births, the only deterministic change is:

$$\begin{aligned}(1-30)d &\Rightarrow (31-60)d, \\ (31-60)d &\Rightarrow (61-90)d, \\ (61-90)d &\Rightarrow \text{exit (0 individuals)}.\end{aligned}$$

Hence, 30 days later we expect *zero* in 1–30 d; counts in 31–60 d equal the previous 1–30 d bar; counts in 61–90 d equal the previous 31–60 d bar.

Step 2: Compare with candidate panels.

- **Q** and **R** still show many 1–30 d individuals $\Rightarrow$ would require births/immigration (ruled out).
- **S** shows zeros in 31–60 d and nonzero 1–30 d $\Rightarrow$ violates the deterministic aging shift.
- **T** shows 1–30 d = 0, 31–60 d equal to P’s 1–30 d bar, and 61–90 d equal to P’s 31–60 d bar $\Rightarrow$ exactly the expected pattern.

Final Answer: (D) T

Quick Tip

With fixed lifespan and short time steps, track cohorts: each age class shifts right by one class; the oldest class ages out. If births are not mentioned, do not add a new 1–30 d cohort.

Q62. The Shannon–Weaver index H is $H = - \sum_{i=1}^S p_i \ln(p_i)$, where S is the number of species and p_i is the proportional abundance of species i . The table lists abundances of different species in a community. Compute the Shannon–Weaver index of reptile diversity in this community (round to two decimals).

Species	Abundance
Indian gliding lizard	270
Malabar flying frog	325
Travancore tortoise	180
Malabar hornbill	160
Forest cane turtle	120
Malabar pit viper	30

Correct Answer: $H \approx 1.19$

Solution:

Step 1: Identify the focal group (reptiles) and total their counts.

Reptiles here are: lizard (270), tortoise (180), turtle (120), pit viper (30).

Total reptiles:

$$N_{\text{reptiles}} = 270 + 180 + 120 + 30 = 600.$$

Step 2: Convert abundances to proportions (relative frequencies).

$$\begin{aligned} p_{\text{lizard}} &= \frac{270}{600} = 0.45, \\ p_{\text{tortoise}} &= \frac{180}{600} = 0.30, \\ p_{\text{turtle}} &= \frac{120}{600} = 0.20, \\ p_{\text{viper}} &= \frac{30}{600} = 0.05. \end{aligned}$$

Sanity check: $0.45 + 0.30 + 0.20 + 0.05 = 1.00 \Rightarrow$ proportions sum to 1 (required).

Step 3: Compute the Shannon terms $p_i \ln p_i$ (natural logs).

$$\ln(0.45) \approx -0.7985, \quad \ln(0.30) \approx -1.2039, \quad \ln(0.20) \approx -1.6094, \quad \ln(0.05) \approx -2.9957.$$

Now multiply each by p_i :

$$p_{\text{lizard}} \ln p_{\text{lizard}} = 0.45 \times (-0.7985) \approx -0.3593,$$

$$p_{\text{tortoise}} \ln p_{\text{tortoise}} = 0.30 \times (-1.2039) \approx -0.3612,$$

$$p_{\text{turtle}} \ln p_{\text{turtle}} = 0.20 \times (-1.6094) \approx -0.3219,$$

$$p_{\text{viper}} \ln p_{\text{viper}} = 0.05 \times (-2.9957) \approx -0.1498.$$

Step 4: Sum the contributions and apply the minus sign.

$$\sum p_i \ln p_i \approx (-0.3593) + (-0.3612) + (-0.3219) + (-0.1498) = -1.1922.$$

Therefore,

$$H = - \sum p_i \ln p_i \approx -(-1.1922) = 1.1922.$$

Step 5: Round and sanity-check the magnitude.

Rounded to two decimals:

$$H \approx 1.19.$$

Bound check: With $S = 4$ reptile species, the maximum Shannon index (perfect evenness) is $\ln S = \ln 4 \approx 1.386$. Our $H = 1.19 < 1.386$ and close to it, consistent with a moderately uneven community (dominant lizard, rare viper).

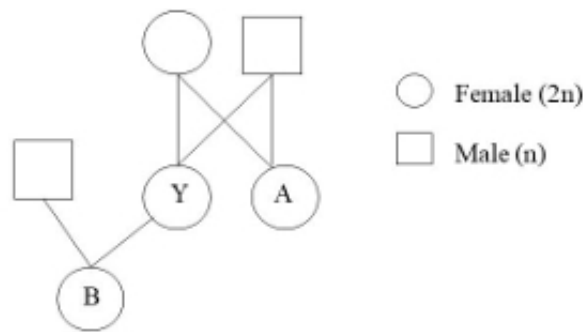
Final Answer:

$$H \approx 1.19$$

Quick Tip

Shannon index steps: (1) restrict to the focal group, (2) convert to proportions that sum to 1, (3) compute $p_i \ln p_i$ with natural log, (4) sum and negate, (5) compare with $\ln S$ to gauge evenness ($E = H / \ln S$; here $E \approx 1.19 / 1.386 \approx 0.86$).

Q63. In haplodiploid organisms, males are haploid and females are diploid. In the pedigree, female A has a full-sister Y; Y has a daughter B. Compute the genetic relatedness between A and B (round to three decimals).



Correct Answer: 0.375

Solution:

Step 1: State transmission rules under haplodiploidy.

- A **haploid father** contributes *all* his genome to each daughter $\Rightarrow r(\text{father} \rightarrow \text{daughter}) = 1$.

- A **diploid mother** contributes a random half to each offspring $\Rightarrow$

$$r(\text{mother} \rightarrow \text{offspring}) = \frac{1}{2}.$$

- By symmetry, the probability that two offspring share the same maternal allele at a locus is $\frac{1}{2}$.

Step 2: Recall full-sister relatedness in haplodiploids.

Two full sisters (same father and mother) share:

- *Paternal set*: identical (from haploid father) $\Rightarrow$ contribution $1 \times \frac{1}{2} = 0.5$ (the factor $\frac{1}{2}$ weights the paternal genome in each sister).

- *Maternal set*: expected half in common $\Rightarrow \frac{1}{2} \times \frac{1}{2} = 0.25$.

$$\text{Total } r_{\text{sisters}} = 0.5 + 0.25 = 0.75.$$

Step 3: Chain relatedness from A to B through Y (aunt $\rightarrow$ niece).

$A \xrightarrow{0.75} Y$ (full sisters), and $Y \xrightarrow{0.5} B$ (mother to daughter).

Multiply along the path (path method):

$$r_{A,B} = r_{A,Y} \times r_{Y,B} = 0.75 \times 0.5 = 0.375.$$

Step 4: Sanity check via allele-tracking.

Pick a random locus in A. Probability it is shared with Y is 0.75; conditional on sharing with Y, the chance Y transmits that allele to B is 0.5. Product $0.75 \times 0.5 = 0.375 \Rightarrow$ consistent.

Final Answer:

0.375

Quick Tip

In kinship problems, *multiply* relatedness along each parent–offspring link and *sum* over independent paths if multiple exist. Haplodiploidy boosts sister relatedness to 0.75, which then halves to an aunt–niece value of 0.375.

Q64. Mixed-species flocks contain exactly 5 species: 2 social (from 5 available) and 3 solitary (from 10 available). How many distinct species-composition types are possible? (Answer in integer)

Correct Answer: 1200

Solution:

Step 1: Interpret “types of flocks with unique species composition.”

Order does *not* matter (a set of species). We choose subsets: 2 from the 5 social species, and 3 from the 10 solitary species — independent choices.

Step 2: Count choices with combinations.

$$\binom{5}{2} = \frac{5!}{2!3!} = 10, \quad \binom{10}{3} = \frac{10!}{3!7!} = 120.$$

Step 3: Multiply independent categories.

$$\text{Total distinct compositions} = \binom{5}{2} \times \binom{10}{3} = 10 \times 120 = \boxed{1200}.$$

Step 4: Reasonableness check.

Maximum possible 5-species sets from 15 species is $\binom{15}{5} = 3003$. Our constraint (exactly 2 social + 3 solitary) reasonably narrows this to 1200.

Quick Tip

When compositions are constrained by categories, count choices within each category using combinations and then multiply — the multiplication rule for independent selections.

Q65. In Zoo 1, 3 lions and 4 tigers eat 390 kg/week. In Zoo 2, 4 lions and 5 tigers eat 500 kg/week. All lions eat the same amount L kg/week and all tigers the same amount T kg/week. Find L (Answer in integer).

Correct Answer: 50

Solution:

Step 1: Translate word problem into equations.

$$3L + 4T = 390 \quad (\text{Zoo 1})$$

$$4L + 5T = 500 \quad (\text{Zoo 2})$$

Step 2: Eliminate one variable (classic 2×2 system).

Multiply (1) by 4 and (2) by 3 to align L :

$$12L + 16T = 1560 \quad (1')$$

$$12L + 15T = 1500 \quad (2')$$

Subtract (2') from (1'): $(12L - 12L) + (16T - 15T) = 1560 - 1500 \Rightarrow T = 60$.

Step 3: Back-substitute to get L .

From (1): $3L + 4(60) = 390 \Rightarrow 3L + 240 = 390 \Rightarrow 3L = 150 \Rightarrow L = \boxed{50}$.

Step 4: Consistency check in the second equation.

$4L + 5T = 4(50) + 5(60) = 200 + 300 = 500$ — matches the given amount.

Quick Tip

For two-species diet problems, set up a linear system (coefficients are counts of animals). Align coefficients to eliminate one variable, solve, and verify in the other equation to catch arithmetic slips.
