GATE Ecology and Evolution

Sample Paper – 9

Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Ecology and Evolution** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Unless stated otherwise, take $\ln 2 = 0.693$, and assume large, randomly mating populations for all Hardy–Weinberg calculations.

Fundamentals of Ecology

Q1. A species that is highly sensitive to a particular environmental stress, and whose presence, absence or physiological condition is used to assess the quality of a habitat, is best described as: **[1 mark]**

(A) a bioindicator (indicator species)

(B) a keystone species

(C) an invasive species

(D) an ecological generalist

Q2. The progressive disappearance of sensitive epiphytic lichens from tree bark across an industrial city is most widely used as a biological indicator of: **[1 mark]**

(A) high soil phosphorus content

(B) elevated rainfall

(C) rising groundwater levels

(D) air pollution by sulphur dioxide

Q3. Hutchinson defined the niche as an "n-dimensional hypervolume." In this formal concept, each of the n dimensions (axes) represents: **[1 mark]**

(A) a different competing species

(B) a separate geographic locality

(C) one environmental variable (a resource or condition axis)

(D) a single individual organism

Q4. As regional climate warms, many species track their preferred thermal conditions by shifting their geographic ranges. In the Northern Hemisphere the most commonly documented direction of such range shifts is: **[1 mark]**

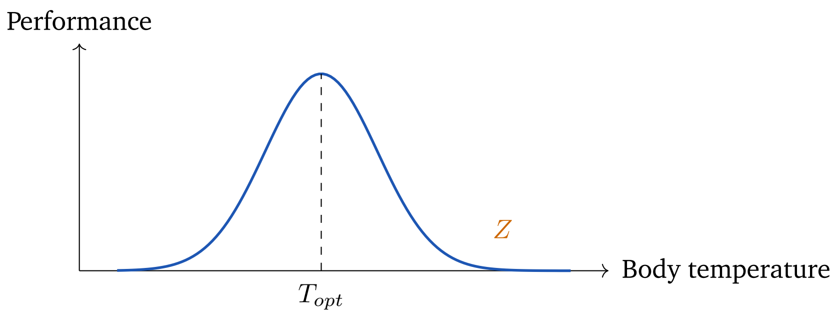
(A) poleward (northward) and upward to higher elevations

(B) toward the equator and down to lower elevations

(C) with no consistent direction at all

(D) strictly downward into valley bottoms

Q5. The curve below shows the thermal performance of an ectotherm plotted against its body temperature, with the optimum at T_{opt}. If continued warming pushes the environment beyond T_{opt} into the region marked Z, the organism's performance will: **[1 mark]**



(A) decline sharply as the temperature moves past the optimum

(B) keep increasing without any limit

(C) stay exactly constant

(D) rise to a new maximum value

Q6. A transition zone between two adjacent communities, such as the boundary strip between a forest and a grassland, which frequently supports higher species richness (the edge effect), is called: **[1 mark]**

(A) a biome

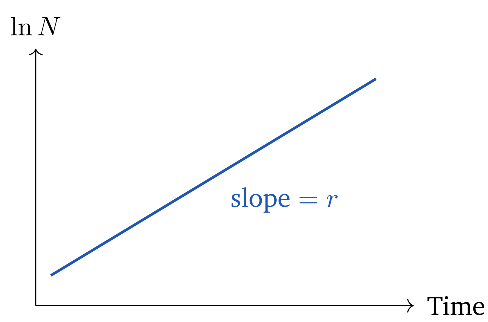
(B) a fundamental niche

(C) a guild

(D) an ecotone

Population and Community Ecology

Q7. When the natural logarithm of population size, $\ln N$, is plotted against time and the data fall on a straight line, as sketched below, the slope of that line estimates: **[1 mark]**



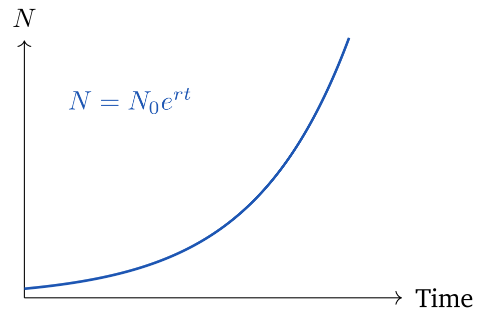
(A) the carrying capacity K

(B) the intrinsic per-capita growth rate r

(C) the initial population size N_0

(D) the mean generation time

Q8. A bacterial culture grows exponentially, as shown, with intrinsic rate $r = 0.0231\ \text{min}^{-1}$. Using the doubling-time formula $t_d = \dfrac{\ln 2}{r}$ with $\ln 2 = 0.693$, its doubling time is: **[1 mark]**



(A) 15 min

(B) 60 min

(C) 30 min

(D) 45 min

Q9. A population has a finite (geometric) rate of increase $\lambda = 1.2$ per year. Starting from $N_0 = 500$ individuals, the size after one year, given by $N_1 = \lambda N_0$, is: **[1 mark]**

(A) 500 individuals

(B) 600 individuals

(C) 720 individuals

(D) 416 individuals

Q10. An interspecific interaction in which one species benefits while the other is harmed, as between a tapeworm and its mammalian host, is classified as: **[1 mark]**

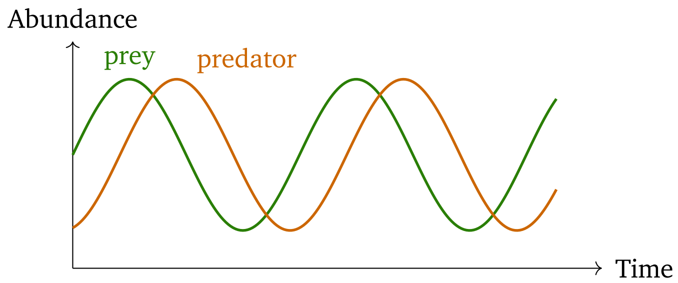
(A) mutualism (+/+)

(B) parasitism $(+/-)$

(C) commensalism $(+/0)$

(D) interference competition $(-/-)$

Q11. The Lotka–Volterra predator–prey model produces the coupled oscillations sketched below. A characteristic feature of these cycles is that the peaks in predator abundance: **[1 mark]**



(A) lag behind (follow) the peaks in prey abundance

(B) exactly coincide with the prey peaks

(C) always precede the prey peaks

(D) never change over time

Q12. On a rocky shore the sea star *Pisaster*, whose experimental removal lets mussels outcompete and eliminate many other invertebrates and algae, is a classic example of a: **[1 mark]**

(A) pioneer species

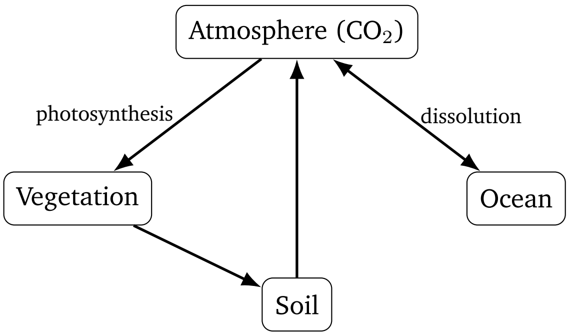
(B) keystone species

(C) invasive species

(D) cryptic species

Ecosystems and Biogeochemical Cycles

Q13. In the simplified global carbon cycle shown, and ignoring the very slow deep-sedimentary rock pool, the largest *actively exchanging* reservoir of carbon is: **[1 mark]**



(A) the atmosphere

(B) the oceans (dissolved inorganic carbon)

(C) terrestrial vegetation

(D) the soil organic pool

Q14. The dominant human activity responsible for the sustained rise in atmospheric CO_2 concentration over the past century is: **[1 mark]**

(A) combustion of fossil fuels

(B) volcanic outgassing

(C) respiration by wild animals

(D) radioactive decay within crustal rocks

Q15. In the global carbon budget, terrestrial gross primary production fixes about 120 Pg C per year, while plant (autotrophic) respiration returns about 60 Pg C per year to the atmosphere. The terrestrial net primary production is therefore about: **[1 mark]**

(A) 180 Pg C per year

(B) 120 Pg C per year

(C) 30 Pg C per year

(D) 60 Pg C per year

Q16. The single biological process that transfers carbon from the atmospheric CO_2 pool into the living biomass of an ecosystem is: **[1 mark]**

(A) photosynthesis

(B) denitrification

(C) sedimentation

(D) ammonification

Q17. When atmospheric CO_2 dissolves in seawater it forms carbonic acid and lowers the pH of the surface ocean. This ongoing change is called: [1 mark]

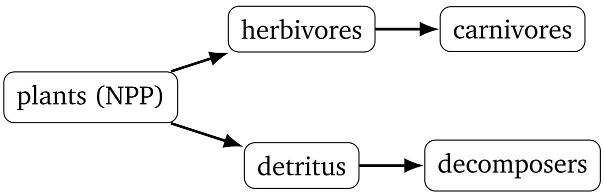
(A) eutrophication

(B) biomagnification

(C) ocean acidification

(D) thermal stratification

Q18. In most terrestrial ecosystems, as suggested by the two energy pathways shown, the largest fraction of net primary production is ultimately processed by: [1 mark]



(A) apex predators

(B) grazing herbivores

(C) decomposers and detritivores

(D) primary carnivores

Mechanisms of Evolution

Q19. A widely cited evolutionary advantage of sexual reproduction over asexual reproduction is that sex: [1 mark]

(A) always yields more offspring per parent

(B) creates new combinations of alleles through recombination

(C) removes the need for meiosis

(D) guarantees offspring genetically identical to the parent

Q20. The "twofold cost of sex" captures the disadvantage that, compared with an asexual female, a sexual female: **[1 mark]**

(A) produces exactly twice as many offspring

(B) lives twice as long on average

(C) mutates at twice the normal rate

(D) devotes half her reproductive output to producing males

Q21. "Muller's ratchet" explains why small, strictly asexual populations tend, over many generations, to: **[2 marks]**

(A) lose all deleterious mutations very rapidly

(B) accumulate deleterious mutations irreversibly

(C) acquire beneficial mutations without any limit

(D) maintain a mutation-free genome indefinitely

Q22. The Red Queen hypothesis accounts for the maintenance of sexual reproduction chiefly as an adaptation to: **[2 marks]**

(A) a completely stable, unchanging physical environment

(B) the pressure exerted by rapidly coevolving parasites and pathogens

(C) the total absence of predators

(D) an unusually low background mutation rate

Q23. For a deleterious recessive allele kept in the population by recurrent mutation, the equilibrium frequency at mutation–selection balance is $\hat{q} = \sqrt{\mu/s}$. With mutation rate $\mu = 10^{-4}$ and selection coefficient $s = 0.01$ against the homozygote, $\hat{q}$ equals: **[2 marks]**

(A) 0.01

(B) 0.001

(C) 0.5

(D) 0.1

Q24. At a locus the three genotypes leave, on average, $AA = 8$, $Aa = 10$ and $aa = 6$ surviving offspring. Taking relative fitness as absolute fitness divided by the largest value, the relative fitness of the AA genotype is: **[2 marks]**

(A) 1.0

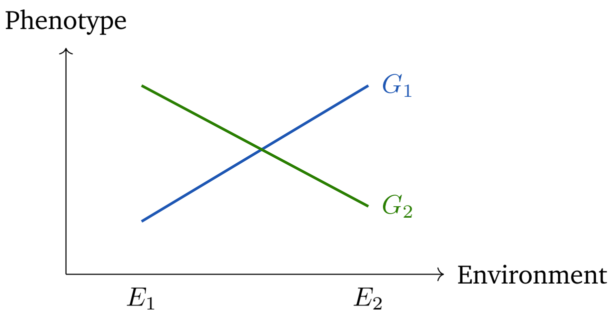
(B) 0.6

(C) 0.8

(D) 0.5

Population and Quantitative Genetics

Q25. The plot below shows the phenotype produced by two genotypes, G_1 and G_2, across two environments E_1 and E_2. Because the two reaction-norm lines cross, the figure demonstrates: **[2 marks]**



(A) the complete absence of genetic variation

(B) no effect of the environment on the phenotype

(C) a genotype-by-environment ($G \times E$) interaction

(D) simple complete dominance at one locus

Q26. When interaction is included, phenotypic variance partitions as $V_P = V_G + V_E + V_{G\times E}$. For a trait with $V_G = 20$, $V_E = 25$ and $V_{G\times E} = 5$, the broad-sense heritability $H^2 = V_G/V_P$ equals: **[2 marks]**

(A) 0.80

(B) 0.10

(C) 0.50

(D) 0.40

Q27. In a Hardy–Weinberg population the dominant allele A has frequency $p = 0.7$. The expected frequency of homozygous recessive (aa) individuals, given by q^2, is: **[2 marks]**

(A) 0.49

(B) 0.09

(C) 0.21

(D) 0.42

Q28. Narrow-sense heritability h^2 can be estimated from the slope of the regression of offspring mean phenotype on mid-parent phenotype. If, in a selection study, that slope is measured as 0.6, then h^2 is: **[2 marks]**

(A) 0.36

(B) 1.0

(C) 0.4

(D) 0.6

Q29. A plant breeder selects for seed mass with a selection differential $S = 5$ g in a population whose narrow-sense heritability is $h^2 = 0.4$. The response to selection per generation, $R = h^2S$, is: **[2 marks]**

(A) 5 g

(B) 4.5 g

(C) 0.4 g

(D) 2 g

Q30. In a sample of 200 diploid individuals the genotype counts are $AA = 98$, $Aa = 84$ and $aa = 18$. The frequency of allele A in this sample is: [2 marks]

(A) 0.49

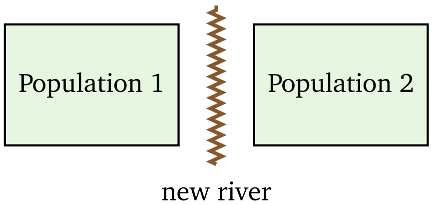
(B) 0.70

(C) 0.42

(D) 0.30

Speciation, Phylogeny and Macroevolution

Q31. The splitting of a single ancestral range into two isolated parts by the appearance of a geographic barrier, such as the new river shown below, is the biogeographic process known as: [2 marks]



(A) long-distance dispersal

(B) sympatry

(C) vicariance

(D) adaptive radiation

Q32. The Wallace Line is a sharp biogeographic boundary that separates the strikingly different faunas of: [2 marks]

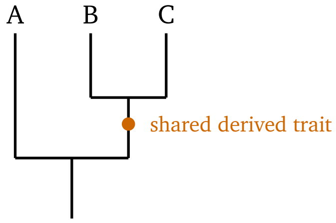
(A) the Oriental (Asian) and Australian faunal regions

(B) North America and South America

(C) Europe and Africa

(D) the Arctic and Antarctic

Q33. On the cladogram below, the shared derived character (marked •) that unites taxa B and C into a clade and is used to group them is called a: [2 marks]



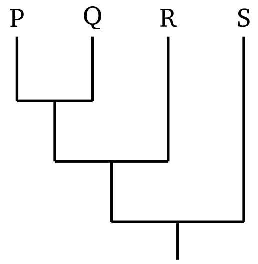
(A) a synapomorphy (shared derived trait)

(B) a plesiomorphy (shared ancestral trait)

(C) an autapomorphy (unique to one taxon)

(D) a homoplasy (independently evolved trait)

Q34. In the phylogenetic tree shown for taxa P, Q, R and S, the sister group of the clade (P, Q) is: **[2 marks]**



(A) taxon S

(B) taxon P

(C) taxon R

(D) taxon Q

Q35. The "molecular clock" hypothesis proposes that, for a given gene, the number of neutral sequence differences accumulated between two lineages is approximately proportional to: **[2 marks]**

(A) the current sizes of the two populations

(B) the time elapsed since they diverged from a common ancestor

(C) the body sizes of the organisms

(D) the strength of natural selection acting on them

Q36. The rapid diversification of a single ancestral finch lineage into many species with distinct beak shapes and diets across the Galapagos Islands is a textbook example of: **[2 marks]**

(A) convergent evolution

(B) coevolution

(C) genetic drift acting alone

(D) adaptive radiation

Behavioural Ecology

Q37. Organisms that are small-bodied, mature early and produce many small offspring with little parental care, thriving in disturbed or ephemeral habitats, are typically described as: **[2 marks]**

(A) strongly K-selected

(B) obligately iteroparous

(C) r-selected

(D) exclusively semelparous

Q38. A Pacific salmon that channels all its resources into one enormous reproductive event and then dies exhibits a life-history strategy called: **[2 marks]**

(A) iteroparity

(B) monogamy

(C) semelparity

(D) polygyny

Q39. Hamilton's rule states that an altruistic act is favoured when $rB > C$. A ground squirrel gives an alarm call at a cost $C = 1$ that benefits a cousin, to whom its coefficient of relatedness is $r = 0.125$. For the behaviour to be favoured by kin selection, the benefit B to the cousin must exceed: **[2 marks]**

(A) 8

(B) 4

(C) 2

(D) 1

Q40. The table below gives the payoffs to the row player in a two-strategy game (Cooperate "C" versus Defect "D"). A strategy qualifies as an evolutionarily stable strategy (ESS) if, once adopted by essentially the whole population, it: **[2 marks]**

	C	D
C	3	0
D	5	1

(A) maximizes the total payoff of the whole group

(B) is always the pure Cooperate strategy

(C) changes from one generation to the next

(D) cannot be invaded by any rare alternative strategy

Q41. Bateman's principle predicts that the sex making the larger investment per gamete (usually the female) will be: **[2 marks]**

(A) the more selective (choosier) sex about mates

(B) the far less selective sex about mates

(C) always the physically larger sex

(D) generally unable to reproduce at all

Quantitative Ecology, Biostatistics and Mathematics

Q42. For the quadrat counts $\{3, 7, 5, 9, 11\}$ recorded at five sampling stations, the median value is: **[2 marks]**

(A) 5

(B) 7

(C) 9

(D) 35

Q43. A small sample has the three values $\{2, 4, 6\}$, whose mean is 4. The sample variance, defined as $s^2 = \dfrac{1}{n-1}\sum_i (x_i - \bar{x})^2$, equals: **[2 marks]**

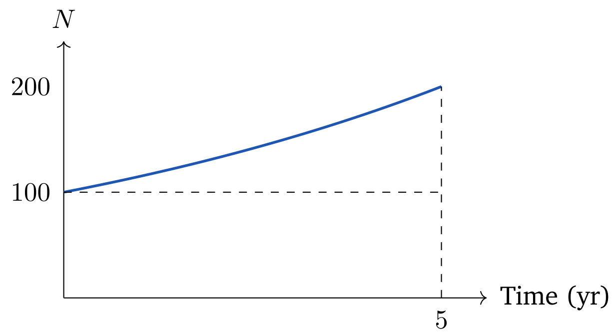
(A) 4

(B) 8

(C) 2.67

(D) 16

Q44. A population is counted as $N_0 = 100$ and, five years later, as $N_5 = 200$, as sketched below. Assuming exponential growth, the per-capita growth rate is $r = \dfrac{1}{t}\ln\left(\dfrac{N_t}{N_0}\right)$. Using $\ln 2 = 0.693$, r is about: **[2 marks]**



(A) $0.693\ \text{yr}^{-1}$

(B) $0.05\ \text{yr}^{-1}$

(C) $0.139\ \text{yr}^{-1}$

(D) $0.20\ \text{yr}^{-1}$

Q45. In a mark–recapture study $M = 50$ animals are captured, marked and released. In a second sample of $n = 40$ animals, $R = 10$ are found to carry marks. The Lincoln–Petersen estimate of population size, $\hat{N} = \dfrac{Mn}{R}$, is: **[2 marks]**

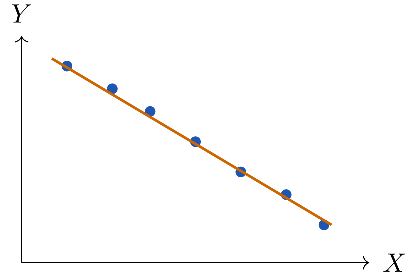
(A) 200

(B) 100

(C) 400

(D) 20

Q46. The scatter plot below shows a fitted straight line of clearly negative slope passing through a tightly clustered cloud of points. The correlation coefficient r for these data is best described as: **[2 marks]**



(A) exactly $+1$

(B) positive, with $0 < r < 1$

(C) exactly 0

(D) negative, close to -1

Detailed Solutions

Q1.

Solution

Concept – indicator species and bioindication: Some species respond to environmental change long before instruments would flag it. Ecologists monitor such species to judge the health of a habitat.

Step 1 – read the definition given: The species is "highly sensitive" and its condition is used to "assess the quality of a habitat."

Step 2 – match the term: A species used in this way is a bioindicator, also called an indicator species.

Step 3 – why the others are wrong: A keystone species has a large effect on community structure but is not defined by sensitivity; an invasive species is a spreading non-native; a generalist simply tolerates many conditions and so makes a poor indicator.

Final Answer: a bioindicator (indicator species) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept – lichens as air-quality indicators: Lichens absorb water and gases directly across their surface, with no protective cuticle, so they take up dissolved pollutants readily.

Step 1 – identify the sensitive pollutant: Epiphytic lichens are especially intolerant of sulphur dioxide from fossil-fuel combustion.

Step 2 – interpret the pattern: Their disappearance across an industrial city tracks a gradient of rising SO_2, so it signals air pollution.

Step 3 – reject the others: Soil phosphorus, rainfall and groundwater do not selectively remove bark lichens the way air-borne SO_2 does.

Final Answer: air pollution by sulphur dioxide $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – Hutchinson's n-dimensional niche: Hutchinson pictured the niche as a volume in an abstract space whose axes are the environmental factors that matter to the species.

Step 1 – interpret "dimension": Each axis is one measurable environmental variable, such as temperature, humidity or prey size.

Step 2 – build the hypervolume: Stacking many such axes gives the n-dimensional hypervolume within which the species can persist.

Step 3 – reject the others: Competitors, localities and individuals are not the axes; the axes are the conditions and resources themselves.

Final Answer: one environmental variable (a resource or condition axis) $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

Q4.

Solution

Concept – range shifts under climate warming: A species keeps to the band of temperatures it tolerates. When the climate warms, that band moves, and the species must move with it to stay in suitable conditions.

Step 1 – ask where cooler conditions now lie: In the Northern Hemisphere, cooler conditions lie toward the pole (northward) and at higher elevations up a mountain.

Step 2 – predict the direction of movement: To track its climate, the species shifts poleward and upslope.

Step 3 – match the evidence: Long-term surveys of birds, butterflies and plants show exactly this poleward and upward shift.

Final Answer: poleward and upward to higher elevations $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – the thermal performance curve: Performance rises to a peak at the thermal optimum T_{opt} and then falls steeply as temperature climbs toward the upper critical limit.

Step 1 – locate region Z: Z lies to the right of T_{opt}, on the descending arm of the curve.

Step 2 – read the slope there: On that arm the curve drops sharply as body temperature increases.

Step 3 – state the consequence: As warming pushes the animal past T_{opt} into Z, its performance declines sharply rather than continuing to rise.

Final Answer: performance declines sharply past the optimum $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – the ecotone: Where two communities meet, their species mingle in a transition strip that often holds species from both sides plus some edge specialists.

Step 1 – read the description: A boundary strip between forest and grassland with raised richness.

Step 2 – name the zone: That transition zone is an ecotone, and its raised richness is the edge effect.

Step 3 – reject the others: A biome is a large climatic community type; a niche is a role, not a place; a guild is a set of species using a resource similarly.

Final Answer: an ecotone $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – estimating r from a log plot: Exponential growth is $N(t) = N_0e^{rt}$. Taking natural logs linearises it.

Step 1 – take the log of the growth law: $\ln N = \ln N_0 + rt$

Step 2 – read this as a straight line: It has the form $y = c + mx$ with $y = \ln N$, $x = t$, intercept $c = \ln N_0$ and slope $m = r$.

Step 3 – identify the slope: Therefore the slope of the $\ln N$-versus-time line is the intrinsic per-capita growth rate r.

Step 4 – reject the others: K is the intercept-independent ceiling of logistic growth (not present here); N_0 is the intercept, not the slope; generation time is a separate quantity.

Final Answer: the intrinsic per-capita growth rate $r \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept – doubling time of exponential growth: The time to double satisfies $2N_0 = N_0 e^{rt_d}$, which rearranges to $t_d = \dfrac{\ln 2}{r}$.

Step 1 – list the data: $r = 0.0231 \text{ min}^{-1}$ and $\ln 2 = 0.693$.

Step 2 – substitute into the formula: $t_d = \dfrac{0.693}{0.0231}$

Step 3 – carry out the division: $t_d = 30 \text{ min}$

Step 4 – sanity check: $0.0231 \times 30 = 0.693 = \ln 2$, confirming one doubling in 30 minutes.

Final Answer: $30 \text{ min} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q8

Q9.

Solution

Concept – the finite rate of increase λ: In discrete time the population one step later is $N_1 = \lambda N_0$, where λ is the multiplicative growth factor per time step.

Step 1 – list the data: $\lambda = 1.2$ and $N_0 = 500$.

Step 2 – substitute: $N_1 = 1.2 \times 500$

Step 3 – evaluate: $N_1 = 600$

Step 4 – interpret: Since $\lambda > 1$, the population has grown, by 20%, to 600 individuals.

Final Answer: 600 individuals $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

Concept – signs of species interactions: Each partner in an interaction is scored $+$, $-$ or 0 for the effect it experiences.

Step 1 – score the tapeworm: The tapeworm gains nutrients from the host, so it is scored $+$.

Step 2 – score the host: The host loses nutrients and may be weakened, so it is scored $-$.

Step 3 – name the $+/-$ interaction: A living-together relationship where one gains and the other loses is parasitism.

Step 4 – reject the others: Mutualism is $+/+$, commensalism is $+/0$, and competition is $-/-$; none matches $+/-$.

Final Answer: parasitism $(+/-) \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – predator–prey cycles: In the Lotka–Volterra model predators depend on prey for food, so predator numbers can only build up after prey become abundant.

Step 1 – trace the sequence: Prey increase first; with more food, predators then increase.

Step 2 – follow the crash: Abundant predators drive prey down; the predators, now short of food, decline afterward.

Step 3 – describe the phase relation: The predator curve therefore rises and falls a quarter-cycle behind the prey curve, so predator peaks lag prey peaks.

Step 4 – reject the others: The peaks do not coincide, predators cannot peak before their food supply, and the cycles clearly change over time.

Final Answer: predator peaks lag behind prey peaks $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – keystone species: A keystone species has an effect on its community far larger than its abundance would suggest; removing it reorganises the whole assemblage.

Step 1 – read Paine's classic result: Removing *Pisaster* lets mussels monopolise the rock and squeeze out other species.

Step 2 – diagnose the role: By preying on the dominant competitor, the sea star maintains diversity, the defining action of a keystone species.

Step 3 – reject the others: A pioneer colonises bare ground; an invasive is a spreading non-native; a cryptic species is one hard to tell apart from another, none of which fits.

Final Answer: a keystone species $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept – reservoirs of the carbon cycle: Carbon is stored in the atmosphere, in living vegetation, in soils and, in vastly the largest actively exchanging amount, dissolved in the oceans.

Step 1 – compare the pools: The oceans hold on the order of $38{,}000$ Pg C as dissolved inorganic carbon, dwarfing the atmosphere (~ 870 Pg), vegetation (~ 450–650 Pg) and soils (~ 1500–2400 Pg).

Step 2 – exclude the slow rock pool: The question sets aside deep sedimentary rocks, which turn over far too slowly to count as actively exchanging.

Step 3 – choose the largest remaining pool: Among the actively exchanging reservoirs the ocean is by far the largest.

Final Answer: the oceans (dissolved inorganic carbon) $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – the anthropogenic carbon source: The industrial-era rise in atmospheric CO_2 is traced by isotopes and inventories to the burning of buried organic carbon.

Step 1 – identify the largest human flux: Combustion of coal, oil and natural gas releases several Pg C per year that had been locked away for millions of years.

Step 2 – compare with the alternatives: Volcanic outgassing is small and roughly steady; animal respiration is part of a closed short-term loop; radioactive decay does not release CO_2.

Step 3 – conclude: Fossil-fuel burning is the dominant driver of the CO_2 increase.

Final Answer: combustion of fossil fuels $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – GPP, respiration and NPP: Net primary production is what is left of gross production after the plants respire: NPP $=$ GPP $- R_a$.

Step 1 – list the fluxes: GPP $= 120$ Pg C per year and autotrophic respiration $R_a = 60$ Pg C per year.

Step 2 – substitute: NPP $= 120 - 60$

Step 3 – evaluate: NPP $= 60$ Pg C per year

Step 4 – interpret: About half of the carbon fixed by photosynthesis is respired back, leaving roughly 60 Pg C for growth and the rest of the food web.

Final Answer: 60 Pg C per year $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – entry of carbon into biomass: Carbon leaves the inorganic atmospheric pool and enters living tissue only when autotrophs fix CO_2 into organic molecules.

Step 1 – name the fixing process: Photosynthesis converts atmospheric CO_2 into sugars in green plants and algae.

Step 2 – confirm the direction: This is the one step that moves carbon from the atmosphere into the biomass of the ecosystem.

Step 3 – reject the others: Denitrification and ammonification belong to the nitrogen cycle; sedimentation removes carbon to sediments rather than into living tissue.

Final Answer: photosynthesis $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – carbon dioxide and seawater chemistry: Dissolved CO_2 reacts with water: $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$, releasing hydrogen ions.

Step 1 – track the pH: Adding H^+ lowers the pH of surface seawater.

Step 2 – name the process: A steady fall in ocean pH driven by rising CO_2 is called ocean acidification.

Step 3 – reject the others: Eutrophication is nutrient over-enrichment; biomagnification is the build-up of toxins up a food chain; thermal stratification is a temperature-layering phenomenon.

Final Answer: ocean acidification $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q17

Q18.

Solution

Concept – grazing versus detrital pathways: Net primary production can flow either up the grazing chain (herbivores, then carnivores) or into the detrital chain (dead matter, then decomposers).

Step 1 – weigh the two routes: In most terrestrial ecosystems herbivores eat only a small share of living plant tissue.

Step 2 – follow the bulk of NPP: The great majority of plant material dies uneaten and enters the detritus pool.

Step 3 – identify the main consumers: Decomposers and detritivores therefore process the largest fraction of NPP.

Step 4 – reject the others: Apex predators, grazers and primary carnivores together handle only a minor share of the energy.

Final Answer: decomposers and detritivores $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – the benefit of recombination: Sexual reproduction shuffles alleles from two parents through meiosis and fertilisation, producing offspring with novel genetic combinations.

Step 1 – ask what sex uniquely provides: It generates new combinations of existing alleles that did not occur in either parent.

Step 2 – state the advantage: This variation lets a lineage respond faster to changing selection and bring together favourable alleles.

Step 3 – reject the others: Sex does not raise offspring number (it lowers it, the cost of males); it still requires meiosis; and it does not make identical clones.

Final Answer: it creates new allele combinations through recombination $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – the twofold cost of sex: An asexual female converts all her offspring into daughters that also reproduce; a sexual female produces daughters and sons, and sons do not themselves bear young.

Step 1 – count reproducing offspring: Half of a sexual female's offspring are males, which cannot produce eggs.

Step 2 – state the disadvantage: She effectively "wastes" half her reproductive output on producing males, giving the asexual type a twofold per-generation edge in numbers.

Step 3 – reject the others: Sex does not double offspring number, lifespan or mutation rate; the cost is the production of males.

Final Answer: she devotes half her reproductive output to producing males $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – Muller's ratchet: In a finite asexual population, once the class of individuals carrying the fewest deleterious mutations is lost by chance, it cannot be reconstructed without recombination.

Step 1 – note the missing repair: Without sex there is no way to recombine two mutation-loaded genomes into a cleaner one.

Step 2 – follow the ratchet: Each time the least-loaded class is lost, the mutational load clicks up one notch and never comes back down.

Step 3 – state the outcome: Small asexual populations therefore accumulate deleterious mutations irreversibly.

Step 4 – reject the others: The ratchet does not purge mutations, add unlimited beneficial ones, or preserve a perfect genome.

Final Answer: accumulate deleterious mutations irreversibly $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q21

Q22.

Solution

Concept – the Red Queen hypothesis: Parasites evolve rapidly to exploit the commonest host genotypes, so a host lineage must keep changing its genotypes just to stay ahead.

Step 1 – identify the moving threat: Coevolving parasites and pathogens continually track and attack the most abundant host types.

Step 2 – state sex's role: By recombining alleles each generation, sexual hosts produce rare, hard-to-infect genotypes, offsetting the twofold cost of sex.

Step 3 – reject the others: A stable environment, no predators, or a low mutation rate would remove, not create, the need for constant genetic reshuffling.

Final Answer: the pressure of coevolving parasites and pathogens $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – mutation–selection balance: Recurrent mutation adds an allele that selection removes; at balance the two rates match, giving $\hat{q} = \sqrt{\mu/s}$ for a deleterious recessive.

Step 1 – list the data: $\mu = 10^{-4}$ and $s = 0.01 = 10^{-2}$.

Step 2 – form the ratio: $\frac{\mu}{s} = \frac{10^{-4}}{10^{-2}} = 10^{-2}$

Step 3 – take the square root: $\hat{q} = \sqrt{10^{-2}} = 10^{-1}$

Step 4 – write the value: $\hat{q} = 0.1$

Final Answer: $\hat{q} = 0.1 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – relative fitness: Relative fitness rescales absolute fitnesses by dividing each by the largest, so the fittest genotype has a value of 1.

Step 1 – find the maximum absolute fitness: Among 8, 10 and 6, the largest is 10 (the heterozygote Aa).

Step 2 – divide the AA value by the maximum: $w_{AA} = \frac{8}{10}$

Step 3 – evaluate: $w_{AA} = 0.8$

Step 4 – reject the others: 1.0 is the heterozygote's relative fitness; 0.6 is aa's value (6/10); 0.5 does not arise from these numbers.

Final Answer: $w_{AA} = 0.8 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – reaction norms and $G \times E$: A reaction norm plots the phenotype a genotype produces across environments. Parallel lines mean genotype and environment act independently; non-parallel or crossing lines mean they interact.

Step 1 – read the figure: Line G_1 rises from E_1 to E_2 while line G_2 falls, so the two lines cross.

Step 2 – interpret the crossing: The rank order of the genotypes reverses between environments, so the effect of a genotype depends on the environment.

Step 3 – name the pattern: This dependence is a genotype-by-environment ($G \times E$) interaction.

Step 4 – reject the others: Both genotypes and both environments clearly affect the phenotype, and the crossing has nothing to do with dominance at a single locus.

Final Answer: a genotype-by-environment ($G \times E$) interaction $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – broad-sense heritability: H^2 is the share of total phenotypic variance that is genetic: $H^2 = \frac{V_G}{V_P}$, with $V_P = V_G + V_E + V_{G\times E}$.

Step 1 – add up the total variance: $V_P = 20 + 25 + 5$

Step 2 – evaluate the total: $V_P = 50$

Step 3 – form the ratio: $H^2 = \frac{20}{50}$

Step 4 – evaluate: $H^2 = 0.40$

Final Answer: $H^2 = 0.40 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q26

Q27.

Solution

Concept – Hardy–Weinberg genotype frequencies: With allele frequencies p and $q = 1 - p$, the homozygous recessive frequency is q^2.

Step 1 – find q: $q = 1 - p = 1 - 0.7 = 0.3$

Step 2 – square it: $q^2 = (0.3)^2$

Step 3 – evaluate: $q^2 = 0.09$

Step 4 – reject the others: 0.49 is p^2 (the AA frequency); 0.42 is $2pq$ (heterozygotes); 0.21 is one product pq.

Final Answer: $q^2 = 0.09 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – heritability from mid-parent regression: Regressing offspring phenotype on the average of the two parents gives a slope that directly estimates narrow-sense heritability h^2.

Step 1 – recall the relationship: slope of offspring on mid-parent $= h^2$

Step 2 – read the measured slope: The slope is given as 0.6.

Step 3 – state h^2: Therefore $h^2 = 0.6$.

Step 4 – reject the others: 0.36 would be h^4 or the slope squared; 1.0 implies perfect heritability; 0.4 is the environmental complement $1 - h^2$, none of which is the slope itself.

Final Answer: $h^2 = 0.6 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

Q29.

Solution

Concept – the breeder's equation: The response to one generation of selection is $R = h^2 S$, where S is the selection differential and h^2 the narrow-sense heritability.

Step 1 – list the data: $h^2 = 0.4$ and $S = 5$ g.

Step 2 – substitute: $R = 0.4 \times 5$

Step 3 – evaluate: $R = 2$ g

Step 4 – interpret: The mean seed mass is expected to rise by about 2 g in the offspring generation.

Final Answer: $R = 2 \text{ g} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q29

Q30.

Solution

Concept – allele frequency from genotype counts: Count alleles: each AA carries two A, each Aa carries one A, and there are $2N$ alleles in total.

Step 1 – count the A alleles: A alleles $= 2(98) + 1(84) = 196 + 84 = 280$

Step 2 – count all alleles: Total alleles $= 2 \times 200 = 400$

Step 3 – form the frequency: $\text{freq}(A) = \dfrac{280}{400}$

Step 4 – evaluate: $\text{freq}(A) = 0.70$

Final Answer: $\text{freq}(A) = 0.70 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – vicariance: Vicariance is the fragmentation of a continuous ancestral range by a newly formed barrier, splitting one population into two that can then diverge.

Step 1 – read the figure: A single range is cut in two by a new river running through it.

Step 2 – classify the cause: The barrier arises in place and divides a resident range, which is the hallmark of vicariance.

Step 3 – contrast with dispersal: In dispersal the organisms cross a pre-existing barrier to a new area; here the barrier itself appears and separates them.

Step 4 – reject the others: Sympatry means no geographic separation, and adaptive radiation is a later diversification, not the splitting event.

Final Answer: vicariance $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – the Wallace Line: Alfred Russel Wallace mapped a sharp faunal break running between Bali and Lombok and between Borneo and Sulawesi in the Indonesian archipelago.

Step 1 – identify the two faunas: West of the line the fauna is Oriental (Asian); east of it, it becomes Australian, with marsupials and distinctive birds.

Step 2 – explain the break: A deep-water channel kept the two faunas apart even during low-sea-level periods, so their species pools stayed distinct.

Step 3 – reject the others: The line lies in Southeast Asia, not between the Americas, between Europe and Africa, or at the poles.

Final Answer: the Oriental (Asian) and Australian faunal regions $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept – characters on a cladogram: A shared derived character (one that arose in a common ancestor and is inherited by its descendants) defines a clade; such a character is a synapomorphy.

Step 1 – locate the marked trait: The • sits on the branch leading to the ancestor of B and C.

Step 2 – note who shares it: Only B and C inherit the trait, so it is shared and derived within this group.

Step 3 – name it: A shared derived character used to group taxa is a synapomorphy.

Step 4 – reject the others: A plesiomorphy is ancestral (shared more widely); an autapomorphy is unique to a single taxon; a homoplasy arises independently rather than from common ancestry.

Final Answer: a synapomorphy (shared derived trait) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q33

Q34.

Solution

Concept – reading sister groups from a tree: The sister group of a clade is the lineage that branches off at the node immediately below (basal to) that clade.

Step 1 – find the clade $(\mathbf{P}, \mathbf{Q})$: P and Q join first at the shallowest node.

Step 2 – move down one node: The next node joins the (P, Q) clade with taxon R.

Step 3 – identify the sister: R attaches directly to the branch of (P, Q), so R is their sister group.

Step 4 – reject the others: S is the outgroup, branching off even deeper; P and Q are members of the clade, not its sister.

Final Answer: taxon R $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

Concept – the molecular clock: Neutral mutations accumulate at a roughly steady average rate, so the genetic distance between two lineages grows in step with elapsed time.

Step 1 – state the proportionality: sequence divergence $\propto$ time since the split

Step 2 – use it to date splits: Calibrating the rate with fossils lets the number of differences estimate when two lineages diverged.

Step 3 – reject the others: Population size, body size and selection strength are not what the neutral clock counts; it tracks time.

Final Answer: the time since they diverged from a common ancestor $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q35

Q36.

Solution

Concept – adaptive radiation: Adaptive radiation is the rapid diversification of one ancestral lineage into many species that occupy different ecological roles, often on islands with open niches.

Step 1 – read the scenario: One finch ancestor gave rise to many Galapagos species with different beaks and diets.

Step 2 – match the definition: Rapid branching into varied ecological forms from a single ancestor is adaptive radiation.

Step 3 – reject the others: Convergent evolution involves unrelated lineages; coevolution is reciprocal change between species; drift alone does not build such tight matches between beak and diet.

Final Answer: adaptive radiation $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q36

Q37.

Solution

Concept – r- versus K-selection: r-selected species maximise the rate of increase in unstable habitats through many cheap offspring; K-selected species are adapted to crowded, stable habitats with fewer, better-provisioned young.

Step 1 – read the traits listed: Small body, early maturity, many small offspring, little parental care.

Step 2 – match the syndrome: That combination is the classic r-selected life history.

Step 3 – reject the others: K-selection describes the opposite traits; iteroparity and semelparity refer only to how often reproduction occurs, not to this whole syndrome.

Final Answer: r-selected $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q37

Q38.

Solution

Concept – semelparity versus iteroparity: A semelparous organism reproduces once in a single large effort and then dies; an iteroparous one reproduces repeatedly over its life.

Step 1 – read the salmon's schedule: It breeds in one massive event, then dies.

Step 2 – match the term: Reproducing once and dying is semelparity ("big-bang" reproduction).

Step 3 – reject the others: Iteroparity is repeated breeding; monogamy and polygyny describe mating systems, not the number of reproductive episodes.

Final Answer: semelparity $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – Hamilton's rule: Altruism is favoured when $rB > C$, i.e. when the relatedness-weighted benefit to the recipient exceeds the cost to the actor.

Step 1 – write the condition: $rB > C$

Step 2 – solve for B: $B > \dfrac{C}{r}$

Step 3 – substitute the numbers: $B > \dfrac{1}{0.125}$

Step 4 – evaluate: $B > 8$

Step 5 – interpret: The benefit to the cousin must exceed 8 units for the alarm call to be favoured by kin selection.

Final Answer: B must exceed $8 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – evolutionarily stable strategy (ESS): An ESS is a strategy that, when common, does better against the resident population than any rare mutant strategy, so no alternative can spread.

Step 1 – state the invasion test: Ask whether a rare individual using a different strategy could earn a higher payoff and increase.

Step 2 – define stability: If no such rare mutant can do better, the resident strategy cannot be invaded, and it is an ESS.

Step 3 – reject the others: An ESS is judged by individual payoff, not group welfare; it need not be pure Cooperate; and being stable, it does not flip each generation.

Final Answer: it cannot be invaded by any rare alternative strategy $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q40

Q41.

Solution

Concept – Bateman's principle: The sex that invests more per gamete (eggs are costly; sperm are cheap) has its reproductive success limited by access to resources and good mates, not by mate number.

Step 1 – compare gamete investment: Females make few, expensive eggs; males make many, cheap sperm.

Step 2 – predict who is choosy: Because each reproductive attempt costs the female more, she should be selective about her mates.

Step 3 – state the outcome: The high-investment sex (usually the female) becomes the choosier sex, while the low-investment sex competes for access.

Step 4 – reject the others: The high-investment sex is not the less selective one, choosiness is not fixed by body size, and it certainly can reproduce.

Final Answer: the more selective (choosier) sex $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – the median: The median is the middle value once the data are placed in order; for an odd count it is the single central entry.

Step 1 – sort the values: $3,\ 5,\ 7,\ 9,\ 11$

Step 2 – find the middle position: With 5 values the middle is the 3rd entry.

Step 3 – read it off: The 3rd value is 7.

Step 4 – reject the others: 5 and 9 are the neighbouring values, and 35 is the sum, not the median.

Final Answer: median $= 7 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – sample variance: $s^2 = \dfrac{1}{n-1}\sum_i (x_i - \bar{x})^2$, using $n-1$ in the denominator for a sample.

Step 1 – find the deviations from the mean $\bar{x} = 4$: $2-4=-2, \quad 4-4=0, \quad 6-4=2$

Step 2 – square each deviation: $(-2)^2 = 4, \quad 0^2 = 0, \quad 2^2 = 4$

Step 3 – sum the squares: $4+0+4=8$

Step 4 – divide by $n-1=2$: $s^2 = \dfrac{8}{2} = 4$

Final Answer: $s^2 = 4 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q43

Q44.

Solution

Concept – estimating r from two counts: For exponential growth, $r = \dfrac{1}{t}\ln\left(\dfrac{N_t}{N_0}\right)$.

Step 1 – form the ratio of counts: $\dfrac{N_5}{N_0} = \dfrac{200}{100} = 2$

Step 2 – take the natural log: $\ln 2 = 0.693$

Step 3 – divide by the elapsed time $t = 5$ yr: $r = \dfrac{0.693}{5}$

Step 4 – evaluate: $r = 0.1386 \approx 0.139\ \text{yr}^{-1}$

Final Answer: $r \approx 0.139\ \text{yr}^{-1} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q44

Q45.

Solution

Concept – the Lincoln–Petersen estimator: The marked fraction in the second sample equals the marked fraction of the whole population, giving $\hat{N} = \dfrac{Mn}{R}$.

Step 1 – list the data: $M = 50$ marked, $n = 40$ recaptured, $R = 10$ of them marked.

Step 2 – multiply M and n: $Mn = 50 \times 40 = 2000$

Step 3 – divide by R: $\hat{N} = \dfrac{2000}{10}$

Step 4 – evaluate: $\hat{N} = 200$

Final Answer: $\hat{N} = 200 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – sign and size of the correlation coefficient: The correlation coefficient r lies between -1 and $+1$; its sign follows the slope of the trend, and its magnitude reflects how tightly the points hug the line.

Step 1 – read the slope: The fitted line falls from upper left to lower right, so the slope is negative.

Step 2 – fix the sign of r: A negative slope means $r < 0$.

Step 3 – judge the scatter: The points cluster very tightly along the line, so $|r|$ is close to 1.

Step 4 – combine: Negative sign plus tight clustering gives an r near -1.

Final Answer: negative, close to $-1 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q46

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	D	3	C	4	A	5	A
6	D	7	B	8	C	9	B	10	B
11	A	12	B	13	B	14	A	15	D
16	A	17	C	18	C	19	B	20	D
21	B	22	B	23	D	24	C	25	C
26	D	27	B	28	D	29	D	30	B
31	C	32	A	33	A	34	C	35	B
36	D	37	C	38	C	39	A	40	D
41	A	42	B	43	A	44	C	45	A
46	D								