# GATE Ecology and Evolution

## Sample Paper – 7

**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 keystone species is best defined as a species that: **[1 mark]**

(A) exerts an effect on its community out of all proportion to its relative abundance or biomass

(B) is invariably the most abundant species present in the community

(C) is always the largest-bodied top predator in the ecosystem

(D) contributes the greatest share of the community's total biomass

**Q2.** The transition zone between two adjacent ecosystems, such as the boundary between a forest and an open grassland, is called: **[1 mark]**

(A) a biome

(B) an ecocline

(C) an ecotone

(D) an ecological niche

**Q3.** The indirect process by which a top predator suppresses herbivores and thereby allows the plant community to flourish is called: **[1 mark]**

(A) bottom-up control

(B) a trophic cascade (top-down control)

(C) competitive release

(D) a mutualistic interaction

**Q4.** An ectothermic invertebrate has a temperature coefficient $Q_{10} = 3$. If its metabolic rate is $4$ units at $10°$C, its rate at $30°$C is: **[1 mark]**

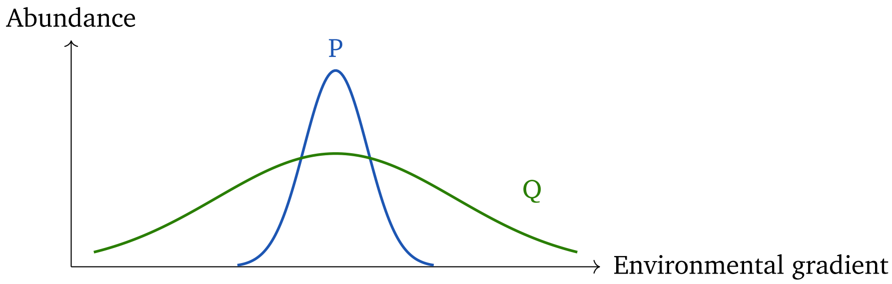
(A) $12$ units

(B) $9$ units

(C) $4$ units

(D) $36$ units

**Q5.** The two abundance curves below plot two species against an environmental gradient. Species P (narrow curve) tolerates only a small part of the gradient, while species Q (broad curve) is abundant across a wide range. Species P is best described as: **[1 mark]**




collegedunia |

(A) a stenotopic (narrow-tolerance) specialist

(B) a eurytopic generalist

(C) a cosmopolitan species with no limits

(D) completely unaffected by this factor

**Q6.** Within a single warm-blooded species, populations living in colder regions tend to have a larger body size than those in warmer regions. This ecogeographic generalization is: **[1 mark]**

(A) Allen's rule

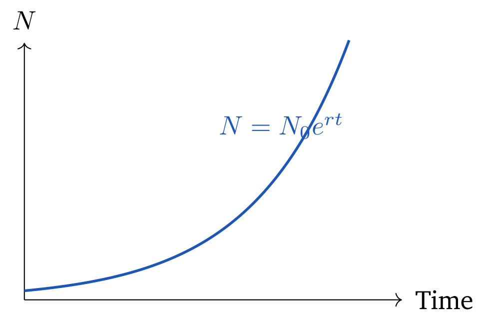
(B) Gloger's rule

(C) Rapoport's rule

(D) Bergmann's rule

## Population and Community Ecology

**Q7.** A bacterial population grows exponentially with intrinsic rate $r = 0.0231\ \text{min}^{-1}$, following $N(t) = N_0 e^{rt}$ as sketched below. Its doubling time (take $\ln 2 = 0.693$) is: **[1 mark]**



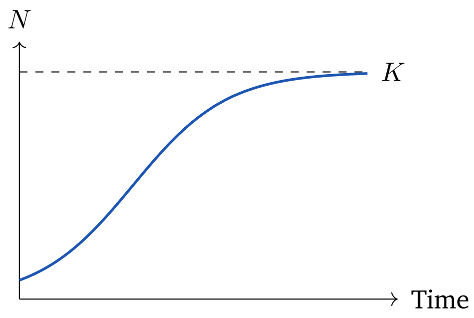

(A) 15 minutes

(B) 60 minutes

(C) 45 minutes

(D) 30 minutes

**Q8.** A population grows logistically with intrinsic rate $r = 0.8\ \text{yr}^{-1}$ and carrying capacity $K = 1000$, following the S-shaped curve shown. When the current size is $N = 250$, the instantaneous growth rate $\frac{dN}{dt}$ is: **[1 mark]**



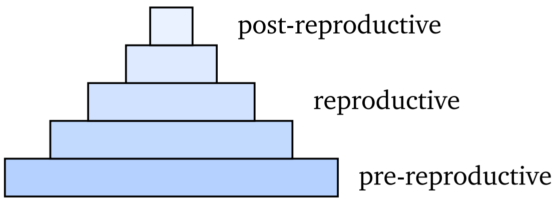

(A) 200 individuals/year

(B) 150 individuals/year

(C) 250 individuals/year

(D) 100 individuals/year

**Q9.** The age-structure pyramid shown, with a very broad base of pre-reproductive individuals and a narrow apex, indicates a population that is: **[1 mark]**



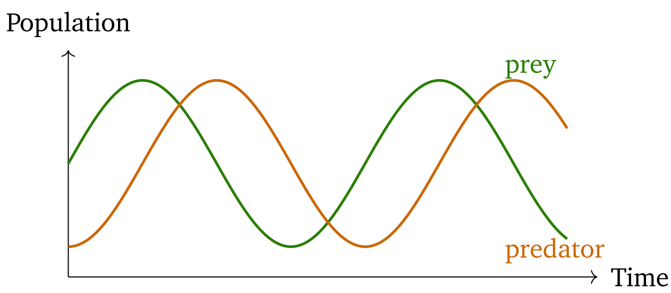

(A) declining steadily toward extinction

(B) stable and stationary in size

(C) exactly at its carrying capacity

(D) expanding (growing rapidly)

**Q10.** In the Lotka–Volterra predator–prey model, the two populations oscillate as shown. Relative to the peak of the prey population, the predator population peaks: **[1 mark]**



(A) exactly in phase with the prey

(B) a full cycle behind the prey

(C) about a quarter-cycle after the prey peak

(D) slightly before the prey peak

**Q11.** The gradual, orderly replacement of species in a community that begins on a bare surface with no pre-existing soil, such as newly cooled volcanic rock, is called: **[1 mark]**

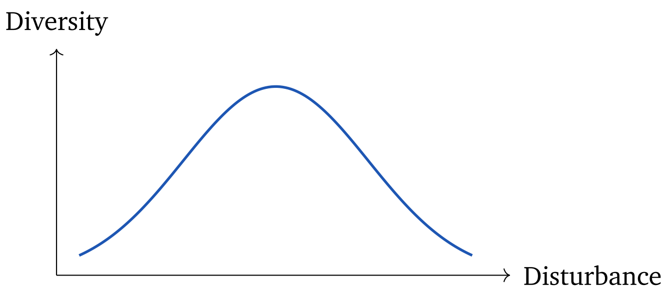
(A) primary succession

(B) secondary succession

(C) a trophic cascade

(D) competitive exclusion

**Q12.** The hump-shaped curve below summarizes the intermediate disturbance hypothesis. It predicts that species diversity in a community is highest when the disturbance regime is: **[1 mark]**




(A) entirely absent

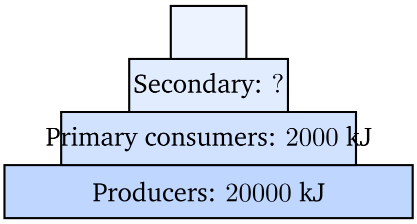
(B) very frequent and severe

(C) intermediate in frequency and intensity

(D) continuous and unchanging

## Ecosystems and Biogeochemical Cycles

**Q13.** Using Lindeman's ten-percent law of energy transfer, illustrated by the pyramid below, if the producers fix $20000$ kJ then the energy available to the secondary consumers (carnivores) is approximately: **[1 mark]**




(A) 2000 kJ

(B) 200 kJ

(C) 20 kJ

(D) 2 kJ

**Q14.** In waterlogged wetland soils, dead plant material accumulates as peat rather than decomposing fully. The main reason is that: **[1 mark]**

(A) decomposers respire much faster in the absence of oxygen

(B) photosynthesis ceases entirely in wetland plants

(C) nitrogen fixation stops completely in waterlogged soil

(D) anoxic (oxygen-poor) waterlogged conditions greatly slow microbial decomposition

**Q15.** Wetlands are one of the largest natural sources of the greenhouse gas methane. In waterlogged anoxic sediments this methane is produced mainly by: **[1 mark]**

(A) aerobic nitrifying bacteria

(B) methanogenesis carried out by archaea

(C) oxygenic photosynthesis by algae

(D) ordinary aerobic respiration

**Q16.** In wetland and freshwater systems, most phosphorus does not have a gaseous phase; it is instead retained in the ecosystem chiefly by: **[1 mark]**

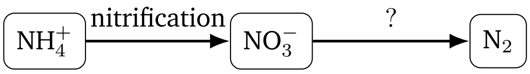
(A) binding to sediments and soil particles

(B) escaping to the atmosphere as phosphine gas

(C) dissolving into the air as $N_2$

(D) forming atmospheric ozone

**Q17.** In the wetland nitrogen pathway shown, the final anaerobic microbial step that converts nitrate ($NO_3^-$) back to nitrogen gas ($N_2$), removing fixed nitrogen from the system, is: **[1 mark]**



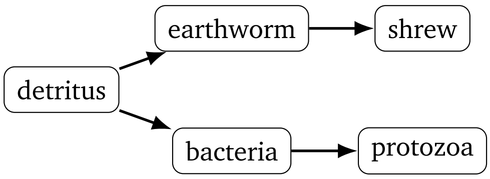

(A) nitrification

(B) nitrogen fixation

(C) denitrification

(D) ammonification

**Q18.** In the wetland detrital food web shown, the earthworms and bacteria that feed directly on dead organic matter (detritus) are the: **[1 mark]**




(A) the primary producers

(B) the primary carnivores

(C) the detritivores

(D) the apex predators

## Mechanisms of Evolution

**Q19.** When a small number of individuals colonize a new, previously uninhabited island and establish a population whose allele frequencies differ from those of the large source population purely by chance, the phenomenon is called: **[1 mark]**

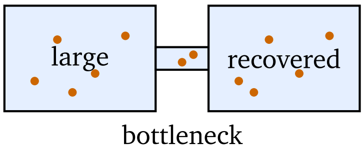
(A) gene flow between two large populations

(B) the founder effect

(C) directional selection

(D) recurrent forward mutation

**Q20.** A severe, short-lived crash that drastically reduces population size and genetic variation, after which the population recovers from only a few surviving individuals, is illustrated below. This is called: **[1 mark]**




(A) a population (genetic) bottleneck

(B) an adaptive radiation

(C) character displacement

(D) stabilizing selection

**Q21.** Genetic drift erodes heterozygosity each generation. In a randomly mating population of effective size $N_e = 50$, the expected fraction of heterozygosity lost per generation, given by $\frac{1}{2N_e}$, is: **[2 marks]**

(A) $0.5$

(B) $0.05$

(C) $0.02$

(D) $0.01$

**Q22.** Under pure genetic drift, the probability that a single, newly arisen *neutral* mutation will eventually become fixed in a diploid population of $N$ individuals is: **[2 marks]**

(A) $1$

(B) $\frac{1}{N}$

(C) $\frac{1}{2}$

(D) $\dfrac{1}{2N}$

**Q23.** In very small populations, slightly deleterious alleles can nevertheless drift to fixation. The correct explanation is that: **[2 marks]**

(A) natural selection is always stronger than drift, regardless of population size

(B) genetic drift can overwhelm weak selection when the population is small

(C) mutation rates rise sharply as population size falls

(D) gene flow always removes deleterious alleles before they spread

**Q24.** In a recipient population the frequency of allele $A$ is $0.4$. In one generation a fraction $m = 0.2$ of the individuals are replaced by migrants from a source population in which the frequency of $A$ is $0.9$. Using $p' = (1 - m)p + m\,p_m$, the new frequency of $A$ is: **[2 marks]**

(A) $0.40$

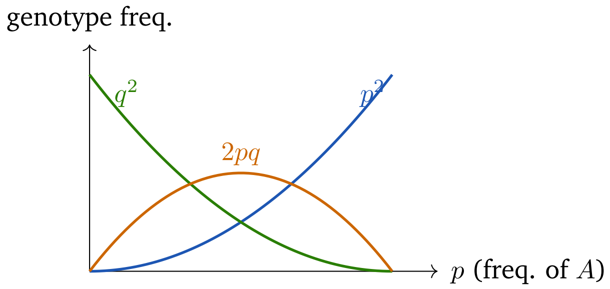
(B) $0.58$

(C) $0.45$

(D) $0.50$

## Population and Quantitative Genetics

**Q25.** In a population at Hardy–Weinberg equilibrium the recessive allele $a$ has frequency $q = 0.2$. From the genotype-frequency curves sketched below, the frequency of heterozygotes ($Aa$), given by $2pq$, is: **[2 marks]**




(A) $0.16$

(B) $0.32$

(C) $0.64$

(D) $0.04$

**Q26.** A recessive genetic disorder affects $1$ in $2500$ individuals, so that $q^2 = 0.0004$. Assuming Hardy–Weinberg equilibrium, the frequency of carriers (heterozygotes) in the population is approximately: **[2 marks]**

(A) $0.0004$

(B) $0.02$

(C) $0.0392$

(D) $0.5$

**Q27.** In the response-to-selection framework, the selection differential $S$ of a quantitative trait is defined as: **[2 marks]**

(A) the difference between the mean phenotype of the selected parents and the mean of the whole population

(B) the ratio of additive genetic variance to total phenotypic variance

(C) the number of offspring produced per selected parent

(D) the per-generation rate of new mutation

**Q28.** The narrow-sense heritability $h^2$ of a quantitative trait is defined as the ratio of: **[2 marks]**

(A) additive genetic variance to total phenotypic variance

(B) dominance variance to environmental variance

(C) environmental variance to phenotypic variance

(D) total genetic variance to additive genetic variance

**Q29.** The breeder's equation predicts the response to selection as $R = h^2S$. If the narrow-sense heritability of a trait is $h^2 = 0.4$ and the selection differential is $S = 10$ g, the predicted response $R$ across one generation is: **[2 marks]**

(A) 10 g

(B) 4 g

(C) 2.5 g

(D) 0.4 g

**Q30.** In a sample of 100 diploid individuals the genotype counts are $AA = 20$, $Aa = 60$ and $aa = 20$. The frequency of allele $A$ in the sample is: **[2 marks]**

(A) 0.20

(B) 0.50

(C) 0.40

(D) 0.60

## Speciation, Phylogeny and Macroevolution

**Q31.** The largest mass extinction in the history of life, which eliminated roughly 90–96% of all marine species, occurred at the boundary marking the end of the: **[2 marks]**

(A) Cretaceous period

(B) Ordovician period

(C) Triassic period

(D) Permian period

**Q32.** The Cretaceous–Paleogene (K–Pg) mass extinction, which wiped out the non-avian dinosaurs about 66 million years ago, is most widely attributed to: **[2 marks]**

(A) a nearby supernova explosion

(B) the sudden spread of flowering plants

(C) continental glaciation acting entirely on its own

(D) a large asteroid impact at Chicxulub

**Q33.** *Archaeopteryx*, a fossil that combines reptilian features such as teeth and a bony tail with bird-like feathers and wings, is a classic example of a: [2 marks]

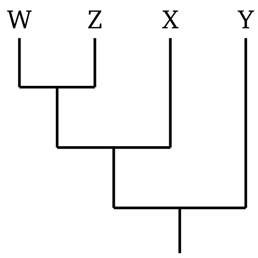
(A) living fossil

(B) transitional (intermediate) fossil

(C) index fossil useful only for dating rock strata

(D) trace fossil

**Q34.** In the phylogenetic tree shown, which two taxa are most closely related, i.e. share the most recent common ancestor? [2 marks]




(A) X and Y

(B) W and Z

(C) W and X

(D) Y and Z

**Q35.** The rapid diversification of a single ancestral lineage into many descendant species that come to occupy a wide range of ecological niches, as seen in the finches of the Galápagos Islands, is called: [2 marks]

(A) convergent evolution

(B) coevolution

(C) adaptive radiation

(D) phyletic gradualism

**Q36.** The pattern seen in many fossil lineages, in which long spans of little morphological change are interrupted by geologically brief bursts of rapid speciation, is described by the model of: [2 marks]

(A) punctuated equilibrium

(B) phyletic gradualism

(C) orthogenesis

(D) strictly neutral evolution

## Behavioural Ecology

**Q37.** The waggle dance performed by a returning honeybee forager, whose angle and duration encode the direction and distance of a food source, is best described as: **[2 marks]**

(A) a fixed action pattern that carries no information

(B) an act of kin-selected altruism toward the queen

(C) symbolic communication conveying the direction and distance of food

(D) an evolutionarily stable strategy in a competitive game

**Q38.** A ground squirrel that gives a loud alarm call warning nearby relatives of a predator, while drawing the predator's attention to itself, is behaving in a way best explained by: **[2 marks]**

(A) mutualism between unrelated individuals

(B) reciprocal altruism alone

(C) kin selection

(D) sexual selection

**Q39.** Hamilton's rule states that an altruistic act is favoured by kin selection when $rB > C$, where $r$ is the coefficient of relatedness between actor and recipient. For a parent and its own offspring, $r$ equals: **[2 marks]**

(A) 0.5

(B) 0.25

(C) 0.125

(D) 1.0

**Q40.** The payoff matrix for the Hawk–Dove game is shown (each entry is the payoff to the row player), with resource value $V = 2$ and cost of injury $C = 6$. Because the cost of escalation exceeds the value of the resource $(C > V)$, the evolutionarily stable outcome in the population is: **[2 marks]**

| | Hawk | Dove |
|---|---|---|
| Hawk | $\frac{V-C}{2}$ | $V$ |
| Dove | $0$ | $\frac{V}{2}$ |

(A) a population of pure Hawks

(B) a population of pure Doves

(C) a stable mixture of Hawks and Doves

(D) neither strategy able to persist at all

**Q41.** According to Zahavi's handicap principle, an exaggerated ornament such as the peacock's tail conveys reliable information about the bearer's quality precisely because it is costly to produce and maintain. Such a signal is therefore an example of: **[2 marks]**

(A) an honest signal made reliable by its cost

(B) a deceptive (dishonest) signal

(C) a cost-free conventional signal

(D) a supernormal stimulus with no cost

## Quantitative Ecology, Biostatistics and Mathematics

**Q42.** For the ordered set of quadrat counts $\{4, 6, 7, 9, 14\}$, the median value is: **[2 marks]**

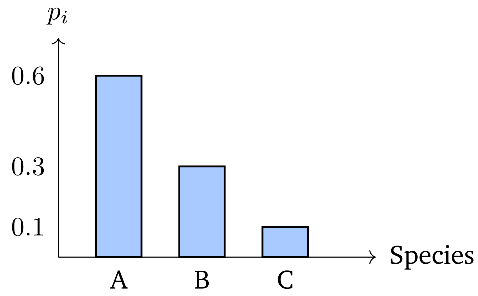
(A) $6$

(B) $7$

(C) $8$

(D) $9$

**Q43.** A community contains three species with proportional abundances $p_1 = 0.6$, $p_2 = 0.3$ and $p_3 = 0.1$, shown in the bar chart. Simpson's index $D = \sum_i p_i^2$ for this community equals: **[2 marks]**




(A) 0.46

(B) 0.54

(C) 1.00

(D) 0.23

**Q44.** When individuals are distributed independently and at random in space, the number counted per quadrat is expected to follow a distribution whose variance equals its mean. That distribution is the: **[2 marks]**

(A) normal distribution

(B) binomial distribution

(C) uniform distribution

(D) Poisson distribution

**Q45.** In a mark–recapture study, 50 animals are captured, marked and released. On a second occasion 40 animals are captured, of which 10 carry marks. Using the Lincoln–Petersen estimator $N = \dfrac{M \times C}{R}$, the estimated population size is: **[2 marks]**

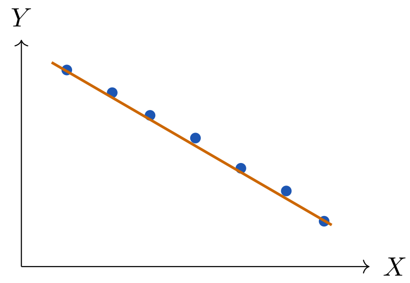
(A) 200

(B) 100

(C) 400

(D) 20

**Q46.** The scatter plot below shows measurements of two variables $X$ and $Y$ together with a fitted straight line of negative slope through the cloud of points. The correlation coefficient $r$ for these data is best described as:**[2 marks]**




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

(B) exactly zero

(C) negative, with $-1 < r < 0$

(D) exactly $+1$

## Detailed Solutions

### Q1.

**Solution**

**Concept – keystone species:** A keystone species holds a community together far more strongly than its numbers alone would suggest; remove it and the community changes drastically.

**Step 1 – separate abundance from influence:** Importance here is measured by effect on community structure, not by how common the species is.

**Step 2 – state the defining feature:** A keystone species has an impact that is large *relative to* its abundance or biomass.

**Step 3 – classic example:** The sea otter is not abundant, yet by eating sea urchins it protects entire kelp forests.

**Step 4 – reject the others:** Keystone species need not be the most abundant, the largest predator, or the biggest contributor of biomass.

**Final Answer:** out of all proportion to its abundance/biomass $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q1

### Q2.

**Solution**

**Concept – the ecotone:** An ecotone is the boundary zone where two different communities meet and blend into one another.

**Step 1 – read the description:** The question describes the transition between a forest and a grassland.

**Step 2 – name the zone:** Such a transition band between two ecosystems is an ecotone, which often shows an edge effect with high species richness.

**Step 3 – reject the others:** A biome is a large climatic community type; an ecocline is a gradual gradient without a sharp junction; a niche is a species' functional role, not a place.

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

**Answer: (C)** Go Back to Q2

## Q3.

**Solution**

**Concept – trophic cascade:** When a change at the top of a food chain ripples down through the lower levels, the indirect chain of effects is a trophic cascade.

**Step 1 – trace the effect:** A predator lowers herbivore numbers, which in turn relieves grazing pressure on plants.

**Step 2 – classify the control:** Because the influence flows downward from the predator, this is top-down control acting as a trophic cascade.

**Step 3 – reject the others:** Bottom-up control runs the opposite way (resources upward); competitive release and mutualism describe different interactions.

**Final Answer:** a trophic cascade $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q3

## Q4.

**Solution**

**Concept – the temperature coefficient $Q_{10}$:** $Q_{10}$ is the factor by which a metabolic rate is multiplied for every 10°C rise. Here $Q_{10} = 3$.

**Step 1 – find the temperature change:** $\Delta T = 30 - 10 = 20°\text{C}$

**Step 2 – count the number of 10°C steps:** $\dfrac{20}{10} = 2$ steps

**Step 3 – apply the multiplier for two steps:** $\text{rate}_{30} = 4 \times 3^2$

**Step 4 – evaluate the power:** $3^2 = 9$

**Step 5 – multiply:** $\text{rate}_{30} = 4 \times 9 = 36$ units

**Final Answer:** 36 units $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q4

## Q5.

**Solution**

**Concept – niche breadth along a gradient:** A species with a narrow tolerance curve can occupy only a small portion of an environmental gradient; a species with a broad curve tolerates a wide range.

**Step 1 – read the figure:** Curve P is tall and narrow, so species P thrives only over a small band of the gradient.

**Step 2 – classify species P:** A narrow tolerance means P is a stenotopic specialist.

**Step 3 – contrast with Q:** The broad, flat curve Q marks a eurytopic generalist that copes across the whole gradient.

**Step 4 – reject the others:** "Cosmopolitan" and "unaffected" both wrongly imply no limits, which contradicts P's narrow curve.

**Final Answer:** a stenotopic specialist $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

## Q6.

**Solution**

**Concept – ecogeographic rules:** Several rules link body form to climate. Bergmann's rule concerns body size and temperature.

**Step 1 – read the pattern:** Colder regions hold larger-bodied populations of the same warm-blooded species.

**Step 2 – match the rule:** Larger bodies have a smaller surface-area-to-volume ratio and lose heat more slowly, which is Bergmann's rule.

**Step 3 – reject the others:** Allen's rule is about the length of extremities; Gloger's rule about pigmentation and humidity; Rapoport's rule about latitudinal range size.

**Final Answer:** Bergmann's rule $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

## Q7.

**Solution**

**Concept – doubling time of exponential growth:** For $N(t) = N_0 e^{rt}$, the population doubles when $e^{rt} = 2$, giving $t_2 = \dfrac{\ln 2}{r}$.

**Step 1 – write the doubling condition:** $N = 2N_0 \;\Rightarrow\; e^{rt_2} = 2$

**Step 2 – take the natural logarithm:** $r\,t_2 = \ln 2$

**Step 3 – solve for $t_2$:** $t_2 = \dfrac{\ln 2}{r} = \dfrac{0.693}{0.0231}$

**Step 4 – evaluate:** $t_2 = 30$ min

**Final Answer:** 30 minutes $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q7

## Q8.

**Solution**

**Concept – evaluating the logistic rate:** Substitute the given values into $\dfrac{dN}{dt} = rN\left(1 - \dfrac{N}{K}\right)$.

**Step 1 – list the data:** $r = 0.8\ \text{yr}^{-1}$, $N = 250$, $K = 1000$.

**Step 2 – compute the bracket:** $1 - \dfrac{N}{K} = 1 - \dfrac{250}{1000} = 1 - 0.25 = 0.75$

**Step 3 – multiply $r$ and $N$:** $rN = 0.8 \times 250 = 200$

**Step 4 – multiply by the bracket:** $\dfrac{dN}{dt} = 200 \times 0.75 = 150$

**Final Answer:** 150 individuals/year $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q8

## Q9.

**Solution**

**Concept – reading an age-structure pyramid:** The shape of an age pyramid reveals whether a population will grow, stay level, or shrink.

**Step 1 – read the figure:** The base of pre-reproductive individuals is very wide compared with the older classes.

**Step 2 – interpret the broad base:** Many young individuals are about to enter the reproductive stage, so births will soon greatly exceed deaths.

**Step 3 – conclude the trend:** A pyramid with a broad base and narrow apex signals a rapidly expanding population.

**Step 4 – reject the others:** A declining population has a narrow base; a stable one has roughly straight sides; carrying capacity is not read from age structure alone.

**Final Answer:** expanding (growing rapidly) $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q9

## Q10.

### Solution

**Concept – phase relationship in Lotka–Volterra cycles:** Prey and predator populations oscillate, but the predator response lags behind the prey because it takes time for extra prey to be converted into extra predators.

**Step 1 – read the figure:** The predator curve rises after the prey curve and reaches its peak later.

**Step 2 – quantify the lag:** In the classic model the predator peak trails the prey peak by about one quarter of a full cycle.

**Step 3 – reason it out:** Predators keep increasing as long as prey are plentiful, so their maximum comes just after prey abundance has already begun to fall.

**Step 4 – reject the others:** The curves are neither exactly in phase, nor a full cycle apart, nor is the predator peak before the prey peak.

**Final Answer:** about a quarter-cycle after the prey peak $\Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q10

## Q11.

### Solution

**Concept – primary versus secondary succession:** Primary succession begins where no soil exists yet; secondary succession begins where a disturbance has left the soil intact.

**Step 1 – read the starting point:** The community develops on bare volcanic rock with no pre-existing soil.

**Step 2 – classify it:** Because soil must first be built by pioneer species such as lichens and mosses, this is primary succession.

**Step 3 – reject the others:** Secondary succession needs leftover soil; a trophic cascade and competitive exclusion are not successional processes.

**Final Answer:** primary succession $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q11

## Q12.

**Solution**

**Concept – the intermediate disturbance hypothesis:** Diversity is not highest at the extremes of disturbance but somewhere in between.

**Step 1 – consider very low disturbance:** With little disturbance a few strong competitors take over and exclude others, lowering diversity.

**Step 2 – consider very high disturbance:** With frequent, severe disturbance only a few hardy pioneers survive, again lowering diversity.

**Step 3 – read the hump-shaped curve:** Diversity peaks at intermediate disturbance, where both good competitors and good colonizers can coexist.

**Final Answer:** intermediate in frequency and intensity $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q12

## Q13.

**Solution**

**Concept – Lindeman's ten-percent law:** Only about $10\%$ of the energy at one trophic level is passed to the next.

**Step 1 – start with the producers:** Energy fixed $= 20000$ kJ.

**Step 2 – transfer to primary consumers:** $10\% \times 20000 = 2000$ kJ

**Step 3 – transfer to secondary consumers:** $10\% \times 2000 = 200$ kJ

**Step 4 – state the result:** The secondary consumers receive about $200$ kJ, i.e. $1\%$ of the producers' energy.

**Final Answer:** $200$ kJ $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

## Q14.

**Solution**

**Concept – why peat accumulates in wetlands:** Decomposition is largely an aerobic process. Where oxygen is scarce, decomposers work slowly and organic matter piles up.

**Step 1 – note the wetland condition:** Waterlogging fills the soil pores with water and excludes oxygen, making the soil anoxic.

**Step 2 – link to decomposition:** Aerobic decomposers cannot function well without oxygen, so breakdown of dead plant matter is very slow.

**Step 3 – state the outcome:** The undecomposed material accumulates as peat.

**Step 4 – reject the others:** Decomposers do not speed up without oxygen; photosynthesis and nitrogen fixation are not the cause of peat build-up.

**Final Answer:** anoxic waterlogged conditions slow decomposition $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q14

## Q15.

### Solution

**Concept – methanogenesis in wetlands:** In the absence of oxygen, specialized archaea break down organic carbon and release methane ($CH_4$).

**Step 1 – identify the environment:** Waterlogged wetland sediments are anoxic.

**Step 2 – identify the microbes:** Only methanogenic archaea can carry out methanogenesis under these anaerobic conditions.

**Step 3 – state the product:** Their metabolism releases methane, making wetlands a major natural methane source.

**Step 4 – reject the others:** Nitrification and aerobic respiration need oxygen; photosynthesis makes oxygen and sugars, not methane.

**Final Answer:** methanogenesis by archaea $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q15

## Q16.

### Solution

**Concept – phosphorus is a sedimentary cycle:** Unlike carbon or nitrogen, phosphorus has no important gaseous form, so it moves through rocks, soils and sediments.

**Step 1 – recall the reservoir:** The main store of phosphorus is in mineral and sedimentary deposits.

**Step 2 – apply to wetlands:** In wetlands phosphorus is held by adsorbing onto sediment and soil particles, for example onto iron and aluminium oxides.

**Step 3 – reject the others:** There is no significant phosphine gas in the air; $N_2$ and ozone belong to the nitrogen and oxygen chemistry, not phosphorus.

**Final Answer:** binding to sediments and soil particles $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

## Q17.

### Solution

**Concept – steps of the nitrogen cycle:** Nitrification oxidises ammonium to nitrate; denitrification reduces nitrate back to nitrogen gas under anaerobic conditions.

**Step 1 – read the arrow in question:** It runs from $NO_3^-$ to $N_2$.

**Step 2 – match the process:** The anaerobic conversion of nitrate to $N_2$ gas is denitrification, which is especially active in waterlogged wetland soils.

**Step 3 – note its effect:** Denitrification removes fixed nitrogen from the ecosystem and returns it to the atmosphere.

**Step 4 – reject the others:** Nitrification is the previous step; fixation makes ammonium from $N_2$; ammonification releases ammonium from organic matter.

**Final Answer:** denitrification $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q17

## Q18.

### Solution

**Concept – detritivores:** Detritivores feed on dead organic matter (detritus), forming the base of the detrital food web.

**Step 1 – read the web:** Earthworms and bacteria take their energy directly from the detritus box.

**Step 2 – assign the functional group:** Organisms that consume dead organic matter are detritivores.

**Step 3 – reject the others:** Producers make their own food; the shrew and protozoa here are consumers further along; apex predators sit at the top, not at the detritus.

**Final Answer:** the detritivores $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q18

## Q19.

**Solution**

**Concept – the founder effect:** When a few colonizers start a new population, the small sample they carry is unlikely to match the source's allele frequencies exactly.

**Step 1 – read the scenario:** Only a handful of individuals colonize an empty island.

**Step 2 – identify the cause:** The mismatch in allele frequencies arises from chance sampling in the small founding group, a special case of genetic drift called the founder effect.

**Step 3 – reject the others:** Gene flow needs ongoing migration between large populations; directional selection and mutation are not random sampling of founders.

**Final Answer:** the founder effect $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q19

## Q20.

**Solution**

**Concept – population bottleneck:** A bottleneck is a sharp, temporary reduction in population size that leaves behind only a small, possibly unrepresentative, sample of the original gene pool.

**Step 1 – read the figure:** A large population is squeezed through a narrow neck (few survivors) and then recovers.

**Step 2 – name the process:** This loss of genetic variation through a size crash is a genetic (population) bottleneck.

**Step 3 – state the consequence:** The recovered population has reduced diversity because rare alleles were lost during the crash.

**Step 4 – reject the others:** Adaptive radiation is diversification, character displacement is niche divergence, and stabilizing selection trims variance without a size crash.

**Final Answer:** a population (genetic) bottleneck $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q20

## Q21.

**Solution**

**Concept – loss of heterozygosity under drift:** Each generation a finite population loses a fraction $\frac{1}{2N_e}$ of its heterozygosity through random sampling of gametes.

**Step 1 – list the data:** $N_e = 50$.

**Step 2 – write the fraction:** $\frac{1}{2N_e} = \frac{1}{2 \times 50}$

**Step 3 – evaluate the denominator:** $2 \times 50 = 100$

**Step 4 – compute:** $\frac{1}{100} = 0.01$

**Final Answer:** $0.01 \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q21

## Q22.

**Solution**

**Concept – fixation probability of a neutral allele:** For a neutral mutation, drift alone decides its fate. Its chance of eventual fixation equals its current frequency in the population.

**Step 1 – count the copies of the new allele:** A single new mutation is one copy.

**Step 2 – count total gene copies:** In a diploid population of $N$ individuals there are $2N$ copies of the gene.

**Step 3 – form the frequency:** Initial frequency $= \frac{1}{2N}$.

**Step 4 – apply the neutral result:** For a neutral allele the fixation probability equals its frequency, so it is $\frac{1}{2N}$.

**Final Answer:** $\frac{1}{2N} \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q22

## Q23.

**Solution**

**Concept – drift versus selection:** Whether selection or drift dominates depends on population size. Selection is effective only when it is strong relative to $\frac{1}{2N}$.

**Step 1 – consider a small population:** Random sampling error (drift) is large when $N$ is small.

**Step 2 – compare with weak selection:** If the selection against an allele is weak, drift can be larger than the deterministic push of selection.

**Step 3 – state the outcome:** Drift can then carry a slightly deleterious allele all the way to fixation.

**Step 4 – reject the others:** Selection is not always stronger than drift, mutation rate does not rise with small size, and gene flow does not reliably remove such alleles.

**Final Answer:** drift can overwhelm weak selection in small populations $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q23

## Q24.

### Solution

**Concept – change in allele frequency due to gene flow:** After migration the new frequency is the weighted average $p' = (1-m)p + m\,p_m$.

**Step 1 – list the data:** $p = 0.4$, $m = 0.2$, $p_m = 0.9$.

**Step 2 – weight the resident frequency:** $(1-m)p = 0.8 \times 0.4 = 0.32$

**Step 3 – weight the migrant frequency:** $m\,p_m = 0.2 \times 0.9 = 0.18$

**Step 4 – add the two contributions:** $p' = 0.32 + 0.18 = 0.50$

**Final Answer:** $p' = 0.50 \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q24

## Q25.

### Solution

**Concept – Hardy–Weinberg heterozygote frequency:** The frequency of heterozygotes is $2pq$, where $p + q = 1$.

**Step 1 – find $p$ from $q$:** $p = 1 - q = 1 - 0.2 = 0.8$

**Step 2 – write the heterozygote term:** $2pq = 2 \times 0.8 \times 0.2$

**Step 3 – multiply the frequencies:** $0.8 \times 0.2 = 0.16$

**Step 4 – apply the factor of two:** $2 \times 0.16 = 0.32$

**Final Answer:** $2pq = 0.32 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q25

## Q26.

**Solution**

**Concept – carrier frequency from disease incidence:** For a recessive disorder, $q^2$ is the frequency of affected homozygotes; carriers are the heterozygotes with frequency $2pq$.

**Step 1 – find $q$:** $q = \sqrt{q^2} = \sqrt{0.0004} = 0.02$

**Step 2 – find $p$:** $p = 1 - q = 1 - 0.02 = 0.98$

**Step 3 – write the carrier frequency:** $2pq = 2 \times 0.98 \times 0.02$

**Step 4 – evaluate:** $2 \times 0.98 \times 0.02 = 0.0392$

**Final Answer:** $\approx 0.0392 \Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q26

## Q27.

**Solution**

**Concept – the selection differential:** The selection differential $S$ measures how far the breeders chosen to reproduce differ, on average, from the population as a whole.

**Step 1 – identify the two means:** One is the mean phenotype of the selected parents; the other is the mean of the entire population.

**Step 2 – form the difference:** $S = \bar{x}_{\text{selected parents}} - \bar{x}_{\text{population}}$.

**Step 3 – state the definition:** $S$ is precisely this difference in means.

**Step 4 – reject the others:** Ratios of variances give heritability, not $S$; offspring number and mutation rate are unrelated to the selection differential.

**Final Answer:** difference between selected-parent mean and population mean $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q27

## Q28.

**Solution**

**Concept – narrow-sense heritability:** Narrow-sense heritability isolates the part of phenotypic variance that responds to selection, namely the additive genetic variance.

**Step 1 – write the definition:** $h^2 = \dfrac{V_A}{V_P}$

**Step 2 – name the terms:** $V_A$ is the additive genetic variance and $V_P$ is the total phenotypic variance.

**Step 3 – contrast with broad sense:** Broad-sense heritability $H^2 = \frac{V_G}{V_P}$ uses all genetic variance, but only the additive part predicts the response to selection.

**Step 4 – reject the others:** Dominance-to-environment, environment-to-phenotype, and genetic-to-additive ratios do not define $h^2$.

**Final Answer:** additive genetic variance to phenotypic variance $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q28

## Q29.

### Solution

**Concept – the breeder's equation:** The response to one generation of selection is $R = h^2 S$.

**Step 1 – list the data:** $h^2 = 0.4$, $S = 10$ g.

**Step 2 – substitute into the equation:** $R = 0.4 \times 10$

**Step 3 – evaluate:** $R = 4$ g

**Step 4 – interpret:** The offspring mean is expected to shift by 4 g in the selected direction.

**Final Answer:** $R = 4$ g $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q29

## Q30.

### Solution

**Concept – allele frequency from genotype counts:** The frequency of $A$ is the number of $A$ copies divided by the total number of gene copies.

**Step 1 – count $A$ copies:** Each $AA$ contributes 2 and each $Aa$ contributes 1: $2 \times 20 + 1 \times 60 = 40 + 60 = 100$

**Step 2 – count total gene copies:** $2 \times 100$ individuals $= 200$

**Step 3 – form the frequency:** $\text{freq}(A) = \frac{100}{200}$

**Step 4 – evaluate:** $\frac{100}{200} = 0.50$

**Final Answer:** $0.50 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q30

## Q31.

**Solution**

**Concept – the "Great Dying":** The end-Permian mass extinction, about 252 million years ago, was the most severe in Earth's history.

**Step 1 – match the severity:** Roughly 90–96% of marine species were lost, the highest of any extinction event.

**Step 2 – name the boundary:** This corresponds to the end of the Permian period (the Permian–Triassic boundary).

**Step 3 – reject the others:** The end-Cretaceous, end-Ordovician and end-Triassic events were serious but each killed a smaller fraction of species.

**Final Answer:** the Permian period $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q31

## Q32.

**Solution**

**Concept – the K–Pg extinction:** The extinction of the non-avian dinosaurs at the end of the Cretaceous is tied to a sudden, global catastrophe.

**Step 1 – recall the evidence:** A worldwide iridium-rich layer and the buried Chicxulub crater in Mexico date to about 66 million years ago.

**Step 2 – identify the cause:** These point to a large asteroid impact, whose dust and climate effects drove the mass extinction.

**Step 3 – reject the others:** A supernova, the rise of flowering plants, and glaciation alone are not supported as the primary trigger of the K–Pg event.

**Final Answer:** a large asteroid impact at Chicxulub $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q32

## Q33.

**Solution**

**Concept – transitional fossils:** A transitional fossil shows a mix of features from an ancestral group and a derived group, documenting an evolutionary link.

**Step 1 – read the features:** *Archaeopteryx* has reptilian teeth and a bony tail together with feathers and wings.

**Step 2 – classify it:** This blend of reptile and bird traits makes it a classic transitional (intermediate) form linking dinosaurs to birds.

**Step 3 – reject the others:** A living fossil is a surviving species little changed over time; an index fossil is used to date rocks; a trace fossil records activity such as footprints, not the body.

**Final Answer:** a transitional fossil $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

## Q34.

### Solution

**Concept – reading a phylogenetic tree:** The two taxa that meet at the most recent (highest) internal node are the most closely related.

**Step 1 – scan the nodes:** W and Z join first, at the highest node in the tree.

**Step 2 – trace the others:** X joins the (W, Z) group only at a deeper node, and Y joins the whole group at the deepest node.

**Step 3 – identify the sister pair:** Sharing the most recent common ancestor, W and Z are the most closely related.

**Step 4 – reject the others:** X and Y, W and X, and Y and Z all share only older, deeper common ancestors.

**Final Answer:** W and Z $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

## Q35.

### Solution

**Concept – adaptive radiation:** Adaptive radiation is the rapid branching of one lineage into many species that adapt to different niches.

**Step 1 – read the example:** Darwin's finches diversified from one ancestor into many forms with different beaks and diets.

**Step 2 – name the process:** This rapid ecological diversification from a common ancestor is adaptive radiation.

**Step 3 – reject the others:** Convergent evolution makes unrelated lineages resemble one another; coevolution is reciprocal change between species; phyletic gradualism is a tempo of change, not diversification.

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

Answer: (C) Go Back to Q35

## Q36.

**Solution**

**Concept – tempo of evolution in the fossil record:** Punctuated equilibrium proposes that species stay much the same for long periods (stasis), with change concentrated in short bursts around speciation.

**Step 1 – read the pattern:** Long stretches of little change alternate with brief episodes of rapid change.

**Step 2 – match the model:** This "stasis punctuated by bursts" pattern is punctuated equilibrium, proposed by Eldredge and Gould.

**Step 3 – reject the others:** Phyletic gradualism predicts slow, steady change; orthogenesis claims an inner drive toward a goal; strict neutral evolution is about molecular substitutions, not this morphological tempo.

**Final Answer:** punctuated equilibrium $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q36

## Q37.

**Solution**

**Concept – the honeybee waggle dance:** The waggle dance is a signal that transmits specific information from one bee to others.

**Step 1 – read the code:** The angle of the waggle run relative to vertical encodes direction, and its duration encodes distance to the food.

**Step 2 – classify it:** Because it conveys learned spatial information to nestmates, it is a form of symbolic communication.

**Step 3 – reject the others:** It is not information-free; it is not altruism in the kin-selection sense; and it is not a game-theoretic ESS.

**Final Answer:** symbolic communication of food direction and distance $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q37

## Q38.

**Solution**

**Concept – kin selection and alarm calls:** An alarm call is risky for the caller but protects nearby individuals. When those individuals are relatives, the caller's shared genes benefit.

**Step 1 – weigh the cost and benefit:** The caller pays a survival cost yet raises the survival of kin who carry copies of its alleles.

**Step 2 – apply the concept:** Behaviour favoured through the reproduction of relatives is explained by kin selection (inclusive fitness).

**Step 3 – reject the others:** Mutualism and reciprocal altruism involve non-relatives or repaid favours; sexual selection concerns mating success.

**Final Answer:** kin selection $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

## Q39.

### Solution

**Concept – coefficient of relatedness:** $r$ is the probability that a gene in one individual is shared by descent with another. For a parent and offspring this is a direct one-generation link.

**Step 1 – trace the inheritance:** An offspring receives exactly half of its genes from a given parent.

**Step 2 – write $r$:** Therefore $r = 0.5$ between a parent and its own offspring.

**Step 3 – reject the others:** $r = 0.25$ is for half-siblings or grandparent–grandchild; $r = 0.125$ is for first cousins; $r = 1.0$ is for identical twins or clones.

**Final Answer:** $r = 0.5 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q39

## Q40.

### Solution

**Concept – the Hawk–Dove game when $C > V$:** If the cost of injury exceeds the value of the resource, neither pure Hawk nor pure Dove can resist invasion by the other.

**Step 1 – test a pure-Hawk population:** Hawks meeting Hawks earn $\frac{V-C}{2} = \frac{2-6}{2} = -2 < 0$, so a rare Dove (which earns $0$ against Hawks) does better and can invade.

**Step 2 – test a pure-Dove population:** Doves earn $\frac{V}{2} = 1$ against each other, but a rare Hawk takes the full $V = 2$ and invades.

**Step 3 – conclude:** Since neither pure strategy is stable, the ESS is a mixed one, a stable mixture of Hawks and Doves (with Hawk frequency $V/C = 2/6 = 1/3$).

**Final Answer:** a stable mixture of Hawks and Doves $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q40

## Q41.

### Solution

**Concept – Zahavi's handicap principle:** A signal is believable only if it is too costly to fake. High cost guarantees honesty.

**Step 1 – read the logic:** Only a genuinely high-quality male can afford to grow and carry a large, costly tail.

**Step 2 – classify the signal:** Because its very cost makes it reliable, the ornament is an honest signal of quality.

**Step 3 – reject the others:** A deceptive signal would misrepresent quality; a cost-free conventional signal could be faked; a supernormal stimulus is an exaggerated releaser, not the point here.

**Final Answer:** an honest signal made reliable by its cost $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q41

## Q42.

### Solution

**Concept – the median:** The median is the middle value of an ordered data set.

**Step 1 – confirm the data are ordered:** $\{4, 6, 7, 9, 14\}$ is already in increasing order.

**Step 2 – count the values:** There are $5$ values, an odd number.

**Step 3 – locate the middle position:** The middle is the $\dfrac{5+1}{2} = 3^{\text{rd}}$ value.

**Step 4 – read it off:** The $3^{\text{rd}}$ value is $7$.

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

Answer: (B) Go Back to Q42

## Q43.

### Solution

**Concept – Simpson's index:** $D = \sum_i p_i^2$ sums the squared proportional abundances of all species.

**Step 1 – square each proportion:** $p_1^2 = 0.6^2 = 0.36$

$p_2^2 = 0.3^2 = 0.09$

$p_3^2 = 0.1^2 = 0.01$

**Step 2 – add the squares:** $D = 0.36 + 0.09 + 0.01$

**Step 3 – evaluate:** $D = 0.46$

**Final Answer:** $D = 0.46 \Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q43

## Q44.

### Solution

**Concept – spatial pattern and the Poisson distribution:** When individuals settle independently and at random, quadrat counts follow a Poisson distribution, for which the variance equals the mean.

**Step 1 – read the requirement:** Random, independent placement of individuals in space.

**Step 2 – match the distribution:** This is exactly the situation the Poisson distribution describes, with variance $=$ mean.

**Step 3 – link to ecology:** A variance-to-mean ratio near $1$ therefore indicates a random dispersion; values well above $1$ indicate clumping and below $1$ indicate a uniform pattern.

**Step 4 – reject the others:** The normal is continuous; the binomial needs a fixed number of trials; the uniform describes an even, non-random spread.

**Final Answer:** Poisson distribution $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q44

## Q45.

### Solution

**Concept – the Lincoln–Petersen estimator:** Population size is estimated from mark–recapture data as $N = \dfrac{M \times C}{R}$, where $M$ is the number first marked, $C$ the number caught in the second sample, and $R$ the marked ones recaptured.

**Step 1 – list the data:** $M = 50$, $C = 40$, $R = 10$.

**Step 2 – multiply $M$ and $C$:** $M \times C = 50 \times 40 = 2000$

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

**Step 4 – evaluate:** $N = 200$

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

Answer: (A) Go Back to Q45

## Q46.

### Solution

**Concept – sign of the correlation coefficient:** The correlation coefficient $r$ lies between $-1$ and $+1$; its sign follows the slope of the trend and its magnitude the tightness of the cloud.

**Step 1 – read the scatter:** $Y$ falls steadily as $X$ rises, and the points cluster near a downward-sloping line.

**Step 2 – fix the sign:** A downward trend means a negative $r$.

**Step 3 – fix the magnitude:** The points lie close to but not exactly on the line, so $-1 < r < 0$ rather than exactly $-1$.

**Final Answer:** negative, with $-1 < r < 0 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q46

## Answer Key

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