GATE Ecology and Evolution

Sample Paper – 3

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. An aquatic organism that can survive and function only within a narrow range of environmental temperature is described as: **[1 mark]**

(A) eurythermal

(B) stenothermal

(C) euryhaline

(D) stenohaline

Q2. The reversible, within-lifetime physiological adjustment that an individual makes on prolonged exposure to a new condition (for example, a mountaineer gradually adjusting to the low oxygen of high altitude) is called: **[1 mark]**

(A) natural selection

(B) evolutionary adaptation

(C) allopatric speciation

(D) acclimatization

Q3. Any environmental factor that, by its scarcity or excess, restricts the growth, abundance, or distribution of a population is most generally termed a: **[1 mark]**

(A) biotic potential

(B) carrying capacity

(C) trophic subsidy

(D) limiting factor

Q4. For an ectotherm the metabolic rate has a temperature coefficient $Q_{10} = 3$. If its metabolic rate is 5 units at $15°$C, then its rate at $25°$C is: **[1 mark]**

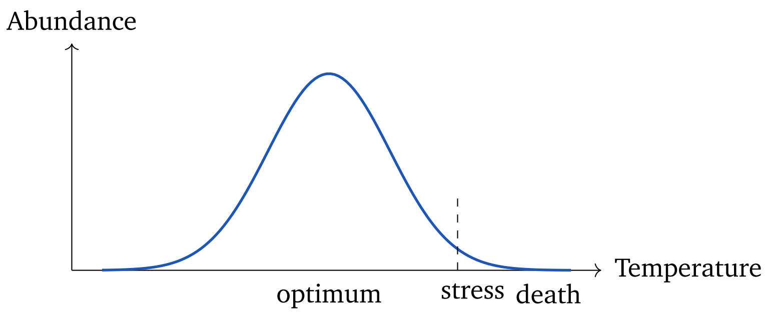
(A) 5 units

(B) 8 units

(C) 15 units

(D) 45 units

Q5. The tolerance curve below plots abundance of a species against temperature. The narrow band marked just inside the upper limit, where individuals still survive but can no longer grow or reproduce, is the zone of: **[1 mark]**



(A) optimum

(B) physiological stress

(C) intolerance (death)

(D) maximum abundance

Q6. Bergmann's rule states that, within a broadly distributed warm-blooded (endothermic) species, populations living in colder climates tend to have: **[1 mark]**

(A) a larger body size

(B) a smaller body size

(C) longer, thinner appendages

(D) no change in body size at all

Population and Community Ecology

Q7. Which one of the following is a *density-dependent* factor regulating the size of a population? **[1 mark]**

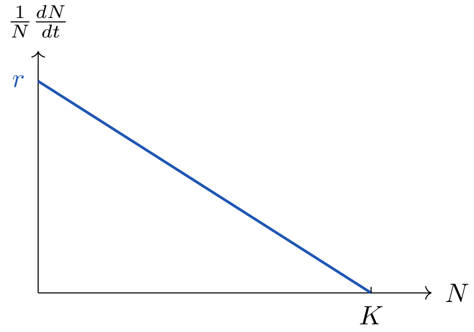
(A) a sudden late-spring frost

(B) a forest fire sweeping through the habitat

(C) intraspecific competition for a limited food supply

(D) a flash flood following heavy rain

Q8. In the logistic model $\dfrac{dN}{dt} = rN\left(1 - \dfrac{N}{K}\right)$, the *per-capita* growth rate $\dfrac{1}{N}\dfrac{dN}{dt}$, plotted below against N, behaves as N increases toward K as follows: **[1 mark]**



(A) it stays constant at r

(B) it increases linearly with N

(C) it decreases linearly, reaching zero at $N = K$

(D) it increases exponentially with N

Q9. A population grows logistically with intrinsic rate $r = 0.2\ \text{yr}^{-1}$ and carrying capacity $K = 800$. When the current size is $N = 200$, the instantaneous growth rate $\dfrac{dN}{dt}$ is: **[1 mark]**

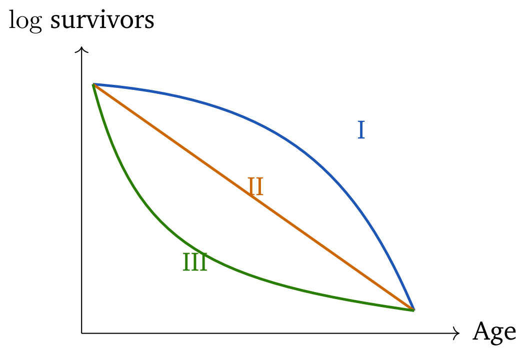
(A) 30 individuals/year

(B) 40 individuals/year

(C) 12 individuals/year

(D) 60 individuals/year

Q10. The three survivorship curves below are plotted as $\log(\text{survivors})$ against age. A species with low mortality through most of life and heavy mortality only in old age (as in humans and many large mammals) follows: **[1 mark]**



(A) Type III

(B) Type I

(C) Type II

(D) a straight diagonal line

Q11. As a population approaches its carrying capacity K, density-dependent regulation typically causes: **[1 mark]**

(A) the birth rate to rise sharply

(B) the death rate to fall toward zero

(C) the birth rate to fall and the death rate to rise

(D) the intrinsic rate r to increase without limit

Q12. An interaction in which one species benefits while the other is neither harmed nor helped (for example, an epiphytic orchid using a tree branch only for support) is called: **[1 mark]**

(A) mutualism

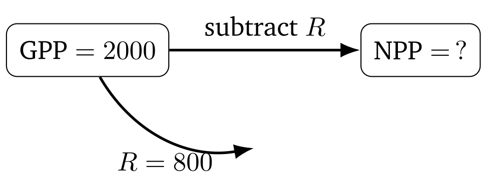
(B) commensalism

(C) parasitism

(D) interference competition

Ecosystems and Biogeochemical Cycles

Q13. In the grassland energy budget shown, gross primary productivity is GPP $= 2000$ g C m^{-2}yr^{-1} and plant respiration is $R = 800$ g C m^{-2}yr^{-1}. The net primary productivity, NPP $=$ GPP $- R$, equals: **[1 mark]**



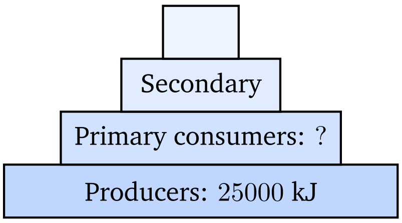
(A) 1200 g C m^{-2}yr^{-1}

(B) 2800 g C m^{-2}yr^{-1}

(C) 800 g C m^{-2}yr^{-1}

(D) 2000 g C m^{-2}yr^{-1}

Q14. According to Lindeman's ten-percent law of energy transfer, illustrated by the pyramid below, if the producers fix 25000 kJ of energy then the energy available to the primary consumers (herbivores) is approximately: **[1 mark]**



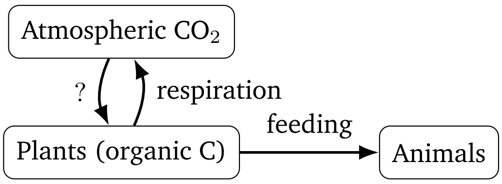
(A) 25000 kJ

(B) 2500 kJ

(C) 250 kJ

(D) 12500 kJ

Q15. In the carbon cycle sketched below, the process labelled "?", by which atmospheric CO_2 is converted into organic compounds by green plants, is: **[1 mark]**



(A) respiration

(B) photosynthesis

(C) combustion

(D) decomposition

Q16. Among the following, which ecosystem type typically has the highest net primary productivity per unit area? **[1 mark]**

(A) the open ocean

(B) a hot desert

(C) a tropical rainforest

(D) arctic tundra

Q17. Because energy is lost as heat at every transfer, the ecological pyramid of energy for a natural ecosystem is: **[1 mark]**

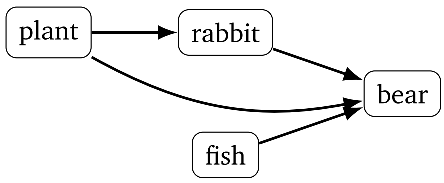
(A) always upright (broad base, narrow apex)

(B) always inverted

(C) sometimes inverted, depending on season

(D) always perfectly rectangular

Q18. In the food web shown, the bear feeds on plants, rabbits, and fish and therefore obtains its energy from more than one trophic level. Such an animal is best described as a(n): **[1 mark]**



(A) omnivore

(B) strict herbivore

(C) primary producer

(D) decomposer

Mechanisms of Evolution

Q19. Kimura's neutral theory of molecular evolution proposes that the great majority of evolutionary changes seen at the molecular (DNA and protein) level are caused by: **[1 mark]**

(A) strong positive Darwinian selection acting on every substitution

(B) overdominant balancing selection at most loci

(C) directional selection steadily favouring advantageous mutations

(D) random fixation of selectively neutral mutations by genetic drift

Q20. A central result of the neutral theory is that the rate of substitution (fixation) of strictly neutral mutations per generation is equal to: [1 mark]

(A) the neutral mutation rate μ, independent of population size

(B) $2N\mu$, and so rises with population size

(C) $4N\mu$, and so rises with population size

(D) μ/N, and so falls with population size

Q21. In protein-coding genes, synonymous (silent) substitutions generally accumulate faster over evolutionary time than nonsynonymous (amino-acid-changing) substitutions. The best explanation is that synonymous changes are: [2 marks]

(A) mostly free of selective constraint (nearly neutral)

(B) always strongly favoured by positive selection

(C) almost always immediately lethal

(D) physically unable to occur in DNA

Q22. For a protein-coding gene the ratio of nonsynonymous to synonymous substitution rates is estimated as $dN/dS = 1.6$. A value clearly greater than 1 is usually interpreted as evidence of: [2 marks]

(A) strong purifying (negative) selection

(B) complete selective neutrality

(C) positive (diversifying) Darwinian selection

(D) no evolutionary change at the locus

Q23. A genotype experiences a selection coefficient of $s = 0.1$ acting against it. Its relative fitness, defined by $w = 1 - s$, is: [2 marks]

(A) 0.1

(B) 1.1

(C) 0.9

(D) 0.5

Q24. In a recipient population the frequency of allele A is 0.3. In one generation a fraction $m = 0.25$ of the individuals are replaced by migrants from a source population in which the frequency of A is 0.7. Using $p' = (1-m)p + m\,p_m$, the new frequency of A is: **[2 marks]**

(A) 0.40

(B) 0.30

(C) 0.55

(D) 0.25

Population and Quantitative Genetics

Q25. A breeding population consists of 10 reproducing males and 40 reproducing females. Using $N_e = \dfrac{4\,N_m N_f}{N_m + N_f}$, the effective population size N_e is: **[2 marks]**

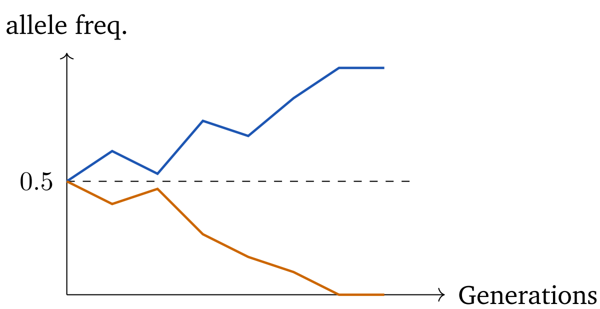
(A) 50

(B) 25

(C) 40

(D) 32

Q26. The two lines below trace allele frequency across generations in two finite populations of effective size N_e; one drifts to fixation and the other to loss. The expected fraction of heterozygosity *lost per generation* due to genetic drift alone is: **[2 marks]**



(A) $\frac{1}{N_e}$

(B) $\frac{1}{2N_e}$

(C) $2N_e$

(D) $\frac{1}{4N_e}$

Q27. When population size varies from generation to generation (for example 100, then 10, then 100), the long-term effective population size is given by which average of the successive sizes? **[2 marks]**

(A) the arithmetic mean

(B) the geometric mean

(C) the largest of the values

(D) the harmonic mean

Q28. 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) 0.50

(B) 0.20

(C) 0.60

(D) 0.40

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

(A) 4 g

(B) 2.5 g

(C) 10 g

(D) 0.4 g

Q30. A recessive genetic disorder occurs with genotype frequency $q^2 = 0.04$ in a population at Hardy–Weinberg equilibrium. The frequency of carriers (heterozygotes) in the population is: **[2 marks]**

(A) 0.04

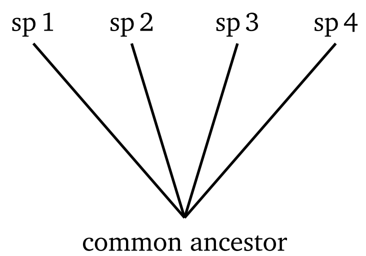
(B) 0.16

(C) 0.20

(D) 0.32

Speciation, Phylogeny and Macroevolution

Q31. The rapid diversification of a single ancestral lineage into many descendant species that occupy a variety of ecological niches, as sketched below and exemplified by Darwin's finches on the Galápagos, is called: **[2 marks]**



(A) convergent evolution

(B) coevolution

(C) phyletic gradualism

(D) adaptive radiation

Q32. The streamlined, torpedo-shaped body has evolved independently in sharks (fish), dolphins (mammals), and the extinct ichthyosaurs (reptiles), all fast ocean swimmers. This independent origin of similar form in unrelated lineages is: **[2 marks]**

(A) divergent evolution

(B) convergent evolution

(C) descent from a recent common aquatic ancestor

(D) adaptive radiation

Q33. Two closely related frog species live in the same pond but breed in different months, so their gametes never meet. This form of reproductive isolation is a: **[2 marks]**

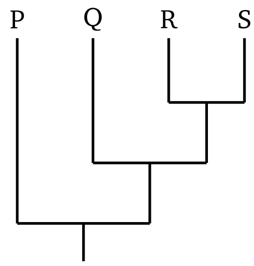
(A) prezygotic barrier (temporal isolation)

(B) postzygotic barrier (hybrid sterility)

(C) postzygotic barrier (hybrid inviability)

(D) postzygotic barrier (hybrid breakdown)

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



(A) P and Q

(B) P and S

(C) R and S

(D) P and R

Q35. The forelimb of a human, the flipper of a whale, and the wing of a bat all share the same underlying pattern of bones inherited from a shared ancestor, though they serve different functions. Such structures are: **[2 marks]**

(A) analogous structures

(B) vestigial structures

(C) homologous structures

(D) products of convergent evolution

Q36. The macroevolutionary model in which species stay morphologically stable for long stretches of geological time, interrupted by brief bursts of rapid change concentrated around speciation events, is called: **[2 marks]**

(A) phyletic gradualism

(B) orthogenesis

(C) saltation within individuals

(D) punctuated equilibrium

Behavioural Ecology

Q37. An animal is expected to defend a feeding territory only when the benefits of exclusive access to its resources outweigh the costs of defending it. This cost–benefit condition for territoriality is known as: **[2 marks]**

(A) the handicap principle

(B) economic defendability

(C) the marginal value theorem

(D) reciprocal altruism

Q38. A stable, roughly linear dominance hierarchy in which each individual dominates those ranked below it and yields to those ranked above it, first described in domestic hens, is commonly called a: **[2 marks]**

(A) lek

(B) pecking order

(C) eusocial caste system

(D) resource-holding potential

Q39. Hamilton's rule ($rB > C$) uses the coefficient of relatedness r between actor and recipient. For a pair of *half-siblings* (sharing exactly one parent), the value of r is: **[2 marks]**

(A) 0.5

(B) 0.125

(C) 0.25

(D) 0.0625

Q40. The payoff matrix for the Hawk–Dove game (resource value V, injury cost C) is shown, each entry being the payoff to the row player. The pure Hawk strategy is the only evolutionarily stable strategy (ESS) precisely when: **[2 marks]**

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

(A) $V < C$

(B) $V = 0$

(C) $C = 0$ but only if $V < 0$

(D) $V > C$

Q41. A male songbird that sings loudly and repeatedly from exposed perches around the boundary of its territory is doing so mainly to: **[2 marks]**

(A) attract the attention of predators

(B) advertise ownership of the territory and warn off rival males

(C) raise its own body temperature

(D) camouflage itself among the leaves

Quantitative Ecology, Biostatistics and Mathematics

Q42. For the quadrat counts $\{3, 5, 7, 7, 8\}$ recorded at five sampling stations, the median value is: **[2 marks]**

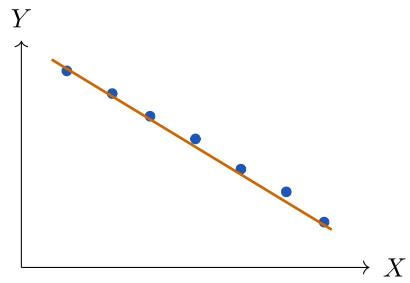
(A) 6

(B) 7

(C) 5

(D) 8

Q43. The scatter plot below shows measurements of two variables X and Y; the points cluster closely around a straight line that slopes downward, and a fitted line of negative slope is drawn through them. The correlation coefficient r for these data is best described as: **[2 marks]**



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

(B) exactly $+1$

(C) exactly zero

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

Q44. In the simple linear regression model $Y = a + bX$, the slope b (the least-squares estimate) is calculated as: **[2 marks]**

(A) $\dfrac{\text{var}(X)}{\text{cov}(X,Y)}$

(B) $\dfrac{\text{cov}(X,Y)}{\text{var}(Y)}$

(C) $\dfrac{\text{var}(Y)}{\text{var}(X)}$

(D) $\dfrac{\text{cov}(X,Y)}{\text{var}(X)}$

Q45. The correlation coefficient between two measured variables is $r = 0.8$. The coefficient of determination r^2, i.e. the fraction of the variance in Y that is explained by X, equals: **[2 marks]**

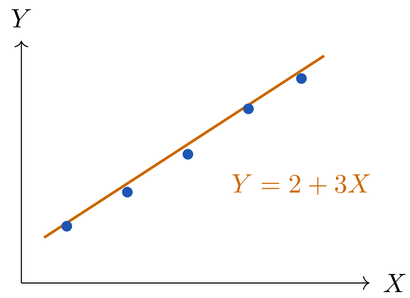
(A) 0.80

(B) 0.90

(C) 0.64

(D) 0.40

Q46. A least-squares regression line fitted to a set of ecological data is $Y = 2 + 3X$, and its rising trend is shown below. The predicted value of Y when $X = 4$ is: **[2 marks]**



(A) 14

(B) 12

(C) 9

(D) 20

Detailed Solutions

Q1.

Solution

Concept – "steno-" versus "eury-": The prefix "steno-" means narrow and "eury-" means broad; the suffix "-thermal" refers to temperature and "-haline" to salinity.

Step 1 – decode the requirement: The organism tolerates only a narrow range of temperature.

Step 2 – assemble the term: narrow (steno) $+$ temperature (thermal) $=$ stenothermal.

Step 3 – reject the others: Eurythermal is broad temperature; euryhaline and stenohaline both refer to salinity, not temperature.

Final Answer: stenothermal $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – acclimatization versus adaptation: Acclimatization is a reversible physiological adjustment made by an individual during its own lifetime; adaptation is a heritable change in a population over generations.

Step 1 – read the key words: The change is within one lifetime and is reversible (adjusting to altitude).

Step 2 – match the definition: An individual-level, reversible response is acclimatization.

Step 3 – eliminate the others: Natural selection, evolutionary adaptation, and speciation are all multi-generation, heritable processes, not within-lifetime adjustments.

Final Answer: acclimatization $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – limiting factors: A limiting factor is any resource or condition whose scarcity or excess holds back the growth, abundance, or spread of a population.

Step 1 – read the description: A factor that "restricts growth, abundance, or distribution."

Step 2 – match the term: That is exactly the definition of a limiting factor.

Step 3 – reject the others: Biotic potential is the maximum reproductive capacity; carrying capacity is the ceiling the environment supports; a trophic subsidy is imported energy or nutrients, not a restriction.

Final Answer: limiting factor $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – the temperature coefficient Q_{10}: Q_{10} is the factor by which a rate changes for every $10°$C rise. Here $Q_{10} = 3$ means the rate triples per $10°$C.

Step 1 – find the temperature change: $\Delta T = 25 - 15 = 10°\text{C}$

Step 2 – count the number of $10°$C steps: $\dfrac{10}{10} = 1$ step

Step 3 – apply the multiplier once: $\text{rate}_{25} = 5 \times 3^1$

Step 4 – evaluate: $\text{rate}_{25} = 5 \times 3 = 15$ units

Final Answer: 15 units $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q4

Q5.

Solution

Concept – zones of the tolerance curve: Moving out from the optimum, one passes through a zone of physiological stress (survival without growth or reproduction) and then a zone of intolerance (death) at each lethal limit.

Step 1 – locate the marked band: It lies just inside the upper limit, past the optimum but before death.

Step 2 – name that region: Where individuals persist but cannot grow or reproduce is the zone of physiological stress.

Step 3 – reject the others: The optimum is the central peak; intolerance is the lethal tail; "maximum abundance" is not a tolerance zone.

Final Answer: physiological stress $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

Concept – Bergmann's rule: Within a warm-blooded species, body size tends to be larger in colder parts of the range, because a larger body has a smaller surface-area-to-volume ratio and so loses heat more slowly.

Step 1 – link size to heat loss: Larger bodies conserve heat better in the cold.

Step 2 – state the prediction: Colder-climate populations therefore evolve larger body size.

Step 3 – separate from Allen's rule: Shorter (not longer) appendages in the cold is Allen's rule; "no change" contradicts the observed trend.

Final Answer: a larger body size $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q6

Q7.

Solution

Concept – density-dependent versus density-independent factors: A density-dependent factor acts more strongly as population density rises; a density-independent factor (usually abiotic or catastrophic) hits the same fraction regardless of density.

Step 1 – test each option: Frost, fire, and flood strike whether the population is dense or sparse, so they are density-independent.

Step 2 – identify the density-dependent one: Competition for a limited food supply intensifies as more individuals crowd in, so it is density-dependent.

Step 3 – conclude: Intraspecific competition for food is the density-dependent factor.

Final Answer: intraspecific competition for food $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – the per-capita rate in the logistic model: Dividing $\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$ by N gives the per-capita rate.

Step 1 – divide by N: $\frac{1}{N}\frac{dN}{dt} = r\left(1 - \frac{N}{K}\right)$

Step 2 – read this as a function of N: $r\left(1 - \frac{N}{K}\right) = r - \frac{r}{K}N$, a straight line in N with negative slope.

Step 3 – evaluate the ends: At $N = 0$ the rate is r; at $N = K$ the bracket is zero, so the rate is 0.

Step 4 – describe the behaviour: It falls linearly from r to 0 as N rises to K, exactly as plotted.

Final Answer: decreases linearly, reaching zero at $N = K \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q8

Q9.

Solution

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

Step 1 – list the data: $r = 0.2\ \text{yr}^{-1}$, $N = 200$, $K = 800$.

Step 2 – compute the bracket: $1 - \frac{N}{K} = 1 - \frac{200}{800} = 1 - 0.25 = 0.75$

Step 3 – multiply r and N: $rN = 0.2 \times 200 = 40$

Step 4 – multiply by the bracket: $\frac{dN}{dt} = 40 \times 0.75 = 30$

Final Answer: 30 individuals/year $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q9

Q10.

Solution

Concept – the three survivorship curves: Type I is convex (low early mortality, high late mortality); Type II is a straight line on a log scale (constant mortality); Type III is concave (very high early mortality).

Step 1 – read the requirement: Low mortality for most of life, heavy mortality only in old age.

Step 2 – match the curve: A shallow start that plunges only at the end is the convex Type I curve.

Step 3 – give an example: Humans and large mammals with high parental care follow Type I.

Final Answer: Type I $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – regulation near carrying capacity: Density-dependent regulation brings the growth rate to zero at K by adjusting births and deaths as crowding rises.

Step 1 – picture the crowded population: Near K, food, space, and mates are scarce and wastes and disease build up.

Step 2 – deduce the demographic response: Scarcity lowers the per-capita birth rate while crowding and disease raise the death rate.

Step 3 – reject the others: A soaring birth rate, a death rate falling to zero, or an ever-rising r would all prevent the population from levelling off at K.

Final Answer: the birth rate falls and the death rate rises $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q11

Q12.

Solution

Concept – classifying species interactions by $(+, 0, -)$: Label each partner by the effect it feels. Commensalism is $(+, 0)$: one gains, the other is unaffected.

Step 1 – read the scenario: The orchid gains support $(+)$; the tree is neither helped nor harmed (0).

Step 2 – match the sign pattern: $(+, 0)$ is commensalism.

Step 3 – reject the others: Mutualism is $(+, +)$; parasitism is $(+, -)$; interference competition is $(-, -)$.

Final Answer: commensalism $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept – net primary productivity: NPP is what is left of the energy fixed in photosynthesis (GPP) after the plants spend some on their own respiration R.

Step 1 – write the identity: $\text{NPP} = \text{GPP} - R$

Step 2 – substitute the values: $\text{NPP} = 2000 - 800$

Step 3 – evaluate: $\text{NPP} = 1200 \text{ g C m}^{-2}\text{yr}^{-1}$

Step 4 – sanity check: NPP must be less than GPP, and $1200 < 2000$, so the value is reasonable.

Final Answer: $1200 \text{ g C m}^{-2}\text{yr}^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

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 $= 25000$ kJ.

Step 2 – transfer to the primary consumers: $10\% \times 25000 = 0.10 \times 25000$

Step 3 – evaluate: $0.10 \times 25000 = 2500$ kJ

Step 4 – state the result: The herbivores receive about 2500 kJ.

Final Answer: $2500 \text{ kJ} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q14

Q15.

Solution

Concept – entry of carbon into the biosphere: Green plants take up atmospheric CO_2 and, using light energy, build organic compounds such as sugars. This fixing step is photosynthesis.

Step 1 – read the arrow in question: It runs from atmospheric CO_2 into the plant's organic carbon pool.

Step 2 – name the process: Converting inorganic CO_2 into organic matter in plants is photosynthesis.

Step 3 – reject the others: Respiration and combustion release CO_2; decomposition breaks down dead organic matter. None of these fixes atmospheric carbon into plants.

Final Answer: photosynthesis $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q15

Q16.

Solution

Concept – global patterns of productivity: Productivity rises with warmth, abundant water, and a long growing season. Tropical rainforests have all three year-round.

Step 1 – compare the options: Deserts lack water; tundra is cold with a short season; the open ocean is nutrient-poor over vast areas.

Step 2 – identify the richest: The tropical rainforest, warm and wet all year, has the highest NPP per unit area of these choices.

Step 3 – conclude: Tropical rainforest is the most productive.

Final Answer: tropical rainforest $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q16

Q17.

Solution

Concept – the pyramid of energy: Because roughly 90% of energy is lost as heat at each transfer, the energy available always shrinks from one trophic level to the next.

Step 1 – track the energy: Producers hold the most energy; each higher level holds much less.

Step 2 – deduce the shape: A broad base narrowing upward gives an upright pyramid.

Step 3 – note the strict rule: Unlike pyramids of numbers or biomass, the energy pyramid can never be inverted, because energy cannot be created along the chain.

Final Answer: always upright $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – feeding across trophic levels: An omnivore eats both plant material (producer level) and animal material (consumer level), so it feeds at more than one trophic level.

Step 1 – read the bear's diet: Plants, rabbits, and fish are eaten.

Step 2 – classify the feeding: Eating plants and animals from different levels is the omnivore's habit.

Step 3 – reject the others: A strict herbivore eats only plants; a producer makes its own food; a decomposer breaks down dead matter.

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

Answer: (A) Go Back to Q18

Q19.

Solution

Concept – Kimura's neutral theory: The neutral theory holds that most substitutions at the molecular level are selectively neutral and become fixed by random genetic drift rather than by selection.

Step 1 – recall the central claim: Most molecular variants have little or no effect on fitness.

Step 2 – identify the fixing force: Neutral variants change frequency and eventually fix purely by chance, i.e. by drift.

Step 3 – reject the selectionist options: Strong positive, balancing, or directional selection acting on every substitution is exactly what the neutral theory argues against.

Final Answer: random fixation of neutral mutations by drift $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q19

Q20.

Solution

Concept – neutral substitution rate: For strictly neutral alleles the rate of fixation per generation equals the neutral mutation rate, and the population size cancels out.

Step 1 – count new neutral mutations per generation: In a diploid population of size N there are $2N\mu$ new neutral mutations each generation.

Step 2 – give each its fixation probability: A single neutral allele fixes with probability equal to its frequency, $\frac{1}{2N}$.

Step 3 – multiply to get the rate: $k = 2N\mu \times \frac{1}{2N} = \mu$

Step 4 – interpret: The rate equals μ and does not depend on N.

Final Answer: the neutral mutation rate $\mu \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q20

Q21.

Solution

Concept – synonymous versus nonsynonymous sites: Synonymous changes do not alter the amino acid, so they are largely invisible to selection; nonsynonymous changes alter the protein and are usually held back by purifying selection.

Step 1 – ask which changes selection "sees": Nonsynonymous changes affect protein function and are mostly removed; synonymous changes are nearly neutral.

Step 2 – link freedom from selection to rate: Because they are nearly neutral, synonymous substitutions accumulate faster.

Step 3 – reject the others: They are neither uniformly favoured nor lethal, and synonymous substitutions certainly do occur.

Final Answer: mostly selectively neutral $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q21

Q22.

Solution

Concept – interpreting dN/dS**:** $dN/dS < 1$ signals purifying selection, $dN/dS \approx 1$ signals neutrality, and $dN/dS > 1$ signals positive (diversifying) selection because amino-acid changes are being favoured.

Step 1 – read the value: $dN/dS = 1.6 > 1$.

Step 2 – apply the rule: Nonsynonymous changes are fixing faster than the neutral synonymous baseline, which means they are being actively favoured.

Step 3 – name the process: Excess amino-acid change signals positive (diversifying) Darwinian selection.

Final Answer: positive (diversifying) selection $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q22

Q23.

Solution

Concept – fitness and the selection coefficient: Relative fitness and the selection coefficient are complementary: $w = 1 - s$.

Step 1 – list the data: $s = 0.1$.

Step 2 – substitute into the definition: $w = 1 - 0.1$

Step 3 – evaluate: $w = 0.9$

Final Answer: $w = 0.9 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q23

Q24.

Solution

Concept – allele frequency after gene flow: After migration the resident frequency becomes a weighted average of residents and migrants: $p' = (1 - m)p + m\,p_m$.

Step 1 – list the data: $p = 0.3$, $m = 0.25$, $p_m = 0.7$.

Step 2 – weight the resident term: $(1 - m)p = 0.75 \times 0.3 = 0.225$

Step 3 – weight the migrant term: $m\,p_m = 0.25 \times 0.7 = 0.175$

Step 4 – add the two contributions: $p' = 0.225 + 0.175 = 0.40$

Final Answer: $p' = 0.40 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – effective size with unequal sex ratio: When the numbers of breeding males and females differ, the effective size is pulled toward the rarer sex: $N_e = \dfrac{4\,N_m N_f}{N_m + N_f}$.

Step 1 – list the data: $N_m = 10$, $N_f = 40$.

Step 2 – compute the numerator: $4\,N_m N_f = 4 \times 10 \times 40 = 1600$

Step 3 – compute the denominator: $N_m + N_f = 10 + 40 = 50$

Step 4 – divide: $N_e = \dfrac{1600}{50} = 32$

Step 5 – interpret: Although 50 individuals breed, the skewed sex ratio lowers N_e to 32.

Final Answer: $N_e = 32 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q25

Q26.

Solution

Concept – loss of heterozygosity under drift: In an idealised finite population, random drift erodes heterozygosity at a steady per-generation rate of $\dfrac{1}{2N_e}$.

Step 1 – recall the recurrence: $H_{t+1} = \left(1 - \dfrac{1}{2N_e}\right) H_t$

Step 2 – read off the fractional loss: Each generation the heterozygosity is multiplied by $\left(1 - \dfrac{1}{2N_e}\right)$, so a fraction $\dfrac{1}{2N_e}$ is lost.

Step 3 – connect to the figure: Smaller N_e makes $\dfrac{1}{2N_e}$ larger, so drift drives the allele to fixation or loss faster, as the two wandering lines show.

Final Answer: $\dfrac{1}{2N_e} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – effective size over fluctuating generations: When size varies across generations, the long-term N_e is the harmonic mean of the generational sizes, which is dominated by the smallest (bottleneck) value.

Step 1 – recall the formula: $\frac{1}{N_e} = \frac{1}{t}\sum_{i=1}^{t}\frac{1}{N_i}$, the definition of a harmonic mean.

Step 2 – test with $100, 10, 100$: $\frac{1}{N_e} = \frac{1}{3}\left(\frac{1}{100}+\frac{1}{10}+\frac{1}{100}\right) = \frac{1}{3}(0.12) = 0.04$, so $N_e = 25$.

Step 3 – note what dominates: $N_e = 25$ lies far below the arithmetic mean of 70, pulled down by the single small generation.

Step 4 – name the average: This is the harmonic mean.

Final Answer: the harmonic mean $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q27

Q28.

Solution

Concept – allele frequency from genotype counts: Each AA carries two A alleles and each Aa carries one, out of $2N$ total alleles.

Step 1 – count the A alleles: $2(AA) + (Aa) = 2(20) + 60 = 40 + 60 = 100$

Step 2 – count all alleles: $2N = 2 \times 100 = 200$

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

Step 4 – evaluate: $\text{freq}(A) = 0.50$

Final Answer: $0.50 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q28

Q29.

Solution

Concept – the breeder's equation: The response to selection is the heritability times the selection differential: $R = h^2 S$.

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

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

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – carrier frequency at Hardy–Weinberg equilibrium: With q^2 the frequency of affected homozygotes, the carrier (heterozygote) frequency is $2pq$.

Step 1 – find q: $q = \sqrt{q^2} = \sqrt{0.04} = 0.2$

Step 2 – find p: $p = 1 - q = 1 - 0.2 = 0.8$

Step 3 – compute the carrier frequency: $2pq = 2 \times 0.8 \times 0.2$

Step 4 – evaluate: $2 \times 0.8 \times 0.2 = 0.32$

Final Answer: $0.32 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – adaptive radiation: Adaptive radiation is the rapid branching of one ancestral lineage into many species that specialise on different resources or niches.

Step 1 – read the figure and example: One ancestor fans out into several species, as with Darwin's finches diversifying by beak and diet.

Step 2 – match the term: Rapid diversification into many niches from a single ancestor is adaptive radiation.

Step 3 – reject the others: Convergence makes unrelated lineages resemble each other; coevolution is reciprocal change between interacting species; phyletic gradualism is slow, steady change within a lineage.

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

Answer: (D) Go Back to Q31

Q32.

Solution

Concept – convergent evolution: Convergent evolution is the independent origin of similar traits in distantly related lineages facing similar selective pressures.

Step 1 – note the lineages: Sharks, dolphins, and ichthyosaurs are only distantly related (fish, mammal, reptile).

Step 2 – note the shared trait and driver: All evolved the same streamlined shape independently because fast swimming favours it.

Step 3 – name the pattern: Independent evolution of the same form in unrelated groups is convergent evolution.

Step 4 – reject the others: Divergence makes relatives differ; they share no recent aquatic ancestor; adaptive radiation is diversification from one ancestor, not convergence of many.

Final Answer: convergent evolution $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – prezygotic versus postzygotic barriers: Prezygotic barriers act before a zygote forms; temporal isolation, where species breed at different times, is one of them.

Step 1 – read the scenario: The two frog species breed in different months, so mating never happens.

Step 2 – classify the timing: Because fertilisation is prevented before any zygote forms, this is a prezygotic barrier.

Step 3 – name the specific type: Isolation by breeding at different times is temporal isolation.

Step 4 – reject the others: Hybrid sterility, inviability, and breakdown are all postzygotic, requiring that a hybrid first be formed.

Final Answer: prezygotic barrier (temporal isolation) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q33

Q34.

Solution

Concept – reading a phylogenetic tree: The two taxa that join at the most recent (highest) branch point share the most recent common ancestor.

Step 1 – find the highest node: R and S join first, at the topmost internal node.

Step 2 – trace the deeper nodes: Q joins the (R, S) clade lower down, and P joins even lower, so P and Q branch off earlier.

Step 3 – pick the closest pair: The pair meeting at the shallowest node, R and S, are most closely related.

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

Answer: (C) Go Back to Q34

Q35.

Solution

Concept – homologous structures: Homologous structures share a common ancestral origin and the same basic plan, even when their functions differ.

Step 1 – read the description: Human arm, whale flipper, and bat wing share the same bone arrangement inherited from a common ancestor.

Step 2 – match the term: Same ancestral plan, different function, is the definition of homology.

Step 3 – reject the others: Analogous structures (and convergence) share function but not ancestry; vestigial structures are reduced remnants, which is not the point here.

Final Answer: homologous structures $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q35

Q36.

Solution

Concept – punctuated equilibrium: Punctuated equilibrium describes long periods of morphological stasis broken by short bursts of rapid change, usually at speciation.

Step 1 – read the pattern: Long stability, then brief rapid change tied to speciation.

Step 2 – match the model: That description is punctuated equilibrium (Eldredge and Gould).

Step 3 – reject the others: Phyletic gradualism predicts slow, steady change; orthogenesis wrongly claims an inner drive toward a goal; saltation within an individual is not a valid macroevolutionary mechanism.

Final Answer: punctuated equilibrium $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q36

Q37.

Solution

Concept – economic defendability: A territory is worth defending only when the benefit of exclusive resource access exceeds the cost of defence; this cost–benefit threshold is called economic defendability.

Step 1 – read the condition: Defend only when benefits outweigh the costs of defence.

Step 2 – name the idea: That cost–benefit rule for territoriality is economic defendability.

Step 3 – reject the others: The handicap principle explains honest signalling; the marginal value theorem is about patch-leaving time; reciprocal altruism concerns repeated helping between individuals.

Final Answer: economic defendability $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – dominance hierarchy: A pecking order is a linear rank system in which each individual dominates those below and defers to those above, named from studies of hens.

Step 1 – read the description: A stable linear rank where each bird dominates lower ranks and yields to higher ones.

Step 2 – match the term: This is the pecking order.

Step 3 – reject the others: A lek is a communal display arena; a eusocial caste system is a division of labour in social insects; resource-holding potential is an individual's fighting ability, not the hierarchy itself.

Final Answer: pecking order $\Rightarrow \boxed{\text{B}}$

Answer: (B) 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 the other. Full siblings have $r = 0.5$; half-siblings share only one parent, halving that.

Step 1 – start from full siblings: Full sibs share both parents and have $r = 0.5$.

Step 2 – account for a single shared parent: Half-sibs share only one parent, so the relatedness is halved.

Step 3 – compute: $r = \frac{0.5}{2} = 0.25$

Final Answer: $r = 0.25 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q39

Q40.

Solution

Concept – ESS in the Hawk–Dove game: Hawk is the sole ESS only when escalation pays, i.e. when the resource value exceeds the cost of injury.

Step 1 – write Hawk's payoff against a Hawk: From the matrix, Hawk versus Hawk earns $\frac{V - C}{2}$.

Step 2 – require Hawk to resist invasion by Dove: Pure Hawk is stable only if a Hawk against another Hawk still does at least as well as a rare Dove would, which needs $\frac{V - C}{2} > 0$.

Step 3 – solve the inequality: $\frac{V - C}{2} > 0 \;\Rightarrow\; V - C > 0 \;\Rightarrow\; V > C$

Step 4 – interpret: When $V > C$ the resource is worth the risk, so all-out fighting (Hawk) is the ESS. When $V < C$ the ESS is instead a mix of Hawk and Dove.

Final Answer: $V > C \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q40

Q41.

Solution

Concept – song as a territorial signal: Loud, repeated song from boundary perches functions to broadcast that the territory is occupied and to deter intruding males (and to attract mates).

Step 1 – note where and how he sings: Conspicuously and repeatedly, from the edges of the territory.

Step 2 – infer the function: This advertises ownership and warns rival males to stay out.

Step 3 – reject the others: Attracting predators and camouflage are costs or contradictions, not the purpose; raising body temperature is not the function of song.

Final Answer: advertise ownership and repel rival males $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q41

Q42.

Solution

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

Step 1 – order the data: $3,\ 5,\ 7,\ 7,\ 8$ (already in increasing order).

Step 2 – locate the middle position: With five values the middle is the third one.

Step 3 – read off the value: The third value is 7.

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

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – sign of 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 as X rises, and the points hug a downward line.

Step 2 – fix the sign: A downward trend gives a negative r.

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

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

Answer: (D) Go Back to Q43

Q44.

Solution

Concept – least-squares slope: The best-fit slope in $Y = a + bX$ is the covariance of X and Y divided by the variance of X.

Step 1 – recall the minimisation result: Minimising the squared residuals gives $b = \dfrac{\text{cov}(X, Y)}{\text{var}(X)}$.

Step 2 – check the logic: The slope measures how Y co-varies with X per unit of spread in X, so $\text{cov}(X, Y)$ is scaled by $\text{var}(X)$.

Step 3 – reject the others: Dividing by $\text{var}(Y)$, or using ratios of variances, does not give the regression slope of Y on X.

Final Answer: $\dfrac{\text{cov}(X, Y)}{\text{var}(X)} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – coefficient of determination: The fraction of variance in Y explained by X is r^2, the square of the correlation coefficient.

Step 1 – list the data: $r = 0.8$.

Step 2 – square the correlation: $r^2 = (0.8)^2$

Step 3 – evaluate: $r^2 = 0.64$

Step 4 – interpret: About 64% of the variation in Y is accounted for by its linear relationship with X.

Final Answer: $r^2 = 0.64 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – predicting from a regression line: Substitute the given X into the fitted equation $Y = a + bX$.

Step 1 – write the line: $Y = 2 + 3X$

Step 2 – substitute $X = 4$: $Y = 2 + 3(4)$

Step 3 – multiply: $3 \times 4 = 12$

Step 4 – add the intercept: $Y = 2 + 12 = 14$

Final Answer: $Y = 14 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q46

Answer Key

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