

AP Biology – Units 5–8 Practice Set

AP Biology (College Board, Units 5–8) · Total marks: 47 · Answers on the last page

FRQ-style practice questions covering heredity, gene expression, natural selection, and ecology. A calculator is permitted. For chi-square tests, use $\chi^2_{\text{critical}} = 7.815$ at $p = 0.05$ with 3 degrees of freedom.

Section A – Heredity and Gene Expression (Units 5–6)

- In a large, randomly mating population at Hardy-Weinberg equilibrium, 9% of individuals show a recessive phenotype.
 - Calculate the frequency of the recessive allele, q .
 - Calculate the frequency of the dominant allele, p .
 - Calculate the percentage of the population that are heterozygous carriers. [5]
- A dihybrid cross expected to produce a 9 : 3 : 3 : 1 phenotypic ratio gave the following observed counts among 556 offspring: 315, 101, 108 and 32.
 - Calculate the expected number of offspring in each phenotype class.
 - Calculate the chi-square statistic, $\chi^2 = \sum \frac{(O - E)^2}{E}$.
 - State, with a reason, whether the observed data are consistent with the expected 9 : 3 : 3 : 1 ratio. [6]
- Describe the process by which a mutation in the promoter region of a gene could reduce the amount of protein produced from that gene, referring to RNA polymerase and transcription factors. [3]
- Using the lac operon in *E. coli* as an example, explain how gene expression in prokaryotes can be regulated in response to the environment. [4]

Section B – Natural Selection and Evolution (Unit 7)

- Distinguish between directional selection, stabilizing selection and disruptive selection, giving a brief example of each. [3]
- A population of 200 organisms grows exponentially at a per capita growth rate of $r = 0.05$ per year. Using $N = N_0 e^{rt}$, calculate the population size after 10 years. [3]
- Explain, using the founder effect and genetic bottlenecks, how genetic drift can reduce genetic diversity within a small population. [4]
- Describe two distinct types of evidence (other than direct observation of allele frequency change) that support the theory of evolution by natural selection, and explain what each type of evidence demonstrates. [4]

Section C – Ecology (Unit 8)

- In a terrestrial ecosystem, producers fix $20,000 \text{ kJ m}^{-2} \text{ yr}^{-1}$ of energy. Assume an ecological efficiency (energy transfer efficiency) of 10% between each trophic level.
 - Calculate the energy available to primary consumers.
 - Calculate the energy available to secondary consumers.
 - Explain why energy pyramids are always upright (never inverted), unlike some biomass or numbers pyramids. [5]

10. Describe the main processes by which carbon moves between the atmosphere, living organisms, and long-term storage (e.g. fossil fuels) in the carbon cycle. [4]
11. Explain how competitive exclusion can lead to resource partitioning between two species with overlapping ecological niches. [3]
12. Explain how increased atmospheric carbon dioxide concentration, resulting from human activity, is contributing to ocean acidification, and describe one consequence of this for marine ecosystems. [3]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- $q^2 = 0.09$, so $q = \sqrt{0.09} = 0.30$.
 - $p = 1 - q = 1 - 0.30 = 0.70$.
 - Heterozygote frequency $= 2pq = 2(0.70)(0.30) = 0.42$, i.e. 42% of the population.
- Expected numbers: $556 \times \frac{9}{16} = 312.75$; $556 \times \frac{3}{16} = 104.25$ (for each of the two 3 classes); $556 \times \frac{1}{16} = 34.75$.
 - $\chi^2 = \frac{(315 - 312.75)^2}{312.75} + \frac{(101 - 104.25)^2}{104.25} + \frac{(108 - 104.25)^2}{104.25} + \frac{(32 - 34.75)^2}{34.75} = 0.47$.
 - Since $\chi^2 = 0.47$ is less than the critical value of 7.815 (at $p = 0.05$, 3 degrees of freedom), the null hypothesis is not rejected: the observed data are consistent with (do not differ significantly from) the expected 9 : 3 : 3 : 1 ratio.
- The promoter is the DNA sequence to which RNA polymerase (together with transcription factors) binds to initiate transcription. A mutation in the promoter can reduce its complementarity to, or binding affinity for, transcription factors and RNA polymerase, so the transcription initiation complex forms less efficiently or less often. This reduces the rate of transcription of the gene into mRNA, resulting in less mRNA being available for translation and therefore less protein being produced.
- The lac operon contains genes for lactose metabolism under the control of a single promoter and operator. In the absence of lactose, a repressor protein binds to the operator, physically blocking RNA polymerase from transcribing the structural genes, so they are expressed at very low levels. When lactose is present, a lactose derivative (allolactose) binds to the repressor, changing its shape so it can no longer bind the operator; RNA polymerase can then bind the promoter and transcribe the structural genes, producing the enzymes needed to metabolise lactose. This allows the bacterium to only produce these enzymes (an energy cost) when the substrate they act on is actually available.
- Directional selection favours one extreme phenotype over the others, shifting the population's phenotype distribution over time (e.g. increasing beak size in finches during a drought that favours larger, harder seeds). Stabilizing selection favours the intermediate phenotype and selects against both extremes, reducing variation (e.g. human birth mass, where average-mass babies have the highest survival rate). Disruptive selection favours both extreme phenotypes over the intermediate, potentially leading to two distinct forms in the population (e.g. bill size in African seedcracker finches favouring both large and small bills, with intermediate bills less efficient at cracking either seed type available).
- $N = 200 e^{(0.05)(10)} = 200 e^{0.5} = 200(1.6487) = 330$ (to 3 significant figures).
- Genetic drift is the random change in allele frequencies from one generation to the next due to chance alone, and its effect is proportionally larger in small populations. In the founder effect, a small number of individuals establish a new, isolated population; by chance, the allele frequencies of this small founding group may not represent the frequencies of the original population, so some alleles may be over-represented, under-represented, or entirely absent. In a genetic bottleneck, a population is drastically and suddenly reduced in size (e.g. by a natural disaster or disease), so the surviving individuals carry only a random subset of the original population's alleles; when the population later recovers in size, its genetic diversity remains reduced because the lost alleles cannot be regained except by mutation or migration.

8. Any two, e.g.: (1) Comparative anatomy/homologous structures – similar underlying skeletal structures with different functions across species (e.g. the pentadactyl limb) indicate descent with modification from a common ancestor. (2) Molecular evidence – the degree of similarity in DNA or amino acid sequences between species correlates with how recently they shared a common ancestor, with more closely related species showing more similar sequences. (3) The fossil record – transitional fossils and the appearance of increasingly complex or modern forms in progressively younger rock layers show a pattern of gradual change over geological time consistent with common descent.
9. (a) $20,000 \times 0.10 = 2,000 \text{ kJ m}^{-2}\text{yr}^{-1}$.
(b) $2,000 \times 0.10 = 200 \text{ kJ m}^{-2}\text{yr}^{-1}$.
(c) At each trophic level, a large proportion of energy is lost as heat through cellular respiration, lost in faeces/undigested material, or not consumed at all (e.g. remains in dead matter), so the amount of energy actually transferred and available to the next trophic level is always less than the level below it. Because energy cannot be recycled (unlike matter/nutrients) and each transfer necessarily loses energy, the total available energy must decrease at each successive trophic level, so an energy pyramid can never be inverted.
10. Carbon dioxide is removed from the atmosphere by photosynthesis in producers, which fix carbon into organic compounds; this carbon is passed along food chains through consumption by consumers. Carbon is returned to the atmosphere as CO_2 through cellular respiration by producers, consumers and decomposers, and through the combustion of fossil fuels and biomass. Decomposers break down dead organic matter, releasing CO_2 (or, under anaerobic conditions, methane); over geological time, some organic matter that does not fully decompose can be converted into fossil fuels (coal, oil, natural gas), which store carbon for long periods until it is released by combustion.
11. The competitive exclusion principle states that two species with identical niches cannot stably coexist in the same habitat indefinitely, since one will out-compete the other for limited shared resources, eventually leading to local extinction or exclusion of the less competitive species. To avoid complete exclusion, natural selection can favour individuals that use resources slightly differently from the competing species (e.g. feeding at different times, in different locations, or on slightly different food types); over time, this can lead to resource partitioning, in which the two species evolve to occupy narrower, non-overlapping realized niches, allowing them to coexist.
12. Some of the additional atmospheric CO_2 produced by human activities (e.g. burning fossil fuels) dissolves into the oceans, where it reacts with water to form carbonic acid ($\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$), which dissociates and increases the concentration of hydrogen ions, lowering the ocean's pH (ocean acidification). Consequence: the increased acidity reduces the availability of carbonate ions needed by many marine organisms (e.g. corals, molluscs) to build calcium carbonate shells and skeletons, impairing their growth and survival and potentially disrupting the wider marine food web that depends on them.

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