

# 國立中山大學 115 學年度 碩士班考試入學招生考試試題

科目名稱：生物化學與分子生物學【生科系碩士班選考】

## — 作答注意事項 —

考試時間：100 分鐘

- 考試開始鈴響前不得翻閱試題，並不得書寫、劃記、作答。請先檢查答案卷（卡）之應考證號碼、桌角號碼、應試科目是否正確，如有不同立即請監試人員處理。
- 答案卷限用藍、黑色筆(含鉛筆)書寫、繪圖或標示，可攜帶橡皮擦、無色透明無文字墊板、尺規、修正液（帶）、手錶(未附計算器者)。每人每節限使用一份答案卷，請衡酌作答。
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- 可否使用計算機請依試題資訊內標註為準，如「可以」使用，廠牌、功能不拘，唯不得攜帶書籍、紙張（應考證不得做計算紙書寫）、具有通訊、記憶、傳輸或收發等功能之相關電子產品或其他有礙試場安寧、考試公平之各類器材入場。
- 試題及答案卷（卡）請務必繳回，未繳回者該科成績以零分計算。
- 試題採雙面列印，考生應注意試題頁數確實作答。
- 違規者依本校招生考試試場規則及違規處理辦法處理。

國立中山大學 115 學年度碩士班考試入學招生考試試題

科目名稱：生物化學與分子生物學【生科系碩士班選考】

題號：421001

※本科目依簡章規定「不可以」使用計算機【選擇題50題(單選)每題兩分】

共7頁第1頁

1. Which of the following is NOT a distinctive property of living systems?
  - A. Living organisms exhibit a high level of organization.
  - B. Biological structures are related to specific functions.
  - C. Living systems have the capacity for reproduction.
  - D. Living systems do not carry out energy transformation.
2. Energy and materials are consumed by organisms primarily to:
  - A. Increase entropy within the cell.
  - B. Maintain stability and internal order.
  - C. Eliminate all metabolic by-products.
  - D. Promote interaction with the environment.
3. Which additional element distinguishes amino acids from carbohydrates?
  - A. Phosphorus
  - B. Nitrogen
  - C. Oxygen
  - D. Hydrogen
4. What property makes carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorus especially suitable for biological molecules?
  - A. Their ability to form ionic bonds in water
  - B. Their high atomic mass
  - C. Their capacity to form stable covalent bonds
  - D. Their radioactive properties
5. Which type of interaction is LEAST involved in biomolecular recognition?
  - A. Covalent bond
  - B. Hydrogen bonding
  - C. Ionic interactions
  - D. Hydrophobic interactions
6. Which property of water is LEAST related to its solvent properties?
  - A. High dielectric constant
  - B. Polarity of the water molecule
  - C. High specific heat capacity
  - D. Ability to form hydrogen bonds
7. Water can dissolve nonionic polar molecules, such as sugars, because:
  - A. Water forms covalent bonds with them
  - B. Water has a high dielectric constant
  - C. Water disrupts all intermolecular forces
  - D. Water can form hydrogen bonds with them
8. A solution has a pH of 5. How does its hydrogen ion concentration compare to that of a solution with a pH of 7?
  - A. 10 times greater
  - B. 100 times greater
  - C. 1,000 times greater
  - D. None of the above

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共7頁第2頁

9. Which statement best describes an acid with a larger  $K_a$  value?
- A. It dissociates less in water
  - B. It is a stronger weak acid
  - C. It has a higher pH at the same concentration
  - D. It produces fewer hydrogen ions
10. Which change will decrease the pH of a weak acid solution?
- A. Increasing  $K_a$
  - B. Decreasing  $K_a$
  - C. Decreasing the concentration of the acid
  - D. Diluting the solution with water
11. Understanding energy flow requires knowledge of systems, heat, and work. What type of system do living cells belong to?
- A. Isolated system
  - B. Adiabatic system
  - C. Open system
  - D. Closed system
12. Which of the following is NOT a bioenergetic characteristic of biological systems?
- A. Exchange of energy between a system and its surroundings occurs as either heat or work.
  - B. Heat is a useful energy source for cells.
  - C. Work is the use of energy to drive a process other than heat flow.
  - D. Temperature, pressure, and volume of the system are essentially constant during biological reactions.
13. Which equation correctly describes the relationship between free energy (G), enthalpy (H), entropy (S), and temperature (T)?
- A.  $\Delta G = \Delta H + T\Delta S$
  - B.  $\Delta G = T\Delta H - \Delta S$
  - C.  $\Delta G = \Delta H - T\Delta S$
  - D.  $\Delta G = \Delta S - T\Delta H$
14. Based upon the following reactions, what is the  $\Delta G^{\circ'}$  for the formation of ATP from phosphoenolpyruvate (PEP) and ADP?
- |  |  |
|--|--|
| $\text{ATP} \rightarrow \text{ADP} + \text{Pi}$                      | $\Delta G^{\circ'} = -35.7 \text{ kJ/mol}$ |
| $\text{phosphoenolpyruvate} \rightarrow \text{pyruvate} + \text{Pi}$ | $\Delta G^{\circ'} = -62.2 \text{ kJ/mol}$ |
- A.  $-97.9 \text{ kJ/mol}$
  - B.  $-26.5 \text{ kJ/mol}$
  - C.  $+26.5 \text{ kJ/mol}$
  - D.  $+97.9 \text{ kJ/mol}$
15. Which parameter indicates that a system tends to proceed from an organized to a more disordered state?
- A.  $\Delta S > 0$
  - B.  $\Delta S < 0$
  - C.  $\Delta H > 0$
  - D.  $\Delta H < 0$

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共7頁第3頁

16. Which type of amino acid is positively charged at physiological pH?  
A. Nonpolar amino acids  
B. Polar, uncharged amino acids  
C. Acidic amino acids  
D. Basic amino acids
17. Uncommon amino acids are often formed by post-translational modification because they:  
A. Cannot be synthesized by cells  
B. Provide specialized functional or regulatory roles  
C. Are more stable than common amino acids  
D. Are required for all proteins
18. What is the pH of a glycine solution in which the  $\alpha$ -NH<sub>3</sub><sup>+</sup> group is one-third dissociated?  
(Given: pK<sub>a</sub> of  $\alpha$ -COOH = 2.3; pK<sub>a</sub> of  $\alpha$ -NH<sub>3</sub><sup>+</sup> = 9.6)  
A. 9.3  
B. 9.7  
C. 10.1  
D. 10.5
19. Which of the following amino acids does not absorb UV light?  
A. Phenylalanine  
B. Tyrosine  
C. Glycine  
D. Tryptophan
20. Aspartic acid has pK<sub>a</sub> values of 2.1, 3.9, and 9.8. Calculate the isoelectric point (pI) of aspartic acid.  
A. 3.0  
B. 3.9  
C. 5.0  
D. 8.9
21. The regular folding patterns stabilized mainly by hydrogen bonding between backbone atoms, such as  $\alpha$ -helices and  $\beta$ -sheets, define the \_\_\_\_\_ structure of proteins.  
A. primary  
B. secondary  
C. tertiary  
D. quaternary
22. Protein three-dimensional structural information is most commonly stored in which file format?  
A. FASTA  
B. GenBank  
C. PDB  
D. BLAST
23. Which protein separation technique primarily exploits differences in molecular size?  
A. Salting out  
B. Ion-exchange chromatography  
C. Affinity chromatography  
D. Gel filtration chromatography

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共7頁第4頁

24. Which of the following represents the correct order of steps in protein sequencing?
- I. Identify N- and C-termini
  - II. Cleave disulfide bonds
  - III. Separate chains
  - IV. Cleave into fragments
  - V. Repeat cleavage with different method
  - VI. Reconstruct sequence
- A. I, II, III, IV, VI, V  
B. III, I, IV, II, V, VI  
C. III, II, I, IV, V, VI  
D. IV, I, III, V, VI, II
25. In proteomics, proteins are first separated by isoelectric point and then by molecular weight using:
- A. Western blotting
  - B. Two-dimensional gel electrophoresis
  - C. Native PAGE
  - D. Size-exclusion chromatography
26. The following statements regarding enzymes are correct, EXCEPT:
- A. All enzymes are proteins.
  - B. Enzymes lower the activation energy of biochemical reactions.
  - C. Enzyme specificity can arise from molecular recognition based on structural complementarity.
  - D. The activation energy ( $E_a$ ) is the energy required to raise reactants to the transition state.
27. Which of the following statements is CORRECT?
- A. Increasing the activation energy ( $E_a$ ) increases the reaction rate.
  - B. An increase in temperature decreases the activation energy ( $E_a$ ).
  - C. The Arrhenius equation is  $k = \Delta G / RT$ .
  - D. The Arrhenius equation describes the relationship between the rate constant ( $k$ ), activation energy ( $E_a$ ), and temperature ( $T$ ).
28. According to the Michaelis-Menten equation,  $V_o = [S] (V_{max}) / ([S] + K_m)$ , a high  $K_m$  value for an enzyme-substrate pair indicates:
- A. The enzyme has a high specificity for the substrate.
  - B. The enzyme works at maximum rate even at low substrate concentration.
  - C. The enzyme is saturated at very low substrate concentration.
  - D. The enzyme has a low affinity for the substrate.
29. Which kinetic change is expected during noncompetitive inhibition?
- A. Increased  $V_{max}$  with unchanged  $K_m$
  - B. Increased  $K_m$  with unchanged  $V_{max}$
  - C. Decreased  $V_{max}$  with unchanged  $K_m$
  - D. Decreased  $K_m$  with decreased  $V_{max}$

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共7頁第5頁

30. In the presence of increasing concentrations of succinate, the inhibitory effect of malonate on succinate dehydrogenase can be reduced. This observation indicates that malonate is a(n):
- A. Uncompetitive inhibitor
  - B. Competitive inhibitor
  - C. Noncompetitive inhibitor
  - D. Irreversible inhibitor
31. Which of the following is NOT a function of biological membranes?
- A. Maintenance of electrochemical gradients
  - B. Reproduction
  - C. Replication of DNA
  - D. Transport of ions and metabolites
32. Which statement BEST describes the fluid mosaic model of biological membranes?
- A. Membranes are rigid structures composed of fixed proteins.
  - B. Membranes consist of a phospholipid bilayer with embedded proteins that can move laterally.
  - C. Membranes are composed only of lipids arranged in a mosaic pattern.
  - D. Membrane proteins freely diffuse between different cellular membranes.
33. The plasma membrane is richer in cholesterol compared to mitochondrial membranes mainly because:
- A. Cholesterol increases membrane rigidity and stability required for cell-environment interactions.
  - B. Cholesterol is synthesized only in the plasma membrane.
  - C. Mitochondria cannot incorporate lipids.
  - D. Cholesterol enhances ATP synthesis directly.
34. Which statement correctly distinguishes peripheral (extrinsic) membrane proteins from integral (intrinsic) membrane proteins?
- A. Peripheral proteins contain only hydrophobic amino acids.
  - B. Integral proteins can be removed without disrupting the membrane.
  - C. Peripheral proteins associate more tightly with the membrane than integral proteins.
  - D. Integral proteins span the lipid bilayer, whereas peripheral proteins do not.
35. What is the main principle behind using a hydropathy plot to analyze membrane protein topology?
- A. It identifies charged amino acids involved in active sites.
  - B. It detects regions of high secondary structure content.
  - C. It identifies hydrophobic regions that span lipid bilayers.
  - D. It predicts post-translational modification sites.
36. Which domain of an ion channel protein is primarily responsible for determining which ions can pass through the channel?
- A. Voltage-sensing domain
  - B. Selectivity filter
  - C. Ligand-binding domain
  - D. Cytoplasmic regulatory domain

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37. Which of the following can serve as an energy source for active transport across biological membranes?
- ATP hydrolysis
  - Light energy
  - Ion concentration gradient
  - All of the above
38. Bacteriorhodopsin contributes to cellular energy production in *Halobacterium halobium* by:
- Direct synthesis of ATP
  - Transporting electrons across the plasma membrane
  - Generating a proton gradient using light energy
  - Importing glucose into the cell
39. Carrier proteins responsible for drug resistance primarily function by:
- Metabolizing drugs into inactive forms
  - Blocking drug entry into the cell
  - Sequestering drugs inside lysosomes
  - Actively exporting drugs out of the cell using energy
40. P-glycoprotein, a key protein involved in cancer drug resistance, belongs to which transporter family?
- ATP-binding cassette (ABC) transporters
  - Proton-dependent antiporters
  - Secondary active transporters
  - Ligand-gated channels
41. The following statements about the DNA molecule are correct, EXCEPT:
- DNA is a double-stranded helix composed of antiparallel strands.
  - DNA is synthesized in the 5'→3' direction.
  - DNA contains ribose sugar in its backbone.
  - The backbone of DNA consists of sugar and phosphate groups.
42. Based on Chargaff's data, if a DNA sample contains 30% guanine, what is the percentage of adenine?
- 20%
  - 30%
  - 40%
  - 60%
43. Which strand of DNA will form the MOST STABLE double-stranded DNA duplex?
- pGACTTCAAATAT
  - pGACTTCGACTCG
  - pGACTTCCGAT
  - pGACTTCAAATGC
44. The stability of double-stranded DNA primarily arises from which two non-covalent interactions?
- Hydrogen bonding and ionic interactions
  - Covalent phosphodiester bonding and hydrogen bonding
  - Van der Waals forces and disulfide bonds
  - Hydrogen bonding and base-stacking interactions

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共7頁第7頁

45. Which of the following is TRUE when comparing DNA and RNA?
- A. RNA is generally single-stranded, allowing diverse secondary structures
  - B. DNA contains uracil, whereas RNA contains thymine
  - C. RNA is more chemically stable than DNA due to the lack of a 2'-OH group
  - D. DNA is primarily found in the nucleus, while RNA is found only in the cytoplasm
46. Which feature allows transcription and translation to be coupled in prokaryotes but not in eukaryotes?
- A. Presence of ribosomes in the nucleus
  - B. Absence of a nuclear membrane in prokaryotes
  - C. Use of different start codons in prokaryotes
  - D. Presence of introns in prokaryotic genes
47. Alternative splicing is especially important in higher eukaryotes because it:
- A. Allows simultaneous transcription and translation
  - B. Eliminates introns from all genes
  - C. Enables tissue-specific and developmental-stage-specific protein expression
  - D. Ensures that all mRNAs encode functional proteins
48. Which process requires both the 5' cap and the poly-A tail for optimal efficiency?
- A. DNA replication
  - B. RNA splicing
  - C. Transcription elongation
  - D. Translation initiation
49. What does it mean that the genetic code is "redundant"?
- A. More than one codon can specify the same amino acid
  - B. Each codon can specify more than one amino acid
  - C. Codons are read in overlapping groups
  - D. The same codon has different meanings in different organisms
50. Which of the following codons functions as a stop codon in translation, and what amino acid does it encode?
- A. UGG; tryptophan
  - B. UAA; leucine
  - C. UGA; no amino acid
  - D. AUG; methionine

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科目名稱：普通生物學【生科系碩士班選考】

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科目名稱：普通生物學【生科系碩士班選考】

題號：421002

※本科目依簡章規定「不可以」使用計算機(混合題)

共 9 頁第 1 頁

## Section 1: Multiple Choice

This section contains **20 questions (Questions 1–20; 2.5% each)**, for a total of **50%**.

Each question has **one best answer** unless otherwise stated. Read each question carefully and select the option that most accurately answers the question based on scientific principles and the information provided. Choose the best answer even if more than one option appears partially correct.

1. Which of the following is **NOT** considered a valid line of scientific evidence supporting biological evolution? (2.5%)
  - A. The ability of individuals to adapt to their environment during their lifetime.
  - B. The fossil record showing transitional forms and changes in species over geological time.
  - C. Homologous structures in different species, indicating common ancestry.
  - D. Similarities in early embryonic development across vertebrate species.
  - E. Molecular similarities, such as shared DNA sequences and proteins among organisms.
2. The Hardy-Weinberg principle states that allele and genotype frequencies in a population will remain constant from generation to generation if certain conditions are met. Which of the following is one of the required assumptions for a population to be in Hardy-Weinberg equilibrium? (2.5%)
  - A. Natural selection favors heterozygotes.
  - B. Mutations occur at equal rates in both directions.
  - C. The population is infinitely large and mating is random.
  - D. Allele frequencies change slowly over time.
  - E. Individuals acquire beneficial traits during their lifetime.
3. In a population that is in Hardy-Weinberg equilibrium. For a locus with two alleles, A and a. If the allele frequency of A is 0.4. What is the frequency of Aa heterozygotes? (2.5%)
  - A. 0.04
  - B. 0.16
  - C. 0.24
  - D. 0.48
  - E. 0.36
4. Which of the following descriptions **is incorrect** for a recognized type of natural selection? (2.5%)
  - A. Directional selection: A mode of natural selection in which individuals with phenotypes at one extreme of a trait distribution have higher fitness than those with intermediate or opposite extreme phenotypes.
  - B. Stabilizing selection: A mode of natural selection that favors both phenotypic extremes over intermediates, potentially increasing variation and leading to a bimodal distribution or speciation.
  - C. Balancing selection: A mode of natural selection that maintains genetic diversity in a population by favoring multiple alleles, often through mechanisms like heterozygote advantage or varying selection pressures across environments.
  - D. Purifying selection: A mode of selection that removes deleterious mutations or alleles, preserving functional genetic sequences and reducing genetic variation at conserved loci.
  - E. Frequency-dependent selection: A mode of selection where a phenotype's fitness depends on its frequency in the population—often, rare phenotypes have higher fitness.
5. Which of the following situations is best explained by the Biological Species Concept? (2.5%)
  - A. Two populations of frogs live in the same habitat and overlap in breeding season, but mating between them produces no viable or fertile offspring due to intrinsic reproductive barriers.
  - B. Fossil shells from different sedimentary layers show gradual changes in shape over millions of years, allowing paleontologists to distinguish "species" based on morphology.

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共 9 頁第 2 頁

- C. Two groups of bacteria are classified as different species because they have less than 70% DNA similarity and differ in several metabolic pathways.
- D. Closely related orchid varieties are considered separate species because each is pollinated exclusively by a different insect species, even though they could produce fertile hybrids in a greenhouse.
- E. Two populations of birds have diverged genetically on different islands and form a monophyletic group on a phylogenetic tree, distinct from all other birds.
6. Continuing from **Question 5**, which of the situations above is best explained by the Phylogenetic Species Concept? (2.5%)
- A. A
- B. B
- C. C
- D. D
- E. E
7. Which of the following is an example of gametic isolation? (2.5%)
- A. Two fern species with overlapping ranges produce hybrid spores that germinate poorly and fail to develop into viable gametophytes due to differences in ploidy.
- B. In sympatric frog populations, one species calls only at night while the other calls during the day, preventing mating attempts.
- C. Pollen grains from one plant species land on the stigma of another species but fail to germinate.
- D. Two populations of lizards on adjacent islands rarely meet due to geographic separation by ocean barriers.
- E. Two bird species have distinct courtship dances; females mate only with males performing the correct display.
8. Continuing from **Question 7**, which of above scenarios is an example of postzygotic isolation? (2.5%)
- A. A
- B. B
- C. C
- D. D
- E. E
9. Which statement best supports the endosymbiotic theory for the origin of mitochondria and chloroplasts? (2.5%)
- A. They are found only in multicellular eukaryotes.
- B. They contain their own linear DNA similar to nuclear chromosomes.
- C. They divide asexually by mitosis within eukaryotic cell.
- D. They have circular DNA and 70S ribosomes.
- E. Mitochondria and chloroplasts are surrounded by a single membrane, similar to the plasma membrane of some prokaryotes.
10. Which of the following eukaryotic groups lacks a multicellular stage with cellular differentiation in their life cycle? (2.5%)
- A. Animals (Metazoa)
- B. Land plants (Embryophyta)
- C. Red algae (Rhodophyta)
- D. Brown algae (Phaeophyta)
- E. Diatoms (Diatomeae)

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11. Which leaf trait is most directly associated with efficient photosynthesis in high-light environments? (2.5%)
- A. A thick cuticle and reduced stomatal density, which primarily limit water loss.
  - B. Kranz anatomy, in which bundle sheath cells rich in chloroplasts surround the vascular tissue and are encircled by mesophyll cells, enabling spatial separation of initial CO<sub>2</sub> fixation and the Calvin cycle.
  - C. Large intercellular air spaces in the spongy mesophyll that facilitate internal gas diffusion.
  - D. A thin epidermis lacking chloroplasts, allowing light to penetrate underlying tissues.
  - E. Increased trichome density on the leaf surface, reflecting excess radiation.
12. What is a primary ecological consequence of spring turnover in dimictic lakes following ice melt? (2.5%)
- A. Permanent establishment of thermal stratification that lasts through winter.
  - B. Redistribution of oxygen from surface to deep layers and nutrients from sediments to the surface photic zone.
  - C. Depletion of nutrients in surface waters as they sink with dense cold water.
  - D. Immediate onset of anoxia throughout the water column due to rapid mixing.
  - E. Suppression of phytoplankton blooms because cold water remains at the surface.
13. Which of the following survivorship curves is most characteristic of a species that exhibits an r-strategy (r-selected) life history? (2.5%)
- A. Type I: High survivorship through most of life, with mortality concentrated at old age.
  - B. Type II: Constant mortality rate throughout life, with a relatively straight line on a log scale.
  - C. Type III: Extremely high early mortality, with very few individuals surviving to reproductive age, but high survivorship thereafter.
  - D. Type I with a slight dip in mid-life due to predation pressure.
  - E. A curve that starts flat and then drops sharply at reproductive maturity.
14. In which type of environment would you most expect a species with a K-selected life history to be favored? (2.5%)
- A. Environments with frequent disturbances, rapid population turnover, and strong selection for early reproduction.
  - B. Highly variable habitats where success depends on producing many small offspring quickly.
  - C. Stable, resource-limited environments where competitive ability, stress tolerance, and long lifespan are favored.
  - D. Newly colonized habitats with abundant open space and low competition.
  - E. Environments dominated by density-independent mortality such as floods or fires.
15. Which of the following scenarios best illustrates commensalism between two organisms? (2.5%)
- A. Clownfish live among the tentacles of sea anemones, gaining protection from predators while the anemones benefit from increased nutrient input.
  - B. Cattle egrets forage near grazing rhinoceroses, catching insects disturbed by the rhinos' movement, without affecting the rhinos.
  - C. A harmless hoverfly evolves yellow-and-black stripes resembling those of stinging wasps, deterring predators.
  - D. Mycorrhizal fungi form associations with plant roots, providing nutrients to the plant in exchange for sugars produced by photosynthesis.
  - E. Orchids of the genus *Anguloa* produce flowers that mimic the scent and shape of female Euglossine bees, attracting male bees that attempt to mate and inadvertently pollinate the flowers.

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16. Continuing from **Question 15**, which of the situations above is an example of Batesian mimicry? (2.5%)
- A. A
  - B. B
  - C. C
  - D. D
  - E. E
17. Which of the following statements best illustrates the difference between a realized niche and a fundamental niche? (2.5%)
- A. The realized niche is the full range of environmental conditions under which a species can survive and reproduce in the absence of competitors or predators, while the fundamental niche is the actual portion of that range the species occupies when biotic interactions are present.
  - B. The realized niche is limited only by abiotic factors such as temperature and moisture, while the fundamental niche also includes the species' preferred habitat selected through evolutionary adaptation.
  - C. The realized niche is always larger than the fundamental niche because species evolve to specialize in narrower conditions over time.
  - D. The realized niche describes where a species currently lives in nature, while the fundamental niche represents the broader conditions it could theoretically tolerate in laboratory experiments.
  - E. The realized niche and fundamental niche are identical in most species because biotic interactions rarely restrict distribution.
18. Which of the following statements best describes the relationships among species richness, abundance, and the components of regional diversity? (2.5%)
- A. Alpha diversity is the total species richness of a region, beta diversity measures evenness of abundance within a single site, and gamma diversity is the average across local sites.
  - B. Species richness is simply the number of species in a community, while abundance refers to the relative number of individuals per species.
  - C. Beta diversity is always higher than alpha diversity because it includes rare species missed in local sampling, while gamma diversity is the product of alpha and species abundance.
  - D. Gamma diversity equals alpha diversity because regional scale simply aggregates local communities without adding new species through turnover.
  - E. Evenness (abundance distribution) has no effect on species richness, and beta diversity is calculated solely from differences in species abundance, not composition.
19. Which of the following scenarios best illustrates top-down control in an ecosystem? (2.5%)
- A. Nutrient enrichment in a lake increases phytoplankton growth, which then supports higher zooplankton and fish populations.
  - B. Reintroducing wolves to Yellowstone reduces elk grazing pressure, triggering a trophic cascade that allows woody vegetation and associated animal populations to recover.
  - C. Increased sunlight due to forest clearing boosts primary production, leading to higher herbivore biomass and more predators.
  - D. Fertilization of a grassland stimulates plant growth, resulting in larger populations of insects and insectivorous birds.
  - E. Drought reduces plant productivity, causing declines in herbivore numbers and subsequently fewer carnivores.
20. Which of the following best explains why ocean acidification, driven by increasing atmospheric CO<sub>2</sub> from global warming, poses a major threat to organisms that build shells or skeletons from calcium

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carbonate ( $\text{CaCO}_3$ )? (2.5%)

- A. Rising sea temperatures directly dissolve existing  $\text{CaCO}_3$  structures in corals and mollusks.
- B. Increased  $\text{CO}_2$  in seawater reacts to form carbonic acid, lowering pH and decreasing the concentration of carbonate ions ( $\text{CO}_3^{2-}$ ), making it harder for marine organisms to precipitate  $\text{CaCO}_3$ .
- C. Global warming reduces ocean salinity, preventing calcium ions from binding effectively with carbonate ions.
- D. Ocean acidification increases the availability of carbonate ions, causing excessive and uncontrolled  $\text{CaCO}_3$  deposition that smothers organisms.
- E. Higher  $\text{CO}_2$  levels promote photosynthesis in calcifying algae, depleting calcium ions from seawater and starving shell-forming animals.

## Section 2: Select All That Apply

This section contains **two question sets: Questions 21–24 (7.5% each) and Questions 25–26 (5% each)**, for a total of **40%**.

For each question, **one or more options may be correct**. Select all options that apply.

- 21. Based on the mammalian phylogeny shown in **Figure 1**, which of the following statements are **true**? (7.5%; select all that apply).
  - A. Marsupialia is much more ancient than all other mammalian lineages.
  - B. Marsupialia is phylogenetically more closely related to Afrotheria than to Rodentia.
  - C. Chiroptera is phylogenetically more closely related to Perissodactyla than to Primates.
  - D. Lagomorpha is the sister group to Rodentia.
  - E. The rate of nucleotide evolution in Primates is much faster than in Lagomorpha.
- 22. Based on the inferred evolutionary history of diet shown in **Figure 1**, which of the following statements are **true**? (7.5%; select all that apply).
  - A. Herbivory is homoplasy within Marsupialia.
  - B. The occurrence of carnivory in Chiroptera and Eulipotyphla is the result of convergent evolution.
  - C. Herbivorous Chiroptera forms a paraphyletic group.
  - D. Omnivory has been lost multiple times within Perissodactyla + Cetartiodactyla.
  - E. Herbivory is a synapomorphic trait of Lagomorpha.

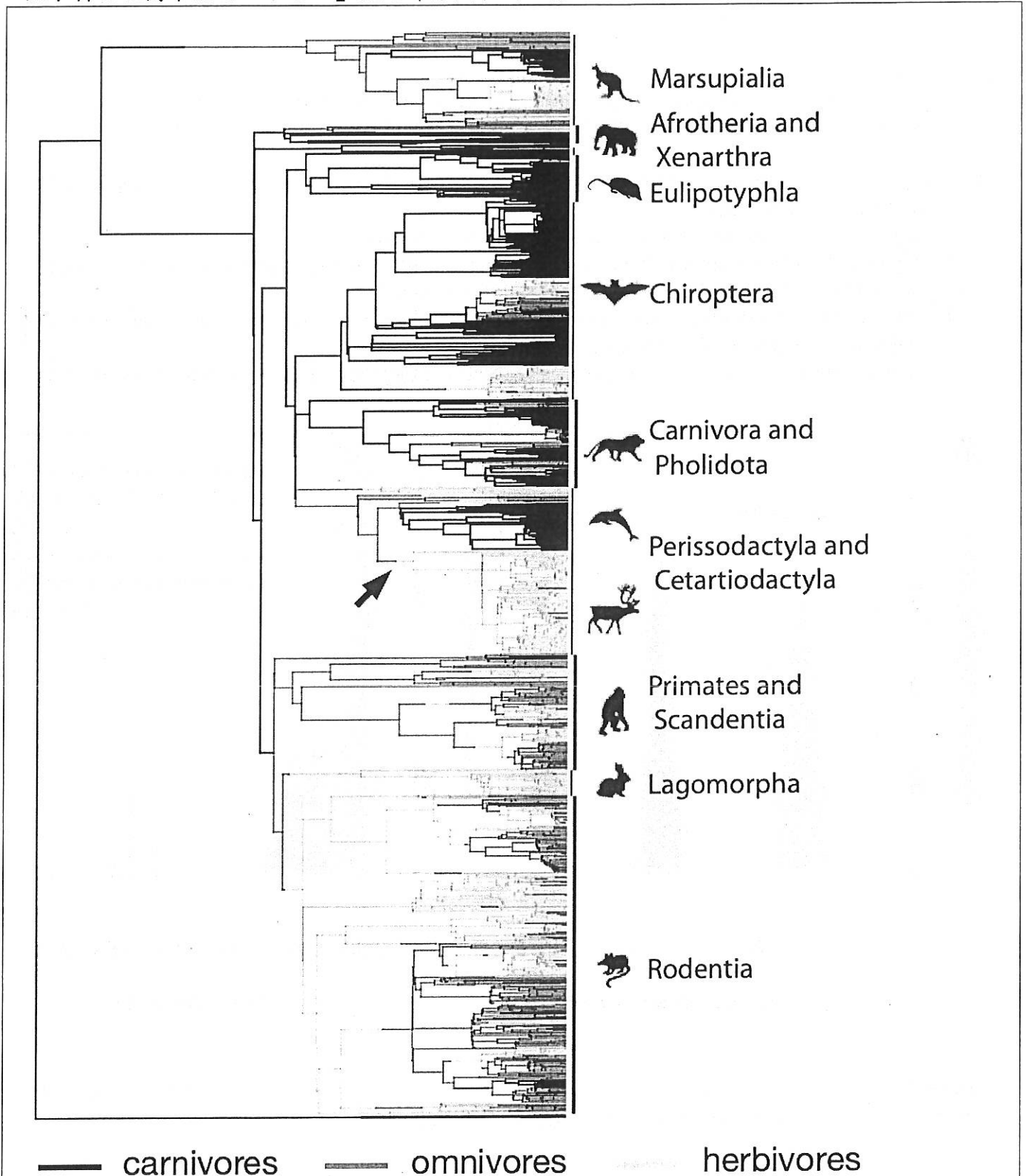
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Price et al. (2012) Tempo of trophic evolution and its impact on mammalian diversification, *PNAS* 109 (18) 7008-7012

- Fig. 1. A mammalian phylogeny illustrating one possible reconstruction of dietary evolution.
23. Figure 2 and Figure 1 are derived from the same dataset. Based only on the information shown in **Figure 2**, which of the following statements can be supported? (7.5%; Select all that apply).
- A. This study addresses macroevolutionary processes, rather than microevolutionary processes.
  - B. Herbivorous mammals exhibit a higher nucleotide evolutionary rate than omnivorous and

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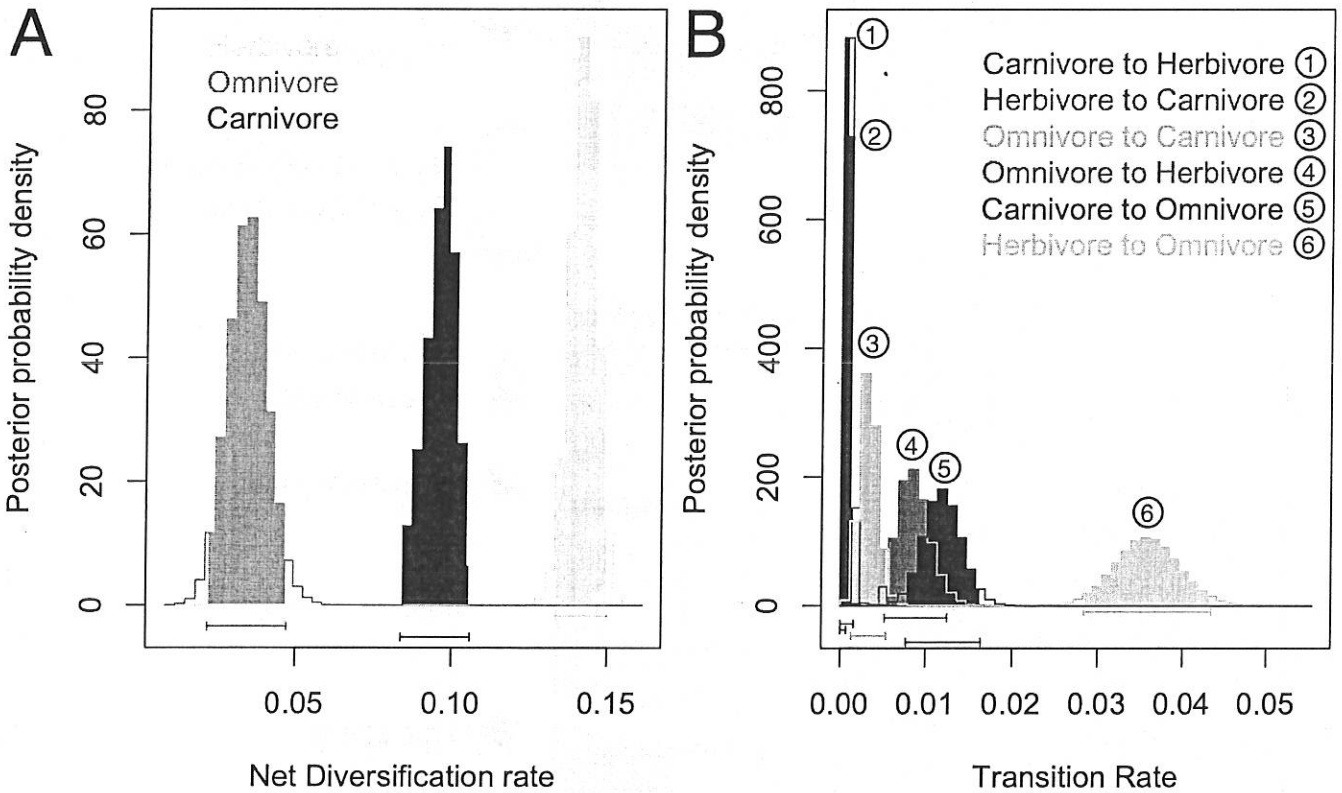
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carnivorous mammals.

- C. Herbivorous mammals exhibit a higher speciation rate than omnivorous and carnivorous mammals.
- D. More omnivorous lineages were derived from herbivores than from omnivores.
- E. An herbivorous lineage is more likely to transition to omnivory than to carnivory.

24. Considering both **Figure 1** and **Figure 2** which of the following conclusions are best supported? (7.5%; Select all that apply).

- A. Dietary strategy has no effect on mammalian diversification.
- B. Repeated transitions among dietary strategies have contributed to mammalian diversification.
- C. Omnivory is an irreversible evolutionary state in mammals.
- D. The inferred probability of direct transitions between herbivory and carnivory is low, with most transitions occurring via an intermediate omnivorous stage.
- E. Ecological specialization, in this case, can promote rather than limit long-term diversification.



Price et al. (2012) Tempo of trophic evolution and its impact on mammalian diversification, *PNAS* 109 (18) 7008-7012

**Figure 2.** Posterior distributions of (A) net diversification rates (speciation minus extinction) and (B) dietary transition rates among herbivorous, omnivorous, and carnivorous mammals.

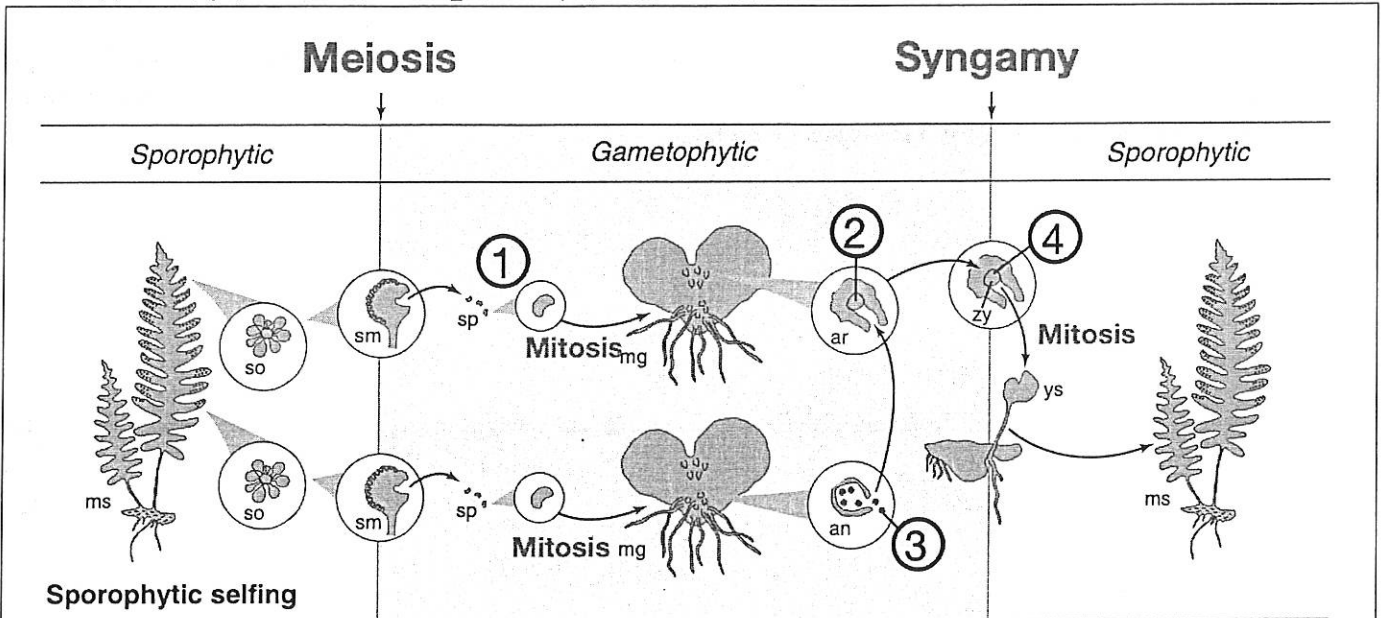
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an, antheridium; ar, archegonium; mg, mature gametophyte; ms, mature sporophyte; sm, sporangium; so, sorus; sp, spore; ys, young sporophyte; zy, zygote.

Haufler et al. (2016). Sex and the Single Gametophyte: Revising the Homosporous Vascular Plant Life Cycle in Light of Contemporary Research. *BIOSCIENCE*, 66(11), pp. 928–937.

**Figure 3.** Linearized sporophytic selfing life cycle of a fern, illustrating alternation of generations from sporophyte to gametophyte and back to sporophyte.

25. **Figure 3** illustrates the life cycle of a fern, in which four unicellular stages are labeled ①–④. Assuming the haploid chromosome number ( $n$ ) = 34, which of the following statements are true? (5%; select all that apply.)
- A. Cell ① is derived from a spore mother cell through meiosis. Each spore mother cell produces 64 spores in leptosporangiate ferns.
  - B. Cell ② is produced by mitosis in a female or hermaphroditic gametophyte.
  - C. Cell ② has 17 chromosomes in its nucleus.
  - D. Cell ③ is the male gamete of the fern.
  - E. Cell ④ is expected to be homozygous across the genome.
26. Based on the life cycle of ferns shown in **Figure 3**, which of the following statements are true? (5%; select all that apply).
- A. The life cycle of this fern is haplodiplontic.
  - B. The alternation of generations in this fern is isomorphic.
  - C. This fern is isogamous.
  - D. Cell ① is the primary dispersal unit in this fern.
  - E. The young sporophyte is dispersed within maternal protective tissue (a seed).

### Section 3: Long Answer

This section contains **one question worth 10%**. Your response should clearly explain key concepts, use appropriate biological terminology, demonstrate logical reasoning, and provide relevant examples.

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27. Explain the concept of reinforcement in the context of speciation. Include a definition, how it works, and provide a specific example from nature. Your answer should be clear, concise, and demonstrate understanding of speciation processes (10%).