# Life and Cell

## Multiple Choice Questions

**In a bacterial cell, the DNA is in the:**
A) cell envelope.
B) cell membrane.
C) cytoplasma.
D) nucleus.
E) ribosomes.

**A major change occurring in the evolution of eukaryotes from prokaryotes was the development of:**
A) DNA.
B) photosynthetic capability.
C) plasma membranes.
D) ribosomes.
E) the nucleus.

**In eukaryotes, the nucleus is enclosed by a double membrane called the:**
A) cell membrane.
B) nuclear envelope.
C) nucleolus.
D) nucleoplasm.
E) nucleosome.

**Which group of single-celled microorganisms has many members found growing in extreme environments?**
A) Bacteria
B) Archaea
C) Eukaryotes
D) Heterotrophs
E) None of the above

**The bacterium *E. coli* requires simple organic molecules for growth and as an energy source — it is therefore a:**
A) chemoautotroph.
B) chemoheterotroph.
C) lithotroph.
D) photoautotroph.
E) photoheterotroph.

**The three-dimensional structure of macromolecules is formed and maintained primarily through noncovalent interactions. Which one of the following is *not* considered a noncovalent interaction?**

A) carbon-carbon bonds
B) hydrogen bonds
C) hydrophobic interactions
D) ionic interactions
E) van der Waals interactions

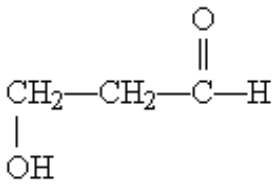
**Which one of the following is *not* among the four most abundant elements in living organisms?**

A) Carbon
B) Hydrogen
C) Nitrogen
D) Oxygen
E) Phosphorus

**The four covalent bonds in methane ($CH_4$) are arranged around carbon to give which one of the following geometries?**

A) Linear
B) Tetrahedral
C) Trigonal bipyramidal
D) Trigonal planar
E) Trigonal pyramidal

**What functional groups are present on this molecule?**



A) Ether and aldehyde
B) Hydroxyl and aldehyde
C) Hydroxyl and carboxylic acid
D) Hydroxyl and ester
E) Hydroxyl and ketone

**The macromolecules that serve in the storage and transmission of genetic information are:**

A) carbohydrates.
B) lipids.
C) membranes.
D) nucleic acids.
E) proteins.

**Stereoisomers that are nonsuperimposable mirror images of each other are known as:**
A) anomers.
B) cis-trans isomers.
C) diastereoisomers.
D) enantiomers.
E) geometric isomers.

**If heat energy is absorbed by the system during a chemical reaction, the reaction is said to be:**
A) at equilibrium.
B) endergonic.
C) endothermic.
D) exergonic.
E) exothermic.

**If the free energy change □G for a reaction is -46.11 kJ/mol, the reaction is:**
A) at equilibrium.
B) endergonic.
C) endothermic.
D) exergonic.
E) exothermic.

**The major carrier of chemical energy in all cells is:**
A) acetyl triphosphate.
B) adenosine monophosphate.
C) adenosine triphosphate.
D) cytosine tetraphosphate.
E) uridine diphosphate.

**Enzymes are biological catalysts that enhance the rate of a reaction by:**
A) decreasing the activation energy.
B) decreasing the amount of free energy released.
C) increasing the activation energy.
D) increasing the amount of free energy released.
E) increasing the energy of the transition state.

**Energy requiring metabolic pathways that yield complex molecules from simpler ones are:**
A) amphibolic.
B) anabolic.
C) autotrophic.
D) catabolic.
E) heterotrophic.

**Hereditary information (with the exception of some viruses) is preserved in:**
A) deoxyribonucleic acid.
B) membrane structures.
C) nuclei.
D) polysaccharides.
E) ribonucleic acid.

**When a region of DNA must be repaired by removing and replacing some of the nucleotides, what ensures that the new nucleotides are in the correct sequence?**
A) DNA cannot be repaired and this explains why mutations occur.
B) Specific enzymes bind the correct nucleotides.
C) The new nucleotides basepair accurately with those on the complementary strand.
D) The repair enzyme recognizes the removed nucleotide and brings in an identical one to replace it.
E) The three-dimensional structure determines the order of nucleotides.

**The three-dimensional structure of a protein is determined primarily by:**
A) electrostatic guidance from nucleic acid structure.
B) how many amino acids are in the protein.
C) hydrophobic interaction with lipids that provide a folding framework.
D) modification during interactions with ribosomes.
E) the sequence of amino acids in the protein.

**According to Oparin's theory for the origin of life, the prebiotic atmosphere:**
A) already contained some primitive RNA molecules.
B) basically was very similar to the atmosphere of today.
C) contained many amino acids.
D) had an abundance of methane, ammonia, and water.
E) was rich in oxygen.

## Short Answer Questions

1. **Most cells of higher plants have a cell wall outside the plasma membrane. What is the function of the cell wall?**

2. **(a) List the types of noncovalent interactions that are important in providing stability to the three-dimensional structures of macromolecules. (b) Why is it important that these interactions be noncovalent, rather than covalent, bonds?**

3. **Draw the structures of the following functional groups in their un-ionized forms: (a) hydroxyl, (b) carboxyl, (c) amino, (d) carbonyl.**

4. **Name two functions of (a) proteins, (b) nucleic acids, (c) polysaccharides, (d) lipids.**

5. **What is an asymmetric carbon atom, why it is called a chiral center?**

6. **What is optical activity?**

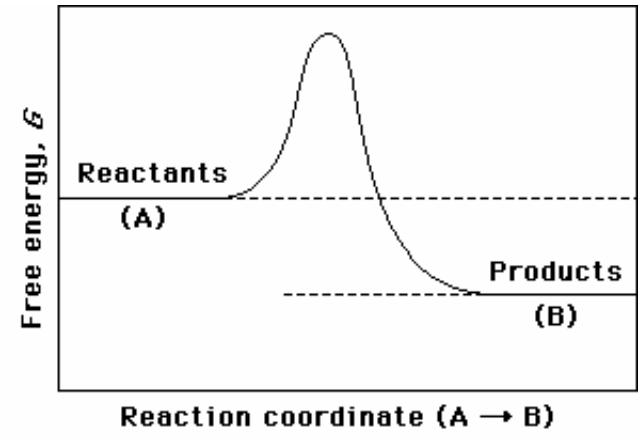
7. **The free-energy change for the formation of a product (e.g. protein from the individual amino acids) is positive and is thus an endergonic reaction. How, then, do cells accomplish this process (generally)?**

8. **Instant cold packs get cold when the contents, usually solid urea and liquid water, are mixed, producing an aqueous solution of urea. Although this process is clearly spontaneous, the products are colder than the reactants. Explain how this is possible in terms of the difference between ΔG and ΔH.**

9. **Describe Stanley Miller's experiment (1953) and its relevance.**

10. **Draw schematically what is meant by endosymbiotic association? What arise from endosymbiosis?**

11. **On the reaction coordinate diagram shown below, label the transition state and the overall free-energy change (ΔG) for the uncatalyzed reaction A -> B. (b) Is this an exergonic or endergonic reaction? (c) Draw a second curve showing the energetics of the reaction if it were enzyme-catalyzed.**



# Water

## Multiple Choice Questions

**Which of these statements about hydrogen bonds is *not* true?**

A) Hydrogen bonds account for the anomalously high boiling point of water.
B) In liquid water, the average water molecule forms hydrogen bonds with three to four other water molecules.
C) Individual hydrogen bonds are much weaker than covalent bonds.
D) Individual hydrogen bonds in liquid water exist for many seconds and sometimes for minutes.
E) The strength of a hydrogen bond depends on the linearity of the three atoms involved in the bond.

**A true statement about hydrophobic interactions is that they:**

A) are the driving force in the formation of micelles of amphipathic compounds in water.
B) do not contribute to the structure of water-soluble proteins.
C) have bonding energies of approximately 20–40 Kjoule per mole.
D) involve the ability of water to denature proteins.
E) primarily involve the effect of polar solutes on the entropy of aqueous systems.

**What is the approximate strength of hydrogen bonds in water (in kJ . $mol^{-1}$)?**

A) 0.2
B) 2
C) 20
D) 100
E) 200

**Which of the following properties of water does *not* make the aqueous environment excellent for living organisms?**

A) Hydrogen bonding.
B) High heat of vaporization.
C) High specific heat.
D) The density of water is greater than the density of ice.
E) The very low molecular weight of water.

## Short Answer Questions

1. **Name and briefly define four types of noncovalent interactions that occur between biological molecules.**

2. **Explain the fact that ethanol ($CH_3CH_2OH$) is more soluble in water than is ethane ($CH_3CH_3$).**

3. **Explain with an appropriate diagram why amphipathic molecules tend to form micelles in water. What force drives micelle formation?**

4. **If ice were denser than water, how would that affect life on earth?**

# Nucleotides and Nucleic Acids

## Multiple Choice Questions

**The compound that consists of ribose linked by an *N*-glycosidic bond to N-9 of adenine is:**
A) a deoxyribonucleoside.
B) a purine nucleotide.
C) a pyrimidine nucleotide.
D) adenosine monophosphate.
E) adenosine.

**A major component of RNA but not of DNA is:**
A) adenine.
B) cytosine.
C) guanine.
D) thymine.
E) uracil.

**The difference between a ribonucleotide and a deoxyribonucleotide is:**
A) a deoxyribonucleotide has an —H instead of an —OH at C-2.
B) a deoxyribonucleotide has α configuration; ribonucleotide has the β configuration at C-1.
C) a ribonucleotide has an extra —OH at C-4.
D) a ribonucleotide has more structural flexibility than deoxyribonucleotide.
E) a ribonucleotide is a pyranose, deoxyribonucleotide is a furanose.

**Which one of the following is true of the pentoses found in nucleic acids?**
A) C-5 and C-1 of the pentose are joined to phosphate groups.
B) C-5 of the pentose is joined to a nitrogenous base, and C-1 to a phosphate group.
C) The bond that joins nitrogenous bases to pentoses is an *O*-glycosidic bond.
D) The pentoses are always in the β -furanose forms.
E) The straight-chain and ring forms undergo constant interconversion.

**The phosphodiester bonds that link adjacent nucleotides in both RNA and DNA:**
A) always link A with T and G with C.
B) are susceptible to alkaline hydrolysis.
C) are uncharged at neutral pH.
D) form between the planar rings of adjacent bases.
E) join the 3′ hydroxyl of one nucleotide to the 5′ hydroxyl of the next.

**The DNA oligonucleotide abbreviated pATCGAC:**
A) has 7 phosphate groups.
B) has a hydroxyl at its 3′ end.
C) has a phosphate on its 3′ end.
D) has an A at its 3′ end.
E) violates Chargaff's rules.

**For the oligoribonucleotide pACGUAC:**
A) the nucleotide at the 3′ end has a phosphate at its 3′ hydroxyl.
B) the nucleotide at the 3′ end is a purine.
C) the nucleotide at the 5′ end has a 5′ hydroxyl.
D) the nucleotide at the 5′ end has a phosphate on its 5′ hydroxyl.
E) the nucleotide at the 5′ end is a pyrimidine.

**In a double-stranded nucleic acid, cytosine typically base-pairs with:**
A) adenosine.
B) guanine.
C) inosine.
D) thymine.
E) uracil.

**In the Watson-Crick model for the DNA double helix (B form), how many hydrogen bonds are in the A–T and G–C base pairs?**
A) 3, 2.
B) 3, 3.
C) 2, 2.
D) 2, 3.
E) none.

**Chargaff's rules state that in typical DNA:**
A) A = G.
B) A = C.
C) A = U.
D) A + T = G + C.
E) A + G = T + C.

**Based on Chargaff's rules, which of the following are possible base compositions for double-stranded DNA?**

| | %A | %G | %C | %T | %U |
|---|---|---|---|---|---|
| A) | 5 | 45 | 45 | 5 | 0 |
| B) | 20 | 20 | 20 | 20 | 20 |
| C) | 35 | 15 | 35 | 15 | 0 |

D) All of the above.
E) None of the above.

**In the Watson-Crick model of DNA structure:**
A) both strands run in the same direction, 3′ to 5′; they are parallel.
B) phosphate groups project toward the middle of the helix, where they are protected from interaction with water.
C) T can form three hydrogen bonds with either G or C in the opposite strand.
D) the distance between the sugar backbone of the two strands is just large enough to accommodate either two purines or two pyrimidines.
E) the distance between two adjacent bases in one strand is about 3.4 Å.

**Which of the following is *not* true of all naturally occurring DNA?**
A) Deoxyribose units are connected by 3′,5′-phosphodiester bonds.
B) The amount of A always equals the amount of T.
C) The ratio A+T/G+C is constant for all natural DNAs.
D) The two complementary strands are antiparallel.
E) Two hydrogen bonds form between A and T.

**In the Watson-Crick model of DNA structure (now called B-form DNA):**
A) a purine in one strand always hydrogen bonds with a purine in the other strand.
B) A–T pairs share three hydrogen bonds.
C) G–C pairs share two hydrogen bonds.
D) the 5′ ends of both strands are at one end of the helix.
E) the bases occupy the interior of the helix.

**In nucleotides and nucleic acids, syn and anti conformations relate to:**
A) base stereoisomers.
B) rotation around the phosphodiester bond.
C) rotation around the sugar-base bond.
D) sugar pucker.
E) sugar stereoisomers.

**B-form DNA in vivo is a _____-handed helix, _____ Å in diameter, with a rise of ____ Å per base pair.**
A) left; 20; 3.9
B) right; 18; 3.4
C) right; 18; 3.6
D) right; 20; 3.4
E) right; 23; 2.6

**In double-stranded DNA:**
A) only a right-handed helix is possible.
B) sequences rich in A–T base pairs are denatured less readily than those rich in G–C pairs.
C) the sequence of bases is random.
D) the two strands are parallel.
E) the two strands have complementary sequences.

**Which of the following is a palindromic sequence?**

A) AGGTCC
TCCAGG
B) CCTTCC
GCAAGG
C) GAATCC
CTTAGG
D) GGATCC
CCTAGG
E) GTATCC
CATAGG

**Triple-helical DNA structures can result from Hoogsteen (non Watson-Crick) interactions. These interactions are primarily:**

A) covalent bonds involving deoxyribose.
B) covalent bonds involving the bases.
C) hydrogen bonds involving deoxyribose.
D) hydrogen bonds involving the bases.
E) hydrophobic interactions involving the bases.

**Double-stranded regions of RNA:**

A) are less stable than double-stranded regions of DNA.
B) can be observed in the laboratory, but probably have no biological relevance.
C) can form between two self-complementary regions of the same single strand of RNA.
D) do not occur.
E) have the two strands arranged in parallel (unlike those of DNA, which are antiparallel).

**When double-stranded DNA is heated at neutral pH, which change does *not* occur?**

A) The absorption of ultraviolet (260 nm) light increases.
B) The covalent N-glycosidic bond between the base and the pentose breaks.
C) The helical structure unwinds.
D) The hydrogen bonds between A and T break.
E) The viscosity of the solution decreases.

**Which of the following deoxyoligonucleotides will hybridize with a DNA containing the sequence (5′)AGACTGGTC(3′)?**

A) (5′)CTCATTGAG(3′)
B) (5′)GACCAGTCT(3′)
C) (5′)GAGTCAACT(3′)
D) (5′)TCTGACCAG(3′)
E) (5′)TCTGGATCT(3′)

**In the laboratory, several factors are known to cause alteration of the chemical structure of DNA. The factor(s) likely to be important in a *living* cell is (are):**

A) heat.
B) low pH.
C) oxygen.
D) UV light.
E) both C and D.

**In living cells, nucleotides and their derivatives can serve as:**

A) carriers of metabolic energy.
B) enzyme cofactors.
C) intracellular signals.
D) precursors for nucleic acid synthesis.
E) all of the above.

**The "energy carrier" ATP is an example of a(n):**

A) deoxyribonucleoside triphosphate
B) di-nucleotide
C) peptide
D) ribonucleotide
E) ribonucleoside triphosphate

## Short Answer Questions

1. **How are a nucleoside and a nucleotide similar and how are they different?**

2. **Match the type of bond with the role below:**

| Bond type | Role |
|---|---|
| (a) phosphodiester | ___ links base to pentose in nucleotide |
| (b) *N*-glycosidic | ___ joins adjacent nucleotides in one strand |
| (c) phosphate ester | ___ joins complementary nucleotides in two strands |
| (d) hydrogen | ___ difference between a nucleoside and a nucleotide |

3. **Draw the structure of either an adenine or thymine.**

4. **What is the approximate length of a DNA molecule (in the B form) containing 10,000 base pairs?**

5. **Describe briefly what is meant by saying that two DNA strands are complementary.**

6. **In one sentence, identify the most obvious structural difference between A-form (Watson-Crick) DNA and Z-form DNA.**

7. **Mouse DNA hybridizes more extensively with human DNA than with yeast DNA. Explain briefly why.**

8. **What is the principal effect of ultraviolet radiation on DNA?**

# Amino Acids, Proteins

## Multiple Choice Questions

**The chirality of an amino acid results from the fact that its αcarbon:**
A) has no net charge.
B) is a carboxylic acid.
C) is bonded to four different chemical groups.
D) is in the L absolute configuration in naturally occurring proteins.
E) is symmetric.

**Of the 20 standard amino acids, only _____ is not optically active. The reason is that its side chain _____.**
A) alanine; is a simple methyl group
B) glycine; is a hydrogen atom
C) glycine; is unbranched
D) lysine; contains only nitrogen
E) proline; forms a covalent bond with the amino group

**Two amino acids of the standard 20 contain sulfur atoms. They are:**
A) cysteine and serine.
B) cysteine and threonine.
C) methionine and cysteine
D) methionine and serine
E) threonine and serine.

**All of the amino acids that are found in proteins, except for proline, contain a(n):**
A) amino group.
B) carbonyl group.
C) carboxyl group.
D) ester group.
E) thiol group.

**Which of the following statements about *cystine* is correct?**
A) Cystine forms when the —$CH_2$—SH R group is oxidized to form a —$CH_2$—S—S—$CH_2$— disulfide bridge between two cysteines.
B) Cystine is an example of a nonstandard amino acid, derived by linking two standard amino acids.
C) Cystine is formed by the oxidation of the carboxylic acid group on cysteine.
D) Cystine is formed through a peptide linkage between two cysteines.
E) Two cystines are released when a —$CH_2$—S—S—$CH_2$— disulfide bridge is reduced to —$CH_2$—SH.

**Amino acids are ampholytes because they can function as either a(n):**

A) acid or a base.
B) neutral molecule or an ion.
C) polar or a nonpolar molecule.
D) standard or a nonstandard monomer in proteins.
E) transparent or a light-absorbing compound.

**Titration of valine by a strong base, for example NaOH, reveals two p*K*'s. The titration reaction occurring at p$K_2$ (p$K_2$ = 9.62) is:**

A) —COOH + $OH^-$ → —$COO^-$ + $H_2O$.
B) —$COOH$ + —$NH_2$ → —$COO^-$ + —$NH_2^+$.
C) —$COO^-$ + —$NH_2^+$ → —COOH + —$NH_2$.
D) —$NH_3^+$ + $OH^-$ → —$NH_2^-$ + $H_2O$.
E) —$NH_2$ + OH → —NH + $H_2O$.

**In a highly basic solution, the dominant form of glycine is:**

A) $NH_2$—$CH_2$—$COOH$.
B) $NH_2$—$CH_2$—$COO^-$.
C) $NH_2$—$CH_3^+$—COO.
D) $NH_3^+$—$CH_2$—$COOH$.
E) $NH_3^+$—$CH_2$—COO.

**For amino acids with neutral R groups, at any pH below the pI of the amino acid, the population of amino acids in solution will have:**

A) a net negative charge.
B) a net positive charge.
C) no charged groups.
D) no net charge.
E) positive and negative charges in equal concentration.

**The formation of a peptide bond between two amino acids is an example of a(n) _____ reaction.**

A) cleavage
B) condensation
C) group transfer
D) isomerization
E) oxidation reduction

**The peptide alanylglutamylglycylalanylleucine has:**

A) a disulfide bridge.
B) five peptide bonds.
C) four peptide bonds.
D) no free carboxyl group.
E) two free amino groups.

**An octapeptide composed of four repeating glycylalanyl units has:**

A) one free amino group on an alanyl residue.
B) one free amino group on an alanyl residue and one free carboxyl group on a glycyl residue.
C) one free amino group on a glycyl residue and one free carboxyl group on an alanyl residue.
D) two free amino and two free carboxyl groups.
E) two free carboxyl groups, both on glycyl residues.

**At the isoelectric pH of a tetrapeptide:**

A) only the amino and carboxyl termini contribute charge.
B) the amino and carboxyl termini are not charged.
C) the total net charge is zero.
D) there are four ionic charges.
E) two internal amino acids of the tetrapeptide cannot have ionizable R groups.

**Which of the following is correct with respect to the amino acid composition of proteins?**

A) Larger proteins have a more uniform distribution of amino acids than smaller proteins.
B) Proteins contain at least one each of the 20 different standard amino acids.
C) Proteins with different functions usually differ significantly in their amino acid composition.
D) Proteins with the same molecular weight have the same amino acid composition.
E) The average molecular weight of an amino acid in a protein increases with the size of the protein.

**The average molecular weight of the 20 standard amino acids is 138, but biochemists use 110 when estimating the number of amino acids in a protein of known molecular weight. Why?**

A) The number 110 is based on the fact that the average molecular weight of a protein is 110,000 with an average of 1,000 amino acids.
B) The number 110 reflects the higher proportion of small amino acids in proteins, as well as the loss of water when the peptide bond forms.
C) The number 110 reflects the number of amino acids found in the typical small protein, and only small proteins have their molecular weight estimated this way.
D) The number 110 takes into account the relatively small size of nonstandard amino acids.
E) The number 138 represents the molecular weight of conjugated amino acids.

**In a conjugated protein, a prosthetic group is:**

A) a fibrous region of a globular protein.
B) a nonidentical subunit of a protein with many identical subunits.
C) a part of the protein that is not composed of amino acids.
D) a subunit of an oligomeric protein.
E) synonymous with “protomer.”

**Prosthetic groups in the class of proteins known as glycoproteins are composed of:**

A) carbohydrates.
B) flavin nucleotides.
C) lipids.
D) metals .
E) phosphates.

**For the study of a protein in detail, an effort is usually made to first:**

A) conjugate the protein to a known molecule.
B) determine its amino acid composition.
C) determine its amino acid sequence.
D) determine its molecular weight.
E) purify the protein.

**In a mixture of the five proteins listed below, which should elute second in size-exclusion (gel- filtration) chromatography?**

A) cytochrome *c* $M_r$ = 13,000
B) immunoglobulin G $M_r$ = 145,000
C) ribonuclease A $M_r$ = 13,700
D) RNA polymerase $M_r$ = 450,000
E) serum albumin $M_r$ = 68,500

**By adding SDS (sodium dodecyl sulfate) during the electrophoresis of proteins, it is possible to:**

A) determine a protein's isoelectric point.
B) determine an enzyme's specific activity.
C) determine the amino acid composition of the protein.
D) preserve a protein's native structure and biological activity.
E) separate proteins exclusively on the basis of molecular weight.

**To determine the isoelectric point of a protein, first establish that a gel:**

A) contains a denaturing detergent that can distribute uniform negative charges over the protein's surface.
B) exhibits a stable pH gradient when ampholytes become distributed in an electric field.
C) is washed with an antibody specific to the protein of interest.
D) neutralizes all ionic groups on a protein by titrating them with strong bases.
E) relates the unknown protein to a series of protein markers with known molecular weights, $M_r$.

**Which of the following refers to particularly stable arrangements of amino acid residues in a protein that give rise to periodic "short distance" patterns?**

A) Primary structure
B) Secondary structure
C) Tertiary structure
D) Quaternary structure
E) None of the above

**Which of the following describes the overall three-dimensional folding of a polypeptide?**

A) Primary structure
B) Secondary structure
C) Tertiary structure
D) Quaternary structure
E) None of the above

**The functional differences, as well as differences in three-dimensional structures, between two different enzymes from *E. coli* result directly from their different:**

A) affinities for ATP.
B) amino acid sequences.
C) roles in DNA metabolism.
D) roles in the metabolism of *E. coli*.
E) secondary structures.

**One method used to prevent disulfide bond interference with protein sequencing procedures is:**

A) cleaving proteins with proteases that specifically recognize disulfide bonds.
B) protecting the disulfide bridge against spontaneous reduction to cysteinyl sulfhydryl groups.
C) reducing disulfide bridges and preventing their re-formation by further modifying the —SH groups.
D) removing cystines from protein sequences by proteolytic cleavage.
E) sequencing proteins that do not contain cysteinyl residues.

**Even when a gene is available and its sequence of nucleotides is known, chemical studies of the protein are still required to determine:**

A) molecular weight of the protein.
B) the amino-terminal amino acid.
C) the location of disulfide bonds.
D) the number of amino acids in the protein.
E) whether the protein has the amino acid methionine in its sequence.

## Short Answer Questions

1. **What are the structural characteristics common to all amino acids found in naturally occurring proteins?**

2. **Only one of the common amino acids has no free α-amino group. Name this amino acid and draw its structure.**

3. **Briefly name the five major groups of amino acids.**

4. **Draw the structures of the amino acids phenylalanine and aspartate. Why is aspartate very soluble in water, whereas phenylalanine is much less soluble?**

5. **Name two uncommon amino acids that occur in proteins. By what route do they get into proteins?**

6. **Leucine has two dissociable protons, one with a p$K_a$ of 2.3, the other with a p$K_a$ of 9.7. Sketch a properly labeled titration curve for leucine titrated with NaOH; indicate where the pH = p$K$ and the region(s) in which buffering occurs.**

7. **Describe a polypeptide that have only one free amino group and one free carboxyl group?**

8. **Hydrolysis of peptide bonds is an exergonic reaction. Why, then, are peptide bonds quite stable?**

9. **Draw the structure of Gly, Val, Leu.**

10. **For each of these methods of separating proteins, describe the principle of the method, and tell what property of proteins allows their separation by this technique.**
    (a) ion-exchange chromatography
    (b) size-exclusion (gel filtration) chromatography
    (c) affinity chromatography

11. **Define the primary structure of a protein.**

# The Three-Dimensional Structure of Proteins

## Multiple Choice Questions

**All of the following are considered "weak" interactions in proteins, *except:***
A) hydrogen bonds.
B) hydrophobic interactions.
C) ionic bonds.
D) peptide bonds.
E) van der Waals forces.

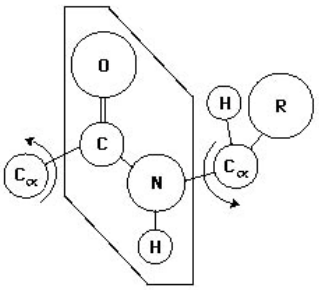
**In an aqueous solution, protein conformation is determined by two major factors. One is the formation of the maximum number of hydrogen bonds. The other is the:**
A) formation of the maximum number of hydrophilic interactions.
B) maximization of ionic interactions.
C) minimization of entropy by the formation of a water solvent shell around the protein.
D) placement of hydrophobic amino acid residues within the interior of the protein.
E) placement of polar amino acid residues around the exterior of the protein.

**Pauling and Corey's studies of the peptide bond showed that:**
A) at pH 7, many different peptide bond conformations are equally probable.
B) peptide bonds are essentially planar, with no rotation about the C—N axis.
C) peptide bonds in proteins are unusual, and unlike those in small model compounds.
D) peptide bond structure is extraordinarily complex.
E) primary structure of all proteins is similar, although the secondary and tertiary structure may differ greatly.

**Which of the following pairs of bonds within a peptide backbone show free rotation around both bonds?**
A) $C_\alpha$—C and N—$C_\alpha$
B) C=O and N—C
C) C=O and N—$C_\alpha$
D) N—C and $C_\alpha$—C
E) N—$C_\alpha$ and N—C

**Roughly how many amino acids are there in one turn of an α helix?**
A) 1
B) 2.8
C) 3.6
D) 4.2
E) 10

**In the diagram below, the plane drawn behind the peptide bond indicates the:**




A) no rotation around the C—N bond because of its partial double-bond character.
B) plane of rotation around the $C_\alpha$—N bond
C) region of steric hindrance determined by the large C=O group.
D) region of the peptide bond that contributes to a Ramachandran plot.
E) theoretical space between –180 and +180 degrees that can be occupied by the Φ and ψ angles in the peptide bond.

**Which of the following best represents the backbone arrangement of two peptide bonds?**
A) $C_\alpha$—N—$C_\alpha$—C—$C_\alpha$—N—$C_\alpha$—C
B) $C_\alpha$—N—C—C—N—$C_\alpha$
C) C—N—$C_\alpha$—$C_\alpha$—C—N
D) $C_\alpha$—C—N—$C_\alpha$—C—N
E) $C_\alpha$—$C_\alpha$—C—N—$C_\alpha$—$C_\alpha$—C

**In the ᾳ helix the hydrogen bonds:**
A) are roughly parallel to the axis of the helix.
B) are roughly perpendicular to the axis of the helix.
C) occur mainly between electronegative atoms of the R groups.
D) occur only between some of the amino acids of the helix.
E) occur only near the amino and carboxyl termini of the helix.

**In an α helix, the R groups on the amino acid residues:**
A) alternate between the outside and the inside of the helix.
B) are found on the outside of the helix spiral.
C) cause only right-handed helices to form.
D) generate the hydrogen bonds that form the helix.
E) stack within the interior of the helix.

**A D-amino acid would interrupt an α helix made of L-amino acids. Another naturally occurring hindrance to the formation of an α helix is the presence of:**
A) a negatively charged Arg residue.
B) a nonpolar residue near the carboxyl terminus.
C) a positively charged Lys residue.
D) a Pro residue.
E) two Ala residues side by side.

**The major reason that antiparallel β-stranded protein structures are more stable than parallel β-stranded structures is that the parallel:**
A) are in a slightly less extended configuration than antiparallel strands.
B) do not have as many disulfide crosslinks between adjacent strands.
C) do not stack in sheets as well as antiparallel strands.
D) have fewer lateral hydrogen bonds than antiparallel strands.
E) have weaker hydrogen bonds laterally between adjacent strands.

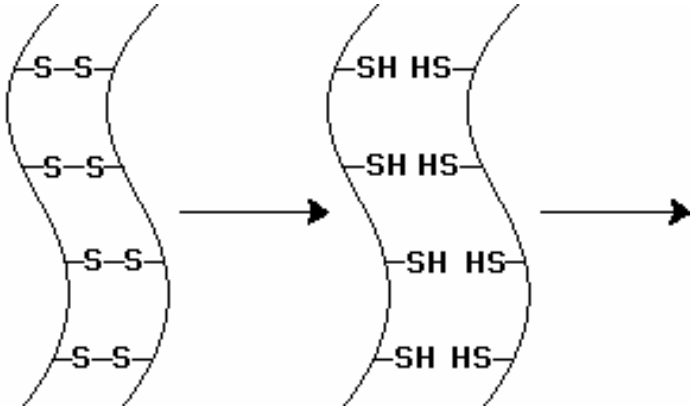
**Amino acid residues commonly found in the middle of β turn are:**
A) Ala and Gly.
B) hydrophobic.
C) Pro and Gly.
D) those with ionized R-groups.
E) two Cys.

**A sequence of amino acids in a certain protein is found to be -Ser-Gly-Pro-Gly- The sequence is most probably part of a(n):**
A) antiparallel β sheet.
B) parallel β sheet.
C) α helix.
D) β sheet.
E) β turn.

**The three-dimensional conformation of a protein may be strongly influenced by amino acid residues that are very far apart in sequence. This relationship is in contrast to secondary structure, where the amino acid residues are:**
A) always side by side.
B) generally near each other in sequence.
C) invariably restricted to about 7 of the 20 standard amino acids.
D) often on different polypeptide strands.
E) usually near the polypeptide chain's amino terminus or carboxyl terminus.

**Determining the precise arrangement of atoms within a large protein is possible only through the use of:**
A) electron microscopy.
B) light microscopy.
C) molecular model building.
D) Ramachandran plots.
E) x-ray diffraction.

**The α -keratin chains indicated by the diagram below have undergone one chemical step. To alter the shape of the α -keratin chains—as in hair waving—what subsequent steps are required?**




A) Chemical oxidation and then shape remodeling
B) Chemical reduction and then chemical oxidation
C) Chemical reduction and then shape remodeling
D) Shape remodeling and then chemical oxidation
E) Shape remodeling and then chemical reduction

**Which of the following statements is *false*?**

A) Collagen is a protein in which the polypeptides are mainly in the α -helix conformation.
B) Disulfide linkages are important for keratin structure.
C) Gly residues are particularly abundant in collagen.
D) Silk fibroin is a protein in which the polypeptide is almost entirely in the β conformation.
E) α -keratin is a protein in which the polypeptides are mainly in the α -helix conformation.

**Proteins often have regions that show specific, patterns of folding. These regions are called:**

A) motifs.
B) oligomers.
C) peptides.
D) sites.
E) subunits.

**The structural classification of proteins (based on motifs) is based primarily on their:**
A) amino acid sequence.
B) evolutionary relationships.
C) function.
D) secondary structure content and arrangement.
E) subunit content and arrangement.

**Proteins are classified within families or superfamilies based on similarities in:**
A) evolutionary origin.
B) chemical properties.
C) structure and/or function.
D) subcellular location.
E) subunit structure.

**Which of the following statements about oligomeric proteins is *false*?**
A) A subunit may be similar to other proteins.
B) All subunits must be identical.
C) May have regulatory roles.
D) Some oligomeric proteins can further associate into large fibers.
E) Some subunits may have nonprotein prosthetic groups.

**An average protein will *not* be denatured by:**
A) a detergent such as sodium dodecyl sulfate.
B) heating to 90°C.
C) iodoacetic acid.
D) pH 11.
E) urea.

**Which of the following is known to be involved in the process of *assisted* folding of proteins?**
A) Chaperonins
B) Molecular crowding
C) Heat dissipation
D) Peptide bond hydrolysis
E) Peptide bond formation

**Protein S will fold into its native conformation only when protein Q is also present in the solution. However, protein Q can fold into its native conformation without protein S. Protein Q, therefore, may function as a _____ for protein S.**
A) ligand
B) molecular chaperone
C) protein precursor
D) structural motif
E) supersecondary structural unit

**Experiments on denaturation and renaturation after the reduction and reoxidation of the —S—S— bonds in the enzyme ribonuclease (RNase) have shown that:**

A) folding of denatured RNase into the native, active conformation requires the input of energy in the form of heat.
B) native ribonuclease does not have a unique secondary and tertiary structure.
C) the completely unfolded enzyme, with all —S—S— bonds broken, is still enzymatically active.
D) the enzyme, dissolved in water, is thermodynamically stable relative to the mixture of amino acids whose residues are contained in RNase.
E) the primary sequence of RNase is sufficient to determine its specific secondary and tertiary structure.

## Short Answer Questions

1. **Any given protein is characterized by a unique amino acid sequence (primary structure) and three-dimensional (tertiary) structure. How are these related?**

2. **Name four factors (bonds or other forces) that contribute to stabilizing the native structure of a protein.**

3. **Draw the structure of a peptide bond, and explain why there is no rotation around the**
4. **C—N bond.**

5. **Draw (or explain) the hydrogen bonding typically found between two residues in an α-helix.**

6. **Describe number of amino acids and stretch (distance) per one turn in an α-helical polypeptide structure, direction of R side chains and hydrogen bonding.**

7. **Why are glycine and proline often found within a β turn?**

8. **What is typically found in the interior of a water-soluble globular protein?**

9. **How does one determine the three-dimensional structure of a protein and what is the path to it?**

10. **Explain what is meant by motifs in protein structure.**

11. **Draw a βαβ loop.**

12. **Describe the quaternary structure (subunits organization) of hemoglobin.**
13. **How can changes in pH alter the conformation of a protein?**

# Protein Function

## Multiple Choice Questions

**The interactions of ligands with proteins:**
A) are relatively nonspecific.
B) are relatively rare in biological systems.
C) are usually irreversible.
D) are usually transient.
E) usually result in the inactivation of the proteins.

**A prosthetic group of a protein is a non-protein structure that is:**
A) a ligand of the protein.
B) a part of the secondary structure of the protein.
C) a substrate of the protein.
D) permanently associated with the protein.
E) transiently bound to the protein.

**When oxygen binds to a heme-containing protein, the two open coordination bonds of $Fe^{2+}$ are occupied by:**
A) one O atom and one amino acid atom.
B) one $O_2$ molecule and one amino acid atom.
C) one $O_2$ molecule and one heme atom.
D) two O atoms.
E) two $O_2$ molecules.

**In the binding of oxygen to myoglobin, the relationship between the concentration of oxygen and the fraction of binding sites occupied can best be described as:**
A) hyperbolic.
B) linear with a negative slope.
C) linear with a positive slope.
D) random.
E) sigmoidal.

**Myoglobin and the subunits of hemoglobin have:**
A) no obvious structural relationship.
B) very different primary and tertiary structures.
C) very similar primary and tertiary structures.
D) very similar primary structures, but different tertiary structures.
E) very similar tertiary structures, but different primary structures.

**An allosteric interaction between a ligand and a protein is one in which:**

A) binding of a molecule to a binding site affects binding of additional molecules to the same site.
B) binding of a molecule to a binding site affects binding properties of another site on the protein.
C) binding of the ligand to the protein is covalent.
D) multiple molecules of the same ligand can bind to the same binding site.
E) two different ligands can bind to the same binding site.

**In hemoglobin, the transition from T state to R state (low to high affinity) is triggered by:**

A) $Fe^{2+}$ binding.
B) heme binding.
C) oxygen binding.
D) subunit association.
E) subunit dissociation.

**Which of the following is *not* correct concerning cooperative binding of a ligand to a protein?**

A) It is usually a form of allosteric interaction.
B) It is usually associated with proteins with multiple subunits.
C) It rarely occurs in enzymes.
D) It helps to bind another molecules.
E) It results in a sigmoidal binding curve.

**Carbon monoxide (CO) is toxic to humans because:**

A) it binds to myoglobin and causes it to denature.
B) it is rapidly converted to toxic $CO_2$.
C) it binds to the globin portion of hemoglobin and prevents the binding of $O_2$.
D) it binds to the Fe in hemoglobin and prevents the binding of $O_2$.
E) it binds to the heme portion of hemoglobin and causes heme to unbind from hemoglobin.

**The amino acid substitution of Val for Glu in Hemoglobin of Sickle-Cell anemia results in aggregation of the protein because of _____ interactions between molecules.**

A) covalent
B) disulfide
C) hydrogen bonding
D) hydrophobic
E) ionic

**The fundamental cause of sickle cell disease is a change in the structure of:**
A) blood.
B) capillaries.
C) hemoglobin.
D) red cells.
E) the heart.

**Which of the following parts of the IgG molecule are *not* involved in binding to an antigen?**
A) Fab
B) Fc
C) Heavy chain
D) Light chain
E) Variable domain

**Which of the following is *not* true about antibody and antigen:**
A) an antibody specifically reacts with an antigen.
B) antibodies are produced by cells of the same organism that produce the antigen.
C) antigens are foreign molecules to an organism.
D) antibodies are synthesized only in living organisms.
E) antibodies have complex of polypeptide chains that recognize an antigen.

**Which of the following generalizations concerning motor proteins is correct?**
A) They convert chemical energy into kinetic energy.
B) They convert chemical energy into potential energy.
C) They convert kinetic energy into chemical energy.
D) They convert kinetic energy into rotational energy.
E) They convert potential energy into chemical energy.

**The predominant structural feature in myosin molecules is:**
A) a β structure.
B) an α helix.
C) the Fab domain.
D) the light chain.
E) the meromyosin domain.

**In muscle hydrolysis of ATP results in the:**
A) conformation of actin.
B) muscle contraction.
C) structure of the myofibrils.
D) structure of the sarcoplasmic reticulum.
E) structure of the Z disk.

## Short Answer Questions

1. **Describe the concept of "induced fit" in ligand-protein binding.**

2. **Explain why organisms use an iron-containing protein for oxygen binding rather than free $Fe^{2+}$.**

3. **Why is carbon monoxide (CO) toxic to aerobic organisms?**

4. **Explain briefly why the relative affinity of heme for oxygen and carbon monoxide is changed in the myoglobin protein.**

5. **Explain why the structure of myoglobin makes it function well as an oxygen-storage protein whereas the structure of hemoglobin makes it function well as an oxygen-transport protein.**

6. **What is the effect of pH on the binding of oxygen to hemoglobin (the Bohr Effect)?**

7. **Describe (draw) briefly the basic structure of an IgG protein molecule (an antibody).**

8. **What is the chemical basis for the specificity of binding of an immunoglobin antibody to a particular antigen?**

9. **What properties of antibodies make them useful biochemical reagents? Describe one biochemical application of antibodies (with more than just the name of the technique).**

10. **Describe briefly the structure of muscle.**

11. **What is the role of ATP and ATP hydrolysis in the cycle of actin-myosin association and disassociation that leads to muscle contraction?**

# Carbohydrates and Glycobiology

## Multiple Choice Questions

**To possess optical activity, a compound must be:**
A) a carbohydrate.
B) a hexose.
C) asymmetric.
D) colored.
E) D-glucose.

**Which of the following monosaccharides is *not* an aldose?**
A) erythrose
B) fructose
C) glucose
D) glyceraldehyde
E) ribose

**The reference compound for naming D and L isomers of sugars is:**
A) fructose.
B) glucose.
C) glyceraldehyde.
D) ribose.
E) sucrose.

**When two carbohydrates are epimers:**
A) one is a pyranose, the other a furanose.
B) one is an aldose, the other a ketose.
C) they differ in length by one carbon.
D) they differ only in the configuration around one carbon atom.
E) they rotate plane-polarized light in the same direction.

**Which of the following is an epimeric pair?**
A) D-glucose and D-glucosamine
B) D-glucose and D-mannose
C) D-glucose and L-glucose
D) D-lactose and D-sucrose
E) L-mannose and L-fructose

**Which of following is an anomeric pair?**
A) D-glucose and D-fructose
B) D-glucose and L-fructose
C) D-glucose and L-glucose
D) α-D-glucose and β-D-glucose
E) α -D-glucose and β-L-glucose

**When the linear form of glucose cyclizes, the product is a(n):**
A) anhydride.
B) glycoside.
C) hemiacetal.
D) lactone.
E) oligosaccharide.

**Which of the following pairs is interconverted in the process of mutarotation?**
A) D-glucose and D-fructose
B) D-glucose and D-galactose
C) D-glucose and D-glucosamine
D) D-glucose and L-glucose
E) α -D-glucose and β -D-glucose

**Which of the following is *not* a reducing sugar?**
A) Galactose
B) Glucose
C) Glyceraldehyde
D) Ribose
E) Sucrose

**Which of the following monosaccharides is *not* a carboxylic acid?**
A) 6-phospho-gluconate
B) gluconate
C) glucose
D) glucuronate
E) muramic acid

**D-Glucose is called a reducing sugar because it undergoes an oxidation-reduction reaction at the anomeric carbon. One of the products of this reaction is:**
A) D-galactose.
B) D-gluconate.
C) D-glucuronate.
D) D-ribose.
E) muramic acid.

**From the abbreviated name of the compound Gal(β1 → 4)Glc, we know that:**
A) C-4 of glucose is joined to C-1 of galactose by a glycosidic bond.
B) the compound is a D-enantiomer.
C) the galactose residue is at the reducing end.
D) the glucose is in its pyranose form.
E) the glucose residue is the β anomer.

**Starch and glycogen are both polymers of:**
A) fructose.
B) glucose1-phosphate.
C) sucrose.
D) α-D-glucose.
E) β -D-glucose.

**Which of the following statements about starch and glycogen is *false*?**
A) Amylose is unbranched; amylopectin and glycogen contain many (α1 → 6) branches.
B) Both are homopolymers of glucose.
C) Both serve primarily as structural elements in cell walls.
D) Both starch and glycogen are stored intracellularly as insoluble granules.
E) Glycogen is more extensively branched than starch.

**Which of the following is a heteropolysaccharide?**
A) Cellulose
B) Chitin
C) Glycogen
D) Hyaluronate
E) Starch

**The basic structure of a proteoglycan consists of a core protein and a:**
A) glycolipid.
B) glycosaminoglycan.
C) lectin.
D) lipopolysaccharide.
E) peptidoglycan.

**In glycoproteins, the carbohydrate moiety is usually attached through the amino acid residues:**
A) asparagine or serine.
B) aspartate or glutamate.
C) glutamine or arginine.
D) glycine or alanine.
E) tryptophan or aspartate.

**Which of the following is a dominant feature of the outer membrane of the cell wall of gram-negative bacteria?**

A) Amylose
B) Cellulose
C) Glycoproteins
D) Lipopolysaccharides
E) Lipoproteins

**The biochemical property of lectins that is the basis for most of their biological effects is their ability to bind to:**

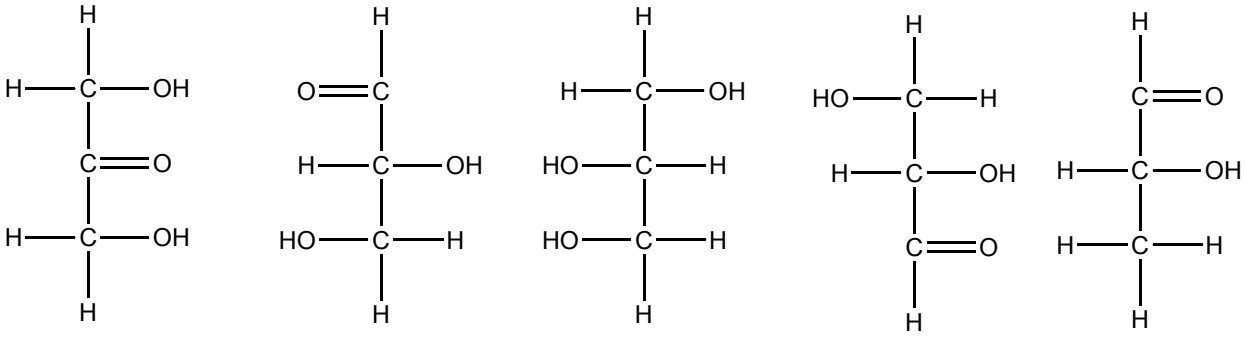
A) amphipathic molecules.
B) hydrophobic molecules.
C) specific lipids.
D) specific oligosaccharides.
E) specific peptides.

## Short Answer Questions

1. **Explain why all mono- and disaccharides are soluble in water.**

2. **Draw a formula of D-glucose, both in Fischer and Haworth projection.**

3. **Categorize each of the following compounds as an aldose, a ketose, or neither.**



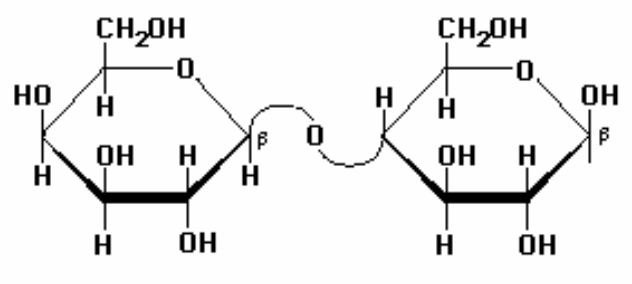
(a) (b) (c) (d) (e)

4. **Define in 20 words or fewer what is:**

   (a) anomeric carbon
   (b) glycoside
   (c) epimers

5. **Draw the structure of any aldohexose in the pyranose ring form. Point to the anomeric carbon. Give the full name of the compound**

6. **Name the following structure:**




(a) How many of the monosaccharide units are furanoses and how many are pyranoses?
(b) What is the linkage between the two monosaccharide units?
(c) Is this a reducing sugar? Explain.

7. **Match these molecules with their biological roles.**

| | | |
|---|---|---|
| (a) | glycogen | __ viscosity, lubrication of extracellular secretions |
| (b) | starch | __ carbohydrate storage in plants |
| (c) | chitin | __ exoskeleton of insects |
| (d) | cellulose | __ extracellular matrix of animal tissues |
| (e) | hyaluronate | __ structural component of plant cell walls |
| (f) | proteoglycan | __ carbohydrate storage in animal liver |

8. **The number of structurally different polysaccharides that can be made with 20 different monosaccharides is far greater than the number of different polypeptides that can be made with 20 different amino acids, if both polymers contain an equal number (say, 100) of total residues. Explain why.**

9. **Describe one biological advantage of storing glucose units in *branched* polymers (glycogen, amylopectin) rather than in linear polymers.**

10. **Explain how it is possible that a polysaccharide molecule, such as glycogen, may have only one reducing end, and yet have many nonreducing ends.**

11. **Draw the structure of the repeating basic unit of (a) amylose and (b) cellulose. (No formulas needed, abbreviations are enough.)**

12. **Explain in molecular terms why humans cannot use cellulose as a nutrient, but goats and cattle can.**

13. **The glycosaminoglycans are negatively charged at neutral pH. What components of these polymers confer the negative charge?**

14. **Describe the differences between a proteoglycan and a glycoprotein.**

15. **What are lectins? What are some biological processes that involve lectins?**

# Lipids

## Multiple Choice Questions

**Which of the following statements concerning fatty acids is correct?**
A) One is the precursor of prostaglandins.
B) Phosphatidic acid is a common one.
C) They all contain one or more double bonds.
D) They are a constituent of sterols.
E) They are strongly hydrophilic.

**Which of the following molecules or substances contain, or are derived from, fatty acids?**
A) Beeswax
B) Prostaglandins
C) Sphingolipids
D) Triacylglycerols
E) All of the above contain or are derived from fatty acids.

**Biological waxes are all:**
A) trimesters of glycerol and palmitic acid.
B) esters of single fatty acids with long-chain alcohols.
C) trimesters of glycerol and three long-chain saturated fatty acids.
D) sphingolipids.
E) none of the above.

**Which of the following statements is true of lipids?**
A) Many contain fatty acids in ester or amide linkage.
B) Some are polymers of isoprene.
C) Testosterone is an important sphingolipid found in myelin.
D) They are more soluble in water than in chloroform.
E) They are not energy-storage molecules.

**Fatty acids are a component of:**
A) carotenes.
B) oils.
C) sterols.
D) vitamin B.
E) vitamin K.

**Which of the following statements about sterols is true?**
A) All sterols share a fused-ring structure with four rings.
B) Sterols are found in the membranes of all living cells.
C) Sterols are soluble in water, but less so in organic solvents such as chloroform.
D) Cholesterol is the principal sterol in fungi.
E) The principal sterol of animal cells is ergosterol.

**Which of the following is *not* true of sterols?**
A) Cholesterol is a sterol that is commonly found in mammals.
B) They are commonly found in bacterial membranes.
C) They are more common in plasma membranes than in intracellular membranes (mitochondria, lysosomes, etc.).
D) They are precursors of steroid hormones.
E) They have a structure that includes four fused rings.

**An example of a glycolipid is:**
A) arachidonic acid.
B) ceramide.
C) phosphatidylinositol.
D) testosterone.
E) vitamin A (retinol).

**Function of lipids is *not* a:**
A) structural role.
B) storage.
C) signaling.
D) protection.
E) transporting.

**Which of the following is *not* a fat-soluble vitamin?**
A) A
B) C
C) D
D) E
E) K

**Which of the following statements about fatty acids is *not* true?**
A) Most are unbranched
B) the unsaturated are in *cis* form
C) they have usually odd number of carbons
D) they can be even polysaturated
E) they are compounds of fat

**Identify the molecule(s) derived from sterols.**

A) Arachidonic acid
B) MGDG
C) Phosphatidylglycerol
D) Prostaglandins
E) Testosteron

## Short Answer Questions

1. **Circle the fatty acid in each of pairs (a, b and c) that has higher melting temperature.**

   (a) $18:1^{\Delta 9}$ $18:2^{\Delta 9,12}$

   (b) 18:0 $18:1^{\Delta 9}$

   (c) 18:0 16:0

2. **Describe the dependence of the melting point of a fatty acid upon (a) chain length and (b) unsaturation; (c) explain these dependencies in molecular terms.**

3. **What is the effect of a double bond on fatty acid structure?**

4. **In cells, fatty acids are stored as triacylglycerols for energy reserves. (a) What is the molecule to which fatty acids are esterified to form triacylglycerols?**

5. **What is the most significant chemical difference between triacylglycerols and glycerophospholipids that leads to their different functions?**

6. **Describe two functions of triacylglycerols in mammals.**

7. **What are the chemical components of a biological wax, and what is their general structure?**

8. **Give the structure of phosphatidylethanolamine containing one palmitate and one oleate (fatty acids can be abbreviated with number of carbons and double bonds). How many ester bonds are there in this compound?**

9. **Draw the structure of phosphatidylserin. Circle the part of the molecule that is polar and draw an arrow to the part that is nonpolar.**

10. **Show schematically the basic structure of all glycerophospholipids.**

**11. Match the compounds on the left with the important roles they play listed on the right. (Answers are used only once.)**

| | | | |
|---|---|---|---|
| (a) | prostaglandins | ___ | blood clotting |
| (b) | sphingolipids | ___ | necessary for sight |
| (c) | thromboxanes | ___ | mediates pain and inflammation |
| (d) | vitamin A | ___ | important component of myelin membranes |

**12. Match each of these vitamins with its biological role: vitamins A, D, E, K.**

____ blood clotting
____ vision
____ $Ca^{2+}$ and phosphate metabolism
____ prevention of oxidative damage

**13. Show the structure of isoprene; explain what is meant by isoprenoid compounds and give an example.**

**14. Explain why extraction of lipids from tissues requires organic solvents.**

# Biological Membranes and Transport

## Multiple Choice Questions

**Which one of the following statements about membranes is true?**
A) Most plasma membranes contain more than 80% proteins.
B) Sterol lipids are common in bacterial plasma membranes.
C) Sterol lipids are common in human cell plasma membranes.
D) Sterol lipids are common in plant cell plasma membranes.
E) The plasma membranes of all cell types within a particular organism have basically the same lipid and protein composition.

**Which of these statements about the composition of biological membranes is false?**
A) In a given eukaryotic cell type (for example, a hepatocyte), all intracellular membranes have essentially the same complement of lipids and proteins.
B) The carbohydrate found in membranes is virtually all part of either glycolipids or glycoproteins.
C) The plasma membranes of the cells of vertebrate animals contain more cholesterol than the mitochondrial membranes.
D) The ratio of lipid to protein varies widely among cell types in a single organism.
E) Triacylglycerols are not commonly found in membranes.

**Which of these statements about the composition of membranes is true?**
A) All biological membranes contain cholesterol.
B) Free fatty acids are major components of all membranes.
C) The inner and outer membranes of mitochondria have different protein compositions.
D) The lipid composition of all membranes of eukaryotic cells is the same.
E) The lipid:protein ratio varies from about 1:4 to 4:1.

**Membrane proteins:**
A) are sometimes covalently attached to lipid moieties.
B) are sometimes covalently attached to carbohydrate moieties.
C) are composed of the same 20 amino acids found in soluble proteins.
D) diffuse laterally in the membrane unless they are anchored.
E) have all of the properties listed above.

**Peripheral membrane proteins:**
A) are generally noncovalently bound to membrane lipids.
B) are usually denatured when released from membranes.
C) can be released from membranes only by treatment with detergent(s).
D) may have functional units on both sides of the membrane.
E) penetrate deeply into the lipid bilayer.

**An integral membrane protein can be extracted with:**
A) a buffer of alkaline or acid pH.
B) a chelating agent that removes divalent cations.
C) a solution containing detergent.
D) a solution of high ionic strength.
E) hot water.

**The shortest α helix segment in a protein that will span a membrane bilayer has about _____ amino acid residues.**
A) 5
B) 20
C) 50
D) 100
E) 200

**A hydropathy plot is used to:**
A) determine the water-solubility of a protein.
B) deduce the quaternary structure of a membrane protein.
C) determine the water content of a native protein.
D) extrapolate for the true molecular weight of a membrane protein.
E) predict whether a given protein sequence contains membrane-spanning segments.

**Which of these statements is generally true of integral membrane proteins?**
A) A hydropathy plot reveals one or more regions with a high hydropathy index.
B) The domains that protrude on the cytoplasmic face of the plasma membrane nearly always have covalently attached oligosaccharides.
C) They are unusually susceptible to degradation by trypsin.
D) They can be removed from the membrane with high salt or mild denaturing agents.
E) They undergo constant rotational motion that moves a given domain from the outer face of a membrane to the inner face and then back to the outer.

**Which of these is a general feature of the lipid bilayer in all biological membranes?**
A) Individual lipid molecules are free to diffuse laterally in the surface of the bilayer.
B) Individual lipid molecules in one face (monolayer) of the bilayer readily diffuse (flip-flop) to the other monolayer.
C) Polar, but uncharged, compounds readily diffuse across the bilayer.
D) The bilayer is stabilized by covalent bonds between neighboring phospholipid molecules.
E) The polar head groups face inward toward the inside of the bilayer.

**The type of motion *least* common in biological membranes is:**
A) flip-flop diffusion of phospholipid from one monolayer to the other.
B) lateral diffusion of individual lipid molecules within the plane of each monolayer.
C) lateral diffusion of membrane proteins in the bilayer.
D) lateral diffusion of protein molecules in the lipid bilayer
E) random motion of the fatty acyl side chains in the interior of the phospholipid bilayer.

**The fluidity of the lipid side chains in the interior of a bilayer is generally increased by:**
A) a decrease in temperature.
B) an increase in fatty acyl chain length.
C) an increase in the number of double bonds in fatty acids.
D) an increase in the percentage of phosphatidyl ethanolamine.
E) the binding of water to the fatty acyl side chains.

**The fluidity of a lipid bilayer will be increased by:**
A) decreasing the number of unsaturated fatty acids.
B) decreasing the temperature.
C) increasing the length of the alkyl chains.
D) increasing the temperature.
E) substituting 18:0 (stearic acid) in place of 18:2 (linoleic acid).

**When a bacterium such as *E. coli* is shifted from a warmer growth temperature to a cooler growth temperature, it compensates by:**
A) increasing its metabolic rate to generate more heat.
B) putting longer-chain fatty acids into its membranes.
C) putting more unsaturated fatty acids into its membranes.
D) shifting from aerobic to anaerobic metabolism.
E) synthesizing thicker membranes to insulate the cell.

**Membrane fusion leading to neurotransmitter release requires the action of:**
A) cadherins.
B) carbohydrates.
C) flipases.
D) proteins.
E) none of the above.

**A process *not* involving the fusion of two membranes or two regions of the same membrane is:**
A) endocytosis.
B) entry of enveloped viruses into cells.
C) entry of glucose into cells.
D) exocytosis.
E) vacuole growing.

**Which of these statements about facilitated diffusion across a membrane is true?**
A) A specific membrane protein lowers the activation energy for movement of the solute through the membrane.
B) It can increase the size of a transmembrane concentration gradient of the diffusing solute.
C) The transported solute is dissolved in the nonpolar interior of the lipid bilayer.
D) It is responsible for the transport of gases such as $O_2$, $N_2$, and $CH_4$ across biological membranes.
E) The rate is unlimited.

**Facilitated diffusion through a biological membrane is:**
A) driven by a difference of solute concentration.
B) driven by ATP.
C) endergonic.
D) always irreversible.
E) not specific with respect to the substrate.

**Glucose transport into erythrocytes by GLUT1 is an example of:**
A) active transport.
B) antiport.
C) electrogenic uniport
D) facilitated diffusion.
E) symport.

**The type of membrane transport that uses ion gradients as the energy source is:**
A) facilitated diffusion.
B) passive transport.
C) primary active transport.
D) secondary active transport.
E) simple diffusion.

**In one catalytic cycle, the $Na^+/K^+$ ATPase transporter transports:**
A) 2 $Na^+$ out, 3 $K^+$ in, and converts 1 ATP to ADP + $P_i$.
B) 3 $Na^+$ out, 2 $K^+$ in, and converts 1 ATP to ADP + $P_i$.
C) 3 $Na^+$ in, 2 $K^+$ out, and converts 1 ATP to ADP + $P_i$.
D) 1 $Na^+$ out, 1 $K^+$ in, and converts 1 ATP to ADP + $P_i$.
E) 2 $Na^+$ out, 3 $K^+$ in, and converts 1 ADP + $P_i$ to ATP.

**Movement of water across membranes is facilitated by proteins called:**
A) annexins.
B) aquaporins.
C) hydropermeases.
D) selectins.
E) transportins.

## Short Answer Questions

**Draw the structure of a biological membrane as proposed by the fluid mosaic model. Indicate the positions and orientations of phospholipids, cholesterol, integral and peripheral membrane proteins, and the carbohydrate moieties of glycoproteins and glycolipids.**

**What is an amphipathic compound? Explain how such compounds contribute to the structure of biological membranes.**

**(a) Define the term *amphipathic*. (b) Diagram two types of assemblies that amphipathic molecules form in water. (c) What are the forces that contribute to the formation of the structures diagrammed in (b)?**

**(a) Explain why phosphoglycerides are capable of spontaneously assembling into the bilayer structure found in biological membranes but triacylglycerols are not. (b) What are the forces that drive bilayer formation?**

**Explain the differences between integral and peripheral membrane proteins.**

**(a) What kinds of forces or bonds anchor an integral membrane protein in a biological membrane? (b) What forces hold a peripheral membrane protein to the membrane?**

**A protein is found to extend all the way through the membrane of a cell. Describe this protein in terms of the location of particular types of amino acid side chains in its structure and its ability to move within the membrane.**

**Draw a hydropathy plot for a hypothetical integral membrane protein with 3 transmembrane segments and containing 190 amino acids. Be sure to label the x-axe appropriately, including numerical values.**

**The bacterium *E. coli* can grow at 20°C or at 40°C. At which growth temperature would you expect the membrane phospholipids to have a higher ratio of saturated to unsaturated fatty acids, and why?**

**What is meant by the transition temperature of a membrane? List the two characteristics of the fatty acids in a biological membrane that affect the transition temperature.**

**What are the membrane rafts?**

**Distinguish between facilitated diffusion (FD), and active transport (AT) across a membrane for the following questions (more than one may be true):**

(a) Which processes are energy dependent?
(b) Which processes need some kind of carrier protein(s)?
(c) Which processes can be saturated by substrate?
(d) Which processes can establish a concentration gradient?

**Explain why nonpolar compounds are generally able to diffuse across biological membranes without the aid of a specific transport system.**

**Compare and contrast symport and antiport. Which term best describes the transport system mediated by the $Na^+K^+$ ATPase?**

# Enzymes

## Multiple Choice Questions

**One of the enzymes involved in glycolysis, aldolase, requires $Zn^{2+}$ for catalysis. Under conditions of zinc deficiency, when the enzyme lack the zinc, it would be referred to as the:**

A) apoenzyme.
B) coenzyme.
C) holoenzyme.
D) prosthetic group.
E) substrate.

**Which one of the following is not among the six internationally accepted classes of enzymes?**

A) Hydrolases
B) Ligases
C) Oxidoreductases
D) Polymerases
E) Transferases

**Enzymes are potent catalysts because they:**

A) are consumed in the reactions they catalyze.
B) are very specific and can prevent the conversion of products back to substrates.
C) drive reactions to completion while other catalysts drive reactions to equilibrium.
D) increase the equilibrium constants for the reactions they catalyze.
E) lower the activation energy for the reactions they catalyze.

**The role of an enzyme in an enzyme-catalyzed reaction is to:**

A) bind a transition state intermediate, such that it cannot be converted back to substrate.
B) ensure that all of the substrate is converted to product.
C) ensure that the product is more stable than the substrate.
D) increase the rate at which substrate is converted into product.
E) make the free-energy change for the reaction more favorable.

**Which one of the following statements is true of enzyme catalysts?**

A) Their catalytic activity is independent of pH.
B) They are generally equally active on D and L isomers of a given substrate.
C) They can increase the equilibrium constant by a thousand-fold or more.
D) They can increase the reaction rate for a given reaction by a thousand-fold or more.
E) To be effective, they must be present at the same concentration as their substrate.

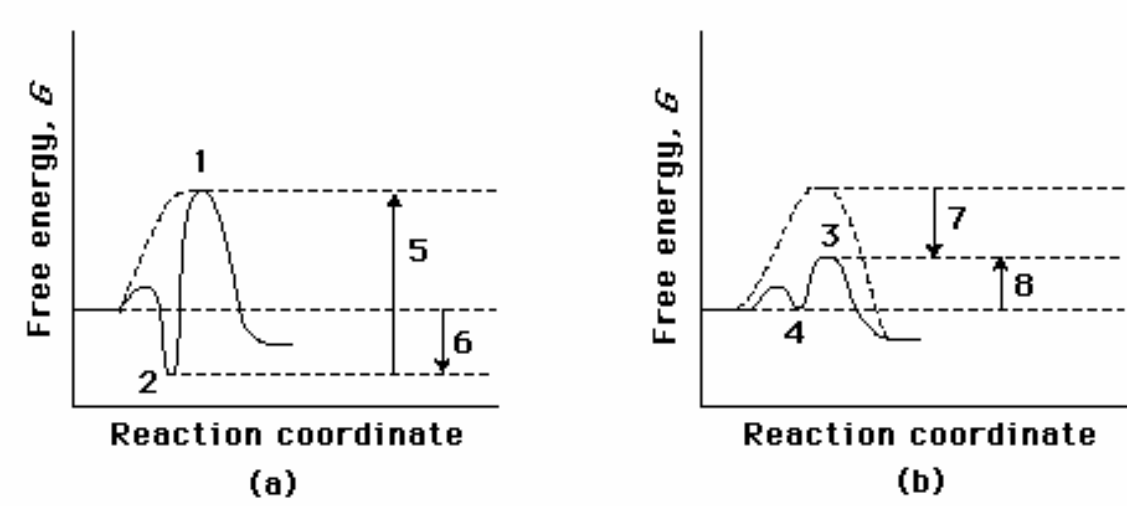
**Which one of the following statements is true of enzyme catalysts?**

A) They bind to substrates, but are never covalently attached to substrate or product.
B) They increase the equilibrium constant for a reaction, thus favoring product formation.
C) They increase the stability of the product of a desired reaction by allowing ionizations, resonance, and isomerizations not normally available to substrates.
D) They lower the activation energy for the conversion of substrate to product.
E) To be effective they must be present at the same concentration as their substrates.

**Which of the following statements is *false*?**

A) A reaction may not occur at a detectable rate even though it has a favorable equilibrium.
B) After a reaction, the enzyme involved becomes available to catalyze the reaction again.
C) For S → P, a catalyst shifts the reaction equilibrium to the right.
D) Lowering the temperature of a reaction will lower the reaction rate.
E) Substrate binds to an enzyme's active site.

**Compare the two reaction coordinate diagrams below and select the answer that correctly describes their relationship. In each case, the single intermediate is the ES complex.**

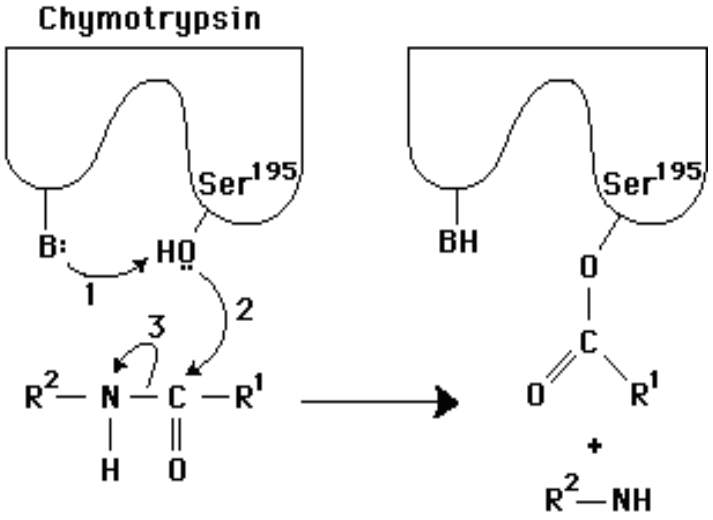



A) (a) describes a strict "lock and key" model, whereas (b) describes a transition-state complementarity model.
B) The activation energy for the *catalyzed* reaction is #5 in (a) and is #7 in (b).
C) The activation energy for the *uncatalyzed* reaction is given by #5 + #6 in (a) and by #7 + #4 in (b).
D) The contribution of binding energy is given by #5 in (a) and by #7 in (b).
E) The ES complex is given by #2 in (a) and #3 in (b).

**The concept of "induced fit" refers to the fact that:**

A) enzyme specificity is induced by enzyme-substrate binding.
B) enzyme-substrate binding induces an increase in the reaction entropy, thereby catalyzing the reaction.
C) enzyme-substrate binding induces movement along the reaction coordinate to the transition state.
D) substrate binding may induce a conformational change in the enzyme, which then brings catalytic groups into proper orientation.
E) when a substrate binds to an enzyme, the enzyme induces a loss of water (desolvation) from the substrate.

**In the following diagram of the first step in the reaction catalyzed by the protease chymotrypsin, the process of general base catalysis is illustrated by the number _____, and the process of covalent catalysis is illustrated by the number _____.**




A) 1; 2
B) 1; 3
C) 2; 3
D) 3; 2
E) none

**The benefit of measuring the *initial* rate of a reaction $V_0$ is that at the beginning of a reaction:**

A) [ES] can be measured accurately.
B) changes in [S] are negligible, so [S] can be treated as a constant.
C) changes in $K_m$ are negligible, so $K_m$ can be treated as a constant.
D) $V_0 = V_{max}$.
E) varying [S] has no effect on $V_0$.

**Which of the following statements about a plot of $V_0$ vs. [S] for an enzyme that follows Michaelis-Menten kinetics is *false*?**

A) As [S] increases, the initial velocity of reaction $V_0$ also increases.
B) At very high [S], the velocity curve becomes a horizontal line that intersects the y-axis at $K_m$.
C) $K_m$ is the [S] at which $V_0 = 1/2\ V_{max}$.
D) The shape of the curve is a hyperbola.
E) The y-axis is a rate term with units of □m/min.

**Michaelis and Menten assumed that the overall reaction for an enzyme-catalyzed reaction could be written as**

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_2} E + P$$

**Using this reaction, the rate of breakdown of the enzyme-substrate complex can be described by the expression:**

A) $k_1$ ([$E_t$] [ES]).
B) $k_1$ ([$E_t$] [ES])[S].
C) $k_2$ [ES].
D) $k_{-1}$ [ES] + $k_2$ [ES].
E) $k_{-1}$ [ES].

**The steady state assumption, as applied to enzyme kinetics, implies:**

A) $K_m = K_s$.
B) the enzyme is regulated.
C) the ES complex is formed and broken down at equivalent rates.
D) the $K_m$ is equivalent to the cellular substrate concentration.
E) the maximum velocity occurs when the enzyme is saturated.

**Which of these statements about enzyme-catalyzed reactions is *false*?**

A) At saturating levels of substrate, the rate of an enzyme-catalyzed reaction is proportional to the enzyme concentration.
B) If enough substrate is added, the normal $V_{max}$ of a reaction can be attained even in the presence of a competitive inhibitor.
C) The rate of a reaction decreases steadily with time as substrate is depleted.
D) The activation energy for the catalyzed reaction is the same as for the uncatalyzed reaction, but the equilibrium constant is more favorable in the enzyme-catalyzed reaction.
E) The Michaelis-Menten constant $K_m$ equals the [S] at which $V = 1/2\ V_{max}$.

**The following data were obtained in a study of an enzyme known to follow Michaelis-Menten kinetics:**

| $V_0$ (μmol/min) | Substrate added (mmol/L) |
|---|---|
| 217 | 0.8 |
| 325 | 2 |
| 433 | 4 |
| 488 | 6 |
| 647 | 1000 |

**The $K_m$ for this enzyme is approximately:**
A) 1 mM.
B) 1000 mM.
C) 2 mM.
D) 4 mM.
E) 6 mM.

**The number of substrate molecules converted to product in a given unit of time by a single enzyme molecule at saturation is referred to as the:**
A) dissociation constant.
B) half-saturation constant.
C) minimum velocity.
D) Michaelis-Menten number.
E) turnover number.

**In competitive inhibition, an inhibitor:**
A) binds at several different sites on an enzyme.
B) binds covalently to the enzyme.
C) binds *only* to the ES complex.
D) binds reversibly at the active site.
E) lowers the characteristic $V_{max}$ of the enzyme.

**$V_{max}$ for an enzyme-catalyzed reaction:**
A) generally increases when pH increases.
B) increases in the presence of a competitive inhibitor.
C) is limited only by the amount of substrate supplied.
D) is twice the rate observed when the concentration of substrate is equal to the $K_m$.
E) is unchanged in the presence of an uncompetitive inhibitor.

**A good transition-state analog:**
A) binds covalently to the enzyme.
B) binds to the enzyme more tightly than the substrate.
C) binds very weakly to the enzyme.
D) is too unstable to isolate.
E) must be almost identical to the substrate.

**Enzyme X exhibits maximum activity at pH = 6.9. X shows a fairly sharp decrease in its activity when the pH goes much lower than 6.4. One likely interpretation of this pH activity is that:**

A) a Leu residue on the enzyme is involved in the reaction.
B) a His residue on the enzyme is involved in the reaction.
C) the enzyme has a metallic cofactor.
D) the enzyme is found in gastric secretions.
E) the reaction relies on covalent catalysis.

**Phenyl-methane-sulfonyl-fluoride (PMSF) inactivates serine proteases by binding covalently to the catalytic serine residue at the active site; this enzyme-inhibitor bond is not cleaved by the enzyme itself. This is an example of what kind of inhibition?**

A) irreversible
B) reversible
C) uncompetitive
D) mixed
E) pH

**A transition-state analog:**

A) is less stable when binding to an enzyme than the normal substrate.
B) resembles the active site of general acid-base enzymes.
C) resembles the transition-state structure of the normal enzyme-substrate complex.
D) stabilizes the transition state for the normal enzyme-substrate complex.
E) always reacts more rapidly with an enzyme than the normal substrate.

**Alloteric enzymes:**

A) are regulated primarily by covalent modification.
B) usually catalyze protein degradation.
C) usually have more than one polypeptide chain.
D) usually have only one active site.
E) usually show strict Michaelis-Menten kinetics.

## Short Answer Questions

1. **Define the terms "cofactor" and "coenzyme."**

2. **Draw and label a reaction coordinate diagram for an uncatalyzed reaction, S → P, and the same reaction catalyzed by an enzyme, E.**

3. **Sometimes the difference in (standard) free-energy content, $\Delta G^{\circ}$, between a substrate S and a product P is very large, yet the rate of chemical conversion, S → P, is quite slow. Why?**

4. **Write an equilibrium expression for the reaction S → P and the relationship between the value of the equilibrium constant and free energy.**

5. **Two different enzymes are able to catalyze the same reaction, A → B. They both have the same $V_{max}$, but differ in their $K_m$ the substrate A. For enzyme 1, the $K_m$ is 1.0 mM; for enzyme 2, the $K_m$ is 10 mM. Which enzyme gives initial higher rate of reaction with the same substrate concentration?**

6. **Write out the equation that describes the mechanism for enzyme action used as a model by Michaelis and Menten.**

7. **For the reaction E + S → ES → P, the Michaelis-Menten constant, $K_m$, is actually a summary of three terms. What are they? How is $K_m$ determined graphically?**

8. **Give the Michaelis-Menten equation and define each term in it.**

9. **A biochemist obtains the following set of data for an enzyme that is known to follow Michaelis-Menten kinetics.**

| Substrate concentration (μM) | Initial velocity (μmol/min) |
|---|---|
| 1 | 49 |
| 2 | 96 |
| 8 | 349 |
| 50 | 621 |
| 100 | 676 |
| 1,000 | 698 |
| 5,000 | 699 |

(a) $V_{max}$ for the enzyme is approximately _____.
(b) $K_m$ for the enzyme is _____. Explain in how you determined $K_m$.

**10. An enzyme catalyzes the reaction A → B. The initial rate of the reaction was measured as a function of the concentration of A. The following data were obtained:**

| [A], micromolar | $V_0$, nmoles/min |
|---|---|
| 0.05 | 0.08 |
| 0.1 | 0.16 |
| 0.5 | 0.79 |
| 1 | 1.6 |
| 5 | 7.3 |
| 10 | 13 |
| 50 | 40 |
| 100 | 53 |
| 500 | 73 |
| 1,000 | 76 |
| 5,000 | 79 |
| 10,000 | 80 |
| 20,000 | 80 |

**(a) What is the $K_m$ of the enzyme for the substrate A?**
**(b) What is the value of $V_{max}$**

**11. Methanol (wood alcohol) is highly toxic because it is converted to formaldehyde in a reaction catalyzed by the enzyme alcohol dehydrogenase:**

$$NAD^+ + \text{methanol} \rightarrow NADH + H^+ + \text{formaldehyde}$$

**12. Part of the medical treatment for methanol poisoning is to administer ethanol (ethyl alcohol) in amounts large enough to cause intoxication under normal circumstances. Explain this in terms of what you know about examples of enzymatic reactions.**

**13. The enzymatic activity of lysozyme is optimal at pH 5.2 and decreases above and below this pH value. Lysozyme contains two amino acid residues in the active site essential for catalysis: $Glu^{35}$ and $Asp^{52}$. The p*K* values for the carboxyl side chains of these two residues are 5.9 and 4.5, respectively. What is the ionization state of each residue at the pH optimum of lysozyme?**

**14. Why does pH affect the activity of an enzyme?**

**15. What is a zymogen (proenzyme)? Explain briefly.**