AP* BIOLOGY

BIOCHEMISTRY

Teacher Packet

Biochemistry

Objective

To review the student on the concepts and processes necessary to successfully answer questions over biochemistry excluding enzymes. Enzymes receive a more thorough treatment in a separate session

Standards

Photosynthesis is addressed in the topic outline of the College Board AP Biology Course Description Guide as described below.

I. Molecules & Cells
- A. Chemistry of Life
  - Water
  - Organic molecules in organisms
  - Free energy changes
  - Enzymes

AP Biology Exam Connections

Biochemistry is tested every year on the multiple choice and also make appearances on the free response section of the exam. As with many AP Biology free response, these topics are often intertwined with other topics. It is not common to see an entire biochemistry free response. Biochemistry questions usually seem to permeate questions about membranes and transpiration. The College Board seems to be especially fond of the four levels of protein structure on the free response portion of the test. The list below identifies free response questions that have been previously asked over these topics. These questions are available from the College Board and can be downloaded free of charge from AP Central http://apcentral.collegeboard.com.

Free Response Questions
2008- Question 1 (a)
2007- Question 1 (a)
2003- Question 3 (a)
2001- Question 4 (a)

Biochemistry

Atoms & Bonding Review

Atoms

→Matter is made up of atoms
→Atoms are made up of p^+, n, and e^-
→Terms to know: elements, atomic number, and atomic mass
→Atomic structure determines chemical characteristics.

- isotopes (ex. C^{12}, C^{13}, C^{14})
- valence electrons: outer most shell of e^-
- orbitals: clouds where electrons tend to be found
- energy levels: distance of e^- measured from the nucleus

Bonding

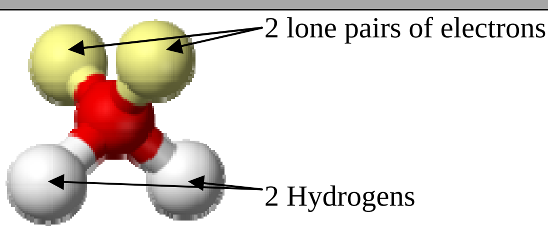
→Ionic bonds: transferring of electrons
→Covalent bonds: sharing of electrons

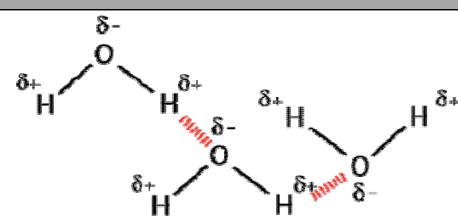
- single, double, triple bonds
- may not share equally (polarity)

→Hydrogen bonds: Occur in polar molecules in which a hydrogen atom is covalently bonded to a very electronegative element, specifically N, O, or F. Hydrogen bonds are technically an intermolecular force, not a bond.

Summary→ The nucleus consists of protons and neutrons. Electrons are found in general areas with general shapes. These areas are called electron clouds. In addition, electron energy can measured as a distance from the nucleus. Energy levels and electron orbitals overlap. It is therefore possible that two electrons be at different energy levels while occupying the same orbital. The valence electrons are most significant as they are involved in bonding.

Water





→Due to the two lone pairs of electrons (represented as the two on top in the picture), the molecular shape of water is bent.
→Though oxygen and hydrogen are bonded covalently, oxygen is *highly electronegative* in comparison to hydrogen. This unequal sharing or electrons results in water molecules being polar with slight negative and slight positive charges as displayed top, right.
→Hydrogen bonds: This polarity results in hydrogen bonding between H_2O molecules.
→Nearly all other characteristics of liquid water can be explained based on the information above.

- Cohesion and surface tension: water "sticks to itself" due to H bonding
- Adhesion: water sticks to other substances so long as H bonds are a possibility.
- Capillary action: such as water traveling up a straw is due to adhesion (water is sticking to the sides) and cohesion (water pulls up more water molecules as it moves up the side).
- High specific heat & high heat of vaporization: Remember that temperature is a measure of kinetic energy. Even though individual H bonds are considered weak, a water molecule must break free from many H bonds when increasing in temperature or changing phase to water vapor.
- Universal solvent: Due to the polarity of water molecules, they are "good dissolvers" of all things polar.

→Ice floats: Due to the crystalline structure of ice, it is less dense than water.

Biological significance

→Due to the high specific heat of water, much energy is needed to raise the temperature of water. During the heat of day, a body can sweat to cool off. A little bit of sweat will result in the absorbance of a great amount of heat. When heat exits the body, the body is cooling. If water did not have a high specific heat, more water would be needed to cool the body increasing the likelihood of dehydration. For the same reasons, bodies of water would experience greater temperature swings from midnight to midday were it not for the high specific heat of water. It may be more challenging for organisms to maintain homeostasis in this environment.

→Ironically, floating ice acts as an insulator to the water underneath. Lakes are less likely to freeze completely due to the fact that ice floats.

→This list is not all inclusive (surface tension: water striders,etc.).

Carbon & Biomolecule Synthesis

Carbon & Bonding

→Remember that the name ending denotes the type of covalent bond (single: -ane, double: ene, triple: yne)

→Carbon bonding is naturally covalent NOT ionic.

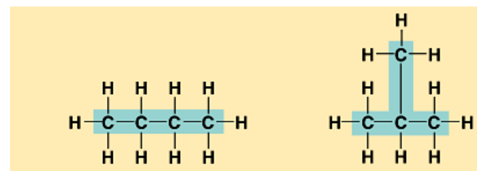
→Carbon has 4 valence electrons resulting in 4 bonds (tetravalent). Recall that shape is important in biomolecules. Because C has 4 bonding sites and can bond with itself, essentially endless chains and shapes can be created. These shapes are important in enzymes, protein channels, etc.

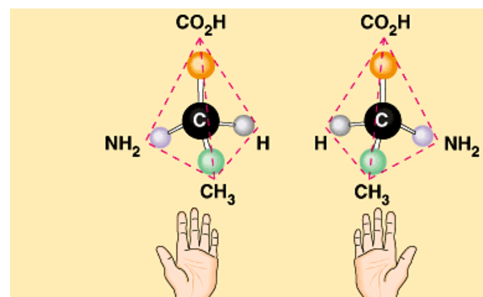
→Functional groups: Be able to identify

- Hydroxyl (-OH)
- Sulfhydryl (-SH)
- Carboxyl (-COOH or $-COO^-$)
- Animo ($-NH_2$ or NH_3^+)
- Phosphate ($-PO_4$)
- Methyl ($-CH_3$)

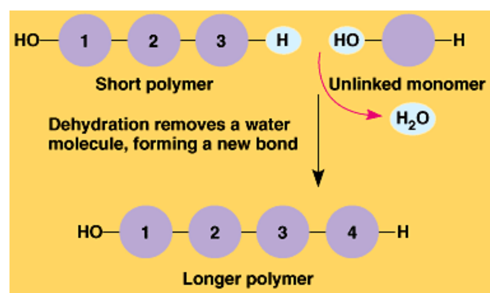
→Isomers: An isomer is a rearrangement of a molecule's components. The same number and kind of each atom is involved, but they are rearranged.

- Structural isomer- relocation of atoms
- Stereoisomer (enantomer)- mirror image.
    - The importance is that arrangement and shape matters: L- amino acids are biologically available, R- are not.


(a) Structural isomers



(c) Enantiomers



Building of macromolecules

→Metabolism is the elegant interplay of catabolic (breaking down) and anabolic (building up) reactions.

→Polymers are made up of smaller units called monomers

→Dehydration synthesis removes an –H from one monomer and an –OH from another to form a bond (H+OH→ H_2O). This bond is called a glycosidic bond in carbohydrates.

→Hydrolysis is the "catabolic reverse" of dehydration synthesis. Water is split, H and OH are added, bonds of the polymer are broken.

Carbohydrates

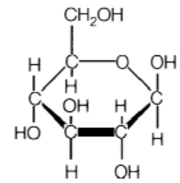
→Carbohydrates have an empirical formula of CH_2O unless they are polysaccharides. For polysaccharides subtract an H_2O for each bond. Example: A polymer of 6 glucose molecules would have 5 bonds created by dehydration synthesis. $C_{30}H_{60}O_{30}$ - 5 H_2O = $C_{30}H_{50}O_{25}$

→Carbohydrates typically have an –ose ending (glucose, fructose, lactose…)

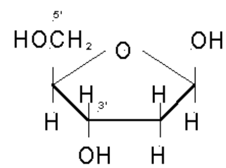
→Functions of carbohydrates

- Energy source (stored in the C-H bonds): Glucose, glycogen
- Structural: cellulose
- Cell recognition: glycoproteins

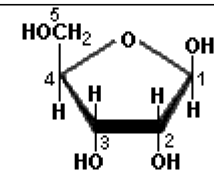
→Carbohydrates may be monosaccharides (glucose, fructose), disaccharides (sucrose, lactose), or polysaccharides (starch, cellulose, glycogen)



Glucose



Deoxyribose



Ribose

*→Students are often asked to identify molecular structures on the exam. Students should be able to identify ribose, deoxyribose, and glucose. Note: Ribose has an –OH group at the 2' carbon, while **Deoxy**ribose has an –H.*

Lipids

→Energy is contained in the C-H bonds of lipids

→Lipids are hydrophobic.

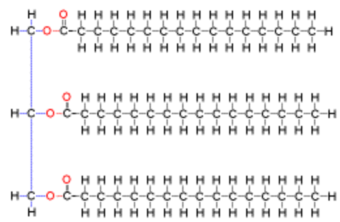
→Common example: triglyceride (glycerol molecule with 3 fatty acid tails)

→Cholesterol is a lipid. While cholesterol is more likely to participate in arterial blockage, cholesterol is needed in membranes for fluidity control and also acts as the precursor to steroid hormones.

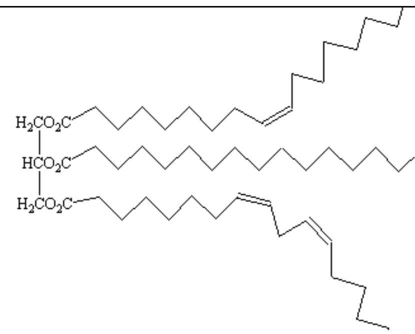
Bonding

→**Saturated fats**: Triglycerides with only single C-C bonds are called saturated. They are "saturated" with the maximum amount of hydrogen. Because the fatty acid tails are straight and uniform it is possible to pack many saturated fats into a small area making a solid. Saturated fats therefore tend to be solid at room temperature. Sticky, hydrophobic fats are still quite sticky when absorbed into the water-based bloodstream. It is thought that these fats are more likely to stick to artery walls; because of this, saturated fats are/were often referred to as "bad" fats.

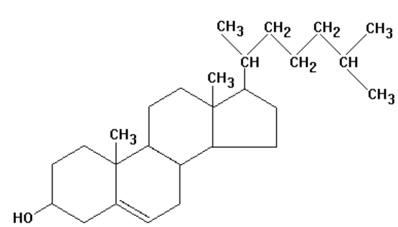
→**Unsaturated fats**: Triglycerides with C=C bonds are not completely saturated with hydrogen (for every C=C two hydrogens must be removed). These are called unsaturated fats. When C=C bonds are introduced, "kinks" are more likely to occur (esp. cis formation). This shape results in the inability of the lipids to pack together closely and because of this, unsaturated fats tend to be liquid at room temperature.



Saturated fat



Unsaturated fat



Cholesterol

→Students are often asked to identify molecular structures on the exam. Students should be able to identify the glycerol molecule a saturated and unsaturated triglyceride, and cholesterol

Proteins

Diversity of Structure & Function
-globular (enzymes, receptors, channels, etc.)
-fibrous (collagen, keratin, actin & myosin, etc.)
-peptides (signals)
→"–ase" ending denotes an enzyme, non-enzyme proteins often end with "-in"

Amino Acids

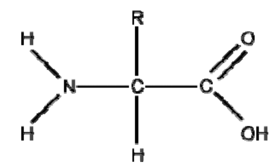
→Note that each amino acid contains an **amino** group and a carboxylic **acid** (carboxyl). These two groups may gain and lose hydrogen depending on pH of the surrounding environment. The amino group may be $-NH_3^+$ or NH_2. The carboxyl group may be -COOH or $-COO^-$

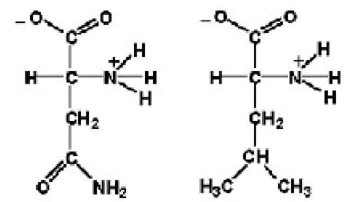
→ Amino acids are the building blocks of proteins. Each amino "R" group = diff. properties = versatility…small, large, polar, nonpolar, charged, etc.

→Amino acids linked via peptide bonds through dehydration synthesis.

→Hydrophobic / hydrophilic interactions shape proteins based on the R groups involved.

→In addition, chaperonin proteins can also sequester amino acid chains to allow proper folding.





Proteins: Levels of Protein Structure

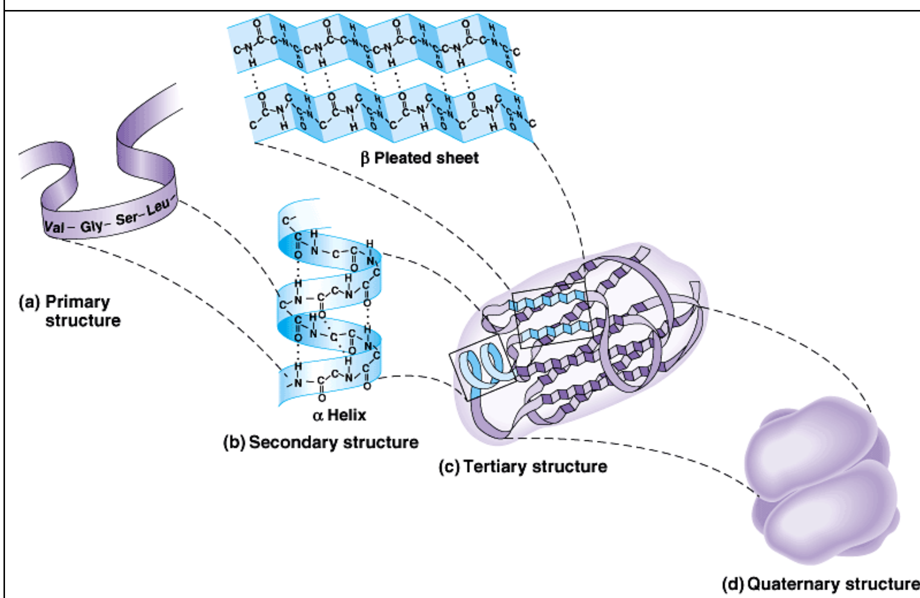
→Primary structure is the order of the amino acids (coded for by DNA/RNA)

→Secondary structure is the interaction of primary structure with itself forming hydrogen bonds within the same chain of amino acids.

- Alpha helix
- Beta pleated sheet

→Tertiary structure is the interaction of secondary structures with other secondary structures within the same chain of amino acids. Disulfide bridges between cysteines are common for added strength & stability.

→Quaternary structure is the introduction of additional amino acid chains. Essentially the tertiary structures of one polymer of amino acids interacting with another (hemoglobin is the most commonly cited example.

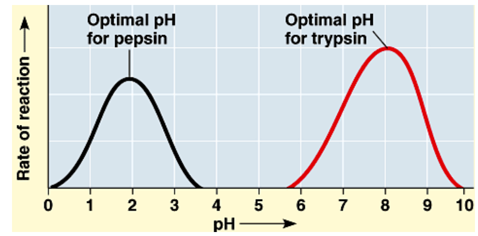


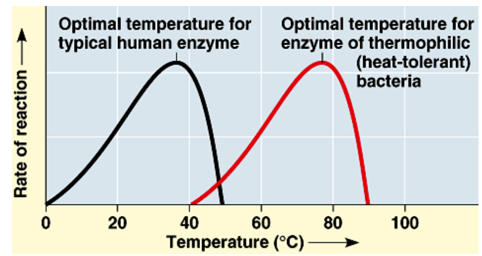
Proteins: Shape & Denaturation

→Be it the active site of an enzyme or the long rod-like shape of myosin, shape is of paramount importance to proteins. Shape is determined based on the sequence of amino acids. One change in an amino acid can have a drastic effect (sickle cell anemia, cystic fibrosis, etc.)

→Denaturation is when the shape of a protein irreversibly changes.

- pH-A high concentration of H^+ ions will certainly interfere with negatively charged "R" groups. Once this occurs the most stable form/shape of the protein may be different from what was originally intended. Low pH may also denature a protein.
- Ion concentration- High concentrations of a specific ion may denature enzymes through a scenario similar to pH.
- High temperature- High temperature results in a shift in protein shape to a form that is more stable at that temperature. Low temperature does not typically denature a protein, enzyme activity at low temperature decreases due to decreased molecular collisions.





Summary→Proteins have a "window of life" in which they function properly. They are able to maintain shape as long as the pH, ion concentrations, and temperature are not at extremes. Protein shape is due to the levels of protein structure which begin with amino acid sequences coded for by DNA. In short genetic diseases can be explained by the following flow chart: A change in the genetic code→possible change in the amino acid sequence ("possible" due to redundancy of the genetic code)→change in shape of the protein→likely useless protein.

→Students are often asked to ID the structure of an amino. Students may also be asked to identify the carboxyl and amino groups within the structure.

Nucleic Acids

→DNA is a polymer the monomer of which is the nucleotide. A nucleotide consists of a phosphate, deoxyribose, and a nitrogenous base(A,T,G,C). RNA is similar with differences being: single stranded, U instead of T, riobose instead of deoxyribose.

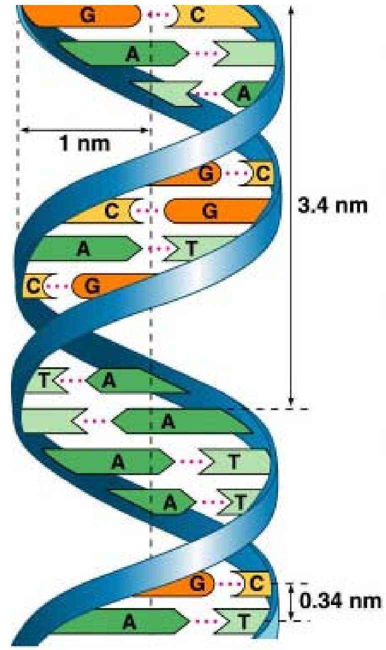
→Notation of sugar 5' and 3'- Students should be able to point out the 5' and 3' and realize that this is a man made mechanism equivalent to giving a molecule a right side up/upside down nomenclature

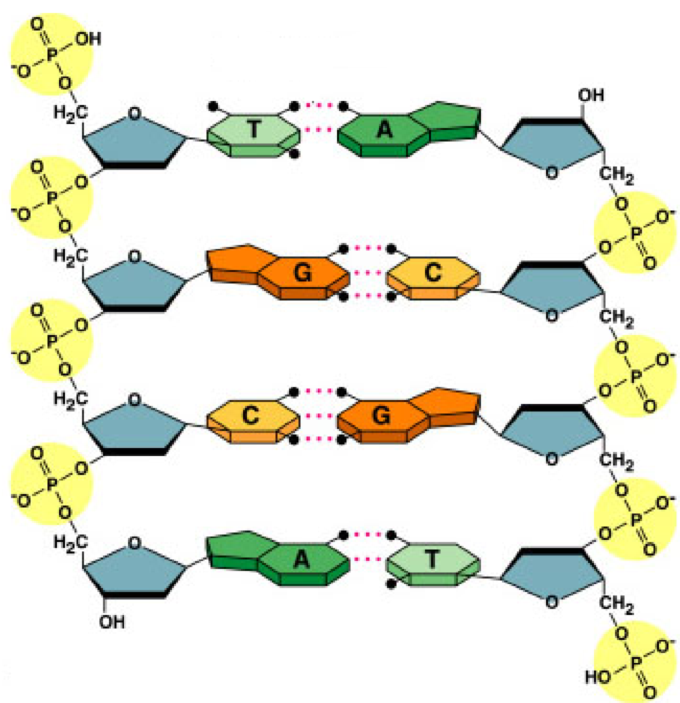
→Adenine is complementary to Thymine; Guanine is complementary to Cytosine.
Note that the A and G are both "double ring structures" and that T and C are "single ring structures." A and G are referred to as purines. T & C are pyrimidines. (Mnemonic: Purines = a,g…Pure as gold). Due to size constraints of the DNA backbone, a purine (big) must combine with a pyrimidine (small) in order to fit. Why can't A:C?...Note that there are three sites for H bonds on G & C and only two on A & T. The only possible combination that due to size and bonding is A:T and G:C.

→DNA is stable. The charged DNA backbone (thanks to phosphate) and polar sugars will be stable in the water based fluid in the nucleus, the hydrophobic bases are shielded internally from H_2O. This is of course reminiscent of the phospholipid bilayer.

→The sugar phosphate backbone is joined via a phosphodiester bond. The joining of this backbone is accomplished via dehydration synthesis.

→DNA has a major groove and a minor groove. Note the difference in groove when looking up at the pic vertically. The significance of the major groove comes later during transcription as transcription factors are thought to "scan" the major grooves before unzipping DNA





→*In the past, students have been asked to identify the "anatomy" of DNA. Students should be able to identify a: purine, pyrimidine, deoxyribose, phosphate group, phosphodiester bond, covalent bond, hydrogen bond, and 5' and 3' carbons on deoxyribose.*

Summary of "Molecules that you absolutely must be able to identify"

Summary of "Molecules and functional groups that you absolutely must be able to identify"

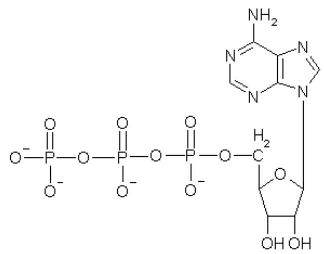
Functional groups

- Hydroxyl (-OH)
- Sulfhydryl (-SH)
- Carboxyl (-COOH or $-COO^-$)
- Animo ($-NH_2$ or NH_3^+)
- Phosphate ($-PO_4$)
- Methyl ($-CH_3$)

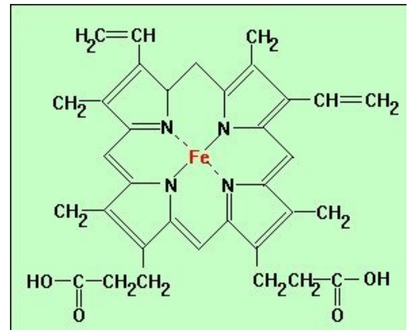
Common Molecules

- Ribose
- Deoxyribose
- Glucose
- Polymers of glucose may be starch, chitin, glycogen, etc. depending on bonding arrangement. No need to be able to decipher between them.
- Glycerol
- Saturated fat
- Unsaturated fat
- Cholesterol
- ATP
- DNA components
    - Purine
    - Pyrimidine
    - Deoxyribose (including 5' and 3' carbon notation)
    - Phosphate
    - Bonds (hydrogen, phosphodiester, covalent)
- Amino acid structure
- Hemoglobin

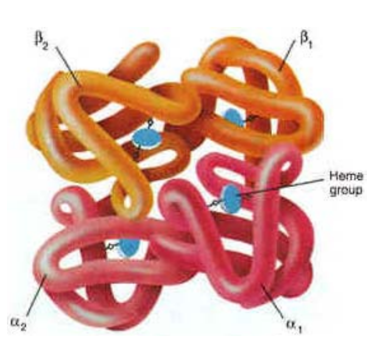
Structures NOT represented previously in this packet



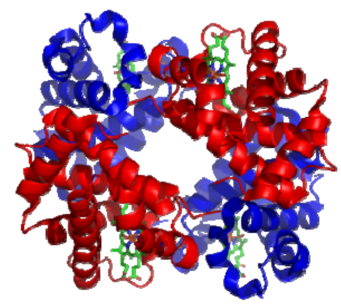
ATP



Hemoglobin



Hemoglobin (another view)



Hemoglobin (another view)

Multiple Choice

1. The secondary structure of a polypeptide is primarily determined by which of the following?

(A) Hydrogen bonding
(B) The number of amino acids
(C) NADH
(D) Golgi apparatus
(E) Ribosomes

A	Hydrogen bonds stabilize the secondary structure.

2. Hydrogen bonds occur

(A) between nonpolar substances
(B) between adenine and thymine
(C) between phosphate and deoxyribose in DNA
(D) when a hydrogen and an oxygen in a water molecule share electrons
(E) between carbon and hydrogen in a molecule of methane

B	Hydrogen bonds occur between complementary base pairs. Answer choice D is describing a covalent bond.

3. Which of the following statements is/are true with regard to a polymer of 6 glucose molecules?

I. The chemical formula is $C_{36}H_{72}O_{36}$
II. The chemical formula is $C_{36}H_{62}O_{31}$
III. The monomers of glucose were joined via hydrolysis
IV. The monomers of glucose were joined via dehydration synthesis

(A) I only
(B) II only
(C) IV only
(D) I and III only
(E) II and IV only

E	6 glucose molecules will form 5 bonds. Each bond represents the subtraction of 2H and 1O due to dehydration synthesis. $C_{36}H_{72}O_{36}$ – 10H and 5O = $C_{36}H_{62}O_{31}$.

4. Which of the following statements regarding lipids is most accurate?

(A) Lipids are synthesized by ribosomes.
(B) The empirical formula for lipids is typically $C_1H_2O_1$.
(C) Saturated fats tend to be solid at room temperature because of polar hydrocarbon chains.
(D) Saturated fats tend to be liquid at room temperature due to hydrogen bonding.
(E) Polyunsaturated fats tend to be liquid at room temperature due to numerous double bonds in the hydrocarbon chains.

E	Polyunsaturated fats contain numerous double bonds making them liquid at room temperature.

5. Chargaff is credited with determining the base pairing rules as they relate to the structure of DNA. Which of the following explanations is accurate regarding the structure of DNA?

(A) Uracil bonds covalently with adenine.
(B) Pyrimidines bond with pyrimidines.
(C) Purines form ionic bonds with pyrimidines.
(D) Adenine hydrogen bonds with thymine.
(E) Guanine bonds covalently with cytosine.

D	Adenine hydrogen bonds with thymine.

6. DNA codes for 20 different amino acids. Which of the following is responsible for making each of the amino acids unique from one another?

(A) hydroxyl group
(B) sulfhydryl group
(C) amino group
(D) methyl group
(E) "R" group

E	The R group is the only unique portion from one amino acid to another.

7. All of the following statements about potential energy are true EXCEPT

(A) fixed potential energy states for electrons are called electron shells or energy levels
(B) electrons with the highest potential energy are closest to the nucleus of the atom
(C) potential energy of electron exists in discrete amounts called quanta
(D) matter tends to move to the lowest state of potential energy
(E) electrons with greater energy exist in outer electron shells

B	Electrons with the highest potential energy are farthest from the nucleus.

8. The insolubility of fats in water is due primarily to

(A) the many nonpolar C-H bonds
(B) the ester linkage between a hydroxyl group and a carboxyl group
(C) the presence of glycerol in the structure makeup
(D) the variety of fatty acids in a fat molecule
(E) the large number of double bonds between carbon atoms

B	Nonpolar C-H bonds are responsible for the insolubility of fats in water.

9. Lipids with four fused carbon rings and various functional groups attached are known as

(A) phospholipids
(B) saturated fats
(C) steroids
(D) fatty acids
(E) chitin

C	Cholesterol based steroid hormones display a "backbone" of four fused ring structures.

10. A folded, coiled macromolecule that consists of one or more polypeptide chains describes a

(A) phospholipid molecule
(B) triacylglycerol molecule
(C) glycogen molecule
(D) cholesterol molecule
(E) protein molecule

E	Peptide bonds are found only in proteins.

11. A polymer of glucose that serves as a storage macromolecule in animals is

(A) chitin
(B) starch
(C) glycogen
(D) cellulose
(E) amylase

C	Cellulose is found in the cell walls of plants. Chitin is found in the cell walls of fungi. Starch is an energy store in plants. Glycogen is stored in the liver of animals.

12. Polysaccharides are best described as:

(A) complex molecules such as starches that are composed of many chains of sugar monomers
(B) chains of amino acids joined by peptide bonds
(C) molecules made of glycerol and three fatty acid chains
(D) nucleotides arranged in a helical pattern
(E) a five- or six-carbon sugar molecule bonded to an aldehyde or ketone group

A	Carbohydrate monomers make up polysaccharides.

13. Storage of fat by the body is advantageous primarily because fats

(A) are insoluble and chemically stable
(B) yield, gram for gram, more than twice as much energy as complex carbohydrates
(C) can be digested with less energy and fewer enzymes than carbohydrates and proteins
(D) store almost all potential energy in chemical bonds
(E) are much easier to produce from surplus molecules that have been broken down by digestive enzymes

B	Fats yield ~9Calories per gram while Carbohydrates and proteins yield ~4 Calories per gram.

14. Cholesterol is important in the metabolism of living things because it can be changed into important compounds that include all of the following EXCEPT

(A) Vitamin D
(B) bile salts
(C) estrogen
(D) keratin
(E) testosterone

D	Keratin is a protein. Remember many non-enzymatic proteins end with –in.

15. The twenty common amino acids differ from each other in the composition of a covalently bonded side chain known as a(n)

(A) polypeptide
(B) dipeptide
(C) R group
(D) amino group
(E) carboxyl group

C	R groups are unique to each individual amino acid.

16. Heating a protein or lowering the pH beyond a protein's range of tolerance can result in denaturing the protein by

(A) breaking the weak hydrogen bonds, causing the protein to unwind or change shape
(B) breaking the strong covalent bonds of the protein's primary structure
(C) dissolving peptide bonds between the amino acids in the polypeptide chain
(D) removing the heme or other group that gives the protein its identity and chemical characteristics
(E) causing the molecule to fold and wind tighter, covering the surface receptor sites

A	Breaking of hydrogen bonds will result in the change to a more stable form of a protein.

17. The two strands of the spiral helix of DNA are held together by

(a) ionic bonds
(b) covalent bonds
(c) peptide bonds
(d) hydrogen bonds
(e) cohesion

D	Hydrogen bonds (2 between A&T, 3 between G&C) hold the two halves of DNA together.

Answer questions 18-20 using the terms below:

I. NAD^+
II. ATP
III. Uracil
IV. Thymine

18. Which of the compounds are nucleotides?

(A) I and II only
(B) I, II, and III only
(C) II and III only
(D) III and IV only
(E) I, II, III, and IV

E	All of the above are nucleotides or nucleotide triphosphates.

19. Which of the compounds serve(s) as an electron carrier in cellular respiration?

(A) I only
(B) I and II
(C) II only
(D) I and III
(E) III and IV only

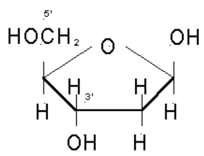
A	Only NAD^+ is an electron carrier in the group listed.

20. Which of the compounds is/are a component of DNA molecules?

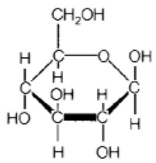
(A) I and II
(B) III only
(C) I and III
(D) III only
(E) IV only

E	ATP can become a component of DNA when phosphates are removed. Only Thymine is a component of DNA.

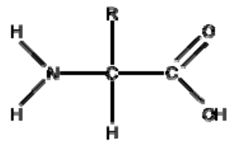
Questions 21-24 refer to the following chemical structures



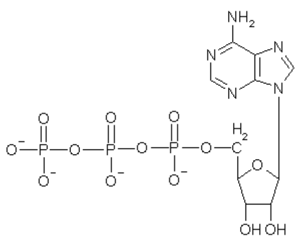
(A)



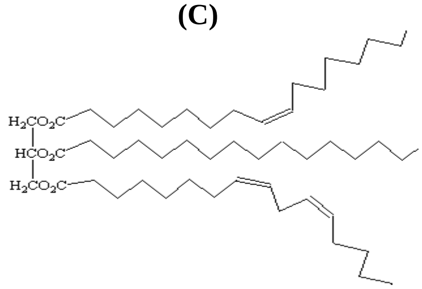
(B)



(C)



(D)



(E)

21. can be modified and used as the fundamental component of a cell membrane

E	Phospholipids are created by removing a fatty acid tail and replacing it with the polar head.

22. is the building block of both hemoglobin and chlorophyll

C	Amino acids are the building blocks of proteins

23. is responsible for providing energy for nearly all endergonic reactions in the human body

D	ATP supplies energy for cellular functions.

24. a carbohydrate utilized in the synthesis of polymers of DNA

A	Deoxyribose is found in the DNA backbone.

Free Response

1. The properties of water dictate many chemical interactions present in the cell.

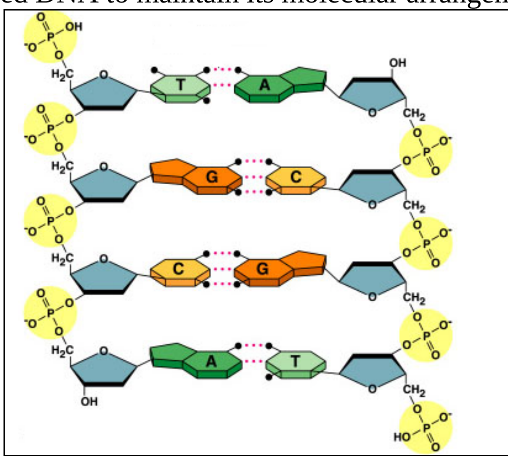
A. Water is cohesive. **Define** cohesion and **explain** the chemical interactions and properties that make water cohesive.
(4 pt maximum)

__cohesion definition.: cohesion is the property of water “sticking” to itself
__electronegativity: Oxygen has a higher electronegativity than hydrogen causing electrons to be unequally shared in the covalent bonds.
__polarity: Due to this unequal distribution, the electrons are more closely associated with the O atom giving them a slight negative charge while H has a slight positive charge.
__hydrogen bonding: These slight negatives in one molecule are attracted to the slight positives in another water molecule. Water is cohesive because molecules of H_2O form a hydrogen bonds with each other
__hydrogen bonds are a type intermolecular force, technically not a chemical bond

B. The characteristics of water are of central importance to the arrangement of the cell membrane. **Describe** and **discuss** how it is that water exerts this effect.

__phospholipids are the primary component of the cell membrane
__phospholipids are amphipathic OR contain polar heads and nonpolar tails
__water is polar
__phospholipids are arranged in a bilayer in such a way that the nonpolar tails are internal and shielded from the surrounding water while the polar heads are exposed to the water.

C. Refer to the graphic of DNA and the solubility data on the nitrogenous bases. DNA is quite stable and soluble in the water based nuclear environment of the cell. **Describe** and **discuss** the chemical interactions that allow uncondensed DNA to maintain its molecular arrangement.

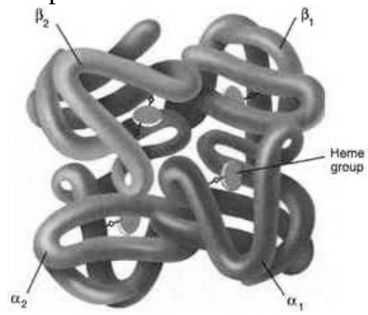


Nitrogenous Base	Solubility in H_2O
Adenine	Very slightly
Thymine	Very slightly
Guanine	Insoluble
Cytosine	Insoluble

__the nuclear environment is polar (the question told the student it is “water-based”).
__the phosphates are charged/polar and are therefore soluble in water
__deoxyribose sugar is soluble in water
__the hydrophobic bases are sequestered internally away from water

Free Response

2. Hemoglobin is responsible for oxygen transport in the bloodstream.



A. Describe the levels of protein structure that make up a complex protein such as hemoglobin depicted above.
(4 pt maximum)

__Primary structure is the amino acid sequence or the order of amino acids
__Secondary structure is the hydrogen bonding of the primary structure to itself
__alpha helix described as a helical structure stabilized by hydrogen bonds (pics with description okay)
__beta-pleated sheets described as folded, accordion style, etc. stabilized by hydrogen bonds (pics with descriptions okay)
__Tertiary structure is made up of secondary structures bonded to themselves and stabilized by covalent or –SH bonds.
__Quaternary structure involves more than one amino acid sequence.

B. Proteins are made from the 20 coded amino acids. Describe the various categories of amino acids and discuss their importance in building proteins.
(4 pt maximum)

__"R" groups of amino acids determine their individual characteristics.
__Different groups will determine shape of protein and characteristics of the protein based on its function. Must mention why shape of protein matters (enzyme active site, receptor site, insertion into phospholipid bilayer, etc.

Up to two points for mention categories of amino acids
__polar amino acids
__charged amino acids
__nonpolar amino acids
__acidic amino acids
__basic amino acids
__large/small "R" groups

C. Explain what is happening at the molecular level when hemoglobin is heated to an extreme temperature. Describe the effect that this event will have on the ability of hemoglobin to carry oxygen.

__Bonds are broken and reformed
__Molecule is changing to a more stable state based on temperature
__hemoglobin will no longer be able to adequately carry oxygen.