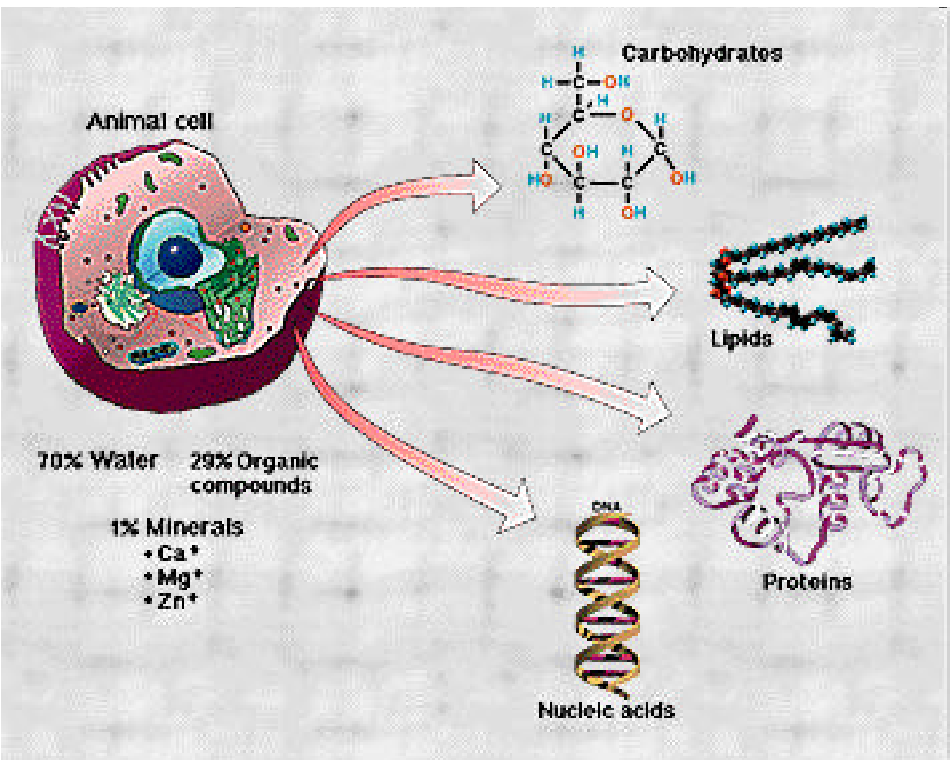
Interactive Biology Multimedia Courseware

Biochemistry: The Chemistry of Life
Program Supplement



Biochemistry: The Chemistry of Life
Teaching Objectives

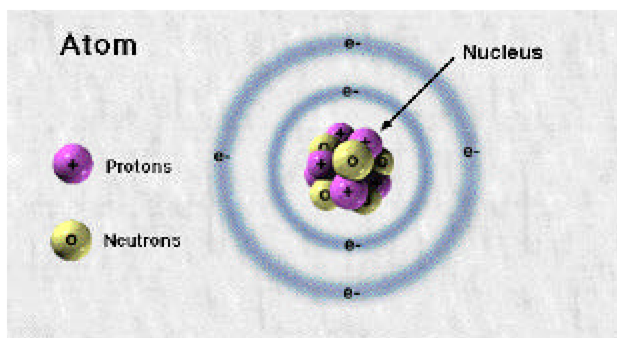
The following subjects are illustrated throughout the Interactive Biology Multimedia Courseware program, Biochemistry*: The Chemistry of Life.* Ideally, these areas would be augmented with additional resources. *(Click on the subjects to jump to that section.)*

- **The structure of atoms including the particles that make up an atom, their locations, and their charges.**
- **The differences between atoms, molecules, and compounds; electron shells and the differences between organic and inorganic compounds.**
- **The importance of valence electrons in chemical bonds; structural formulas.**
- **Covalent bonds, polar molecules, and electronegativity.**
- **Ionic bonds, electrostatic attraction, and hydrogen bonds.**
- **The important properties of water including adhesion, cohesion, and heat storage. The concept of water as solvent.**
- **The make-up of carbohydrates, and the mechanism by which they are linked together and broken apart.**
- **The make-up of lipids, and the difference between saturated and unsaturated fats.**
- **The structure of proteins, amino acids, and the role of peptide bonds in linking amino acids together.**
- **The structural and chemical difference between DNA and RNA. The role of these two macromolecules.**

Study Guide #1
Atoms and Their Structure

For ages, man has been interested in the composition of matter. That is, scientists and philosophers have wondered what exactly makes up the physical structures we see every day, such as rocks, trees, and fish. As early as the third century BC, the Greek philosopher Democritus proposed that "all matter is composed of tiny, indivisible particles called atoms." Although he had no way of proving it at the time, Democritus was correct that matter is composed of atoms.

Different atoms, such as iron atoms and carbon atoms, can have very different characteristics. However, the structure of all atoms is remarkably similar.

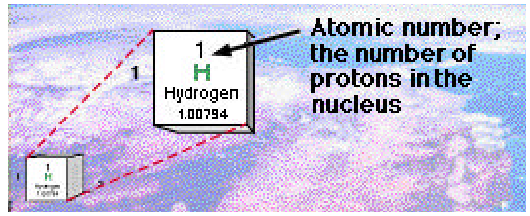


Every atom has a central core known as the nucleus. The nucleus makes up the majority of the atom's mass and is composed of two distinct types of particles - protons and neutrons. Protons carry a positive charge. Neutrons are neutral, that is they carry no charge.

Orbiting the nucleus in distinct energy levels called shells are one or more electrons. Electrons are very small, negatively charged particles, and they only make up a small portion of an atom's mass.

In many instances, the number of electrons is equal to the number of protons. In these atoms, the positive charges and negative charges are equal, and the atom is considered to be electrically neutral.

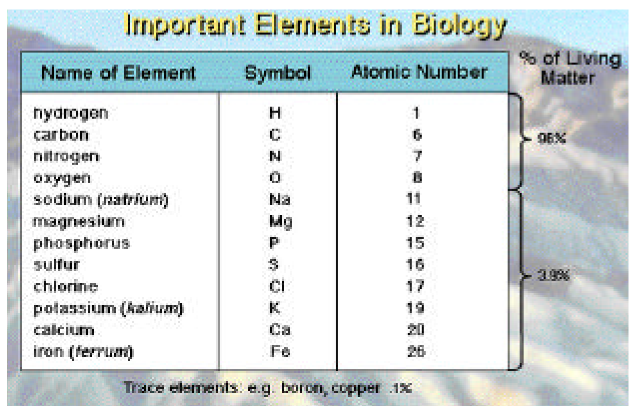
Study Guide #2
Elements, Molecules, and Compounds



Elements are substances composed of only a single type of atom. Therefore, an element cannot be broken down into other substances by chemical reactions. Whether you have one aluminum atom or millions of aluminum atoms, nothing can be done to change them into anything other than aluminum. You can expose these atoms to high heat and get molten aluminum. You can cool them and form solid objects such as cans, but at all stages of this process, aluminum atoms are still aluminum atoms. They can never be changed into carbon, iron, zinc or any other type of atoms. This holds true for all elements.

Elements are arranged, from lightest to heaviest, on the periodic table. The number found above the symbol for each element is the atomic number. The atomic number is the number of protons found in this element. About 90% of the 109 total elements are found in nature. The others are very unstable, short-lived elements produced only under specific conditions.

About 96% of all living material is composed of four elements. These are hydrogen (H), carbon (C), nitrogen (N), and oxygen (O). The remaining 4% consists of trace elements. Trace elements are required by living tissue, but only in small amounts. For example, the elements boron (B) and copper (Cu) are needed to live, but only in small (or *trace)* amounts.

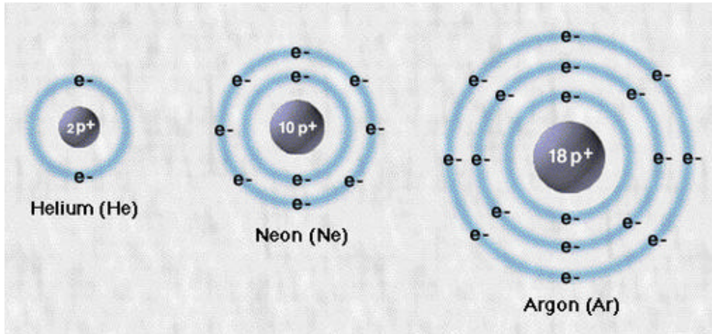


Important Elements in Biology

Name of Element	Symbol	Atomic Number	% of Living Matter
hydrogen	H	1	96%
carbon	C	6	
nitrogen	N	7	
oxygen	O	8	
sodium (*natrium*)	Na	11	3.9%
magnesium	Mg	12	
phosphorus	P	15	
sulfur	S	16	
chlorine	Cl	17	
potassium (*kalium*)	K	19	
calcium	Ca	20	
iron (*ferrum*)	Fe	26	

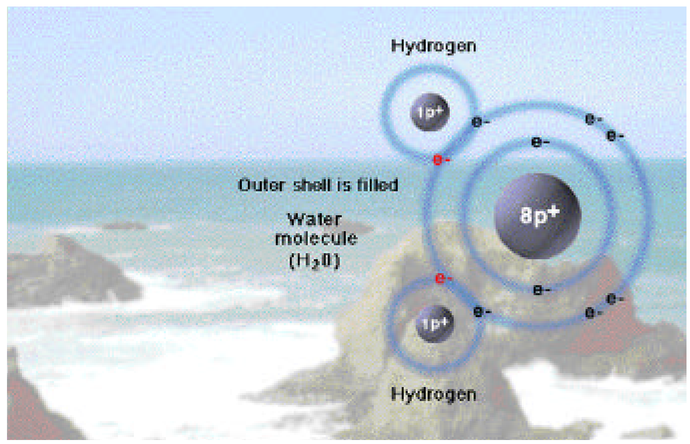
Trace elements: e.g. boron, copper .1%

As stated earlier, electrons are arranged in a system of electron shells or energy levels. The first shell closest to the nucleus can hold only two electrons. Therefore, atoms with more than two electrons must have more than one outer shell. Each outer shell beyond the first one can hold a maximum of eight electrons.



Elements with their outermost shell filled are not chemically active. Typically, these are gasses such as helium (He), argon (Ar), and neon (Ne).

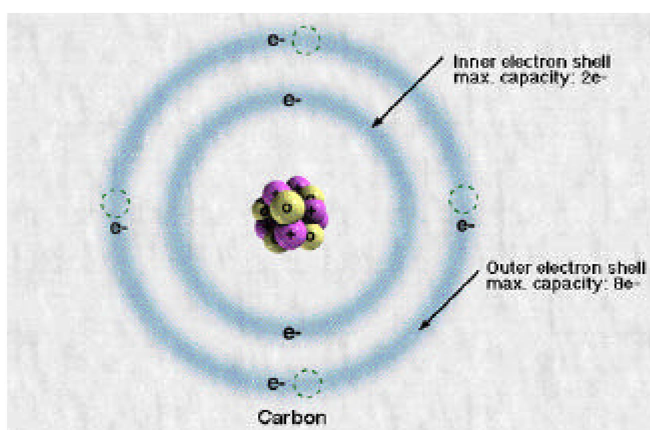
If the outermost electron shells are not filled, the elements are chemically active. That is, these elements will react and form bonds with other atoms. These can react with identical atoms (such as when two oxygen atoms combine to form O2) or they can react with different types of atoms (such as when hydrogen and oxygen atoms combine to form H_2O).



Molecules are formed when two or more atoms bind together. If two different types of atoms combine with each other, a compound is formed. All compounds are considered either organic or inorganic.

Organic compounds always contain the element carbon. In addition to carbon, these compounds frequently contain the elements oxygen, hydrogen, nitrogen, phosphorous, and sulfur. Many organic compounds, such as carbohydrates, lipids (fats), proteins, and nucleic acids are essential to life.

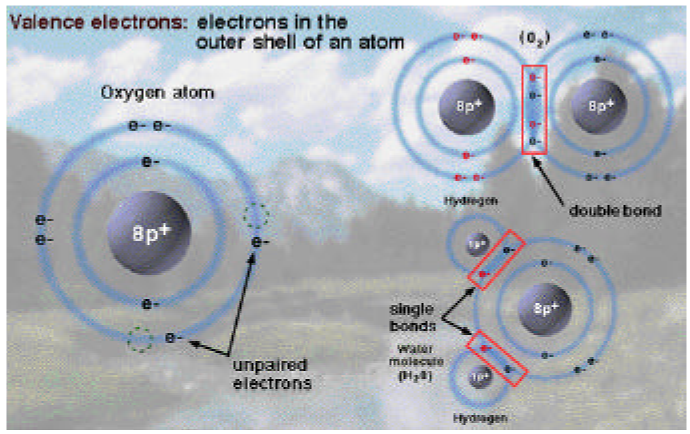
Inorganic compounds normally do not contain the element carbon. There are two exceptions. Carbon monoxide (CO) and carbon dioxide (CO_2) are inorganic compounds that contain carbon. Many inorganic compounds, such as water, oxygen, salts, and carbon dioxide are critical to life.



Study Guide #3
Chemical Bonds

Chemical bonds connect atoms to one another. When atoms come together to form molecules, it is the electrons in their outer shells that are involved in bond formation. These outer-layer, bond-forming electrons are known as valence electrons. The number of valence electrons determines the number of bonds an atom is able to form.

For example, an oxygen atom has two unpaired valence electrons. It can use these to form two single bonds. Water (H_2O) is formed when one oxygen atom uses its two valence electrons to form bonds with two hydrogen atoms. Likewise, the two hydrogen atoms use their single valence electrons when bonding to the oxygen atom.



Oxygen is also able to use its two valence electrons to form one double bond. Molecular oxygen (O_2) is formed when two oxygen atoms each use their two valence electrons to form a double bond.

In addition to single and double bonds, some atoms also form triple bonds. Two nitrogen (N) atoms can come together to form molecular nitrogen (N_2). In this arrangement, a triple bond connects two nitrogen atoms.

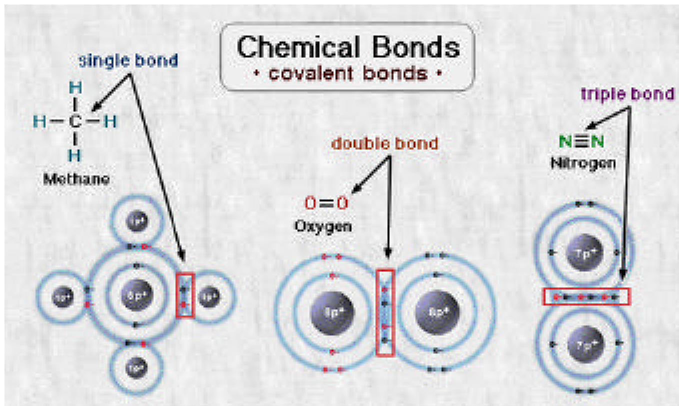
A structural formula shows what atoms are found in a molecule and how these atoms are bound to each other. For instance, the formula for water (H_2O) is written:

H-O-H

and the formula for molecular oxygen (O_2) is written:

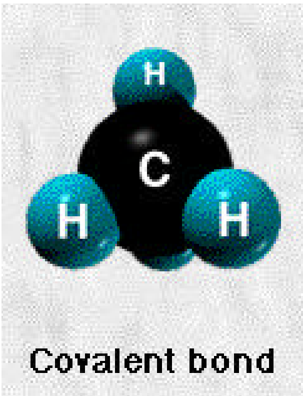
O=O

When you see H-O-H you know that two hydrogen atoms and one oxygen atom are found in this molecule, and you know that single bonds connect everything. When you see O=O you know that two oxygen atoms are found in this molecule and one double bond holds them together. A triple bond is represented by, of course, three lines connecting two atoms. Structural formulas can be very helpful tools.

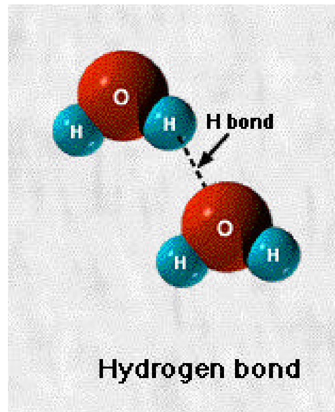


Study Guide #4
Covalent Bonds

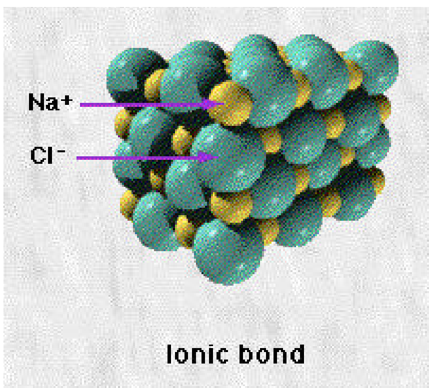
The three principle categories of chemical bonds are covalent, ionic, and hydrogen bonds. Let's take a look at covalent bonds.



A covalent bonds is one in which electrons are equally, or nearly equally, shared between two atoms bound to one another. When oxygen and hydrogen come together to form water, oxygen shares its electrons with the two hydrogen atoms and the two hydrogen atoms each share their electron with the oxygen atom. Covalent bonds are very strong chemical bonds.

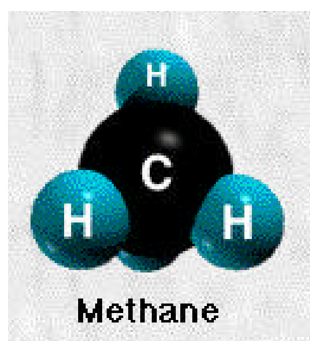


Remember, an outer shell can only accommodate eight electrons before it is filled. A filled outer shell is a very stable arrangement, which is why atoms with full outer shells are not chemically active.



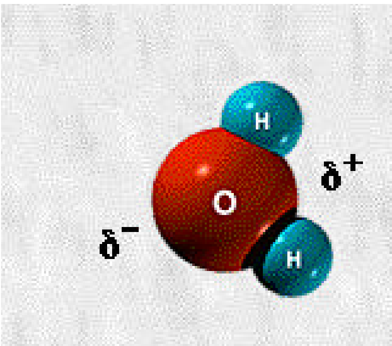
Carbon is a very important element. This versatile element is so critical to earth's organisms that life is, in fact, considered to be "carbon based". Its versatility arises from its four valence electrons, which allows carbon to form four single bonds, two double bonds, a double bond and two single bonds, or a triple bond and a single bond.

When carbon forms four covalent bonds with hydrogen, methane (CH_4) is formed. Carbon in methane shares a total of eight electrons (four of its own and four from the hydrogen atoms) and therefore effectively fills its outer shell. Each of the four hydrogen atoms shares a total of two electrons (one of its own and one from the carbon atom) and effectively fills its outer shell - remember, hydrogen has only the first shell which can accommodate only two electrons. Thus, in molecules such as methane, every atom winds up with full outer shells. These molecules are very stable.



Although electrons are shared in covalent bonds, they are not always shared equally. In these instances, electrons spend more time near the nucleus of one atom than the other atom involved in the bond. Thus, one atom becomes slightly more negative (the atom having the electron more often) and one atom becomes slightly more positive (the atom having the electron less often). This type of covalent bond is known as a polar covalent bond. Molecules with polar covalent bonds are known as polar molecules.

Water (H_2O) is an example of a polar molecule. In water, electrons are more attracted to the oxygen nucleus than the hydrogen nucleus. The electrons, accordingly, spend more time near oxygen, making it slightly more negative and the hydrogen slightly positive.



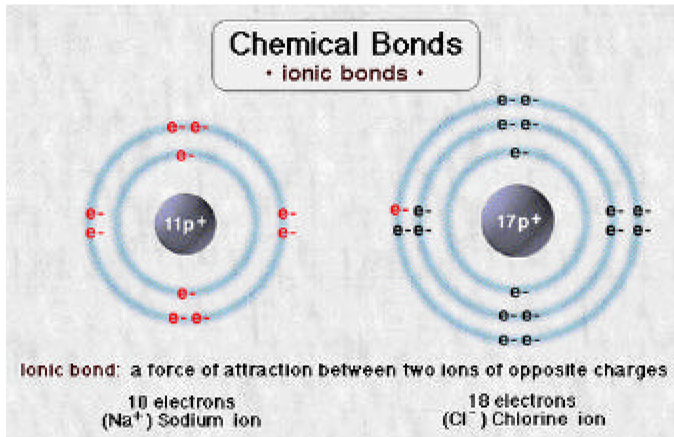
The ability of one atom to attract electrons from another atom is called electronegativity. In water, oxygen is more electronegative than hydrogen. The greater electronegativity of oxygen results in the shared electrons residing near the oxygen nucleus more often than near the hydrogen nucleus.

In contrast to polar molecules, O_2 is a non-polar molecule. In O_2, as with other non-polar molecules, all valence electrons are shared equally among the atoms involved.

Study Guide #5
Ionic and Hydrogen Bonds

Another category of chemical bonds is ionic bonds. These bonds are formed when one atom donates a valence electron to (rather than shares an electron with) another atom. An example of this is seen in sodium chloride, which is the common table salt you use every day.

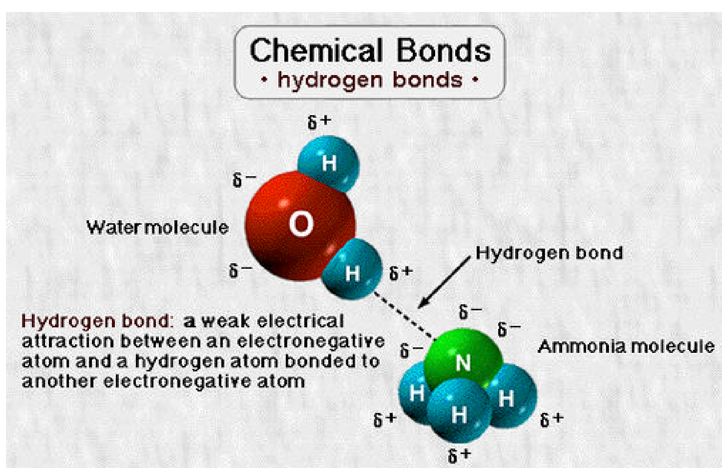
Sodium chloride (NaCl) is formed when a sodium atom (Na) donates one of its valence electrons to a chlorine atom (Cl). Sodium atoms and chlorine atoms are electrically neutral, that is, they have equal numbers of protons and electrons. When an electron is transferred from sodium to chlorine, sodium becomes a sodium ion and chlorine becomes a chloride ion.



An ion is simply a charged atom. Since sodium gives up an electron, it loses a negative charge and becomes positively charged. When chlorine receives an electron, it gains an extra negative charge and becomes negatively charged.

There is an attraction between positive and negative charges (remember, opposites attract). This electrostatic attraction between sodium ion and chloride ion gives rise to an ionic bond.

A third type of chemical bond is the hydrogen bond. Recall that in polar molecules, some atoms are slightly positively charged and others are slightly negatively charged. A hydrogen bond is formed through a weak electrical attraction between a hydrogen atom bonded to an electronegative atom, such as oxygen or nitrogen.

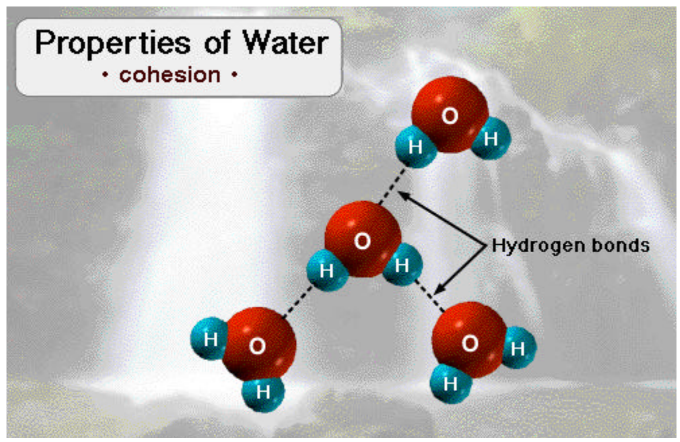


Hydrogen bonding takes place between individual molecules of water. The slightly positive hydrogen atoms in one molecule are attracted to the more electronegative oxygen atoms of other molecules. Hydrogen bonds are much weaker than covalent bonds (about 20 times weaker).

Study Guide #6
Water

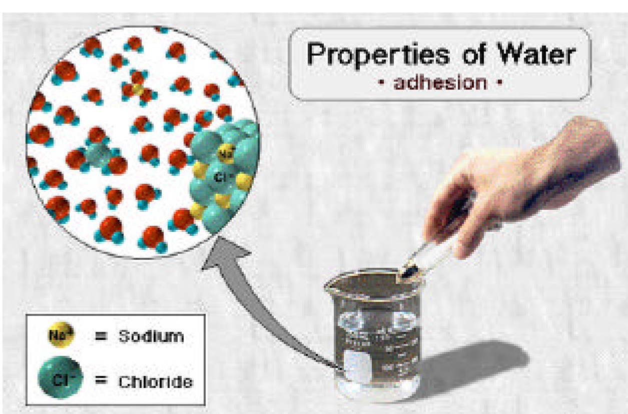
You drink it every day, but were you aware that water is the most important compound on earth? All organisms require water for survival. In fact, this compound makes up about 70% of the average cell. Some important qualities of water are cohesion, adhesion, and the ability to store heat.

Why does rain fall in drops? Why do drops of water form beads on the surface of a freshly washed car? Hydrogen bonding between water molecules in a drop of water attracts these molecules to each other. This property of water molecules "sticking" to one another is known as cohesion.



This high degree of cohesion allows water to store heat better than most other liquids. This property is vital to an organism's ability to withstand dramatic changes in temperature.

As water is exposed to a rise in temperature, much of the heat energy is used to break hydrogen bonds holding the individual water molecules together. By using heat energy to break these bonds, water is able to absorb a great deal of energy without an according rise in temperature. This is why it takes so long to boil a pot of water. The flame beneath the pot is delivering a great deal of heat energy to the water, but this energy first goes to breaking hydrogen bonds. It takes several minutes before the water temperature begins to increase noticeably. This ability of water to store heat protects organisms from otherwise harmful changes in temperature.



Adhesion is the property of one substance clinging to another substance. Water is a polar molecule and adheres to other polar substances. In a common science demonstration, two glass slides - held slightly apart from one another - are dipped into a beaker of water. Water immediately begins moving up the space between the slides. The tendency of water to move up a small space or tube via electrostatic attraction is known as capillary action. Plants use this property to move water up from their roots to their leaves.

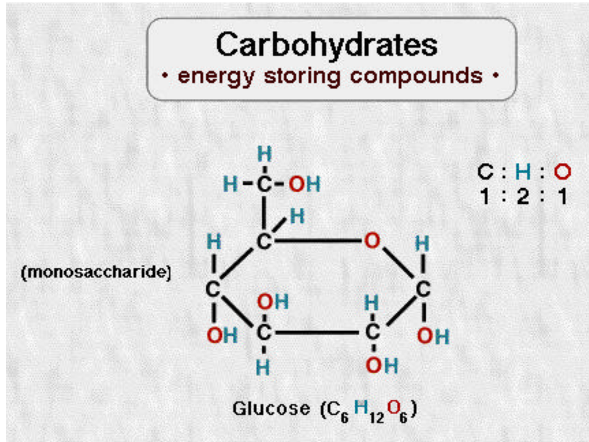
By virtue of being an adhesive, polar molecule, water is a good solvent. That is, many polar compounds will dissolve easily in water. These molecules dissolve easily in water because hydrogen bonds quickly form between water and the other polar molecules. Ammonia (NH_3) is an example of a polar molecule easily dissolved into water.

Ionic compounds such as table salt (NaCl) dissolve quite easily in water as well. NaCl dissociates into Na^+ ions and Cl^- ions when put in water. The electronegative oxygen atoms in H_2O attract the positive sodium ions and the slightly positive hydrogen atoms in H_2O attract the negatively charged chloride ions.

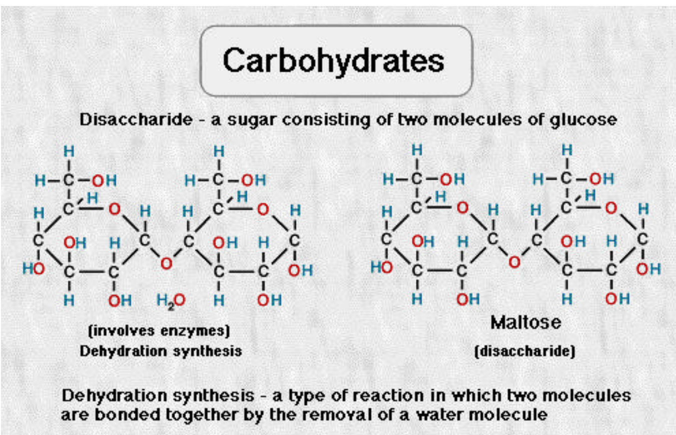
Not all compounds dissolve into water, however. Fats and oils, as you'll learn later, are examples of substances that are not soluble in water.

Study Guide #7
Carbohydrates

Carbohydrates are one of the vital groups of organic molecules mentioned earlier. Carbohydrates are energy-storing compounds containing only the elements carbon, hydrogen, and oxygen. The ratio of these three elements is 1:2:1 in most carbohydrates. That means, there are exactly twice as many hydrogen atoms as there are carbon and oxygen atoms. (i.e. $C_6 H_{12} O_6$).

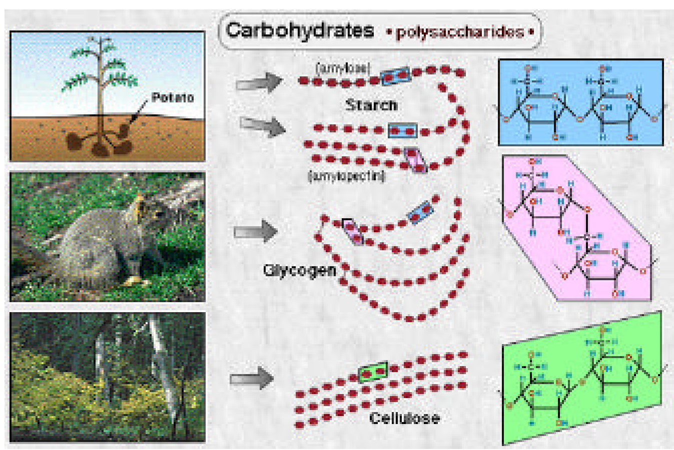


The simplest carbohydrates are called monosaccharides. The most common monosaccharide is the sugar glucose.



Simple sugar molecules can be linked together to form much longer molecules. Two of these simple sugars linked together form a disaccharide. The disaccharide maltose is formed by dehydration synthesis. This process takes its name from the fact that the removal of water is involved in forming the bond linking the two sugars together.

When more than two simple sugars are linked, a polysaccharide is formed. Starch is an energy-storing polysaccharide found in plants. Glycogen is the energy-storing polysaccharide found in animals. The tough, cell walls of plants are composed of the very rigid polysaccharide cellulose. These three polysaccharides - starch, glycogen, and cellulose - have no



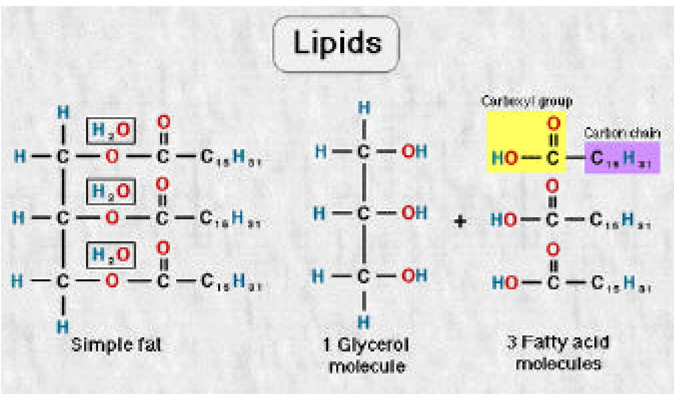
fixed size limits. They can range from hundreds to thousands of glucose molecules in length.

Hydrolysis is the process by which large polysaccharides are broken down into the simple sugars from which they were composed. In this process, a molecule of water reacts with the chain. The bond that was originally formed by the removal of water (dehydration synthesis) is then broken by the addition of water (hydrolysis).

Study Guide #8
Lipids

Another vital group of organic molecules is lipids. These compounds include fats, oils, waxes, phospholipids, and steroids. All lipids share one trait in common; the are not water-soluble.

The most common lipids in human diets and bodies are simple fats. A simple fat molecule is composed of glycerol (which is a simple sugar) and 3 fatty acids. A fatty acid is a chain of carbon and hydrogen atoms with an acid group, known as a carboxyl group, at one end.

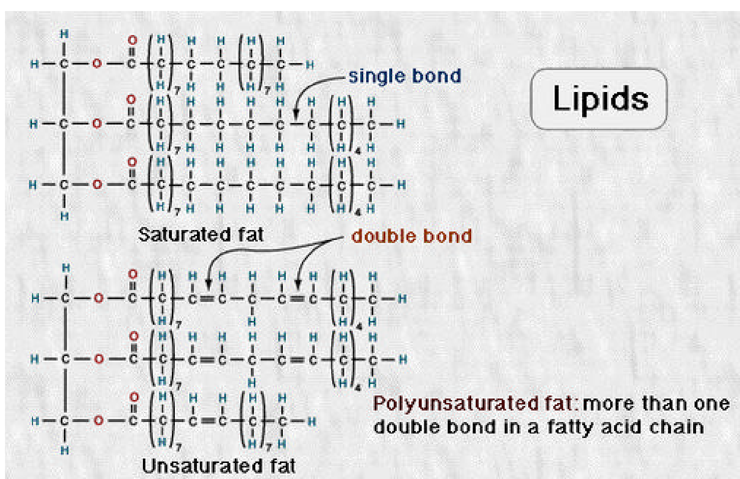


Like carbohydrates, lipids are important energy-storing molecules. However, lipids store about twice as much energy, molecule for molecule, as carbohydrates do. This property makes fats highly efficient at storing energy. There are two categories of fats; saturated and unsaturated.

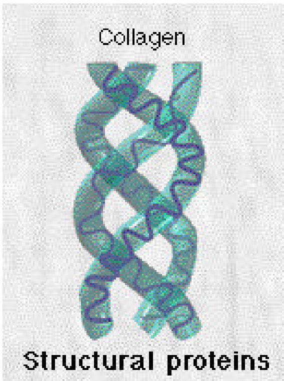
Saturated fats are formed from fatty acids with single carbon-to-carbon bonds. Unsaturated fats are formed from fatty acids with at least one double carbon-to-carbon bond. Polyunsaturated fats have more than one double bond.

An unsaturated fat at room temperature tends to be an oil, such as vegetable oil. A saturated fat at room temperature tends to be solid. Butter is an example of a saturated fat.

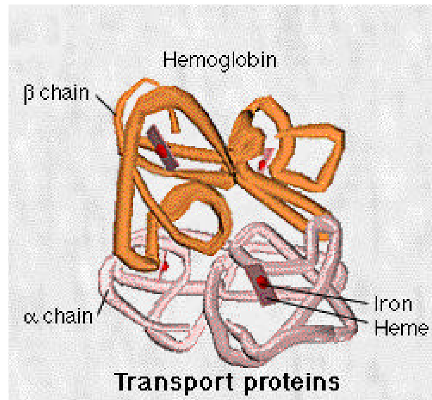
An unsaturated fat can be changed to a saturated fat by a process known as hydrogenation. During hydrogenation, hydrogen atoms are added to the unsaturated fat. The additional hydrogen atoms are incorporated into the unsaturated fat, changing the double bonds into single bonds.



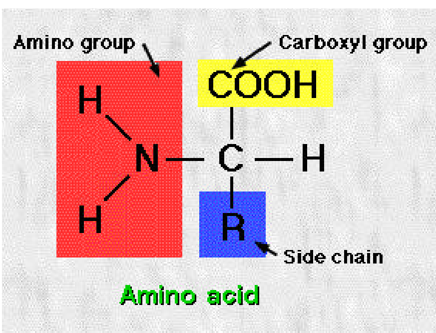
Study Guide #9
Proteins



Proteins are yet another vital group of organic molecules. There are structural proteins, such as collagen, that function as cellular support. There are transport proteins, such as the oxygen-carrying protein in blood, called hemoglobin. Other proteins include enzymes, which speed up reaction rates, and defensive proteins such as antibodies, which help protect against disease.

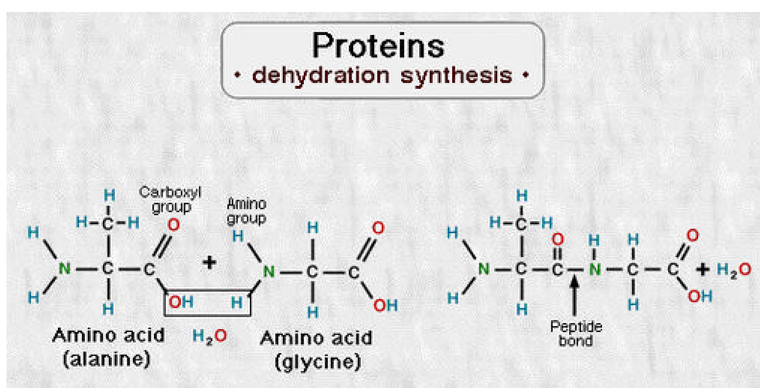


Proteins are composed of amino acids. An amino acid always contains a central carbon atom, a carboxyl group, a nitrogen containing (amino) group, a hydrogen atom, and a side chain.



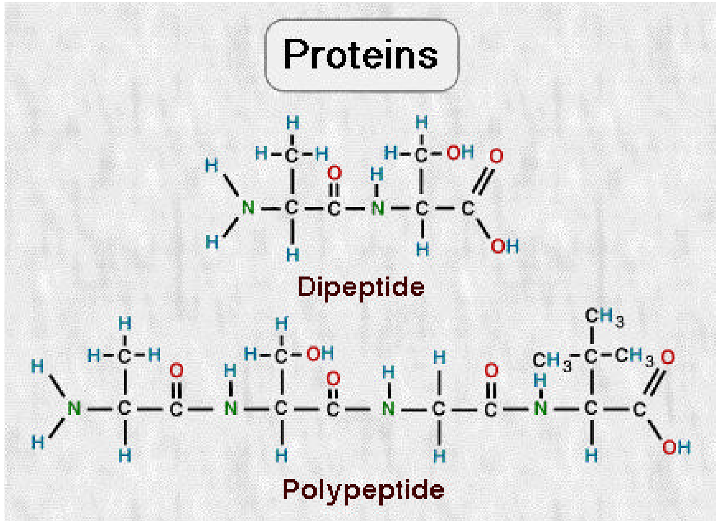
There are 20 different amino acids. What differentiates one amino acid from another is the composition of their side chains.

Dehydration synthesis is important in the formation of proteins. By the mechanism of dehydration synthesis, peptide bonds are formed between amino acids. A peptide bond forms between the carboxyl group of one amino acid and the amino group of a second amino acid. Water is lost in the formation of this bond.

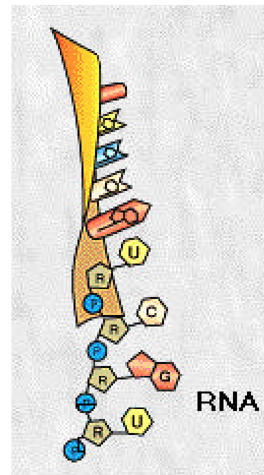


When two amino acids are linked together, a dipeptide has been formed. A long chain of amino acids is called a polypeptide.

Most enzymes are composed of several individual polypeptide subgroups bound together. Enzymes speed up, or catalyze, reaction rates. Without enzymes, most reactions required for you to survive would occur much too slowly. Some of these vital reactions are involved in such processes as digestion, synthesis of molecules, and the storage of, or release of, energy.



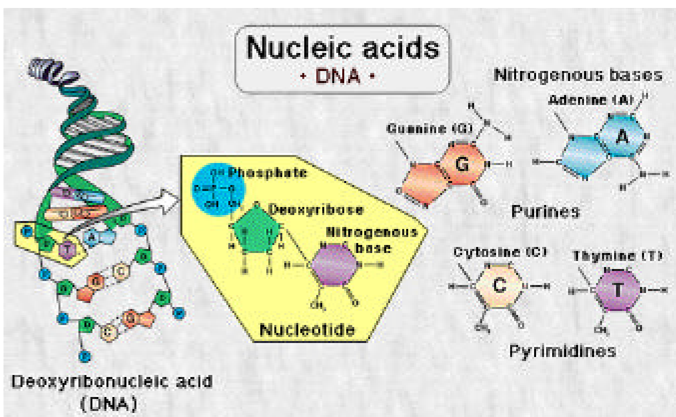
Study Guide #10
Nucleic Acids



The final category of organic molecules we'll look at are the nucleic acids. There are two types of nucleic acids; deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

DNA is the hereditary material passed on from parent to offspring. Contained in DNA are all of the instructions needed to produce a new organism. Once an organism is formed, DNA continues to direct the day-to-day operations that take place inside that organism.

The basic unit of DNA is the nucleotide. Each nucleotide consists of a five carbon sugar called deoxyribose, a phosphate group, and a nitrogenous base.



There are four nitrogenous bases in DNA. These are adenine, guanine, cytosine, and thymine. Adenine and guanine are both purines, and cytosine and thymine are both pyrimidines.

The structure of DNA is called a double helix (like a twisted ladder spiraling from end to end). The sides of this DNA ladder consist of alternating sugar and phosphate groups. The rungs consist of the nitrogenous bases.

DNA bases pair up in a very specific manner. Adenine always pairs with thymine. Guanine always pairs with cytosine. Hydrogen bonds connect the bases in a pair.

RNA helps turn information encoded in DNA into proteins. Although the chemical makeup of RNA is similar to DNA, there are some important differences. The sugar in RNA is ribose instead of deoxyribose. In RNA, the base thymine is replaced by the base uracil. Finally, RNA is structurally different from DNA in that RNA consists of a single strand of nucleic acid instead of two strands.

Biochemistry: The Chemistry of Life
Quiz Pac

The following quizzes are based on information presented in the Interactive Biology program, Biochemistry*: The Chemistry of Life.* Many, but not all, of these questions have been addressed directly in the study guides designed to strengthen student understanding of these topics.

QUIZ #1	Atoms and Their Structure
QUIZ #2	Elements, Molecules, and Compounds
QUIZ #3	Chemical Bonds
QUIZ #4	Covalent Bonds
QUIZ #5	Ionic and Hydrogen Bonds
QUIZ #6	Water
QUIZ #7	Carbohydrates
QUIZ #8	Lipids
QUIZ #9	Proteins
QUIZ #10	Nucleic Acids

Quiz #1
Atoms and Their Structure

1. Democritus proposed that "all matter is composed of tiny, indivisible particles called atoms".

   A. True
   B. False

2. Some, but not all, atoms have a central core called the nucleus.

   A. True
   B. False

3. A nucleus is composed of ________ and ________.

   A. protons, electrons
   B. electrons, neutrons
   C. protons, neutrons
   D. All of the above.

4. Orbiting the nucleus in "shells" are ________.

   A. protons
   B. electrons
   C. neutrons

5. Protons have ________.

   A. no charge
   B. a positive charge
   C. a negative charge

6. Neutrons have ________.

   A. no charge
   B. a positive charge
   C. a negative charge

7. Electrons have ________.

   A. no charge
   B. a positive charge
   C. a negative charge

8. If the positive and negative charges on an atom are balanced, then the atom is ________.

   A. electrically neutral
   B. electrically active
   C. unstable
   D. very unstable

Quiz #2
Elements, Molecules, and Compounds

1. Elements are compounds that can be broken down into different atoms.

   A. True
   B. False

2. Elements are arranged on a periodic table.

   A. True
   B. False

3. The atomic number represents the number of ________ in an atom.

   A. neutrons
   B. protons
   C. electrons

4. 96% of all living material is composed of the elements ________.

   A. hydrogen, carbon, iron, and oxygen
   B. silica, carbon, nitrogen, and oxygen
   C. hydrogen, helium, oxygen, carbon
   D. hydrogen, carbon, nitrogen, and oxygen

5. The first electron shell can hold ________ electrons and the outer electron shells can hold up to ________ electrons.

   A. 2, 4
   B. 4, 2
   C. 2, 8
   D. 8, 2

6. Atoms with filled outer shells ________ usually chemically active.

   A. are
   B. are not

7. ________ are formed when two or more _______ combine.

   A. Atoms, molecules
   B. Molecules, atoms
   C. Elements, atoms
   D. Atoms, elements

8. If two different types of elements combine, such as oxygen and hydrogen, a ________ is formed.

   A. super element
   B. free radical
   C. compound
   D. new atom

9. Organic compounds _________ contain carbon.

   A. do
   B. do not

10. With only two exceptions, inorganic compounds _________ contain carbon.

   A. do
   B. do not

Quiz #3
Chemical Bonds

1. The number of valence electrons determine how many bonds an atom is able to form.

   A. True
   B. False

2. An atom with 2 valence electrons may form ________ bond.

   A. 2 single
   B. 1 double
   C. 1 triple
   D. A and B only.

3. A structural formula shows ________.

   A. what atoms are present in the molecule
   B. how the atoms are connected to one another
   C. Both A and B.

4. A single bond is depicted as ________.

   A. a single line connecting two atoms
   B. two parallel lines connecting two atoms
   C. three parallel lines connecting two atoms

5. A double bond is depicted as _________.

   A. a single line connecting two atoms
   B. two parallel lines connecting two atoms
   C. three parallel lines connecting two atoms

6. A triple bond is depicted as _________.

   A. a single line connecting two atoms
   B. two parallel lines connecting two atoms
   C. three parallel lines connecting two atoms

Quiz #4
Covalent Bonds

1. Life is considered to be "carbon based".

   A. True
   B. False

2. The three categories of chemical bonds are covalent, ionic, and hydrogen.

   A. True
   B. False

3. A covalent bond is one in which electrons are ________ and is very ________.

   A. donated, strong
   B. donated, weak
   C. shared, strong
   D. shared, weak

4. In the compound methane (CH_4), the carbon and hydrogen atoms _________.

   A. are held together with hydrogen bonds
   B. share a common nucleus
   C. all have filled outer electron shells

5. In water, the oxygen atom is _________than the hydrogen atoms.

   A. more stable than
   B. less stable than
   C. more electronegative than
   D. less electronegative than

Quiz #5
Ionic and Hydrogen Bonds

1. Sodium chloride (NaCl) is an example of ionic bonding.

   A. True
   B. False

2. An ion is an atom lacking an electrical charge.

   A. True
   B. False

3. In ionic bonds, one atom ________another atom.

   A. donates an ion to
   B. shares an ion with
   C. donates an electron to
   D. shares an electron with

4. When an atom loses an electron, it becomes more ________ charged.

   A. negatively
   B. positively

5. When an atom gains an electron, it becomes more ________ charged.

   A. negatively
   B. positively

6. The basis behind an ionic bond is _________ between two atoms.

   A. the movement of protons
   B. an exchange of neutrons
   C. an electrostatic attraction
   D. an ion exchange

7. A hydrogen bond is formed through a weak electrical attraction between a hydrogen atom bound to an electronegative atom and ________.

A. a second electronegative atom
B. a second hydrogen atom bound to another electronegative atom
C. a hydrogen atom bound to the same electronegative atom

8. Hydrogen bonds are about 20 times ________ than covalent bonds.

A. stronger
B. weaker

Quiz #6
Water

1. Water is a poor solvent.

   A. True
   B. False

2. Some important qualities of water are adhesion, cohesion, and the ability to store heat.

   A. True
   B. False

3. The property of water molecules "sticking" to one another is called _________.

   A. adhesion
   B. cohesion

4. ________ are the principal cause of water molecules "sticking" to each other.

   A. Ionic bonds
   B. Covalent bonds
   C. Hydrogen bonds

5. The ability of water to store heat tends to ________ organisms.

   A. have no effect on
   B. protect
   C. harm

6. The property of one substance clinging to another is ________.

   A. adhesion
   B. cohesion

7. The tendency of water to move up a small tube via electrostatic attraction is known as _________.

A. fluidity
B. viscosity
C. capillary action
D. turgor pressure

8. Many ________ compounds tend to dissolve easily in water.

A. polar
B. ionic
C. hydrophobic
D. All of the above.
E. A and B only.

9. ________ are examples of compounds that are not soluble in water.

A. Ammonia and table salt
B. Fats and oils

Quiz #7
Carbohydrates

1. The simplest carbohydrates are monosaccharides, the most common of which is glucose.

   A. True
   B. False

2. Most carbohydrates consist of carbon, hydrogen, and oxygen in the ratio of _______.

   A. 2:1:2
   B. 1:2:3
   C. 1:2:1
   D. 1:1:1

3. Two simple sugars linked together are a _________.

   A. bisaccharide
   B. disaccharide
   C. polysaccharide
   D. multisaccharide

4. More than two simple sugars linked together form a ________.

   A. bisaccharide
   B. disaccharide
   C. polysaccharide
   D. multisaccharide

5. ________ is the mechanism by which simple sugars are linked together.

   A. Hydrolysis
   B. Hydrogenation
   C. Dehydration synthesis

6. ________ breaks down long chains of simple sugars.

   A. Hydrolysis
   B. Hydrogenation
   C. Dehydration synthesis

7. ________ is the energy-storing molecule in plants.

   A. Cellulose
   B. Glycogen
   C. Starch

8. ________ is the energy-storing molecule in animals.

   A. Cellulose
   B. Glycogen
   C. Starch

9. ________ is the rigid molecule composing plant cell walls.

   A. Cellulose
   B. Glycogen
   C. Starch

Quiz #8
Lipids

1. A fatty acid is a chain of carbon and hydrogen atoms with a phosphate group at one end.

   A. True
   B. False

2. Lipids include fats, oils, waxes, phospholipids, and steroids.

   A. True
   B. False

3. A simple fat is composed of ________ and _________ fatty acids.

   A. carbon, 3
   B. carbon, 6
   C. glycerol, 3
   D. glycerol, 6

4. Lipids store ________ energy than carbohydrates.

   A. less
   B. more

5. The fatty acids in saturated fats have ________.

   A. all single carbon-to-carbon bonds
   B. at least one double carbon-to-carbon bond

6. The fatty acids in unsaturated fats have ________.

   A. single carbon-to-carbon bonds
   B. at least one double carbon-to-carbon bond

7. An unsaturated fat at room temperature tends to be ________.

   A. solid
   B. an oil

8. A saturated fat at room temperature tends to be ________.

   A. solid
   B. an oil

9. An unsaturated fat can be changed to a saturated fat by the process known as ________.

   A. Hydrolysis
   B. Hydrogenation
   C. Dehydration synthesis

Quiz #9
Proteins

1. Proteins are constructed from amino acids.

   A. True
   B. False

2. There are thousands of different amino acids.

   A. True
   B. False

3. What differentiates one amino acid from another amino acid are their ________.

   A. carboxyl groups
   B. amino groups
   C. side chains
   D. hydrogen atoms

4. ________ is a structural protein and ________ is a protein involved in the transport of oxygen.

   A. Glycogen, collagen
   B. Glycogen, hemoglobin
   C. Hemoglobin, collagen
   D. Collagen, hemoglobin

5. ________ are the bonds that link one amino acid to another.

   A. Hydrogen bonds
   B. Amino bonds
   C. Peptide bonds

6. The bond in question #5 forms between ________ of one amino acid and ________ of the second amino acid.

   A. the carboxyl group, the amino group
   B. the carboxyl group, the phosphate group
   C. the phosphate group, the amino group

7. Enzymes ________ chemical reaction.

   A. play no role in
   B. slow down
   C. catalyze

Quiz #10
Nucleic Acids

1. There are two nucleic acids, RNA and DNA.

   A. True
   B. False

2. DNA stands for dihydronucleic acid.

   A. True
   B. False

3. RNA is the hereditary material passed from parent to offspring.

   A. True
   B. False

4. The basic unit of DNA is ________.

   A. the phospholipid
   B. the chromosome
   C. the nucleotide
   D. All of the above.

5. DNA consists of ________.

   A. the sugar deoxyribose
   B. phosphate groups
   C. nitrogenous bases
   D. All of the above.

6. Which of the following is NOT found in DNA?

   A. Adenine
   B. Uracil
   C. Thymine
   D. Guanine

7. Which of the following is NOT found in RNA?

   A. Adenine
   B. Uracil
   C. Thymine
   D. Guanine

8. ________ forms a double helix, ________ consists of a single strand.

   A. DNA, RNA
   B. RNA, DNA

9. In forming base pairs, ________ pairs with cytosine.

   A. guanine
   B. cytosine
   C. thymine
   D. adenine

10. In forming base pairs, _______ pairs with guanine.

   A. guanine
   B. cytosine
   C. thymine
   D. adenine

11. In forming base pairs, _______ pairs with thymine in DNA.

   A. guanine
   B. cytosine
   C. thymine
   D. adenine

12. ________ bonds link base pairs.

   A. Hydrogen bonds
   B. Ionic bonds
   C. Covalent bonds

13. RNA helps turn information held in DNA into ________.

   A. lipids
   B. carbohydrates
   C. proteins

Biochemistry: The Chemistry of Life
Comprehensive Exam

The following exam is based on the Interactive Biology Multimedia Courseware program, *Biochemistry: The Chemistry of Life.* Most, but not all, of these questions have been addressed directly in the study guides. All of the questions on this exam, however, are based on information put forth in the program.

Please determine if the following statements are true or false.

1. Democritus proposed that "all matter is composed of tiny, indivisible particles called atoms".

   A. True
   B. False

2. Some, but not all, atoms have a central core called the nucleus.

   A. True
   B. False

3. Elements are compounds that can be broken down into different atoms.

   A. True
   B. False

4. Molecules are arranged on a periodic table.

   A. True
   B. False

5. The three categories of chemical bonds are covalent, ionic, and hydrogen.

   A. True
   B. False

6. An ion is an atom lacking an electrical charge.

   A. True
   B. False

7. Water is a poor solvent.

   A. True
   B. False

8. Proteins are constructed from amino acids.

   A. True
   B. False

9. There are two nucleic acids, RNA and DNA.

   A. True
   B. False

10. RNA is the hereditary material passed from parent to offspring.

   A. True
   B. False

In the following portion of the exam, please select the letter next to the word or phrase that best completes each sentence.

11. A nucleus is composed of ________ and ________.

   A. protons, electrons
   B. electrons, neutrons
   C. protons, neutrons
   D. All of the above.

12. Orbiting the nucleus in "shells" are ________.

A. protons
B. electrons
C. neutrons

13. Protons have ________.

A. no charge
B. a positive charge
C. a negative charge

14. Neutrons have ________.

A. no charge
B. a positive charge
C. a negative charge

15. Electrons have ________.

A. no charge
B. a positive charge
C. a negative charge

16. 96% of all living material is composed of the elements ________.

A. hydrogen, carbon, iron, and oxygen
B. silica, carbon, nitrogen, and oxygen
C. hydrogen, helium, oxygen, carbon
D. hydrogen, carbon, nitrogen, and oxygen

17. The first electron shell can hold ________ electrons and the outer electron shells can hold up to ________ electrons.

A. 2, 4
B. 4, 2
C. 2, 8
D. 8, 2

18. ________ are formed when two or more _______ combine.

A. Atoms, molecules
B. Molecules, atoms
C. Elements, atoms
D. Atoms, elements

19. If two different types of elements combine, such as oxygen and hydrogen, a ________ is formed.

A. super element
B. free radical
C. compound
D. new atom

20. A covalent bond is one in which electrons are ________ and is very ________.

A. donated, strong
B. donated, weak
C. shared, strong
D. shared, weak

21. In ionic bonds, one atom ________another atom.

A. donates an ion to
B. shares an ion with
C. donates an electron to
D. shares an electron with

22. When an atom loses an electron, it becomes more ________ charged.

A. negatively
B. positively

23. The basis behind an ionic bond is _________ between two atoms.

A. the movement of protons
B. an exchange of neutrons
C. an electrostatic attraction
D. an ion exchange

24. A hydrogen bond is formed through a weak electrical attraction between a hydrogen atom bound to an electronegative atom and ________.

A. a second electronegative atom
B. a second hydrogen atom bound to another electronegative atom
C. a hydrogen atom bound to the same electronegative atom

25. The property of water molecules "sticking" to one another is called _________.

A. adhesion
B. cohesion

26. ________ are the principal cause of water molecules "sticking" to each other.

A. Ionic bonds
B. Covalent bonds
C. Hydrogen bonds

27. The property of one substance clinging to another is ________.

A. adhesion
B. cohesion

28. Many ________ compounds tend to dissolve easily in water.

A. polar
B. ionic
C. hydrophobic
D. All of the above.
E. A and B only.

29. Most carbohydrates consist of carbon, hydrogen, and oxygen in the ratio of _______.

A. 2:1:2
B. 1:2:3
C. 1:2:1
D. 1:1:1

30. More than two simple sugars linked together form a ________.

A. bisaccharide
B. disaccharide
C. polysaccharide
D. multisaccharide

31. ________ is the mechanism by which simple sugars are linked together.

A. Hydrolysis
B. Hydrogenation
C. Dehydration synthesis

32. ________ breaks down long chains of simple sugars.

A. Hydrolysis
B. Hydrogenation
C. Dehydration synthesis

33. ________ is the energy-storing molecule in plants.

A. Cellulose
B. Glycogen
C. Starch

34. ________ is the energy-storing molecule in animals.

A. Cellulose
B. Glycogen
C. Starch

35. ________ is the rigid molecule composing plant cell walls.

A. Cellulose
B. Glycogen
C. Starch

36. A simple fat is composed of ________ and _________ fatty acids.

A. carbon, 3
B. carbon, 6
C. glycerol, 3
D. glycerol, 6

37. Lipids store ________ energy than carbohydrates.

A. less
B. more

38. The fatty acids in saturated fats have ________.

A. all single carbon-to-carbon bonds
B. at least one double carbon-to-carbon bond

39. An unsaturated fat at room temperature tends to be ________.

A. solid
B. an oil

40. What differentiates one amino acid from another amino acid are their ________.

A. carboxyl groups
B. amino groups
C. side chains
D. hydrogen atoms

41. ________ are the bonds that link one amino acid to another.

A. Hydrogen bonds
B. Amino bonds
C. Peptide bonds

42. DNA consists of ________.

A. the sugar deoxyribose
B. phosphate groups
C. nitrogenous bases
D. All of the above.

43. Which of the following is NOT found in DNA?

A. Adenine
B. Uracil
C. Thymine
D. Guanine

44. Which of the following is NOT found in RNA?

A. Adenine
B. Uracil
C. Thymine
D. Guanine

45. ________ forms a double helix, ________ consists of a single strand.

A. DNA, RNA
B. RNA, DNA

46. In forming base pairs, ________ pairs with cytosine.

A. guanine
B. cytosine
C. thymine
D. adenine

47. In forming base pairs, _______ pairs with guanine.

A. guanine
B. cytosine
C. thymine
D. adenine

48. In forming base pairs, _______ pairs with thymine.

A. guanine
B. cytosine
C. thymine
D. adenine

49. RNA helps turn information held in DNA into ________.

A. lipids
B. carbohydrates
C. proteins

In the following portion of the exam, please fill in the word or words that best completes each sentence.

50. The basic unit of DNA is the ____________________________.

51. Enzymes ___________________________________ chemical reactions.

52. The atomic number represents the number of
_________________________ possessed by an atom.

53. The number of bonds an atom is able to form is determined by the number of ____ the atom has.

54. Organic compounds ________________________ contain carbon.

55. The tendency of water to move up a small tube via electrostatic attraction is known as ____.

Biochemistry: The Chemistry of Life
Answer Guide

Quiz Pac

Quiz 1	Quiz 2	Quiz 3	Quiz 4	Quiz 5	Quiz 6	Quiz 7	Quiz 8	Quiz 9	Quiz 10
1. A	1. B	1. A	1. A	1. A	1. B	1. A	1. B	1. A	1. A
2. B	2. A	2. D	2. A	2. B	2. A	2. C	2. A	2. B	2. B
3. C	3. B	3. C	3. C	3. C	3. B	3. B	3. C	3. C	3. B
4. B	4. A	4. A	4. C	4. B	4. C	4. C	4. B	4. D	4. C
5. B	5. C	5. B	5. C	5. A	5. B	5. C	5. A	5. C	5. D
6. A	6. B	6. C		6. C	6. A	6. A	6. B	6. A	6. B
7. C	7. B			7. A	7. C	7. C	7. B	7. C	7. C
8. A	8. C			8. B	8. E	8. B	8. A		8. A
	9. A				9. B	9. A	9. A		9. A
	10. B								10. B
									11. D
									12. A
									13. C

Comprehensive Exam

1. A	11. C	21. C	31. C	41. C	51. catalyze (or speed up)
2. B	12. B	22. B	32. A	42. D	52. proton
3. B	13. B	23. C	33. C	43. B	53. valence electrons
4. B	14. A	24. A	34. B	44. C	54. do
5. A	15. C	25. B	35. A	45. A	55. capillary action
6. B	16. D	26. C	36. C	46. A	
7. B	17. C	27. A	37. B	47. B	
8. A	18. B	28. E	38. A	48. D	
9. A	19. C	29. C	39. B	49. C	
10. B	20. C	30. C	40. C	50. nucleotide	

Biochemistry: The Chemistry of Life
GLOSSARY

adhesion: the attraction between molecules of two different substances.

amino acid: the basic building block of proteins, consisting of a carboxyl group (COOH), an amino group (NH_2), and a side chain (R).

amino group: a chemical group found in amino acids, consisting of one atom of nitrogen and two atoms of hydrogen.

atom: the smallest basic building block of matter; contains a nucleus of protons and neutrons, around which electrons orbit.

atomic number: the number of protons in the nucleus of an atom.

base-pairing: the linking together of two helical strands of DNA by bonds between complementary bases, adenine pairing with thymine and guanine with cytosine.

capillary action: the upward movement of a liquid through a tube of narrow diameter; capillary action is the result of adhesion.

carbohydrate: organic compounds of carbon, hydrogen, and oxygen in which the ratio of carbon to hydrogen to oxygen is 1:2:1; carbohydrates are important energy-storing compounds.

carboxyl group: the characteristic chemical group of organic acids, consisting of one atom of carbon, one atom of hydrogen, and two atoms of oxygen.

cellulose: a polysaccharide found in plant cell walls that gives plants their rigid structure.

chemical formula: a written representation of a compound in which an element is represented by its chemical symbol; when more than one atom of a particular element is present, the number of each element is written as subscript next to each element.

cholesterol: an essential steroid found in most animal tissues; too much cholesterol leads to hardening of the arteries and heart disease.

cohesion: the attraction between molecules of the same substance; cohesion between water molecules enables water to form drops and store heat.

compound: the combination of two or more atoms of different elements.

covalent bond: a bond formed between atoms in which electrons in the outer electron shell (valence electrons) of each atom are shared so as to fill the outer electron shell of each atom.

dehydration synthesis: a type of reaction in which two molecules are bonded together by the removal of a water molecule.

deoxyribonucleic acid (DNA): a nucleic acid found in all cells; DNA is the hereditary material passed from parents to offspring.

dipeptide: a molecule consisting of two amino acids.

disaccharide: a sugar consisting of two molecules of glucose.

electron: an atomic particle with a negative electric charge; electrons orbit the nucleus of an atom.

electron shell: also called an energy level; a region of space around the nucleus of an atom in which electrons move.

electronegativity: the ability of the nucleus of an atom to attract electrons from other atoms.

element: a substance made of only one kind of atom; an element cannot be broken down to other substances by chemical reactions.

enzyme: a type of protein that acts as a catalyst and therefore speeds up chemical reactions in living cells.

fatty acid: an organic molecule consisting of two parts: a chain of carbon atoms, and one or more carboxyl groups (COOH).

glucose: a simple sugar that serves as the basic building block of complex carbohydrates.

glycerol: a simple sugar that combines with 3 fatty acids to form a simple fat.

glycogen: animal starch; the energy-storing polysaccharide of animals.

hydrogenation: the process by which hydrogen atoms are added to an unsaturated fat, causing it to become a saturated fat.

hydrogen bond: a chemical bond formed by a weak electrical attraction between a hydrogen atom attached to an electronegative atom such as oxygen or nitrogen, and another electronegative atom.

hydrolysis: the process by which molecules are disassembled by the addition of water molecules.

inorganic compound: any compound that is not an organic compound; inorganic compounds usually do not contain carbon.

ion: an atom or group of atoms with an excess electrical charge.

ionic bond: the force of attraction between two ions in a chemical compound.

lipid: an organic compound other than a carbohydrate, that consists of carbon, hydrogen, and oxygen; fats, oils, or waxes.

molecule: a group of atoms bound by covalent bonds with no electrical charge.

neutron: a particle in the nucleus of an atom with no electrical charge; neutrons have about the same mass as protons.

nitrogenous base: a nitrogen-containing compound found in nucleic acids; the nitrogenous bases are divided into purines (adenine, guanine) and pyrimidines (thymine, cytosine).

non-polar bond: a covalent bond between atoms in which valence electrons are shared equally.

nucleic acid: an organic compound that contains phosphorus and nitrogen in addition to carbon, hydrogen, and oxygen; DNA or RNA.

nucleotide: the basic building block of nucleic acids; consists of a five-carbon sugar, a phosphate group and a nitrogenous base.

organic compound: a compound that contains the element carbon and occurs naturally in living things.

peptide bond: the bond formed between two amino acids by dehydration synthesis.

phosphate group: a molecule containing one atom of phosphorus and four atoms of oxygen, that is bound to a five-carbon sugar to form the side chain of a nucleic acid.

polar bond: a covalent bond between atoms in which the valence electrons are not shared equally; the electrons spend more time orbiting the nucleus of the more electronegative atom of the compound.

polypeptide: a chain of amino acids joined by peptide bonds.

polysaccharide: a chain of repeating sugar units formed by joining simple sugars (glucose molecules) by dehydration synthesis.

protein: an organic compound consisting of one or more polypeptides.

proton: a particle in the nucleus of an atom that carries a positive electrical charge.

purines: in nucleic acids (i.e. DNA and RNA), the nitrogenous bases adenine and guanine.

pyrimidines: in nucleic acids (i.e. DNA and RNA), the nitrogenous bases cytosine, thymine, and uracil.

ribonucleic acid (RNA): a nucleic acid, consisting of a single strand of nucleotides, that is involved in the transcription and translation of the genetic code.

saturated fat: a fat formed from fatty acids in which all carbon-to-carbon bonds are single bonds.

solute: the substance which dissolves in the solvent to form a solution.

solvent: the liquid in which the solute dissolves to form a solution.

starch: the energy-storing polysaccharide of plants .

structural formula: a chemical formula that shows how atoms are bonded together.

trace elements: elements needed only in minute quantities by living organisms.

unsaturated fat: a fat formed by fatty acids in which one or more pairs of carbon atoms are bound by double, or in some cases triple, bonds.

valence electrons: electrons occupying the outermost electron shell surrounding an atom.