Basic Biochemistry

- Biochemistry is the chemistry of life.
- In this section we will examine the major groups of molecules that make up living organisms along with some of the properties and functions of these molecules.

1

Objective # 1

Distinguish between organic and inorganic molecules.

2

Objective 1

- Inorganic molecules:
  - Relatively small, simple molecules that usually lack C (a few have one C atom).
  - Examples: CO_2, NH_3, H_2O, O_2, H_2

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Objective 1

- Organic molecules:
  - Larger, more complex molecules whose structure is based on a backbone of C atoms (always contain C as a major part of their structure).
  - Examples: $C_6H_{12}O_6$, C_2H_5COOH
- Living organisms are composed of both inorganic and organic molecules.

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Objective # 2

Describe the structure of the water molecule. List and describe the properties of water, and explain why these properties are so important to all living organisms.

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Objective 2

- Water is a small polar molecule made of one oxygen atom joined to 2 hydrogen atoms.
- Polar means that even though the molecule as a whole is neutral, there are localized regions of positive and negative charge due to an unequal sharing of electrons between the atoms of the molecule.

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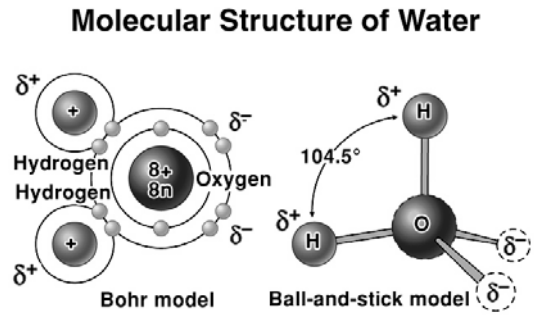
Objective 2

- In the water molecule, the oxygen atom has a slight negative charge and the 2 hydrogen atoms have slight positive charges.

Objective 2



Objective 2, Properties of Water

Cohesion	Water molecules attract other water molecules
Adhesion	Water molecules attract other charged substances
Surface tension	Surface water molecules cling to each other
Capillarity	Water molecules are drawn up a narrow tube

Objective 2, Properties of Water

Objective 2, Properties of Water

High specific heat	A large amount of heat must be absorbed or lost to change the temp. of water
High heat of vaporization	A large amount of heat needed to change water from a liquid to a gas
High heat of fusion	A large amount of heat needed to change water from a solid to a liquid

Objective 2, Properties of Water

Lower density as a solid	Below 0°C a regular crystalline structure forms
Dissolves ions and polar molecules	Substances attracted to water are called hydrophilic
Repels nonpolar molecules	Substances repelled by water are called hydrophobic

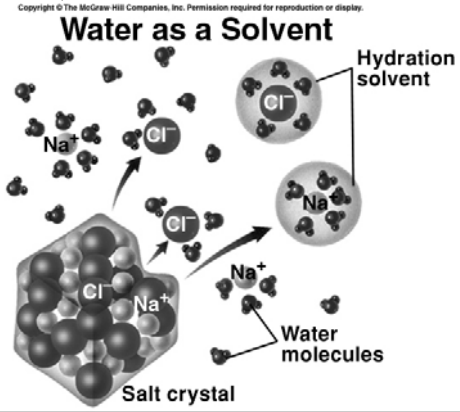
Objective # 3

Describe the process of dissociation and be able to distinguish between acids, bases, and salts.

Objective 3

- Because of the polar structure of water, many ionic and polar substances are pulled apart into oppositely charged ions when they dissolve in water. This is called ionization or dissociation.

Objective 3, Dissociation of NaCl



Objective 3

- Substances held together by relatively weak ionic bonds show a large amount of dissociation in water:
  - $NaCl \rightarrow Na+ + Cl-$
- These substances are called salts. Because they are good conductors of electricity, they are also called electrolytes.

Objective 3

- Substances held together by stronger covalent bonds may also show some dissociation when dissolved in water:
  - $CH_3COOH \rightarrow CH_3COO^- + H^+$
- In fact, water itself undergoes a small amount of dissociation:
  - $H_2O \rightarrow H^+ + OH^-$

Objective 3

- Substances that increase the $[H^+]$ of a solution when they dissociate are called acids:
  - $HCl \rightarrow H^+ + Cl^-$
- Substances that increase the $[OH^-]$ of a solution when they dissociate are called bases:
  - $NaOH \rightarrow Na^+ + OH^-$

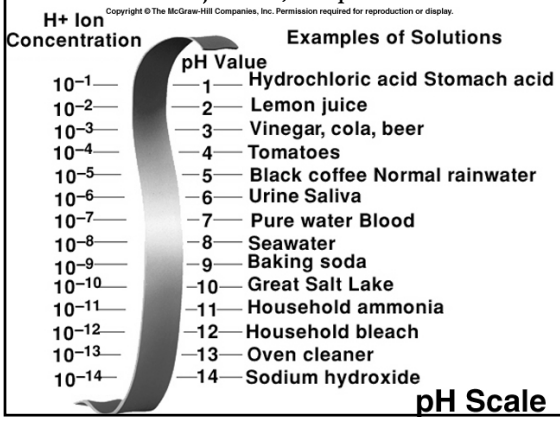
Objective # 4

Describe the pH scale and know how to use it.

Objective 4

- pH is used to measure how acidic or basic a solution is:
  - the pH scale runs from 0 to 14 with 7 being neutral.
  - the lower below 7, the more acidic a solution is
  - the higher above 7, the more basic or alkaline a solution is.

Objective 4, The pH Scale



Objective # 5

Explain the role that buffers play in living organisms.

Objective 5

- A buffer is a substance that helps stabilize the pH of a solution.
- Buffers are important to living organisms because most cells can survive and function only within a relatively narrow range of pH.

Objective # 6

Identify the characteristics of carbon that allow it to play such an important role in the chemistry of life.

Objective 6

- Carbon has an atomic # of 6. This means it has 4 valence electrons.
- Carbon can form 4 strong covalent bonds with up to 4 other atoms.
- Carbon atoms can form strong covalent bonds with each other to produce unbranched chains, branched chains, and rings.

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Objective 6

- Carbon rings can join with each other to form interlocking rings or chains of rings.
- Carbon can form single, double, or triple covalent bonds with other atoms.

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Objective # 7

Define the following terms and be able to give or recognize examples of each:

a) Monomer, dimer, polymer
b) Condensation reaction (or dehydration synthesis)
c) Hydrolysis reaction

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Objective 7

- Large organic molecules are called macromolecules.
- Macromolecules are formed by joining smaller organic molecules called subunits, or building bocks, or monomers.
- When 2 similar or identical monomers are joined we get a dimer.

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Objective 7

- When many similar or identical monomers are joined we get a polymer.
- Joining many similar or identical subunits together to form a polymer is called polymerization.

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Objective 7

- Subunits are joined during a type of reaction called condensation or dehydration synthesis. An –OH is removed from one subnunit, an –H is removed form the other, and H_2O is formed:

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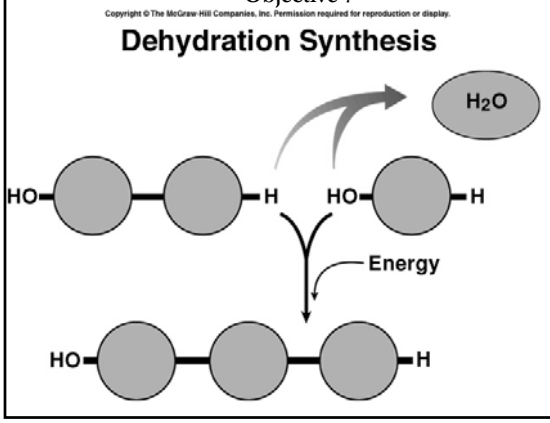
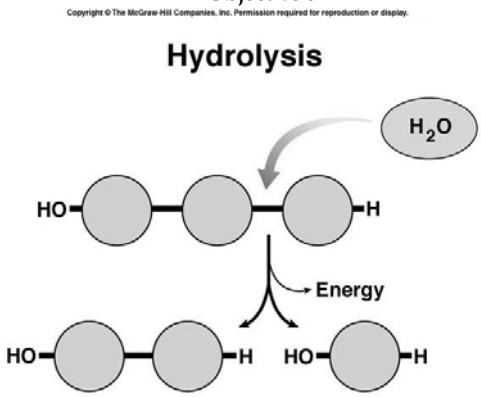
Objective 7



Objective 7

- The reverse reaction is called hydrolysis. It involves breaking a macromolecule into smaller subunits. A molecule of water is added for each subunit that is removed:

Objective 7



Objective # 8

- Describe the structure and functions of each of the following groups of organic compounds. Also be able to identify examples from each group:
  a) Carbohydrates
  b) Lipids
  c) Proteins
  d) Nucleotide-based compounds

Objective 8a

- Carbohydrates are made of monomers called simple sugars or monosaccharides.
- Monosaccharides are used for short term energy storage, and serve as structural components of larger organic molecules.
- They contain C, H, and O in an approximate ratio of 1:2:1.

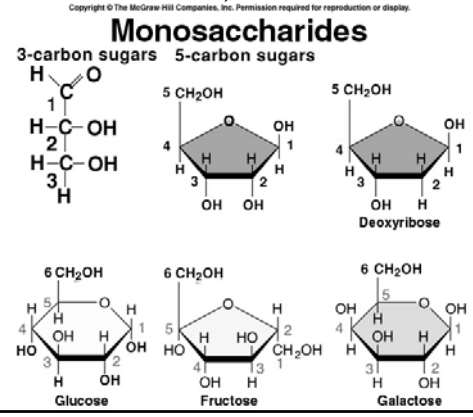
Objective 8a

- Monosaccharides are classified according to the number of C atoms they contain:
  - 3 C = triose e.g. glyceraldehyde
  - 4 C = tetrose
  - 5 C = pentose e.g. ribose, deoxyribose
  - 6 C = hexose e.g. glucose, fructose, galactose
- Monosaccharides in living organisms generally have 3C, 5C, or 6C:

Objective 8a

- When monosaccharides with 5 or more C atoms are dissolved in water (as they always are in living systems) most of the molecules assume a ring shape:

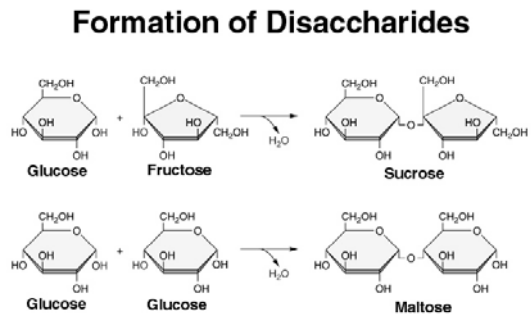
Objective 8a



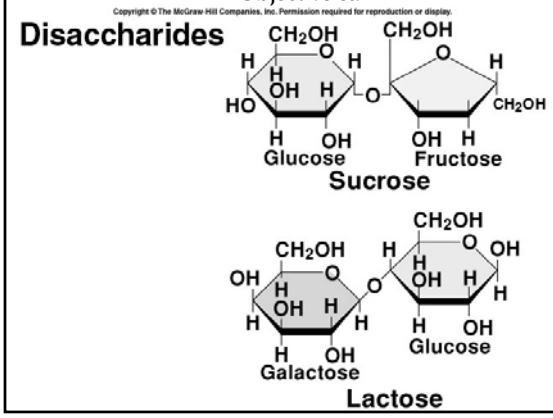
Objective 8a

- Two monosaccharides can be joined by condensation to form a disaccharide plus H_2O.
- Many organisms transport sugar within their bodies in the form of disaccharides.

Objective 8a



Objective 8a



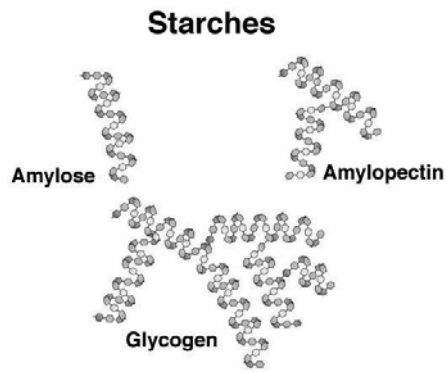
Objective 8a

- Polysaccharides consist of many monosaccharides joined by condensation to form long branched or unbranched chain.
- Some polysaccharides are used to store excess sugars, while others are used as structural materials.

Objective 8a

- Storage Polysaccharides:
  - Plants use glucose subunits to make starches, including amylose (unbranched and coiled) and amylopectin (branched).
  - Animals use glucose subunits to make glycogen which is more extensively branched than amylopectin.

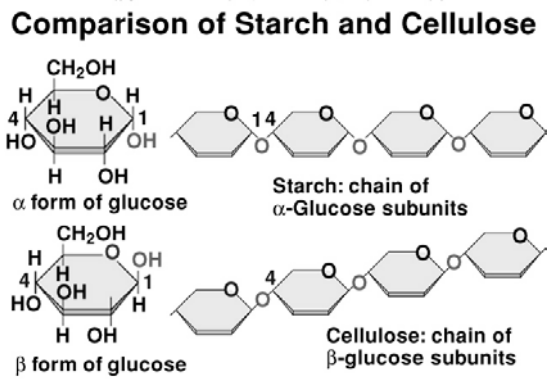
Objective 8a



Objective 8a

- Structural Polysaccharides:
  - Cellulose - a long unbranched chain of glucose subunits. It is a major component of plant cell walls.
  - Chitin - similar to cellulose, but a nitrogen group is added to each glucose. It is found in the exoskeleton of arthropods and cell walls of fungi.

Objective 8a

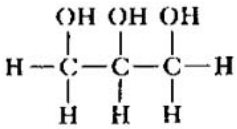


Objective 8b

- Lipids are structurally diverse molecules that are greasy and insoluble in H_2O.
- We will examine 3 types of lipids:
  - Fats and oils
  - Phospholipids
  - Steroids

Objective 8b

- Fats and oils are composed of 2 types of subunits: glycerol and fatty acids.
- Glycerol is an alcohol with 3 carbons, each bearing a hydroxyl group:



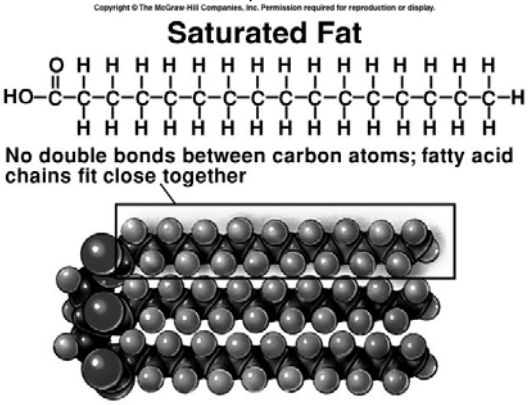
Objective 8b

- A fatty acid has a long hydrocarbon chain with a carboxyl group at one end.
- It may be saturated (no double bonds between the C atoms of the hydrocarbon chain), monounsaturated (one double bond), or polyunsaturated (more than one double bond).
- H can be added to unsaturated fatty acids using a process called hydrogenation.

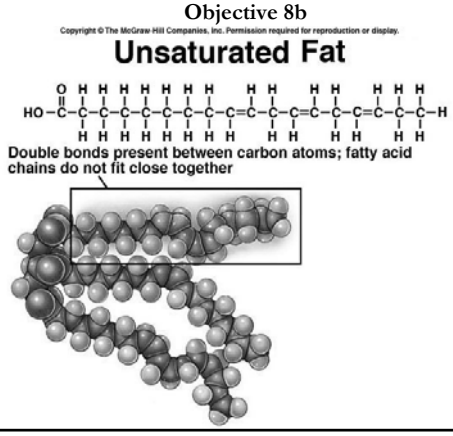
Objective 8b

- Glycerol + 1 fatty acid = monoglyceride
- Glycerol + 2 fatty acids = diglyceride
- Glycerol + 3 fatty acids = triacylglycerol (also called a triglyceride or fat.)

Objective 8b



Objective 8b



Objective 8b

- Most animal fats contain saturated fatty acids and tend to be solid at room temperature.
- Most plant fats contain unsaturated fatty acids. They tend to be liquid at room temperature, and are called oils.

Objective 8b

- Because fats and oils are such concentrated sources of energy, they are often used for long term energy storage.
- In animals, fats also act as insulators and cushions.

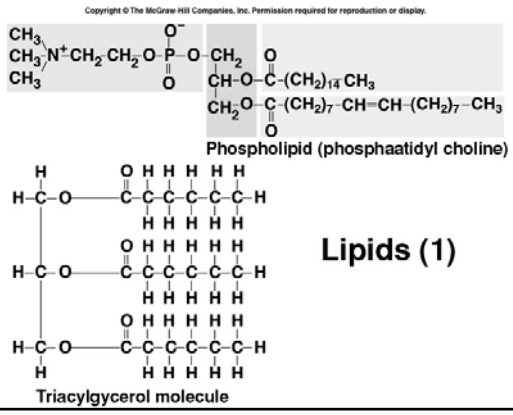
Objective 8b

- In phospholipids, two of the –OH groups on glycerol are joined to fatty acids. The third –OH joins to a phosphate group which joins, in turn, to another polar group of atoms.

Objective 8b

- The phosphate and polar groups are hydrophilic (attracted to water) and are referred to as the "polar head" of the molecule.
- The hydrocarbon chains of the 2 fatty acids are hydrophobic (repel water) and are referred to as the "nonpolar tails".

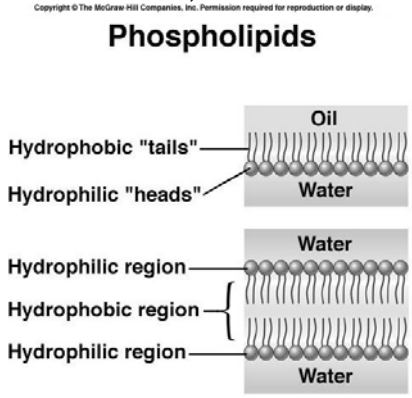
Objective 8b



Objective 8b

- In water, phospholipids will spontaneously orient so that the nonpolar tails are shielded from contact with the polar H_2O molecules.
- Phospholipids are major components of cell membranes.

Objective 8b

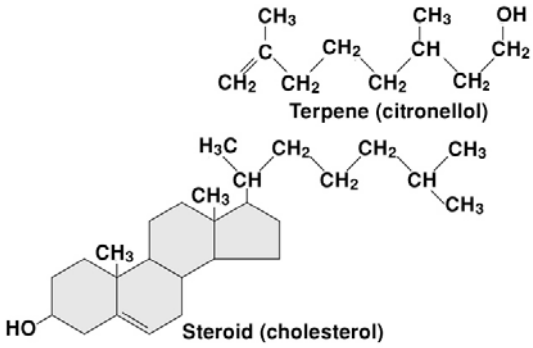


Objective 8b

- Steroids are lipids whose principle component is the steroid nucleus: 4 interlocking rings of carbon atoms.
- Examples:
  - Cholesterol is a component of animal cell membranes.
  - Testosterone and estrogen function as sex hormones.

Objective 8b

Lipids (2)



Objective 8c

- Proteins perform many essential functions in living organisms:

Function	Class of Protein
Catalysis	enzymes
Defense	immunoglobulins, toxins
Cell recognition	antigens
Transport through the body	globins
Membrane transport	transporters

Objective 8c

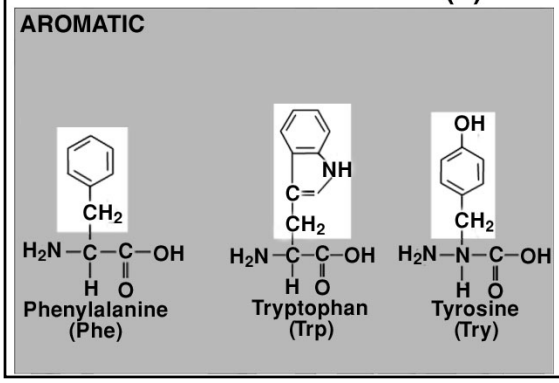
Function	Class of Protein
Structure/support	fibers
Motion	muscle
Osmotic regulation	albumin
Regulating genes	repressors, activators
Messengers	hormones
Storage	Ion binding

Objective 8c

- Proteins are composed of monomers called amino acids.
- An amino acid consists of a central carbon joined to 4 other groups:
  - H atom
  - Amino group
  - Carboxyl group
  - R group

Objective 8c

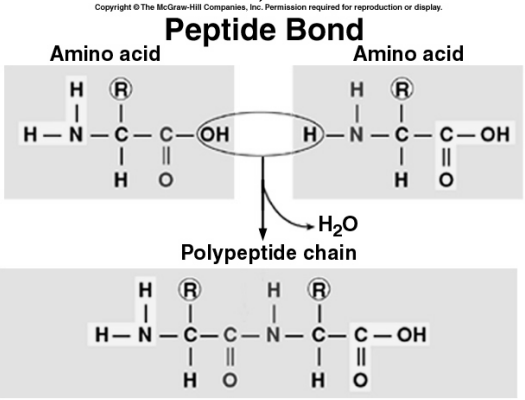
Common Amino Acids (4)



Objective 8c

- About 20 different amino acids occur naturally in proteins. They are identical except for the R group (shaded white on the previous slide).
- Two amino acids can join by condensation to form a dipeptide plus H_2O.
- The bond between 2 amino acids is called a peptide bond.

Objective 8c



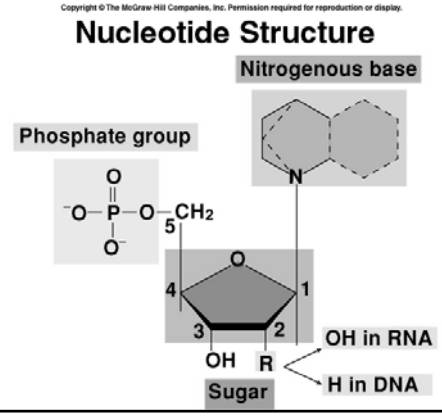
Objective 8c

- A polypeptide consists of many amino acids joined by peptide bonds to form an unbranched chain.
- A protein consists of one or more polypeptides which are coiled and folded into a specific 3-D shape.
- The shape of a protein determines its function.

Objective 8d

- Nucleotide- based compounds are composed of subunits called nucleotides.
- A nucleotide consists of 3 parts:
  - Pentose (5 C) sugar – either ribose or deoxyribose
  - Phosphate group ($-PO_4$)
  - Nitrogenous base

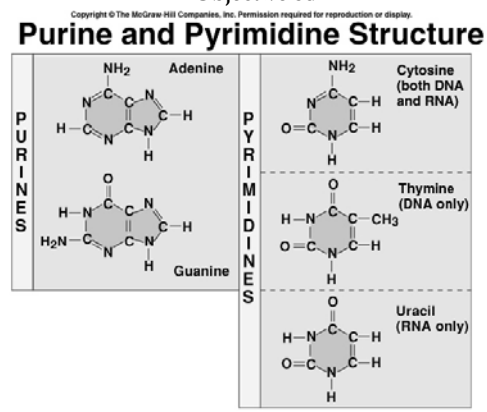
Objective 8d



Objective 8d

- There are 2 types of nitrogenous bases:
  - Purines have a double ring structure and include adenine (A) and guanine (G).
  - Pyrimidines have a single ring structure and include cytosine (C), thymine (T), and uracil (U).

Objective 8d



Objective 8d

- One very important group of molecules made from nucleotides are nucleic acids.
- There are 2 types of nucleic acids: ribonucleic acid (RNA) and deoxyribonucleic acid (DNA).

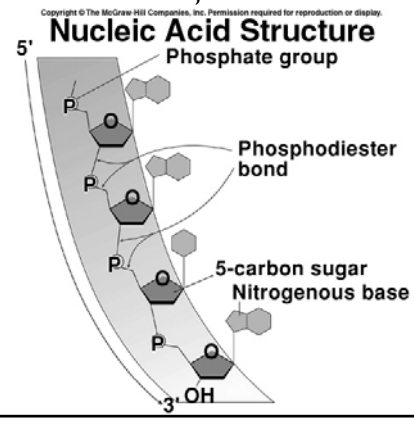
Objective 8d

- The nucleotides in RNA contain the sugar ribose and the bases A, G, C, U.
- The nucleotides in DNA contain the sugar deoxyribose and the bases A, G, C, T.

Objective 8d

- RNA:
  - consists of a single, unbranched chain of RNA nucleotides.
  - plays several important roles during the process of protein synthesis.

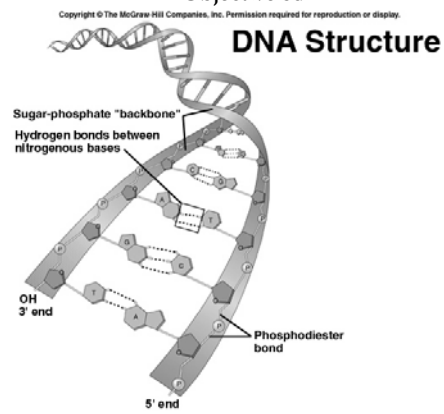
Objective 8d



Objective 8d

- DNA:
  - consists of 2 unbranched chains of DNA nucleotides twisted into a double helix.
  - the 2 chains are held together by H bonds between the nitogenous bases.
  - A always pairs with T, and G with C.
  - functions as the heredity information in all living organisms.

Objective 8d



Objective 8d

DNA Versus RNA