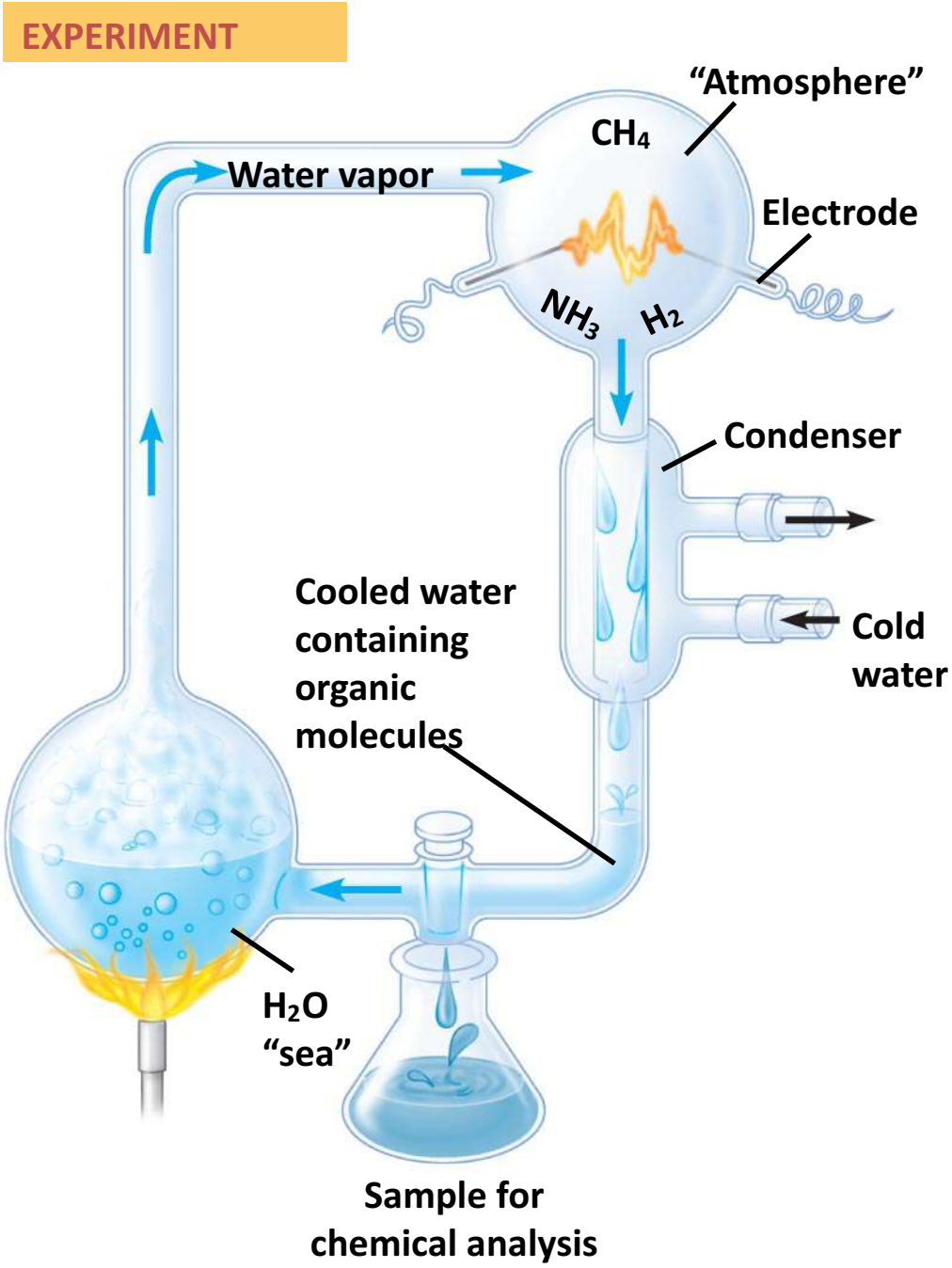
CARBON

Concept 4.1: Organic chemistry is the study of carbon compounds

- **Organic chemistry** is the study of compounds that contain carbon
- Organic compounds range from simple molecules to colossal ones
- Most organic compounds contain hydrogen atoms in addition to carbon atoms

Fig. 4-2



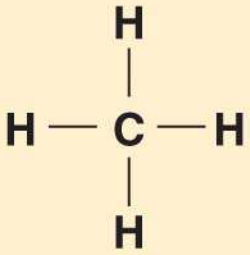
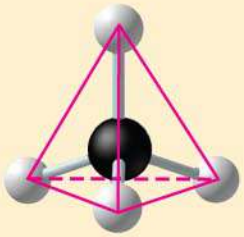
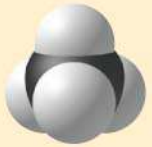
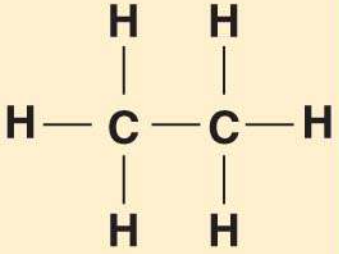
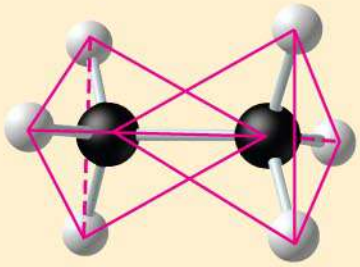
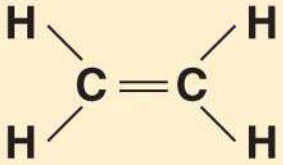
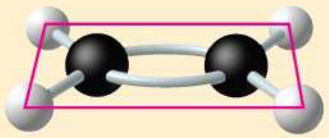
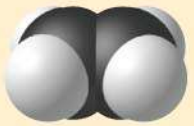
Concept 4.2: Carbon atoms can form diverse molecules by bonding to four other atoms

- Electron configuration is the key to an atom's characteristics
- Electron configuration determines the kinds and number of bonds an atom will form with other atoms

The Formation of Bonds with Carbon

- With four valence electrons, carbon can form four covalent bonds with a variety of atoms
- This *tetravalence* makes large, complex molecules possible
- In molecules with multiple carbons, each carbon bonded to four other atoms has a tetrahedral shape
- However, when two carbon atoms are joined by a double bond, the molecule has a flat shape

Fig. 4-3

Name	Molecular Formula	Structural Formula	Ball-and-Stick Model	Space-Filling Model
(a) Methane	CH_4			
(b) Ethane	C_2H_6			
(c) Ethene (ethylene)	C_2H_4			

- Carbon atoms can partner with atoms other than hydrogen; for example:
  - Carbon dioxide: CO_2
  - Urea: $CO(NH_2)_2$

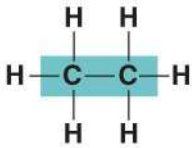
$$O = C = O$$

Molecular Diversity Arising from Carbon Skeleton Variation

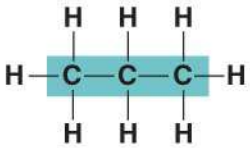
- Carbon chains form the skeletons of most organic molecules
- Carbon chains vary in length and shape

PLAY Animation: Carbon Skeletons

Fig. 4-5

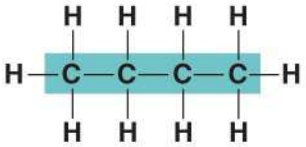


Ethane

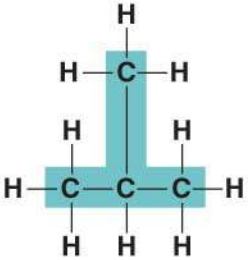


Propane

(a) Length

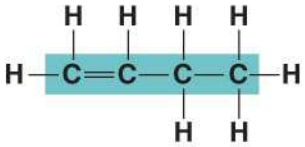


Butane

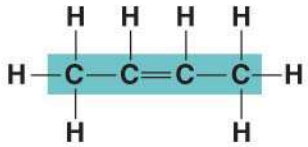


2-Methylpropane
(commonly called isobutane)

(b) Branching

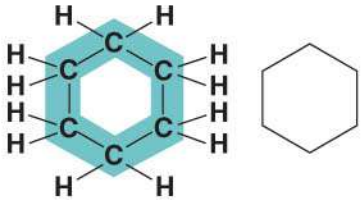


1-Butene

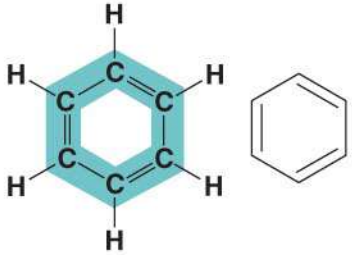


2-Butene

(c) Double bonds



Cyclohexane



Benzene

(d) Rings

Hydrocarbons

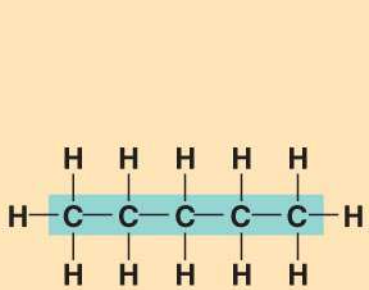
- **Hydrocarbons** are organic molecules consisting of only carbon and hydrogen
- Many organic molecules, such as fats, have hydrocarbon components
- Hydrocarbons can undergo reactions that release a large amount of energy

Isomers

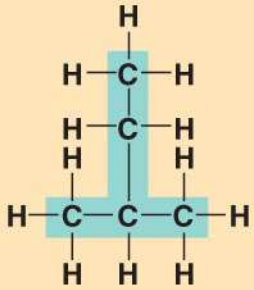
- **Isomers** are compounds with the same molecular formula but different structures and properties:
  - **Structural isomers** have different covalent arrangements of their atoms
  - **Geometric isomers** have the same covalent arrangements but differ in spatial arrangements
  - **Enantiomers** are isomers that are mirror images of each other

PLAY Animation: Isomers

Fig. 4-7

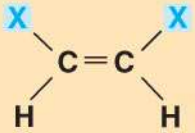


Pentane

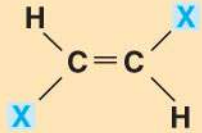


2-methyl butane

(a) Structural isomers

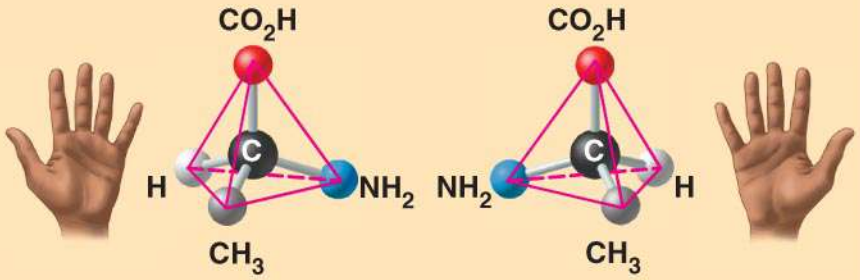


cis isomer: The two Xs are on the same side.



trans isomer: The two Xs are on opposite sides.

(b) Geometric isomers



L isomer

D isomer

(c) Enantiomers

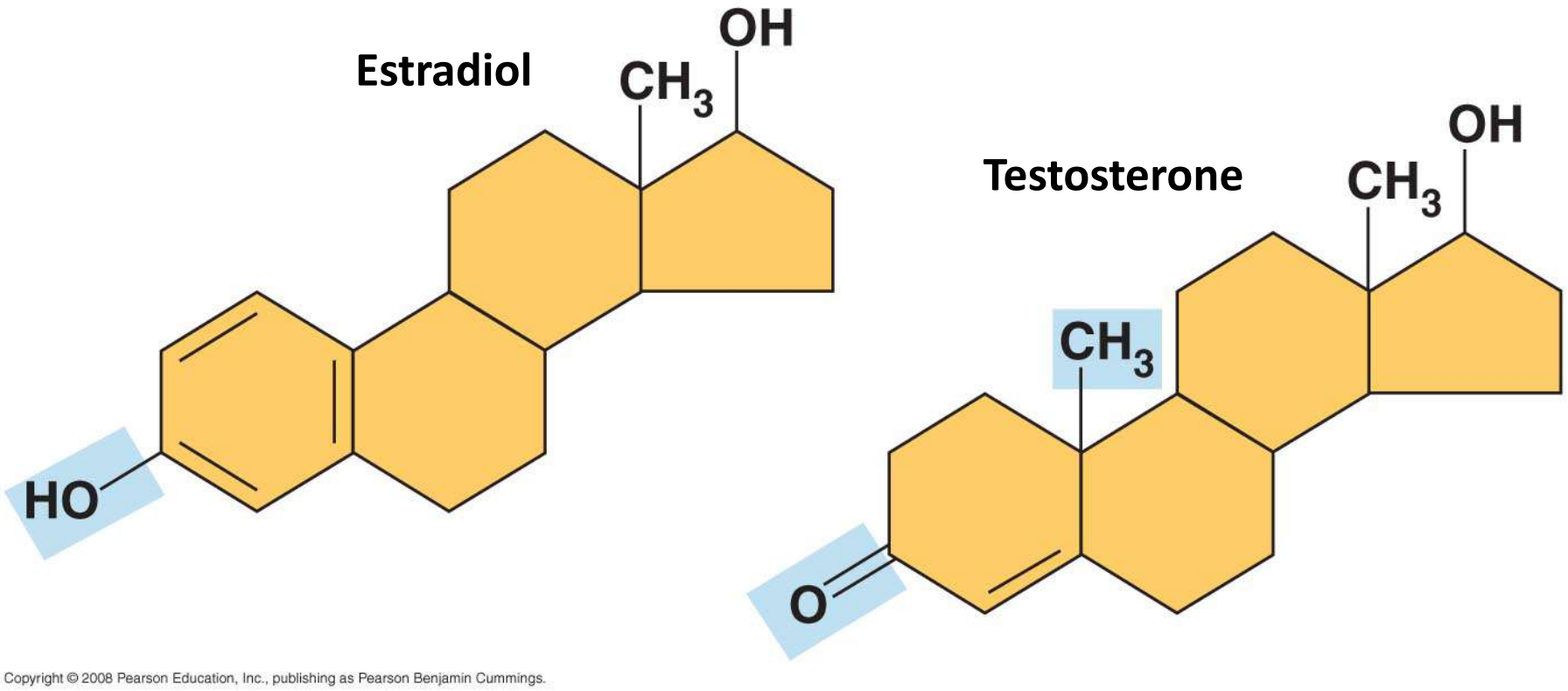
Concept 4.3: A small number of chemical groups are key to the functioning of biological molecules

- Distinctive properties of organic molecules depend not only on the carbon skeleton but also on the molecular components attached to it
- A number of characteristic groups are often attached to skeletons of organic molecules

The Chemical Groups Most Important in the Processes of Life

- **Functional groups** are the components of organic molecules that are most commonly involved in chemical reactions
- The number and arrangement of functional groups give each molecule its unique properties

Fig. 4-9



- The seven functional groups that are most important in the chemistry of life:
  - Hydroxyl group
  - Carbonyl group
  - Carboxyl group
  - Amino group
  - Sulfhydryl group
  - Phosphate group
  - Methyl group

Fig. 4-10a

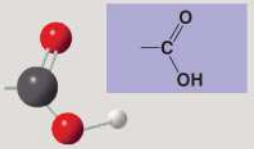
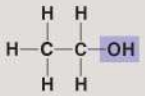
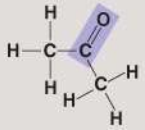
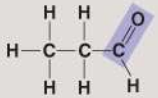
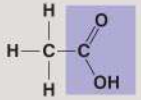
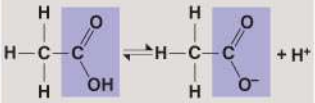
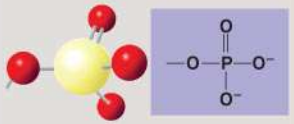
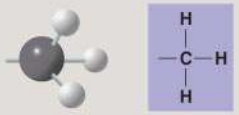
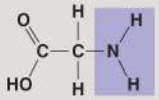
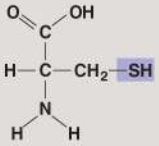
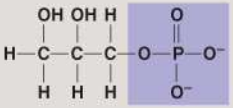
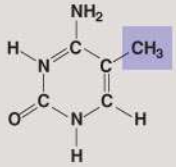
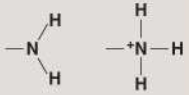
CHEMICAL GROUP	Hydroxyl	Carbonyl	Carboxyl
STRUCTURE	 (may be written HO—)		
	In a hydroxyl group (—OH), a hydrogen atom is bonded to an oxygen atom, which in turn is bonded to the carbon skeleton of the organic molecule. (Do not confuse this functional group with the hydroxide ion, OH^-.)	The carbonyl group (C O) consists of a carbon atom joined to an oxygen atom by a double bond.	When an oxygen atom is double-bonded to a carbon atom that is also bonded to an —OH group, the entire assembly of atoms is called a carboxyl group (—COOH).
NAME OF COMPOUND	Alcohols (their specific names usually end in *-ol*)	Ketones if the carbonyl group is within a carbon skeleton Aldehydes if the carbonyl group is at the end of the carbon skeleton	Carboxylic acids, or organic acids
EXAMPLE	 Ethanol, the alcohol present in alcoholic beverages	 Acetone, the simplest ketone  Propanal, an aldehyde	 Acetic acid, which gives vinegar its sour taste
FUNCTIONAL PROPERTIES	• Is polar as a result of the electrons spending more time near the electronegative oxygen atom. • Can form hydrogen bonds with water molecules, helping dissolve organic compounds such as sugars.	• A ketone and an aldehyde may be structural isomers with different properties, as is the case for acetone and propanal. • These two groups are also found in sugars, giving rise to two major groups of sugars: aldoses (containing an aldehyde) and ketoses (containing a ketone).	• Has acidic properties because the covalent bond between oxygen and hydrogen is so polar; for example,  Acetic acid ⇌ Acetate ion + H^+ • Found in cells in the ionized form with a charge of 1– and called a carboxylate ion (here, specifically, the acetate ion).

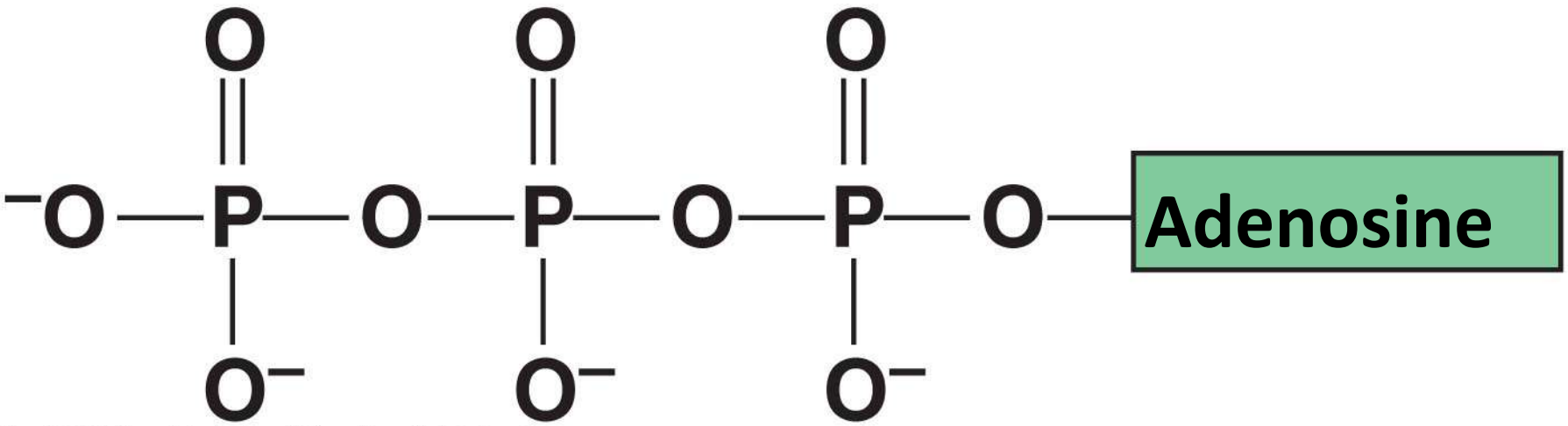
Fig. 4-10b

CHEMICAL GROUP	Amino	Sulfhydryl	Phosphate	Methyl
STRUCTURE		 (may be written HS—)		
	The amino group ($—NH_2$) consists of a nitrogen atom bonded to two hydrogen atoms and to the carbon skeleton.	The sulfhydryl group consists of a sulfur atom bonded to an atom of hydrogen; resembles a hydroxyl group in shape.	In a phosphate group, a phosphorus atom is bonded to four oxygen atoms; one oxygen is bonded to the carbon skeleton; two oxygens carry negative charges. The phosphate group ($—OPO_3^{2-}$, abbreviated) is an ionized form of a phosphoric acid group ($—OPO_3H^2$; note the two hydrogens).	A methyl group consists of a carbon bonded to three hydrogen atoms. The methyl group may be attached to a carbon or to a different atom.
NAME OF COMPOUND	Amines	Thiols	Organic phosphates	Methylated compounds
EXAMPLE	 Glycine	 Cysteine	 Glycerol phosphate	 5-Methyl cytidine
	Because it also has a carboxyl group, glycine is both an amine and a carboxylic acid; compounds with both groups are called amino acids.	Cysteine is an important sulfur-containing amino acid.	In addition to taking part in many important chemical reactions in cells, glycerol phosphate provides the backbone for phospholipids, the most prevalent molecules in cell membranes.	5-Methyl cytidine is a component of DNA that has been modified by addition of the methyl group.
FUNCTIONAL PROPERTIES	• Acts as a base; can pick up an H^+ from the surrounding solution (water, in living organisms).  (nonionized) (ionized) • Ionized, with a charge of 1+, under cellular conditions.	• Two sulfhydryl groups can react, forming a covalent bond. This "cross-linking" helps stabilize protein structure. • Cross-linking of cysteines in hair proteins maintains the curliness or straightness of hair. Straight hair can be "permanently" curled by shaping it around curlers, then breaking and re-forming the cross-linking bonds.	• Contributes negative charge to the molecule of which it is a part (2– when at the end of a molecule; 1– when located internally in a chain of phosphates). • Has the potential to react with water, releasing energy.	• Addition of a methyl group to DNA, or to molecules bound to DNA, affects expression of genes. • Arrangement of methyl groups in male and female sex hormones affects their shape and function.

ATP: An Important Source of Energy for Cellular Processes

- One phosphate molecule, **adenosine triphosphate** (**ATP**), is the primary energy-transferring molecule in the cell
- ATP consists of an organic molecule called adenosine attached to a string of three phosphate groups

Fig. 4-UN3



You should now be able to:

1. Explain how carbon's electron configuration explains its ability to form large, complex, diverse organic molecules
2. Describe how carbon skeletons may vary and explain how this variation contributes to the diversity and complexity of organic molecules
3. Distinguish among the three types of isomers: structural, geometric, and enantiomer

4. Name the major functional groups found in organic molecules; describe the basic structure of each functional group and outline the chemical properties of the organic molecules in which they occur
5. Explain how ATP functions as the primary energy transfer molecule in living cells