Bio-elements

- **Living organisms requires only 27 of the 90 common chemical elements found in the crust of the earth, to be as its essential components.**
- **Most of the chemical components of living organisms are organic compounds of carbon in which carbon atoms are covalently joined with other carbon atoms and with hydrogen, oxygen or nitrogen.**
- **Organic compounds in living matter occur in extraordinary variety and many of them are extremely large and complex.**

- **The four most abundant elements in living organism are:**

Hydrogen
Oxygen
Carbon
Nitrogen

which make up 96% of the mass of most cells

- **Carbon, hydrogen, nitrogen, and oxygen posses a common property: they readily form covalent bonds by electron pair sharing.**

Hydrogen needs one electron
Oxygen needs two electrons
Nitrogen needs three electrons
Carbon needs four

to complete their outer electron shells and thus stable covalent bonds.

- **These four elements thus react with each other to form a large number of different covalent compounds.**
- **Carbon, nitrogen, hydrogen and oxygen are the lightest elements capable of forming covalent bonds.**

- These four elements thus react with each other to form a large number of different covalent compounds.
- Carbon, nitrogen, hydrogen and oxygen are the lightest elements capable of forming covalent bonds.

Carbon atoms

- Carbon atoms posses another and most significant property, the capacity to bond with each other.

In this way covalently linked carbon atoms can form linear or branched or cyclic backbones of different organic molecules.

- **The four covalent single bonds of a carbon atom are spaced in a tetrahedral arrangement with an angle of about 109.5° between any two of them.**
- **This angle varies little from one carbon atom to another in different organic molecules, (because of this characteristic, different organic compounds of carbon can have many different kinds of three-dimensional structures).**
- **There is complete freedom of rotation around each carbon-carbon single.**

- **Covalent bonds of carbon have characterestic bond length. carbon-carbon single bonds have anaverage length of 0.154 nm. whereas carbon-carbon double bonds are shorter, about 0.134 nm long.**
- **Since carbon atom also form covalent bonds with oxygen, hydrogen, nitrogen and sulfur, many different kinds of functional groups can be introduced into the structure of organic molecules.**
- **Most biomolecules (i.e molecules found in living things,) are compounds of carbon.**

for example:

Organic biomolecules have characteristic sizes and three-dimensional conformation.

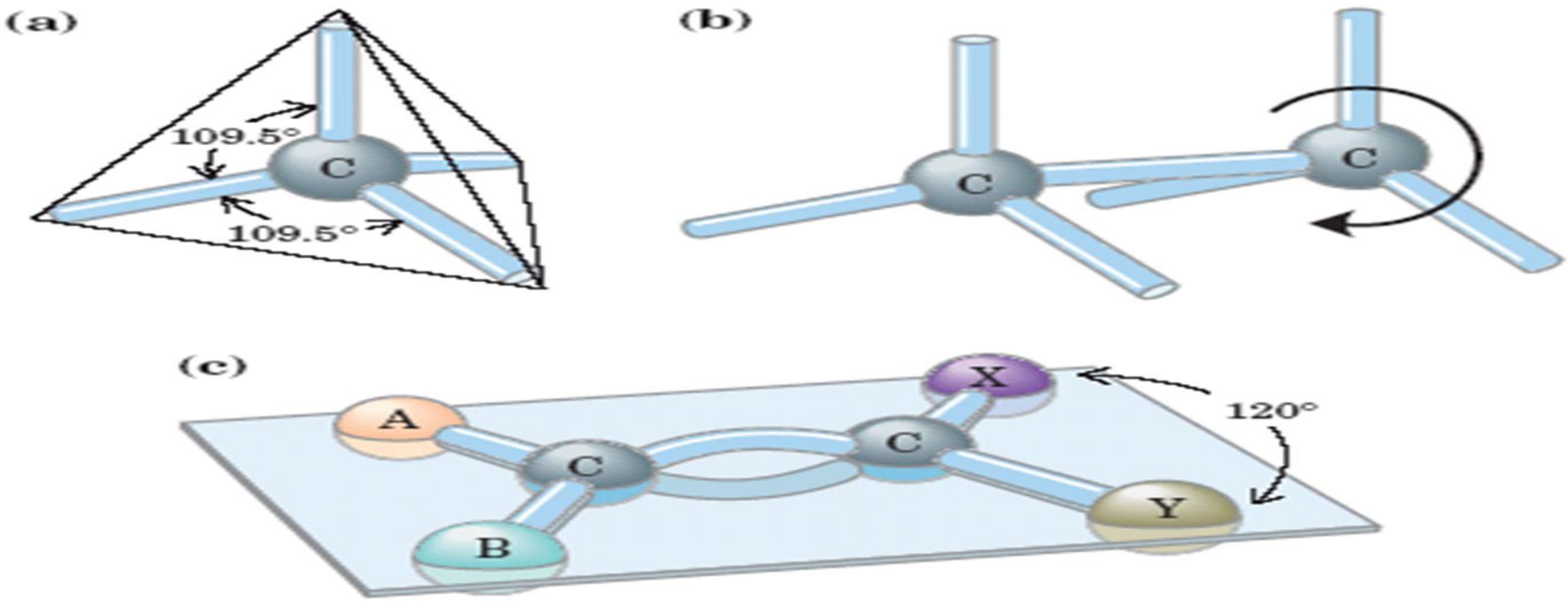


FIGURE 1–14 **Geometry of carbon bonding.** (a) Carbon atoms have a characteristic tetrahedral arrangement of their four single bonds. (b) Carbon–carbon single bonds have freedom of rotation, as shown for the compound ethane (CH_3—CH_3). (c) Double bonds are shorter and do not allow free rotation. The two doubly bonded carbons and the atoms designated A, B, X, and Y all lie in the same rigid plane.

Functional groups of organic biomolecules determine their chemical properties

- **Nearly all organic biomolecules can be regarded as derivatives of hydrocarbons (compounds of carbon and hydrogen in which the backbone consists of carbon atoms joined by covalent bonds and the other bonds of the carbons are shared with hydrogen atoms).**
- **One or more hydrogen atoms of hydrocarbon may be replaced by different kinds of functional groups to yield different families of organic compounds.**

Typical families of organic compounds and their characteristic functional groups are:

- **Alcohols: have hydroxyl groups**
- **Amines: have amino groups**
- **Acids: have carboxyl groups**

- **Several other functional groups are also important in biomolecules.**
- **From functional groups present in organic biomolecules it is possible to analyze and predict their chemical behaviour and reactions.**

- **Most of biomolecules are polyfunctional, containing two or more different kinds of functional groups.**

  example: **Amino acids, Glucose**

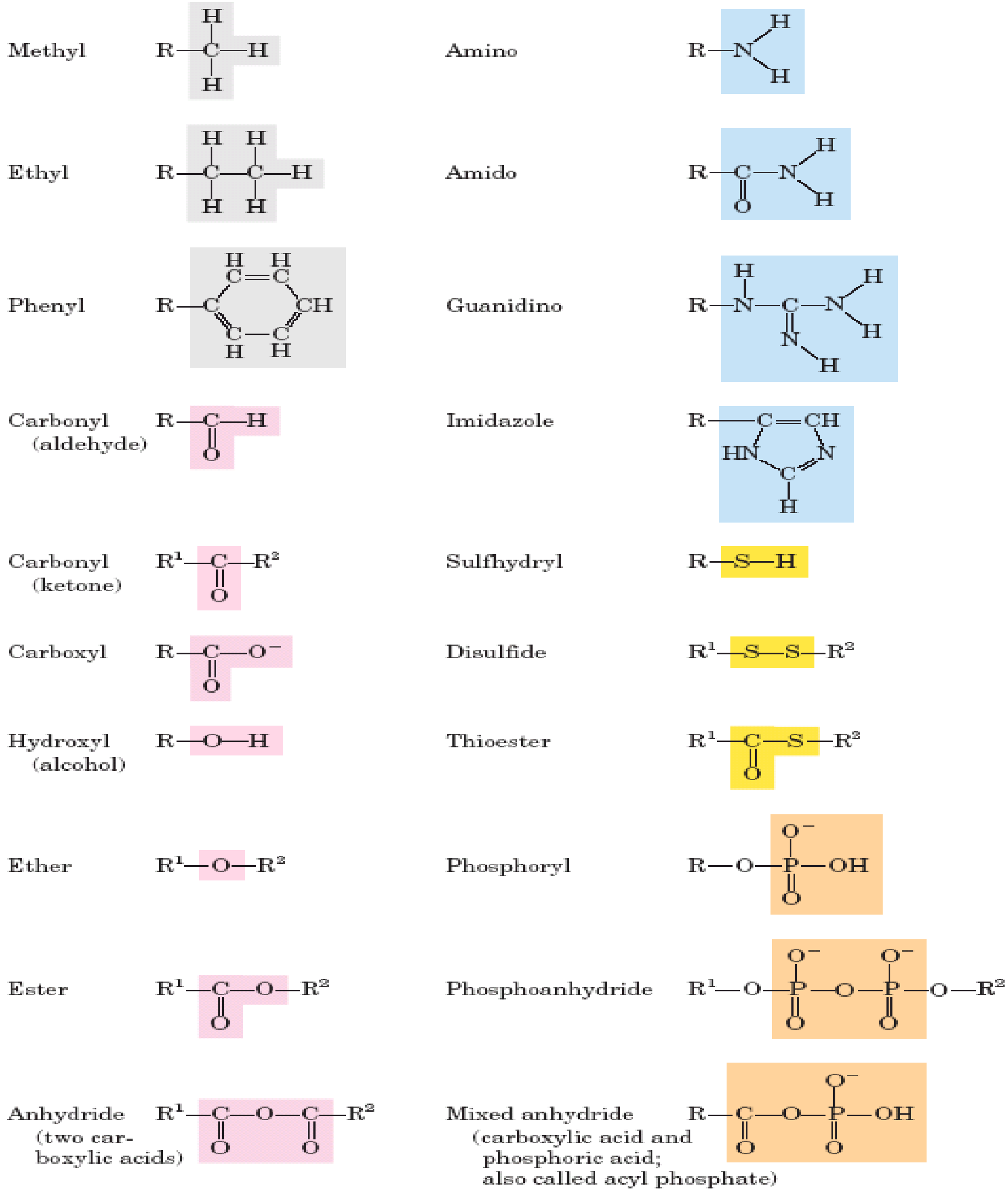


FIGURE 1–15 **Some common functional groups of biomolecules.** In this figure and throughout the book, we use R to represent "any substituent." It may be as simple as a hydrogen atom, but typically it is a carbon-containing moiety. When two or more substituents are shown in a molecule, we designate them R^1, R^2, and so forth.

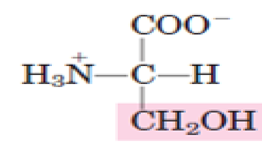
Functional Groups in Biochemistry

Examples from biochemistry

R-OH — Alcohol

—OH — Hydroxyl

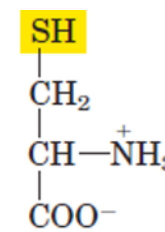
Example:
amino acid
(serine)



R-SH — Thiol

—SH — Sulfahydryl

Example:
amino acid
(cysteine)



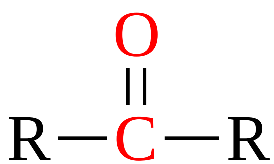
R-C(=O)-OH — Carboxylic acid

—C(=O)—OH R-C(=O)—O⁻ — Carboxylate

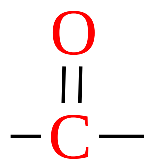
Example:
fatty acid
(Palmitic acid)

$CH_3(CH_2)_{16}COOH$

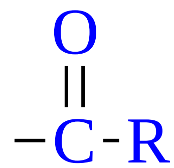
Examples from biochemistry



Ketone

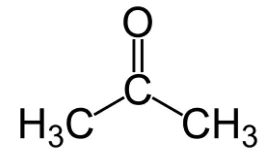


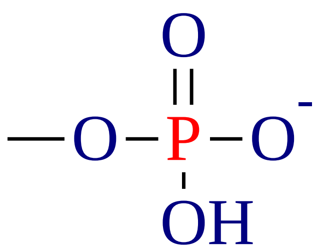
Carbonyl



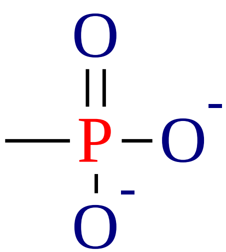
Acyl

Example:
acetone



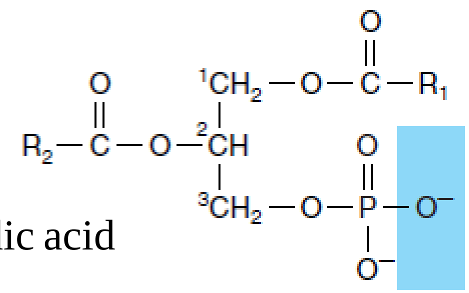


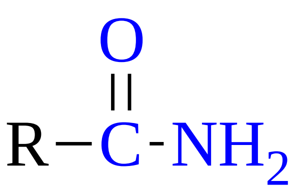
Phosphate



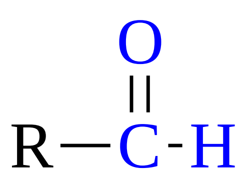
Phosphoryl

Example:
Phosphatidic acid



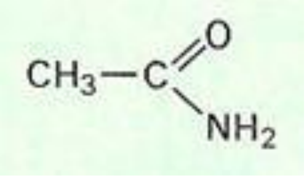


Amide

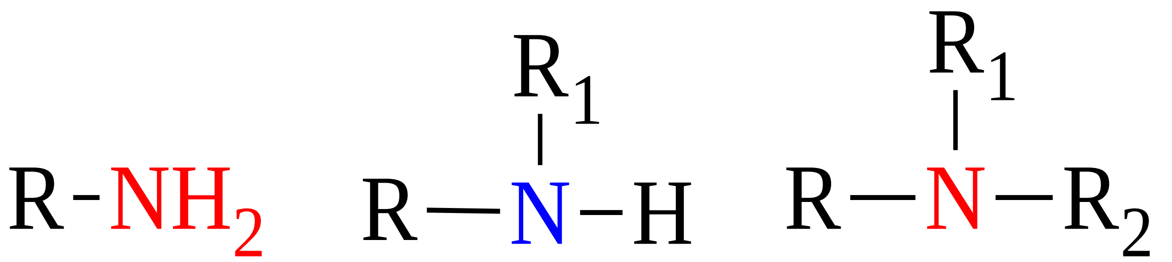


Aldehyde

Example:
acetamide



Examples from biochemistry



Primary Secondary Tertiary

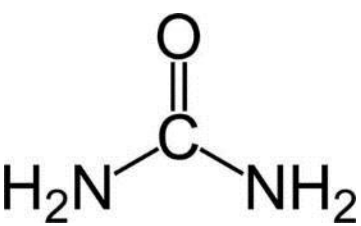
Amines

$-NH_3^+$

$-NH_2$

Amino

Example:
Urea

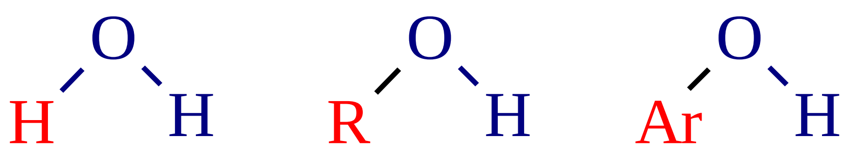


Alcohols & Phenols

Alcohols

- **Any molecule having – OH group (Hydroxyl) bound to an alkyl chain.**
- **Primary, secondary, and tertiary alcohols based on what's bound to the C-OH group.**
- **Important in many biological molecules**
  - **Some Amino acids, carbohydrates, and certain lipids**

Phenols



- **A hydroxyl group bound to an aryl or aromatic group (e.g., phenyl)**
- **Both can be viewed as a substituted water.**

Properties of Alcohols

The - OH in alcohols has properties like H_2O

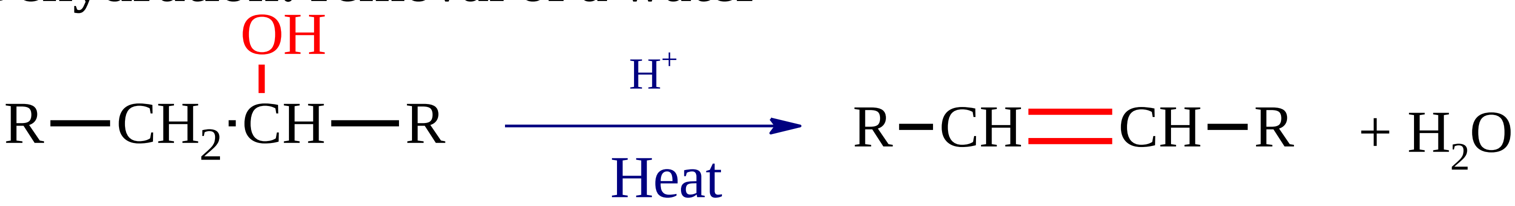
- **Can participate in H-bonding (acceptor & donor)**
- **Polar group**
- **Water soluble**

$$\overset{\delta^-}{-O}-\overset{\delta^+}{H}\cdots\cdots\overset{\delta^-}{A}-$$

- **but long carbon chain reduces solubility: R-OH**
  - **C_1 - C_5** — **Highly soluble**
  - **C_5 - C_7** — **Moderately soluble**
  - **C_8 and above** — **Slightly soluble/insoluble**

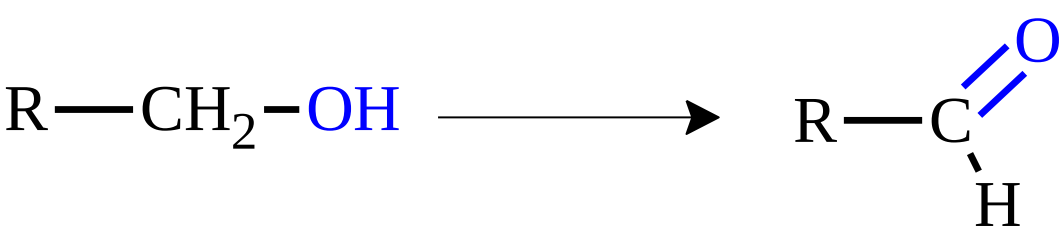
Reactions of alcohols

- **Dehydration: removal of a water**



- **Oxidation: conversion of OH to =O.**

Ketone

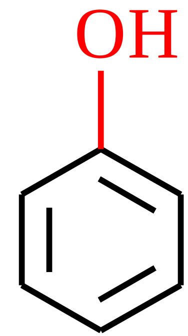


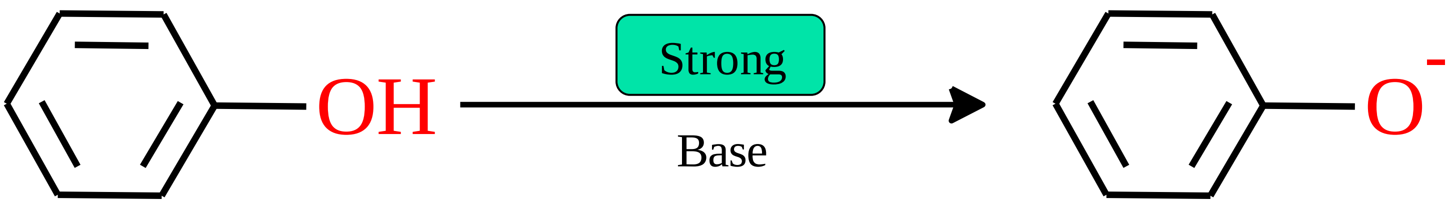
Aldehyde

- **Remember OIL RIG**
  - **Oxidation Is Loss of electron (before, the gain of oxygen)**
  - **Reduction Is Gain of electron (before, the loss of oxygen)**

Phenols

- **Compounds with hydroxyl group bound to a benzene ring**
- **They are weak acids**
  - **Can lose a proton to strong bases.**
  - **(Notice) Aliphatic alcohols do not act as acids.**
    - **The anion formed is not stable.**





- **The ring of phenol is easily oxidized.**
  - ***In vivo*, special enzymes can accomplish this.**
    - ***In vivo* means “in life” or “in a living cell”**
    - ***In vitro* means “in glass”**

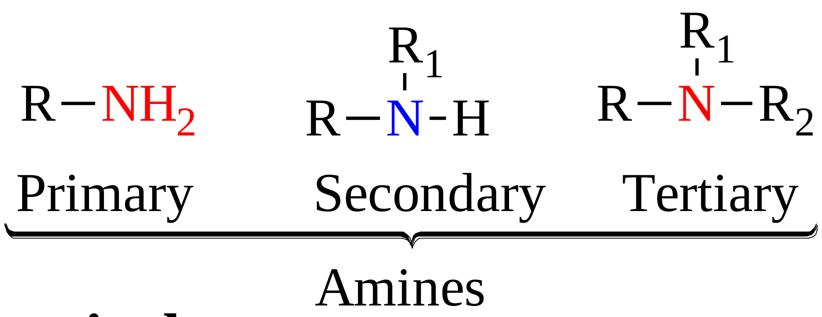
Thiols

- Similar to alcohols but contain S instead of O = R-S-H
  - The -SH can be called the thiol, mercaptan, or sulfhydryl group.
- S is less electronegative than O →
  - Less polar than alcohols
  - Weaker H-boding capability
  - Less water solubility

- Have some of the strongest & unpleasant odors

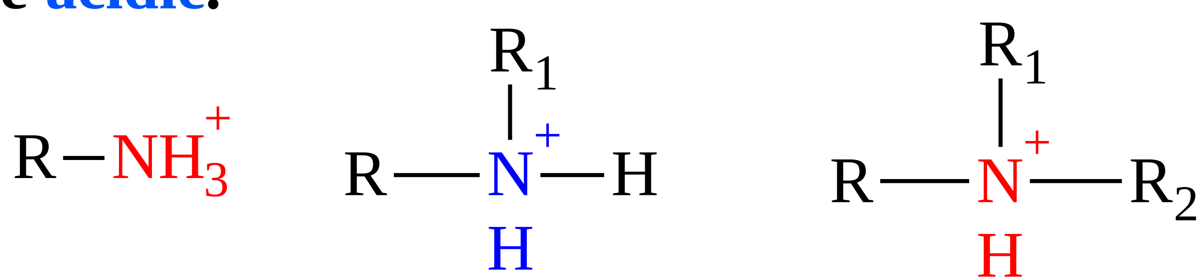
Amines

- **Many biological molecules contain amino groups.**
  - **amino acids, DNA, RNA bases, alkaloids (e.g., caffeine, nicotine)**
- **General formula**



  - **R's are not necessarily identical.**
  - **Can be considered as substituted ammonia molecules.**

- **Amines are basic groups and can accept protons to become acidic.**



Properties of Amines

- **Nitrogen is very but not quite as electronegative as oxygen.**
- **Electronegativity is a chemical property that describes the tendency of an atom or a functional group to attract electrons towards itself**
  - **O > S > N**

$$\overset{\delta^-}{-N}-\overset{\delta^+}{H}\cdots\cdots\overset{\delta^-}{A}-$$

Thus:

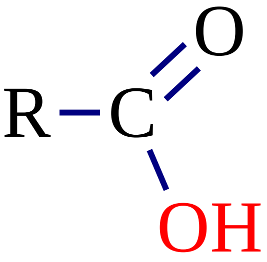
- **Amino group are polar groups**
- **Can participate in H-bonding (acceptor & donors)**
- **Amines can also share H bonds with water, so they are more soluble in water than alkanes.**
- **H bonds are not as strong as in alcohols**
- **Weak bases (similar to ammonia, a common weak inorganic base).**

Carboxylic acids

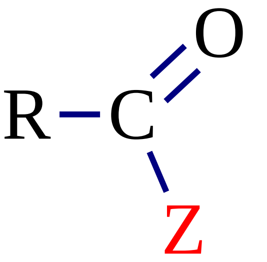
- **Many biological molecules contain carboxylic group or one of its derivatives.**
  - **Proteins, amino acids; , lipids, fatty acids; carbohydrates, sugar, and many others.**

General Formula: -COOH (carboxyl)

- **Any R possible: H, alkyl or aromatic chain**

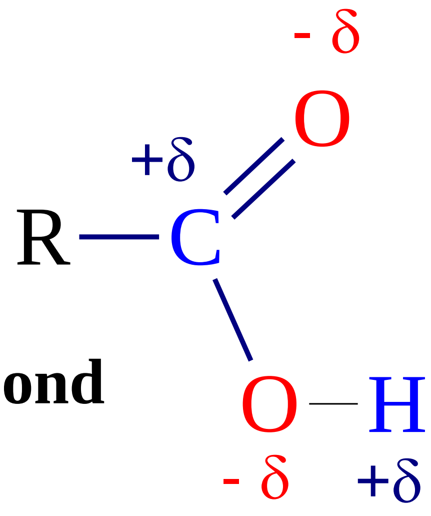


- **Derivatives Formula, where Z = could be:**
- **-Cl (Acid chloride)**
- **-OR, -OAr (Ester)**
- **$-NH_2$, -NHR (Amide)**



Properties of Carboxylic Acids

- **The carboxylic group is one of the most polar groups in biochemistry**
- **Both parts of the group are polar**
  - **-C=O**
  - **-O-H**
    - **–O-H is so polar, it is nearly ionic bond**



- **Presence of carboxylic group:**
  - **increases the solubility in water**
    - **Solubility decreases rapidly as MW increases.**
  - **Adds acidic character**

Acidity of Carboxylic Acids

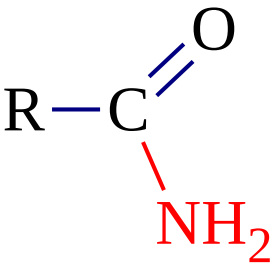
- **All carboxylic acids are weak acids.**

$$R-COOH \rightleftharpoons R-COO^{-} + H^{+}$$

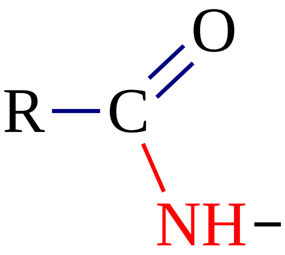
- **They can ionize into H^+ and an anion.**
  - **Addition of strong acids drive the reaction to the right**
- **Carboxylic acids occur largely as their anions in living cells and body fluids.**
- **The carboxylates are salts, example, sodium acetate .**

Amides

- **One of the important bonds in Biochemistry**
  - **Amides are derivatives of carboxylic acids.**



- **General formula:**
  - **Can be prepared from acids**
    - **+ ammonia → simple amides**
    - **+ amine → Substituted amides**



      - **Peptide bond is an amide bond between amino acids**
- **The C-N bond is the amide bond.**
  - **One of the strongest bonds in biochemistry .**
  - **It can be broken but require strong acid or base + high temperatures.**

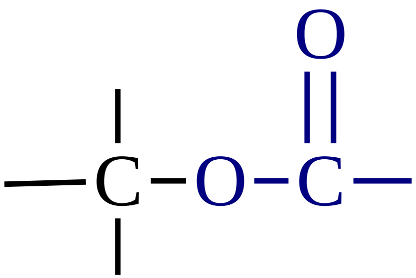
Amide Properties

- **Amide molecules are polar.**
  - **They can participate in H-bonding as donor or acceptor**
  - **The forces among simple amides are so great that all except are solids at room temperature, except methanamide (formamide).**
- **Amides are NOT basic molecules.**

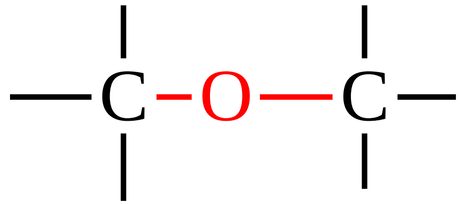
Remember; Amines are basic groups. But Amides aren't

  - **The amine group of amide can not accept protons or get ionized**
  - **They are neutral in an acid-base sense.**

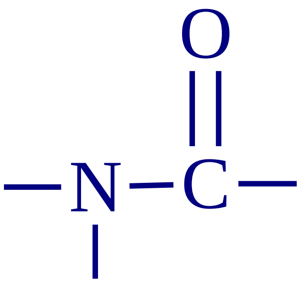
Common Linkages in biochemistry



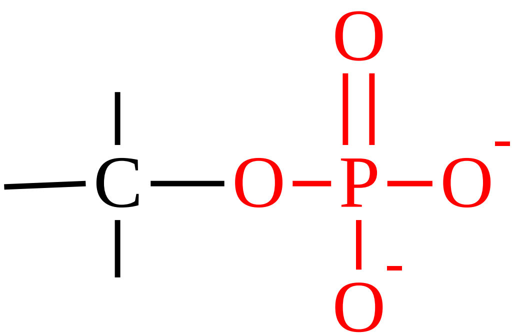
Ester



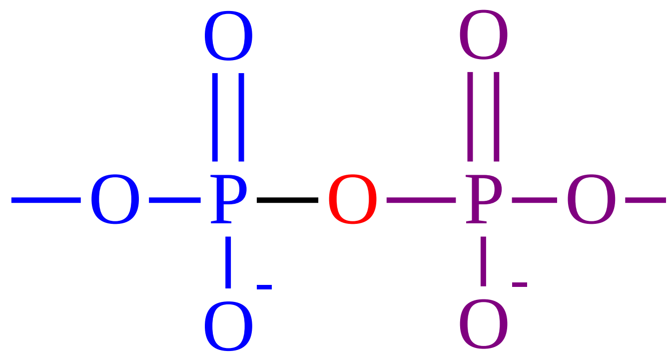
Ether



Amide

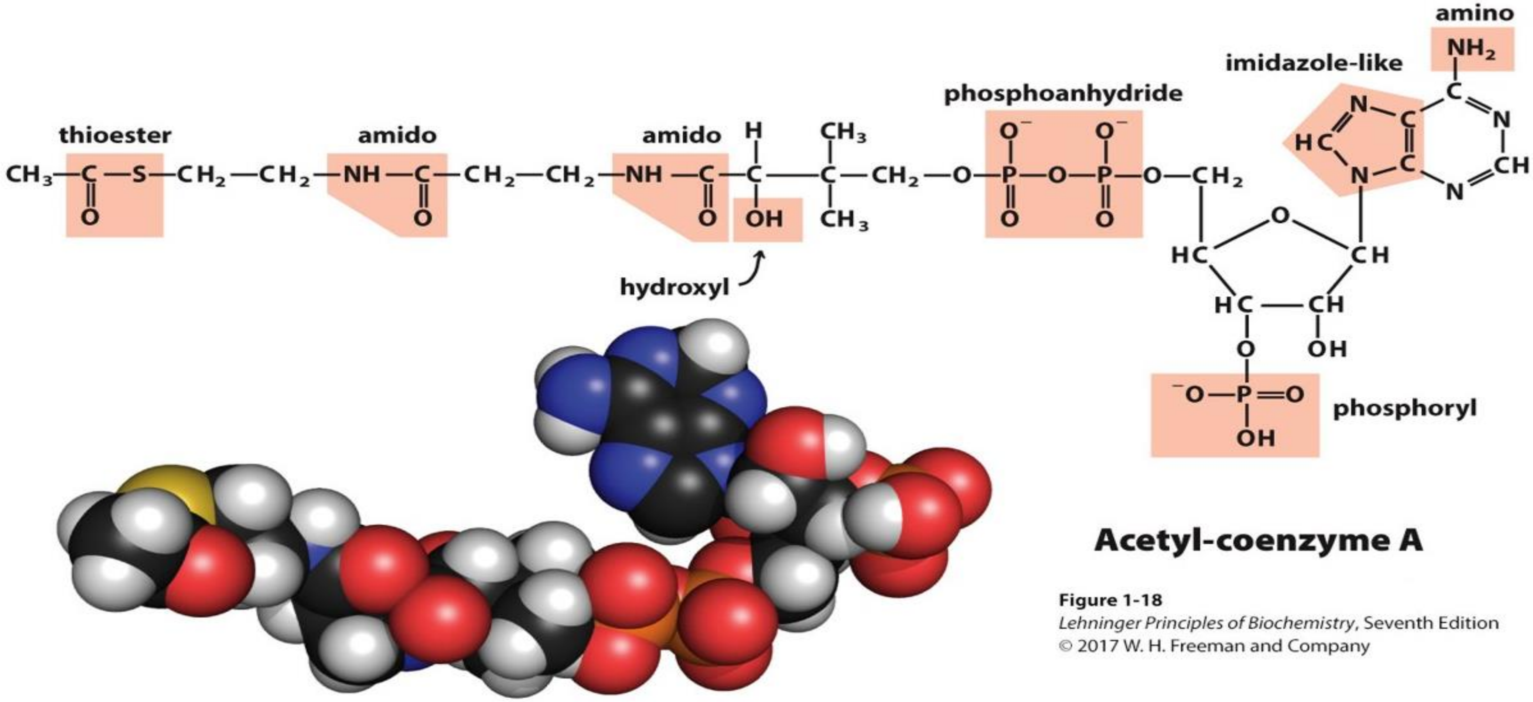


Phosphate Ester



Phosphodiaester
(phosphoanhydride)

Biological Molecules Typically Have Several Functional Groups



Several common functional groups in a single biomolecule. Acetyl-coenzyme A (often abbreviated as acetyl-CoA) is a carrier of acetyl groups in some enzymatic reactions. The functional groups are screened in the structural formula. As we will see in Chapter 2, several of these functional groups can exist in protonated or unprotonated forms, depending on the pH. In the space-filling model, N is blue, C is black, P is orange, O is red, and H is white. The yellow atom at the left is the sulfur of the critical thioester bond between the acetyl moiety and coenzyme A.