CARBON CARBON EVERYWHERE!!

Macromolecules

(a) Some of the amino acids of proteins

![Amino acid structures](image)

- Alanine
- Serine
- Aspartate
- Histidine
- Tyrosine
- Cysteine

The parent sugar

![Glucose structure](image)

α-D-Glucose

The components of nucleic acids

- Uracil
- Thymine
- Cytosine
- Adenine
- Guanine

Nitrogenous bases

- 5'-Ribose
- 2'-Deoxy-5'-ribose

Some components of lipids

- Phosphoric acid
- Choline
- Glycerol
- Palmitate
Importance of carbon

Single bonds with Oxygen

\[ \cdot C \cdot + \cdot H \rightarrow \cdot C: \cdot H \quad -C-H \]

\[ \cdot C \cdot + \cdot O: \rightarrow \cdot C=O \quad -C=O \]

\[ \cdot C \cdot + \cdot O: \rightarrow \cdot C=O \quad -C=O \]

Single bonds with Nitrogen

\[ \cdot C \cdot + \cdot N: \rightarrow \cdot C=N \quad -C=N \]

\[ \cdot C \cdot + \cdot N: \rightarrow \cdot C=N \quad -C=N \]

Single bonds with Carbon

\[ \cdot C \cdot + \cdot C \rightarrow \cdot C: \cdot C \quad -C=C \]

\[ \cdot C \cdot + \cdot C \rightarrow \cdot C= \cdot C \quad -C=C \]

\[ \cdot C \cdot + \cdot C \rightarrow \cdot C= \cdot C \quad -C=C \]
Importance of carbon

Methyl

Ethyl

Sulphydryl

Disulfide

Thioester

Carbonyl (aldehyde)

Carbonyl (ketone)

Carboxyl

Hydroxyl (alcohol)

Phenyl

Amino

Guanidino

Amido

Imidazole

Phosphoryl

Phosphoanhydride

Mixed anhydride (carboxylic acid and phosphoric acid; also called acyl phosphate)

Anhydride (two carboxylic acids)
Importance of carbon

Acetyl-coenzyme A
Importance of carbon Geometry

Compounds of carbon can exist as **stereoisomers**

Stereoisomers - different molecules in which the order of bonding is the same, but the spatial relationship among the atoms is different - differing configuration

Stereospecific - requires specific stereochemistry

**geometric isomers**
Importance of geometry

HIV genome (gray) is made of RNA, it has a complementary surface for an important protein molecule to bind (colored stick model)
**Importance of carbon**

**Chiral carbon**

*Chiral carbon* - asymmetric carbon with 4 different substituents.

![Diagram of chiral and achiral molecules](image-url)
19 of the 20 Amino acids in proteins have a chiral center
Importance of carbon
Chiral carbon

In living organisms, chiral molecules usually exist in only one chiral form.

Amino acids (protein building blocks) - only L isomers
Glucose (carbohydrate building block) - only D isomer
Chemical reactivity

Five MAJOR reaction types in biochemistry

(1) **Oxidation-Reduction Reactions**

OXIDATION = Loss of electrons

REDUCTION = Gain of electrons

A dehydrogenation reaction - when a reactant loses 2 electrons and 2 H\(^+\)
(enzyme = dehydrogenases)  OXIDATION
Chemical reactivity

(2) Cleavage and formation of C-C bonds
Examples:

(a) $\text{C}^{\delta^+}$

(b) $\text{C}^{\delta^-}$

(c) $\text{R}_1\text{C}^{\cdot}\text{C}^{\cdot}\text{OH}$

Aldol condensation

$\text{CoA-S}\text{C}^{\cdot}\text{C}^{\cdot}\text{OH}$

Claisen ester condensation

$\text{R}_1\text{C}^{\cdot}\text{C}^{\cdot}\text{OH}$

Decarboxylation of a $\beta$-keto acid
(2) Cleavage and formation of C-C bonds (or C-N bonds)
Monomeric subunits are joined with the release of water
Chemical reactivity

(2) Cleavage and formation of C-C bonds

\[ \text{C : W} + \text{Z :} \rightleftharpoons \text{C : Z} + \text{W :} \]

Leaving Nucleophile group

Nucleophiles - rich in electrons
Electrophiles - electron deficient

**table 3-4**

<table>
<thead>
<tr>
<th>Some Functional Groups Active as Nucleophiles within Cells^*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water ( \text{H}_{2}\text{O} )</td>
</tr>
<tr>
<td>Hydroxide ion ( \text{HO}^- )</td>
</tr>
<tr>
<td>Hydroxyl (alcohol) ( \text{ROH} )</td>
</tr>
<tr>
<td>Alkoxyl ( \text{RO}^- )</td>
</tr>
<tr>
<td>Sulphydryl ( \text{RSH} )</td>
</tr>
<tr>
<td>Sulfide ( \text{RS}^- )</td>
</tr>
<tr>
<td>Amino ( \text{RNH}_2 )</td>
</tr>
<tr>
<td>Carboxylate [Image of carboxylate group]</td>
</tr>
<tr>
<td>Imidazole [Image of imidazole]</td>
</tr>
<tr>
<td>Inorganic orthophosphate ( \text{PO}_4^{3-} )</td>
</tr>
</tbody>
</table>

^*Listed in order of decreasing strength. Weaker nucleophiles make better leaving groups.
Chemical reactivity

(2) Cleavage and formation of C-C bonds

Nucleophilic substitution - electron-rich group replaces departing anion

(a) SN1 reaction

Substitution nucleophilic, unimolecular

(b) SN2 reaction

Substitution nucleophilic, bimolecular
Chemical reactivity

(3) Internal rearrangements, isomerizations and eliminations

Redistribution of electrons results in
(i) isomerization
(ii) transposition of double bonds
(iii) cis-trans rearrangements of double bonds
Chemical reactivity

(4) Group Transfers
In metabolism - attachment of a good leaving group to a metabolic intermediate to “activate” it for subsequent reaction

Good leaving group

Example

Adenine  Ribose  \( \overset{\text{Glucose}}{\text{ATP}} \)

\( \overset{\text{ADP}}{\text{Glucose 6-phosphate, a phosphate ester}} \)
(5) **Free radical reactions**
Homolytic cleavage of covalent bonds to generate free radicals

Repair of damaged DNA by DNA photolyase