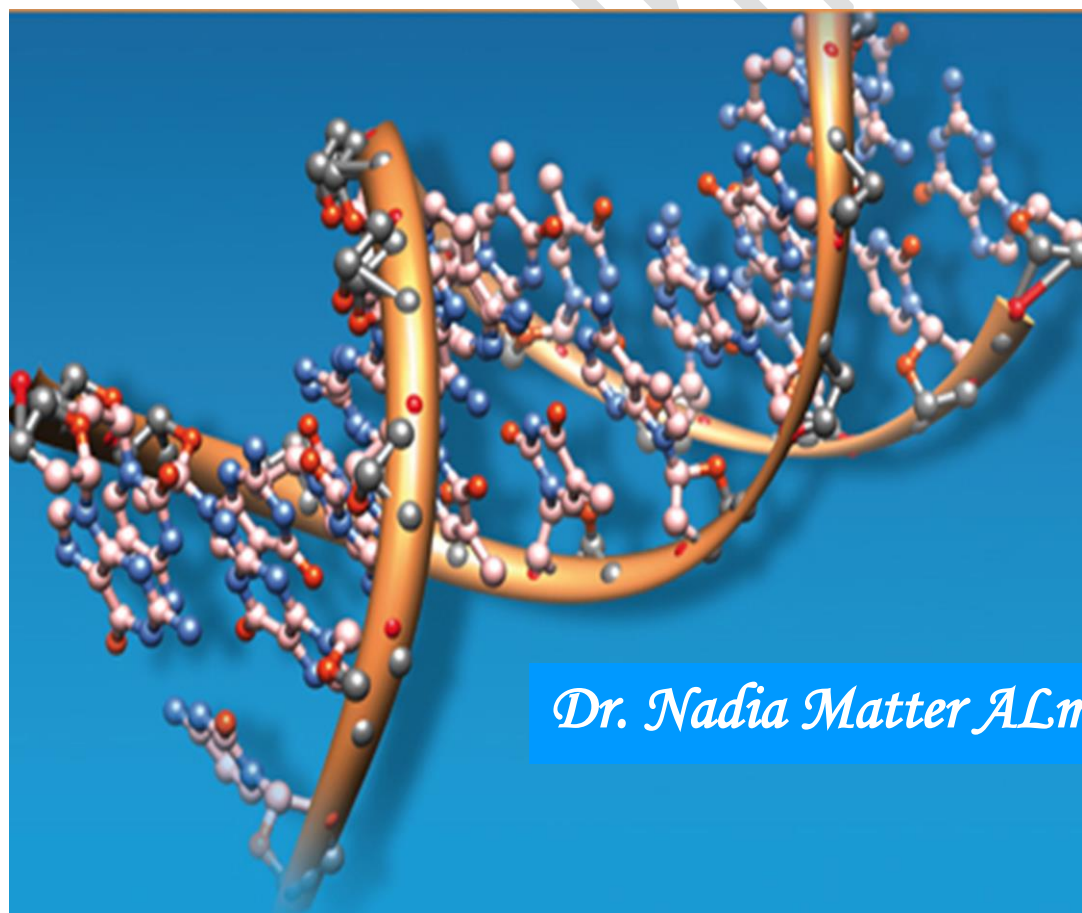


Al-Mustansiriyah University
College of Engineering
Environmental Dept. / 4th year
By: Dr. Nadia Matter Almhana

Biochemistry



The Molecular composition of living cells

All living organisms, from microbes to mammals, are composed of chemical substances from both the inorganic and organic world, that appear in roughly the same proportions, and perform the same general tasks. **Hydrogen, oxygen, nitrogen, carbon, phosphorus, and sulfur** normally make up more than 99% of the mass of living cells, and when combined in various ways, form virtually all known organic biomolecules. They are initially utilized in the synthesis of a small number of building blocks that are, in turn, used in the construction of a vast array of vital macromolecules (figure 1).

The cell is the unit of life. Cells in multicellular organisms function in association with other specialized cells, but many organisms are free-living single cells. Although differing in size, shape, and functions, there are basic common features in all cells. Every cell contains cytoplasm, a colloidal system of large biochemical in a complex solution of smaller organic molecules and inorganic salts. The cytoplasm is bounded by a semi elastic, selectively permeable cell membrane that controls the transport of molecules into and out of the cell. There are biochemical transport mechanisms that spend energy to bring substances into the cell despite unfavorable concentration gradients across the membrane.

Cells are protected by rigid cell walls external to the cell membranes. In most cells, the chromosomes are surrounded by a membrane to form a conspicuous nucleus. Cells with organized nuclei are described as *eukaryotic*. Other intracellular structures serve as specialized sites for cellular activities. For example, photosynthesis is carried out by organelles called chloroplasts. In bacteria and cyanobacteria (formerly called blue-green algae), the chromosomes are not surrounded by a membrane, and there is little apparent subcellular organization. Lacking a discrete nucleus, these organisms are said to be *prokaryotic*.

A **macromolecule** is a very large molecule, such as protein, commonly created by the polymerization of smaller subunits (monomers). They are typically composed of thousands of atoms or more. There are four general classes of macromolecules within living cells: **nucleic acids, proteins, polysaccharides, and lipids**. Synthetic macromolecules include common plastics and synthetic fibers as well as experimental materials such as carbon nanotubes.

Table 1		Macromolecules	
Macromolecule	Subunit	Function	Example
C A R B O H Y D R A T E S			
Starch, glycogen	Glucose	Energy storage	Potatoes
Cellulose	Glucose	Plant cell walls	Paper; strings of celery
Chitin	Modified glucose	Structural support	Crab shells
N U C L E I C A C I D S			
DNA	Nucleotides	Encodes genes	Chromosomes
RNA	Nucleotides	Needed for gene expression	Messenger RNA
P R O T E I N S			
Functional	Amino acids	Catalysis; transport	Hemoglobin
Structural	Amino acids	Support	Hair; silk
L I P I D S			
Fats	Glycerol and three fatty acids	Energy storage	Butter; corn oil; soap
Phospholipids	Glycerol, two fatty acids, phosphate, and polar R groups	Cell membranes	Phosphatidylcholine
Prostaglandins	Five-carbon rings with two nonpolar tails	Chemical messengers	Prostaglandin E (PGE)
Steroids	Four fused carbon rings	Membranes; hormones	Cholesterol; estrogen
Terpenes	Long carbon chains	Pigments; structural support	Carotene; rubber

These compounds, which have molecular weights ranging from 1×10^3 to 1×10^6 , are created through polymerization of building blocks that have molecular weights in the range of 50 to 150. Although subtle differences do exist between cells (e.g., erythrocyte, liver, muscle or fat cell), they all generally contain a greater variety of proteins than any other type of macromolecule, with about 50% of the solid matter of the cell being protein (15% on a wet weight basis). Cells generally contain many more protein molecules than DNA molecules, yet **DNA** is typically the largest biomolecule in the cell.

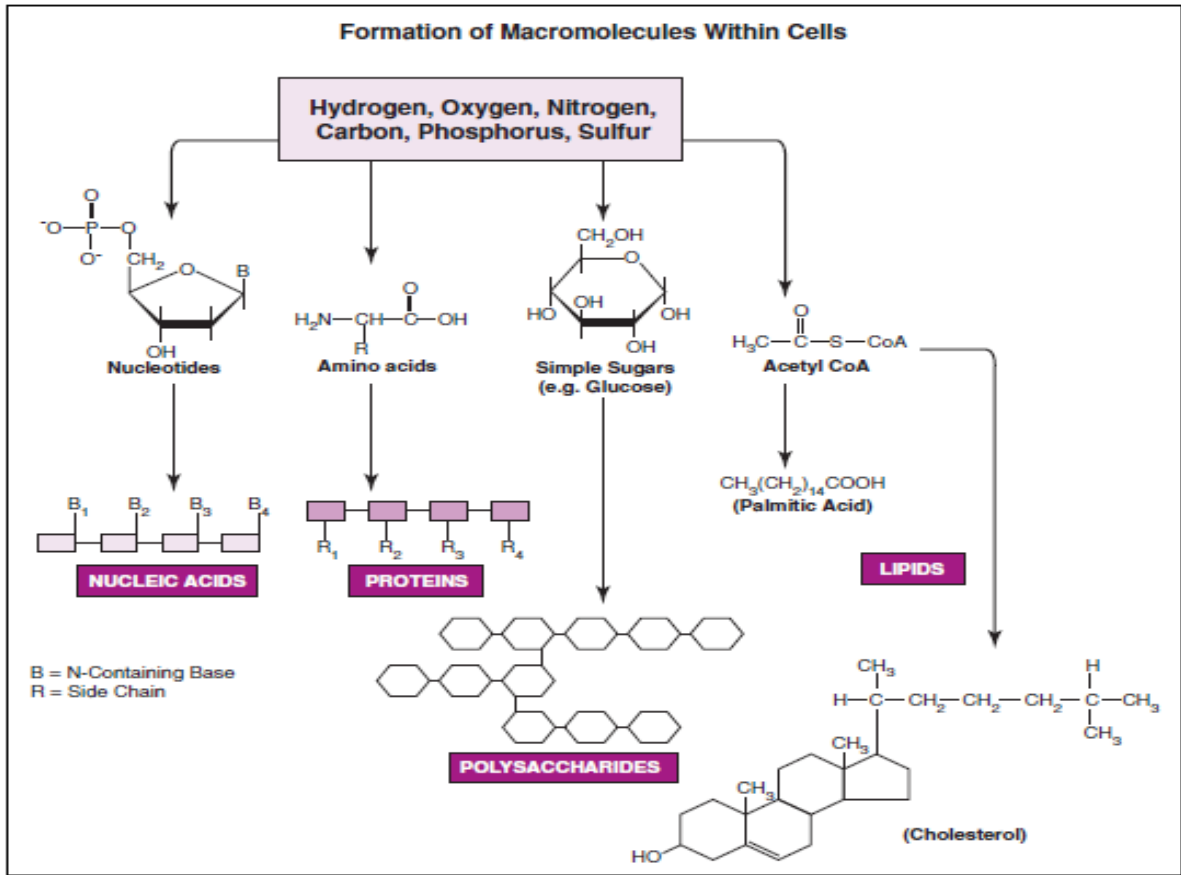


Figure (1): The macromolecules of the living cells.

Composition, Structure and Function of Biomolecules

The molecules found in the organisms are called **biomolecules** and they obey the same laws of physics and chemistry.

Biomolecules are molecules that occur naturally in living organisms. Biomolecules include macromolecules like proteins, carbohydrates, lipids and nucleic acids. It also includes small molecules like primary and secondary metabolites and natural products. Biomolecules consists mainly of carbon and hydrogen with nitrogen, oxygen, sulphur, and phosphorus. Biomolecules are very large molecules of many atoms that are covalently bound together.

Most, but not all, of the carbon-containing molecules in cells are built up from members of one of four different families of small organic molecules: sugars, amino acids, nucleotides, and fatty acids. Each of these families contains a group of molecules that resemble one another in both structure and function. In addition to other important functions, these molecules are used to build large macromolecules. For example, the sugars can be linked to form polysaccharides such as starch and glycogen, the amino acids can be linked to form proteins, the nucleotides can be linked to form the DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) of chromosomes, and the fatty acids can be linked to form the lipids of all cell membranes.

All forms of life are composed of biomolecules only. Biomolecules are organic molecules especially macromolecules like carbohydrates, proteins in living organisms. All living forms bacteria, algae, plant and animals are made of similar macromolecules that are responsible for life. All the carbon compounds we get from living tissues can be called biomolecules.

component	percent of total cell weight
water	70
Inorganic ions (sodium, potassium, magnesium, calcium, chloride, etc.)	1
miscellaneous small metabolites	3
proteins	18
RNA	1.1
DNA	0.25
phospholipids and other lipids	5
polysaccharides	2
Approximate chemical composition of a typical mammalian cell	

Cell membrane

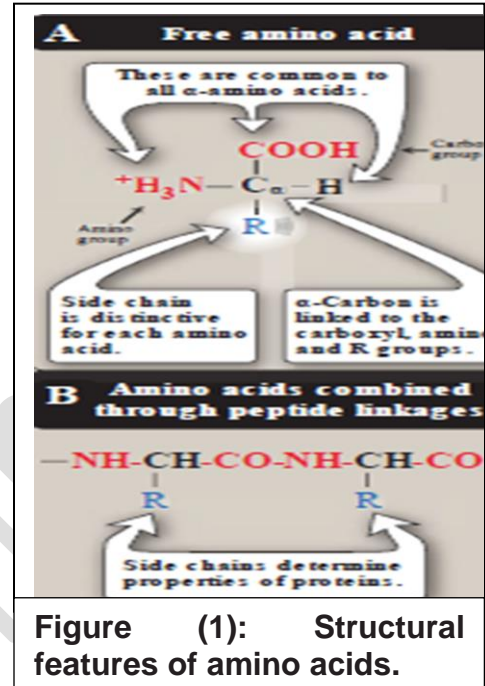
The **cell membrane** (also known as the **plasma membrane** or **cytoplasmic membrane**, and historically referred to as the **plasma lemma**) is a biological membrane that separates the interior of all cells from the outside environment (the extracellular space). It consists of a lipid bilayer with embedded proteins. The basic function of the cell membrane is to protect the cell from its surroundings. The cell membrane controls the movement of substances in and out of cells and organelles. In this way, it is selectively permeable to ions and organic molecules.

Protein Structure and Function

Proteins are the most abundant and functionally diverse molecules in living systems. Virtually every life process depends on this class of macromolecules. For example, enzymes and polypeptide hormones direct and regulate metabolism in the body, whereas contractile proteins in muscle permit movement. In bone, the protein collagen forms a framework for the deposition of calcium phosphate crystals, acting like the steel cables in reinforced concrete.

Structure of amino acids

Although more than 300 different amino acids have been described in nature, only 20 are commonly found as constituents of mammalian proteins. [Note: These are the only amino acids that are coded for by DNA, the genetic material in the cell.] Each amino acid has a carboxyl group, a primary amino group (except for proline, which has a secondary amino group), and a distinctive side chain (“R group”) bonded to the carbon atom (Figure 1A). At physiologic pH (approximately 7.4), the carboxyl group is dissociated, forming the negatively charged carboxylate ion ($-COO^-$), and the amino group is protonated ($-NH_3^+$). In proteins, almost all of these carboxyl and amino groups are combined through peptide linkage and, in general, are not available for chemical reaction except for hydrogen bond formation (Figure 1B). Thus, it is the nature of the side chains that ultimately dictates the role an amino acid plays in a protein. It is, the reform, useful to classify



the amino acids according to the properties of their side chains, that is, whether they are nonpolar (have an even distribution of electrons) or polar (have an uneven distribution of electrons, such as acids and bases) as shown in Figures 2 and 3.

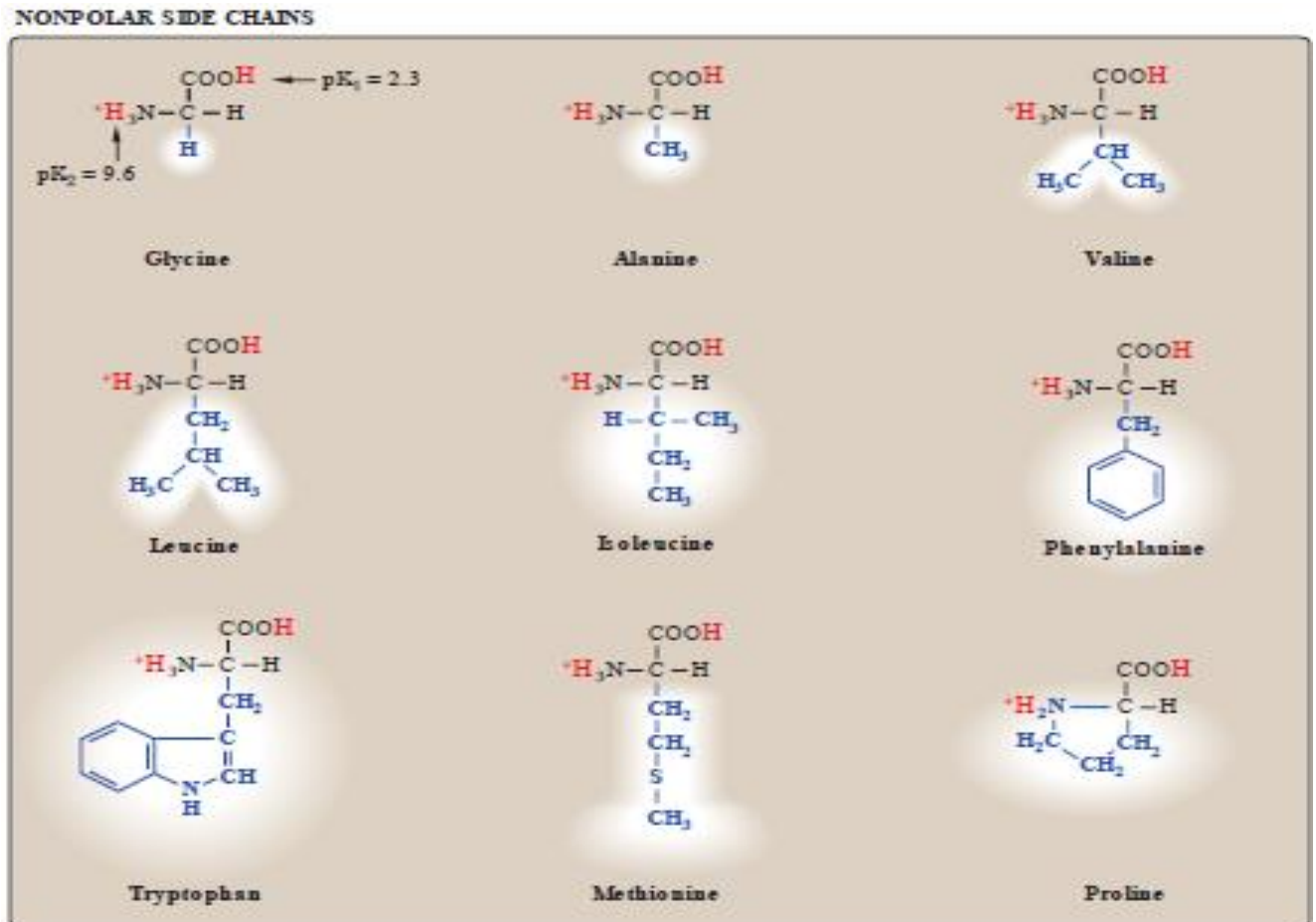


Figure 2: Classification of the 20 amino acids commonly found in proteins, according to the charge and polarity of their side chains at acidic pH is shown here and continues in Figure 3. Each amino acid is shown in its fully protonated form, with dissociable hydrogen ions represented in red print.

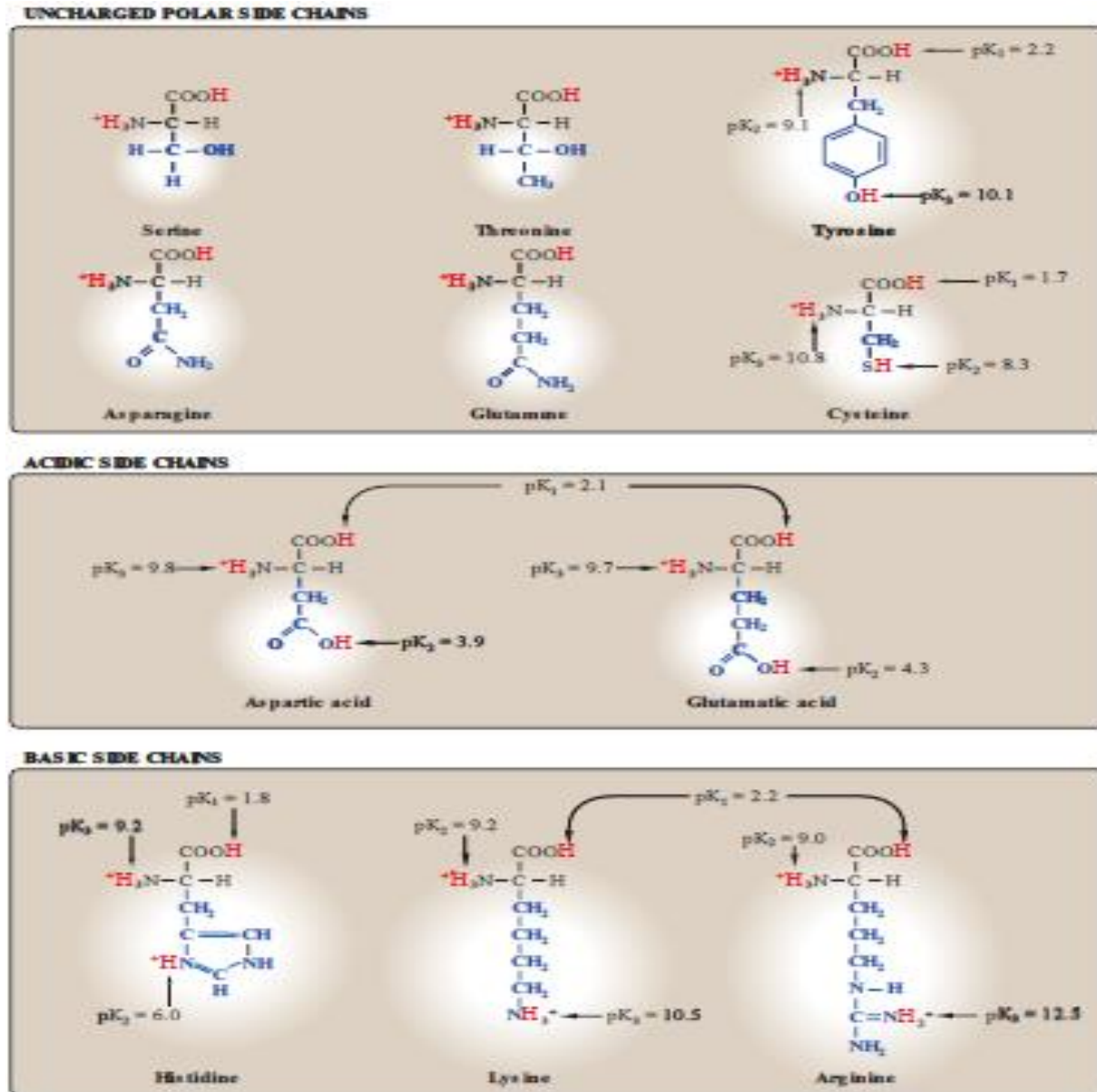


Figure 3: Classification of the 20 amino acids commonly found in proteins, according to the charge and polarity of their side chains at acidic pH (continued from Figure 2).

A. Amino acids with nonpolar side chains

Each of these amino acids has a nonpolar side chain that does not gain or lose protons or participate in hydrogen or ionic bonds (see Figure 2). The side chains of these amino acids can be thought of as “oily” or lipid-like, a property that promotes hydrophobic interactions.

B. Amino acids with uncharged polar side chains

These amino acids have zero net charge at physiologic pH; although the side chains of cysteine and tyrosine can lose a proton at an alkaline pH (see Figure 3). Serine, threonine, and tyrosine each contain a polar hydroxyl group that can participate in hydrogen bond formation (Figure 4). The side chains of asparagine and glutamine each contain a carbonyl group and an amide group, both of which can also participate in hydrogen bonds.

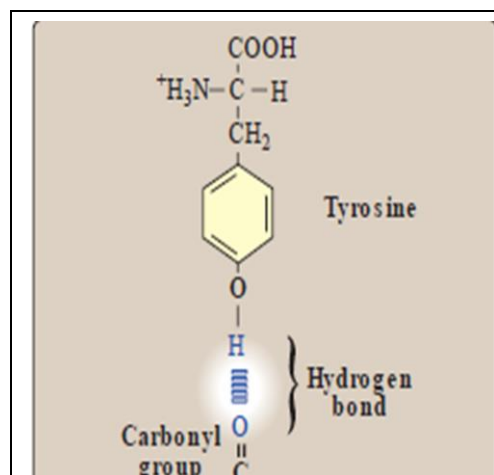


Figure 4: Hydrogen bond between the phenolic hydroxyl group of tyrosine and another molecule containing a carbonyl group.

1. Disulfide bond: The side chain of cysteine contains a sulfhydryl (thiol) group (–SH), which is an important component of the active site of many enzymes. In proteins, the –SH groups of two cysteines can be oxidized to form a covalent cross-link called a disulfide bond (–S–S–). Two disulfide-linked cysteines are referred to as “cystine.”

2. Side chains as sites of attachment for other compounds: The polar hydroxyl group of serine; threonine; and, rarely, tyrosine, can serve as a site of attachment for structures such as a phosphate group. In addition, the amide group of asparagine, as well as the hydroxyl group of serine or threonine, can serve as a site of attachment for oligosaccharide chains in glycoproteins.

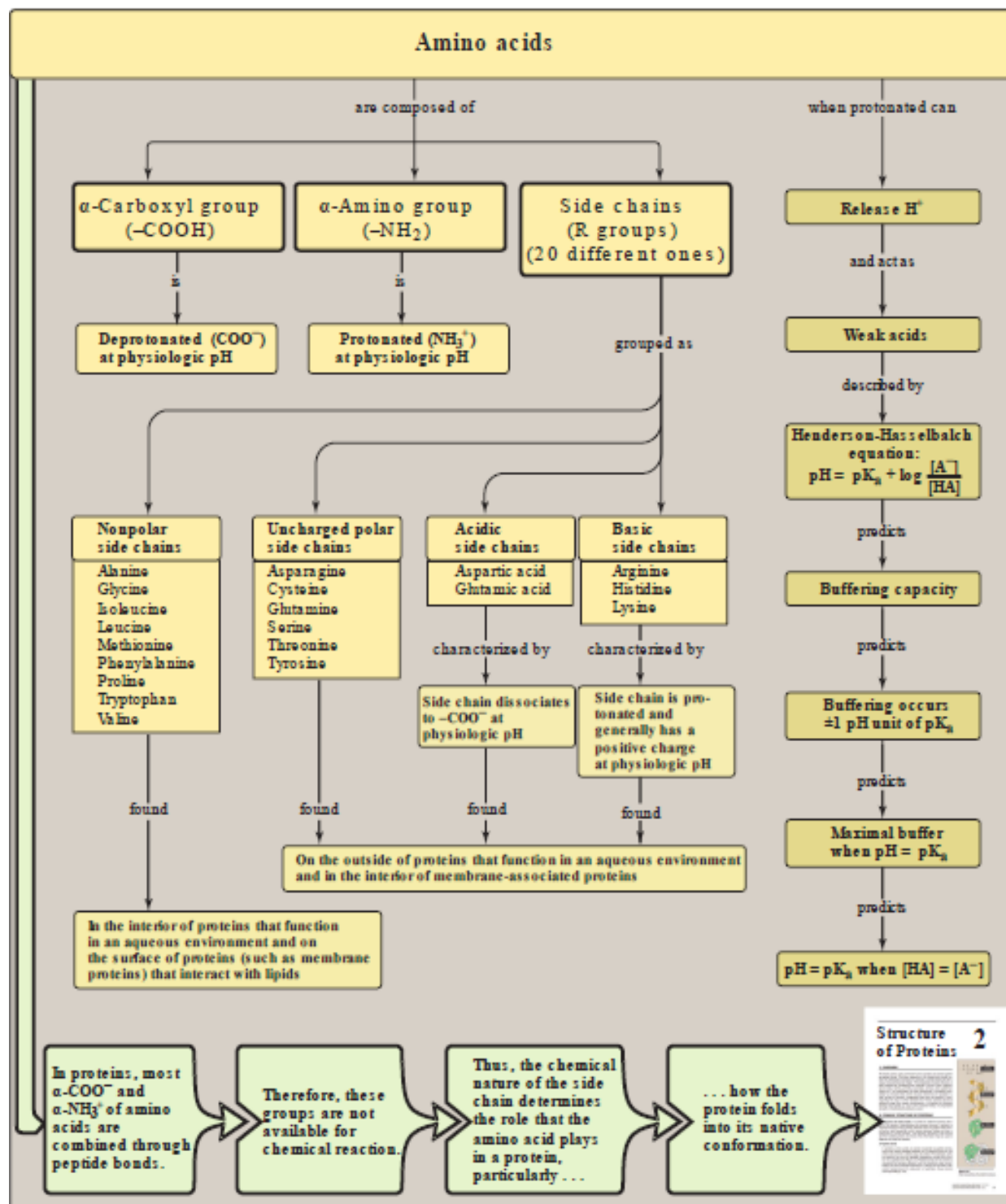
C. Amino acids with acidic side chains

The amino acids aspartic and glutamic acid are proton donors. At physiologic pH, the side chains of these amino acids are fully ionized, containing a negatively charged carboxylate group ($-\text{COO}^-$). They are, therefore, called aspartate or glutamate to emphasize that these amino acids are negatively charged at physiologic pH (see Figure 3).

D. Amino acids with basic side chains

The side chains of the basic amino acids accept protons (see Figure 3). At physiologic pH, the R groups of lysine and arginine are fully ionized and positively charged. In contrast, histidine is weakly basic, and the free amino acid is largely uncharged at physiologic pH.

However, when histidine is incorporated into a protein, its R group can be either positively charged (protonated) or neutral, depending on the ionic environment provided by the protein. This is an important property of histidine that contributes to the buffering role it plays in the functioning of proteins such as hemoglobin. [Note: Histidine is the only amino acid with a side chain that can ionize within the physiologic pH range.]



Release H⁺

and act as

Weak acids:

described by

Henderson-Hasselbalch equation:

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

predict

Buffering capacity

predict

Buffering occurs ≈ 1 pH unit of pK_a

predict

Maximal buffer when pH = pK_a

predict

pH = pK_a when [HA] = [A⁻]

Structure of Proteins 2

In proteins, most α-COO⁻ and α-NH₃⁺ of amino acids are combined through peptide bonds.

Therefore, these groups are not available for chemical reaction.

Thus, the chemical nature of the side chain determines the role that the amino acid plays in a protein, particularly ...

... how the protein folds into its native conformation.

Figure 5: Key concept map for amino acids.

Peptides

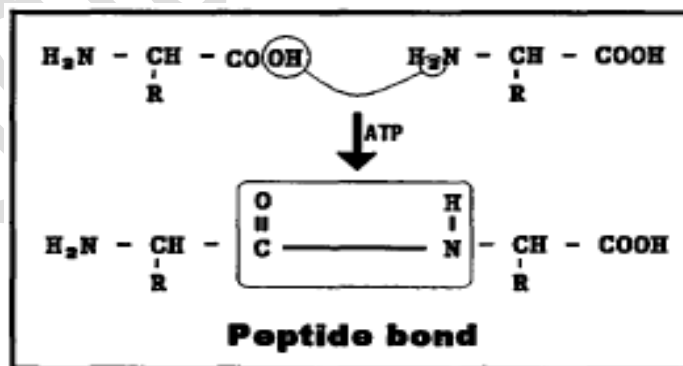
1. Definition:

A. Peptides are compounds, formed of less *than 50 amino acids* linked together by peptide bonds.

1. **Dipeptide** (2 amino acids and one peptide bond).
2. **Tripeptide** (3 amino acids and two peptide bonds).
3. **Oligopeptide** (3-10 amino acids).
4. **Polypeptide** (10-50 amino acids).

B. Peptide bond:

1. It is a covalent bond formed between the carboxyl group of one amino acid and α - amino another.
2. It is formed by removal of water.
3. Peptide formation needs energy, getting from hydrolysis of a high energy phosphate compound e.g. ATP.
4. Peptide bond is semi-rigid bond i.e. no free rotation can occur around bond axis.



Proteins

Proteins are macromolecules that play many roles such as serving as enzymes or components of cell membranes and muscle. The antibodies that protect against invasion by foreign substances are themselves proteins. There are twenty-odd amino acids found regularly in most naturally occurring proteins. Because of the great length of protein chains and the various sequences of amino acids, the theoretical number of possible proteins is astronomical. The amino acid sequence is referred to as the primary structure of a protein. The polypeptide chain is usually coiled or folded to provide secondary structure to the molecule, and linkages through other functional groups (mainly disulfide bonds) form the tertiary structure. For some protein molecules, there may be spatial arrangement forming defined aggregates, known as the quaternary structure of proteins.

For a polypeptide polymer to have biological activity a certain molecular arrangement is necessary. This requires not only the primary and secondary but also tertiary and sometimes quaternary structure. Such a strict structural requirement explains the high specificity of proteins. In the presence of certain chemical reagents, excessive heat, radiation, unfavorable pH, and so on, the protein structure may become disorganized. This is called *denaturation* and may be reversible if not too severe.

Table 2: An Overview of Protein Functions

Type of Protein	Function	Examples
Enzymatic proteins	Selective acceleration of chemical reactions	Digestive enzymes (hydrolyze polymers in food)
Structural proteins	Support	Silk fibers (cocoons and spider webs), collagen and elastin (animal connective tissues), keratin (hair, horns, feathers)
Storage proteins	Storage of amino acids	Ovalbumin (egg white), casein (milk), storage proteins in seeds
Transport proteins	Transport of other substances	Hemoglobin (blood), proteins that transport molecules across cell membranes
Hormonal proteins	Coordination of an organism's activities	Insulin (helps regulate concentration of sugar in blood)
Receptor proteins	Response of cell to chemical stimuli	Nerve cell receptors (detect chemical signals released by other nerve cells)
Contractile and motor proteins	Movement	Actin and myosin (muscles), proteins responsible for undulations of cilia and flagella
Defensive proteins	Protection against disease	Antibodies (combat bacteria and viruses)

Enzymes

Enzymes are energy barriers separating the reactants (substrates) and the products. Virtually all reactions in the body are mediated by enzymes, which are protein catalysts that increase the rate of reactions without being changed in the overall process. Among the many biologic reactions that are energetically possible, enzymes selectively channel reactants (called substrates) into useful pathways. Enzymes thus direct all metabolic events. This chapter examines the nature of this catalytic molecules and their mechanism of action.



Note: (en = In, zyme = yeast).

Definitions:

A. Enzymes: These are specific protein catalysts that:

1. Accelerate the rate of chemical reactions.
2. Enzyme structure is not changed by entering the reactions,
3. Enzyme does not affect the equilibrium constant (i.e. end products) of the reactions.

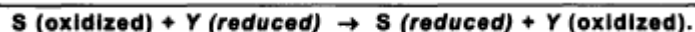
B. Rate of chemical reaction: It is the change in the amount (moles, grams) of starting materials (substrates) or products per unit time.

C. Substrate: Is the substance upon which the enzyme acts.

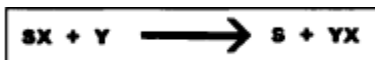
Classification of enzymes:

There are 6 classes of enzymes which are:

A. Oxidoreductase: This group of enzymes catalyzes an oxidation-reduction reaction between two substrates:

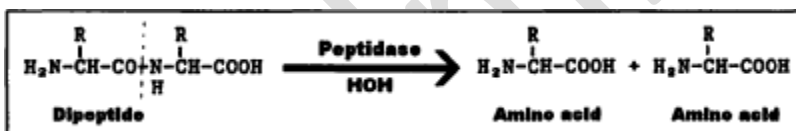


B. Transferase: This group of enzymes catalyzes the transfer of a group other than hydrogen from one substrate to another:

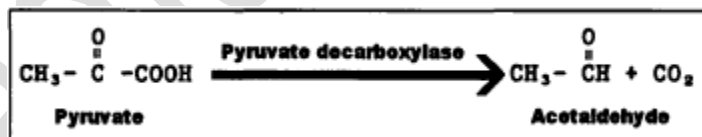


C. Hydrolase: this group catalyzes hydrolysis i.e. breakdown of a chemical bond by addition of water: $A \cdot B + H_2O \rightarrow AH + BOH$

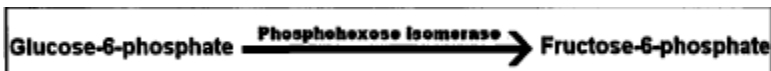
Example: peptidase:



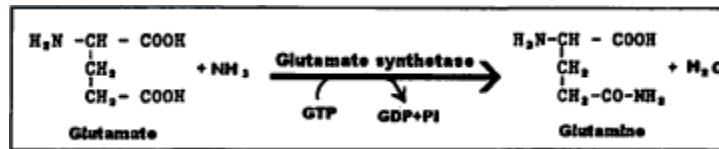
D. Lyases: This group of enzymes catalyzes addition of carbon dioxide, water and ammonia across double bonds, or removes these elements to produce double bonds. Example: Decarboxylase:



E. Isomerases: This group of enzymes catalyzes the Interconversion of one isomer into another. This group Includes: Isomerases, mutases and epimerases. Example: phosphohexose Isomerase:



F. Ligases for synthetases: This group of enzymes catalyzes joining of two substrates using the energy from ATP or GTP. Example: Glutamine synthetase.



Summary of enzyme classes:

Number	Classification	Catalytic activity
1.	Oxidoreductases	They catalyze an oxidation-reduction reaction between two substrates.
2.	Transferases	They catalyze the transfer of a functional group other than hydrogen from one substrate to another.
3.	Hydrolases	They catalyze hydrolysis i.e. breakdown of a chemical bond by addition of water.
4.	Lyases	Add water, ammonia or carbon dioxide across double bonds, or remove these elements to produce double bonds.
6.	Isomerases	They catalyze the interconversion of one isomer into the other.
6.	Ligases	Catalyze reactions in which two chemical groups are joined (or ligated) with the use of energy from ATP.

1. Oxidoreductases Catalyze oxidation-reduction reactions, such as:

$$\begin{array}{c} \text{CH}_3-\text{CH}-\text{COO}^- \\ | \\ \text{OH} \end{array} + \text{NAD}^+ \rightleftharpoons \begin{array}{c} \text{CH}_3-\text{C}-\text{COO}^- \\ || \\ \text{O} \end{array} + \text{NADH} + \text{H}^+$$

Lactate $\xrightarrow{\text{Lactate dehydrogenase}}$ Pyruvate

2. Transferases Catalyze transfer of C-, N-, or P-containing groups, such as:

$$\begin{array}{c} \text{CH}_2 \\ | \\ \text{CH}-\text{COO}^- \\ | \\ \text{OH} \end{array} + \text{THF} \xrightarrow[\text{H}_2\text{O}]{\text{Serine hydroxymethyl transferase}} \begin{array}{c} \text{CH}_2-\text{COO}^- \\ | \\ \text{NH}_3^+ \end{array} + \text{THF}-\text{CH}_2$$

Serine $\xrightarrow{\text{Serine hydroxymethyl transferase}}$ Glycine

3. Hydrolases Catalyze cleavage of bonds by addition of water, such as:

$$\begin{array}{c} \text{NH}_2 \\ | \\ \text{C}-\text{NH}_2 \\ || \\ \text{O} \end{array} + \text{H}_2\text{O} \xrightarrow{\text{Urease}} \text{CO}_2 + 2\text{NH}_3$$

Urea $\xrightarrow{\text{Urease}}$ $\text{CO}_2 + 2\text{NH}_3$

4. Lyases Catalyze cleavage of C-C, C-S, and certain C-N bonds, such as:

$$\begin{array}{c} \text{CH}_3-\text{C} \\ || \\ \text{O} \end{array} - \text{C} \begin{array}{c} \text{COO}^- \\ | \\ \text{O} \end{array} \xrightarrow{\text{Pyruvate decarboxylase}} \begin{array}{c} \text{CH}_3-\text{CH} \\ | \\ \text{O} \end{array} + \text{CO}_2$$

Pyruvate $\xrightarrow{\text{Pyruvate decarboxylase}}$ Acetaldehyde

5. Isomerases Catalyze racemization of optical or geometric isomers, such as:

$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{OOC}-\text{C}-\text{CH}_2-\text{C}-\text{CoA} \\ | \\ \text{O} \end{array} \rightleftharpoons \begin{array}{c} \text{OOC}-\text{CH}_2-\text{CH}_2-\text{C}-\text{CoA} \\ | \\ \text{O} \end{array}$$

Methylmalonyl CoA $\xrightarrow{\text{Methylmalonyl mutase}}$ Succinyl CoA

6. Ligases Catalyze formation of bonds between carbon and O, S, and N coupled to hydrolysis of high-energy phosphates, such as:

$$\begin{array}{c} \text{CH}_3-\text{C}-\text{COO}^- \\ || \\ \text{O} \end{array} + \text{CO}_2 \xrightarrow[\text{ATP} \rightarrow \text{ADP} + \text{P}_i]{\text{Pyruvate carboxylase}} \begin{array}{c} \text{OOC}-\text{CH}_2-\text{C}-\text{COO}^- \\ || \\ \text{O} \end{array}$$

Pyruvate $\xrightarrow{\text{Pyruvate carboxylase}}$ Oxaloacetate

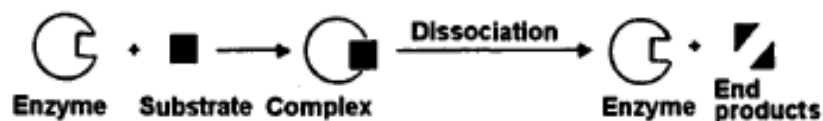
Mechanism of enzyme action:

A. Activation Energy:

1. All the reactions that proceed from initial substrates (initial state) to products (final state) consume energy. This is called free energy of the reaction.
2. However the substrates do not become products directly, but must be energized (absorb energy) to reach an activated or transition state. This energy is called activation energy.
3. At transition state, there is a high probability that a chemical bond will be made or broken to form the product.
4. The definition of activation energy: is the amount of energy required to raise all the molecules in one mole of a substance to the transition state.
5. The effect of enzymes: is to decrease the energy of activation.

B. Active site:

1. The specificity of an enzyme is determined by:
 - a) The functional group of the substrate (or product).
 - b) The functional group of the enzyme and its cofactors.
 - c) The physical proximity of these various functional groups:
 - 1) During the enzyme action, there is a temporary combination between the enzyme and its substrate forming enzyme-substrate complex. This occurs at active site of enzyme.
 - 2) This is followed by dissociation of this complex into enzyme again and products.



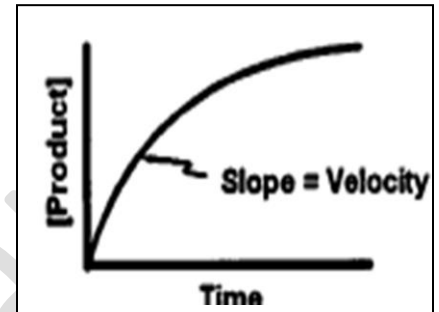
Enzyme kinetics:

It is the study of the velocity (rate) of reactions catalyzed by enzymes.

A. Velocity of reaction: It is the increase in the concentration of product (Or decrease in concentration of substrate) with time.

B. Initial velocity:

1. If an enzyme is incubated with its substrate and the appearance of the product with time is recorded on a graph, the resulting line will have the hyperbolic shape as in the figure:
2. The rate (velocity) of the reaction, which corresponds to the slope of this curve, is initially constant but gradually decreases.
3. The decline in the rate of the reaction may be due to:
 - a) Depletion of the substrate,
 - b) Inhibition of the enzyme by its product.
 - c) Denaturation of the enzyme.
4. *Initial velocity (V_i) of the reaction:* It Is the Initial portion of the reaction where the Increase In the concentration of the product is correlated constantly with time. For this reason, only the initial velocity (V_i) is used in calculating the kinetic parameters of the reaction.
5. The units of velocity: Is concentration of the product per unit time, e.g. micromoles / minute.



C. Factors affecting enzyme activity:

Factors affecting enzyme activity:

1. Concentration of enzyme:

The Initial velocity of a reaction is directly proportional to the amount of the enzyme present, provided that all other conditions remain constant.

(Note: when the amount of enzyme in a reaction is doubled; the amount of substrate converted to product is doubled. Also when the amount of enzyme is tripled, the amount of substrate converted to product is tripled and so on).

2. Concentration of substrate:

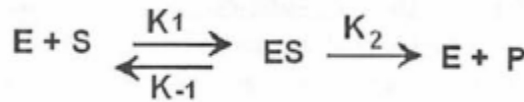
The initial velocity of a reaction is directly proportional to the amount of substrate present till it reaches a maximum point known as maximum velocity (V_{max}), where any further Increase in the amount of substrate causes no increase in substrate concentration the velocity of the reaction. This is true If all other conditions especially enzyme concentration remain constant.

Factors affecting enzyme activity

- Enzyme concentration
- Substrate concentration
- pH
- Temperature
- Enzyme activators
- Enzyme inhibitors

b) Michaelis-Menten Equation:

- 1) This equation describes the dependence of reaction velocity on substrate concentration.
- 2) Michaelis and Menten proposed that in any enzymatic reaction, the enzyme (E) combines with substrate (S) to form an enzyme-substrate (ES) complex.
- 3) ES then breaks down either to enzyme and substrate again or to enzyme and product (P).



- 4) Michaelis and Menten equation describes how reaction velocity varies with substrate concentration as follows:

$$V_i = \frac{V_{\max} [S]}{K_m + [S]}$$

Where: V_i = Initial reaction velocity

V_{\max} = maximal velocity

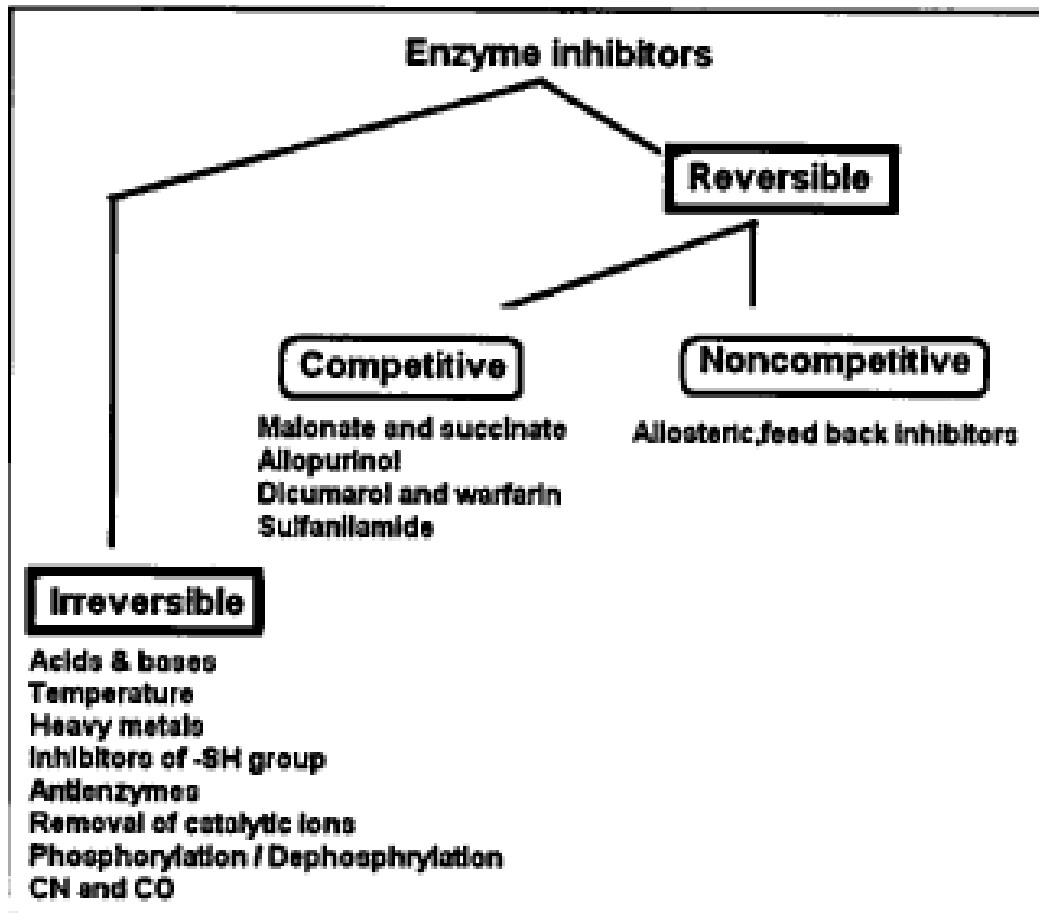
K_m = Michaelis constants = $(k_1 + k_2)/k_{-1}$

$[S]$ = Substrate concentration

Enzyme inhibitors

These are substances that can diminish the velocity of enzymatic reactions.

The Inhibition of enzymes can be classified either as reversible or Irreversible.



Carbohydrates

A **carbohydrate** is a biomolecule consisting of carbon (C), hydrogen (H) and oxygen (O) atoms, usually with a hydrogen–oxygen atom ratio of 2:1 (as in water) and thus with the empirical formula $C_m(H_2O)_n$ (where m may be different from n). This formula holds true for monosaccharides. Some exceptions exist; for example, deoxyribose, a sugar component of DNA, has the empirical formula $C_5H_{10}O_4$. The carbohydrates are technically hydrates of carbon; structurally it is more accurate to view them as aldoses and ketoses.

Carbohydrates (saccharides) are the most abundant organic molecules in nature. They have a wide range of functions, including providing a significant fraction of the dietary calories for most organisms, acting as a storage form of energy in the body, and serving as cell membrane components that mediate some forms of intercellular communication.

Carbohydrates also serve as a structural component of many organisms, including the cell walls of bacteria, the exoskeleton of many insects, and the fibrous cellulose of plants. The empiric formula for many of the simple carbohydrates is $(CH_2O)_n$, where $n \geq 3$, hence the name “hydrate of carbon.” The term is most common in biochemistry, where it is a synonym of 'saccharide', a group that includes sugars, starch, and cellulose.

The saccharides are divided into four chemical groups: monosaccharides, disaccharides, oligosaccharides, and polysaccharides.

Monosaccharides and disaccharides, the smallest (lower molecular weight) carbohydrates, are commonly referred to as sugars. The scientific nomenclature of carbohydrates is complex, the names of the monosaccharides and disaccharides very often end in the suffix -ose, as in the monosaccharides fructose (fruit sugar)

and glucose (starch sugar) and the disaccharides sucrose (cane or beet sugar) and lactose(milk sugar).

Classification and Structure

Monosaccharides (simple sugars) can be classified according to the number of carbon atoms they contain. Examples of some monosaccharides commonly found in humans are listed in Figure 6. They can also be classified by the type of carbonyl group they contain. Carbohydrates with an aldehyde as their carbonyl group are called aldoses, whereas those with a keto as their carbonyl group are called ketoses (Figure 7). For example, glyceraldehyde is an aldose, whereas dihydroxyacetone is a ketose. Monosaccharides can be linked by glycosidic bonds to create larger structures (Figure 8). Disaccharides contain two monosaccharide units, oligosaccharides contain three to ten monosaccharide units, and polysaccharides contain more than ten monosaccharide units and can be hundreds of sugar units in length.

Generic names	Examples
3 Carbons: trioses	Glyceraldehyde
4 Carbons: tetroses	Erythrose
5 Carbons: pentoses	Ribose
6 Carbons: hexoses	Glucose
7 Carbons: heptoses	Sedoheptulose
9 Carbons: nonoses	Neuraminic acid

Figure 6

Examples of monosaccharides found in humans, classified according to the number of carbons they contain.

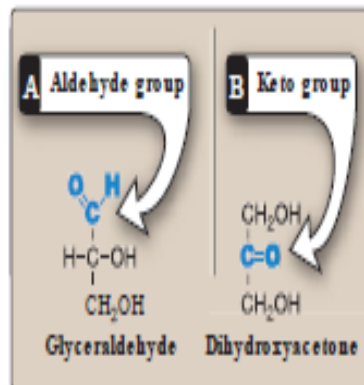


Figure 7

Examples of an aldose (A) and a ketose (B) sugar.

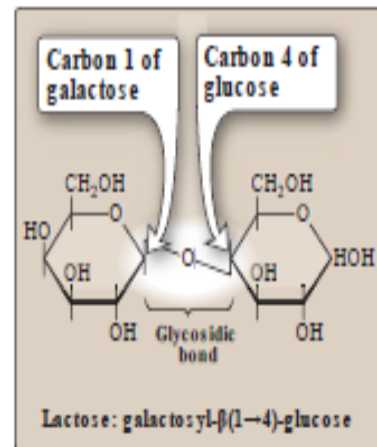


Figure 8

A glycosidic bond between two hexoses producing a disaccharide.

Importance of carbohydrates:

Carbohydrates are widely distributed both in plants and in animal tissues. In plants, they are produced by photosynthesis. Carbohydrates constitute about 60% of our diet. They are important for:

- A.** Energy production e.g. glucose.
- B.** Formation of structural elements in animal and plant cells.
- C.** Formation of glycolipids (carbohydrates combined with lipids) and glycoproteins (carbohydrates combined with protein); both enter in the structure of cell membrane and form the ground substances between tissues.

Classification of carbohydrates:

- A.** Monosaccharides: contain one sugar unit.
- B.** Disaccharides: contain two sugar units.
- C.** Oligosaccharide&: contain 3 - 10 sugar units.
- D.** Polysaccharides: contain more than 10 sugar units.

The major dietary carbohydrates

Class (DPⁿ)	Subgroup	Components
Sugars (1-2)	Monosaccharides	Glucose, galactose, fructose, xylose
	Disaccharides	Sucrose, lactose, maltose, trehalose
	Polyols	Sorbitol, mannitol
Oligosaccharides (3-9)	Malto-oligosaccharides	Maltodextrins
	Other oligosaccharides	Raffinose, stachyose, fructo-oligosaccharides
Polysaccharides (>9)	Starch	Amylose, amylopectin, modified starches
	Non-starch polysaccharides	Glycogen, Cellulose, Hemicellulose, Pectins, Hydrocolloids

Nucleic Acids

Nucleic acids are polynucleotide. They are two types: DNA and RNA.

I. Deoxyribonucleic acid (DNA):

DNA (Deoxyribonucleic acid) is a molecule composed of two chains (made of nucleotides) that coil around each other to form a double helix carrying the genetic instructions used in the growth, development, functioning and reproduction of all known living organisms and many viruses. DNA and ribonucleic acid (RNA) are nucleic acids; alongside proteins, lipids and complex carbohydrates (polysaccharides), nucleic acids are one of the four major types of macromolecules that are essential for all known forms of life.

The two DNA strands are also known as polynucleotides since they are composed of simpler monomeric units called nucleotides. Each nucleotide is composed of one of four nitrogen-containing nucleobases (cytosine [C], guanine [G], adenine [A] or thymine [T]), a sugar called deoxyribose, and a phosphate group. The nucleotides are joined to one another in a chain by covalent bonds between the sugar of one nucleotide and the phosphate of the next, resulting in an alternating sugar-phosphate backbone. The nitrogenous bases of the two separate polynucleotide strands are bound together, according to pairing rules (A with T and C with G), with hydrogen bonds to make double-stranded DNA.

Structure of nucleotides:

A. Nucleotides: are intracellular molecules formed of: Base+ Sugar + Phosphate.
(Base I Sugar I Phosphate)

B. Nucleosides: are formed only of: nitrogenous bases and sugars. (Base I Sugar)

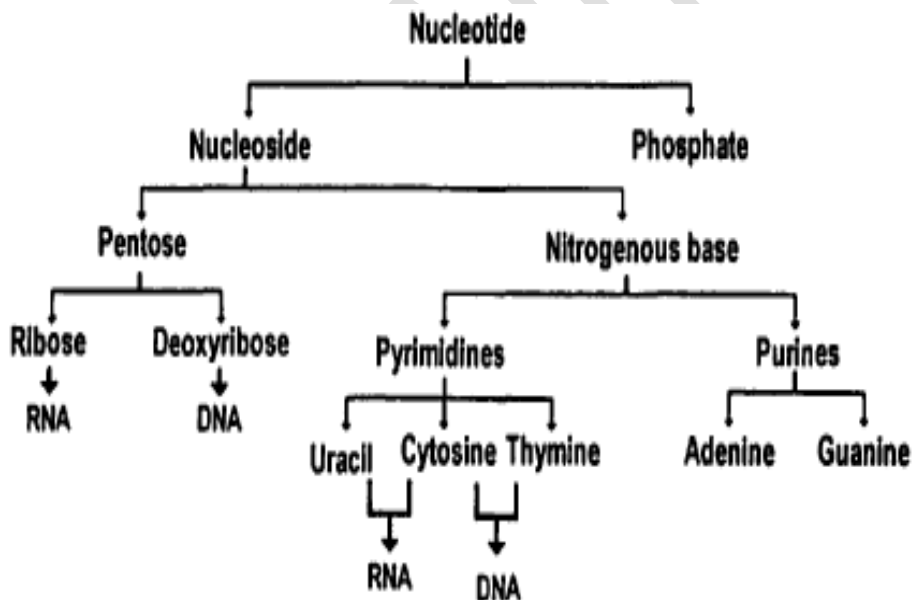
C. Bases: The nitrogenous bases are either pyrimidines or purines.

1. Pyrimidine bases:

a) They contain pyrimidine ring. There are 3 pyrimidines enter in the structure of nucleotides and nucleic acids. These are uracil, thymine and cytosine.

2. Purine bases:

a) Adenine and guanine are the 2 purines which enter in the structure e of nucleic acids (DNA and RNA).



The complementary nitrogenous bases are divided into two groups, pyrimidines and purines. In DNA, the pyrimidines are thymine and cytosine; the purines are adenine and guanine. DNA stores biological information. The DNA backbone is resistant to cleavage, and both strands of the double-stranded structure store the same biological information. This information is replicated as and when the two strands separate. A large part of DNA (more than 98% for humans) is non-coding, meaning that these sections do not serve as patterns for protein sequences.

The two strands of DNA run in opposite directions to each other and are thus antiparallel. Attached to each sugar is one of four types of nucleobases (informally, *bases*). It is the sequence of these four nucleobases along the backbone that encodes genetic information. RNA strands are created using DNA strands as a template in a process called transcription. Under the genetic code, these RNA strands are translated to specify the sequence of amino acids within proteins in a process called translation.

DNA Structure

Nucleic acids are required for the storage and expression of genetic information. There are two chemically distinct types of nucleic acids: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA, the repository of genetic information, is present not only in chromosomes in the nucleus of eukaryotic organisms, but also in mitochondria and the chloroplasts of plants.

Prokaryotic cells, which lack nuclei, have a single chromosome but may also contain non chromosomal DNA in the form of plasmids. The genetic information found in DNA is copied and transmitted to daughter cells through DNA replication. The DNA contained in a fertilized egg encodes the information that directs the development of an organism. This development may involve the production of billions of cells. Each cell is specialized, expressing only those functions that are required for it to perform its role in maintaining the organism.

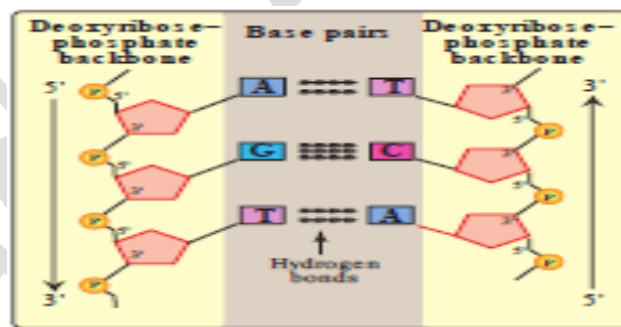


Figure 9
Two complementary DNA sequences.
T = thymine; A = adenine; C = cytosine;
G = guanine.

2. Ribonucleic acid (RNA)

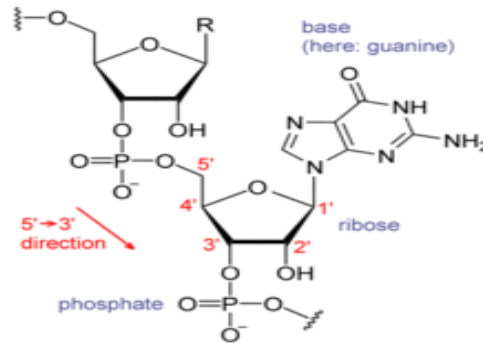
Ribonucleic acid (RNA) is a polymeric molecule essential in various biological roles in coding, decoding, regulation, and expression of genes. RNA and DNA are nucleic acids, and, along with lipids, proteins and carbohydrates, constitute the four major macromolecules essential for all known forms of life. Like DNA, RNA is assembled as a chain of nucleotides, but unlike DNA it is more often found in nature as a single-strand folded onto itself, rather than a paired double-strand. Cellular organisms use messenger RNA (*mRNA*) to convey genetic information (using the nitrogenous bases of guanine, uracil, adenine, and cytosine, denoted by the letters G, U, A, and C) that directs synthesis of specific proteins. Many viruses encode their genetic information using an RNA genome.

Structure of RNA

There are three major types of RNA that participate in the process of protein synthesis: rRNA, tRNA, and mRNA. Like DNA, these three types of RNA are unbranched polymeric molecules composed of nucleoside monophosphates joined together by 3'→5'-phosphodiester bonds. However, they differ from DNA in several ways. For example, they are considerably smaller than DNA, contain ribose instead of deoxyribose and uracil instead of thymine, and exist as single strands that are capable of folding into complex structures. The three major types of RNA also differ from each other in size, function, and special structural modifications.

Some RNA molecules play an active role within cells by catalyzing biological reactions, controlling gene expression, or sensing and communicating responses to cellular signals. One of these active processes is protein synthesis, a universal function where RNA molecules direct the assembly of proteins on ribosomes. This

process uses transfer RNA (*tRNA*) molecules to deliver amino acids to the ribosome, where ribosomal RNA (*rRNA*) then links amino acids together to form proteins.



Chemical structure of RNA

Comparison with DNA

The chemical structure of RNA is very similar to that of DNA, but differs in three primary ways:

- Unlike double-stranded DNA, RNA is a single-stranded molecule in many of its biological roles and consists of a much shorter chain of nucleotides. However, RNA can, by complementary base pairing, form intrastrand (i.e., single-strand) double helices, as in tRNA.
- While the sugar-phosphate "backbone" of DNA contains *deoxyribose*, RNA contains *ribose* instead. Ribose has a hydroxyl group attached to the pentose ring in the 2' position, whereas deoxyribose does not. The hydroxyl groups in the ribose backbone make RNA less stable than DNA because it is more prone to hydrolysis.
- The complementary base to adenine in DNA is thymine, whereas in RNA, it is uracil, which is an unmethylated form of thymine.

Lipid

In biology and biochemistry, a **lipid** is a biomolecule that is soluble in nonpolar solvents. Non-polar solvents are typically hydrocarbons used to dissolve other naturally occurring hydrocarbon lipid molecules that do not (or do not easily) dissolve in water, including fatty acids, waxes, sterols, fat-soluble vitamins (such as vitamins A, D, E, and K), monoglycerides, diglyceride, triglycerides, and phospholipids.

A. Definitions:

1. Lipids are a heterogeneous group of compound related to fatty acids.
2. Lipids are relatively insoluble in water.
3. They are soluble in nonpolar solvents such as ether, chloroform or benzene.

B. The hydrophobic (water-hating) nature of lipids is due to the Classes of lipids predominance of hydrocarbon chains (-CH₂-CH₂-CH₂-) in their structure.

C. Classification: lipids are classified into simple, complex (compound) and derived lipids:

D. Functions (biomedical Importance):

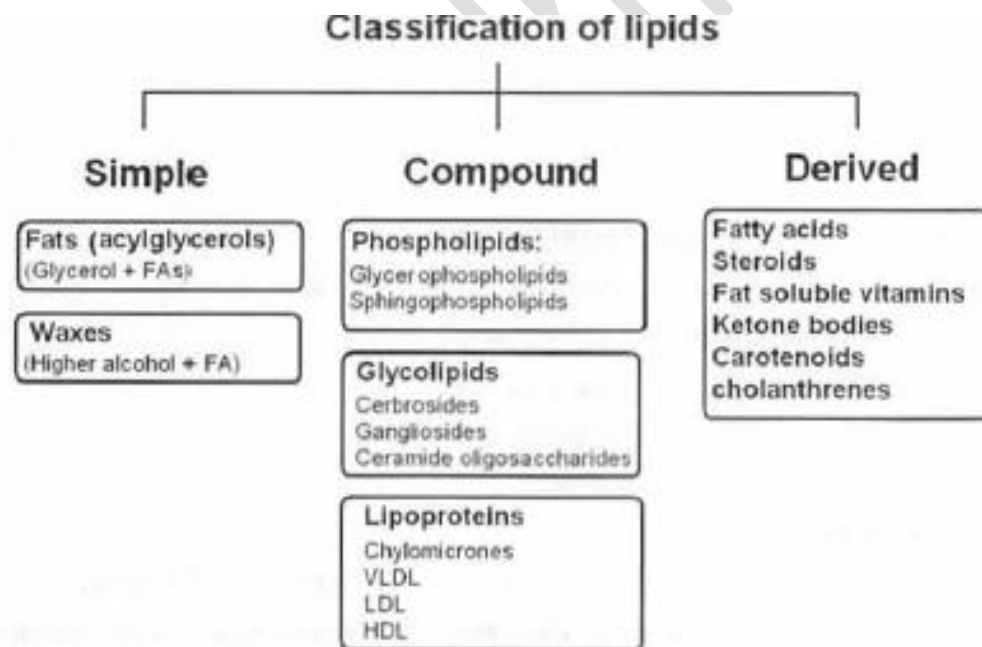
1. **In diet:** Lipids are important constituent of diet due to:
 - a) They are a source of high energy value.
 - b) They contain fat soluble vitamins.
 - c) They contain essential fatty acids.
 - d) They make diet palatable.

2. In the body:

- a) Lipids in adipose tissue serve as storage form of energy.
- b) They serve as thermal insulator in the subcutaneous tissues.
- c) **Nonpolar lipids** act as electrical Insulator, allowing rapid propagation of waves along myelinated nerves.
- d) **Lipoproteins** (a combination of fat and proteins) are important because:
 - 1) They enter in the structure of cell membranes.
 - 2) They serve as a transport form of energy in the blood.

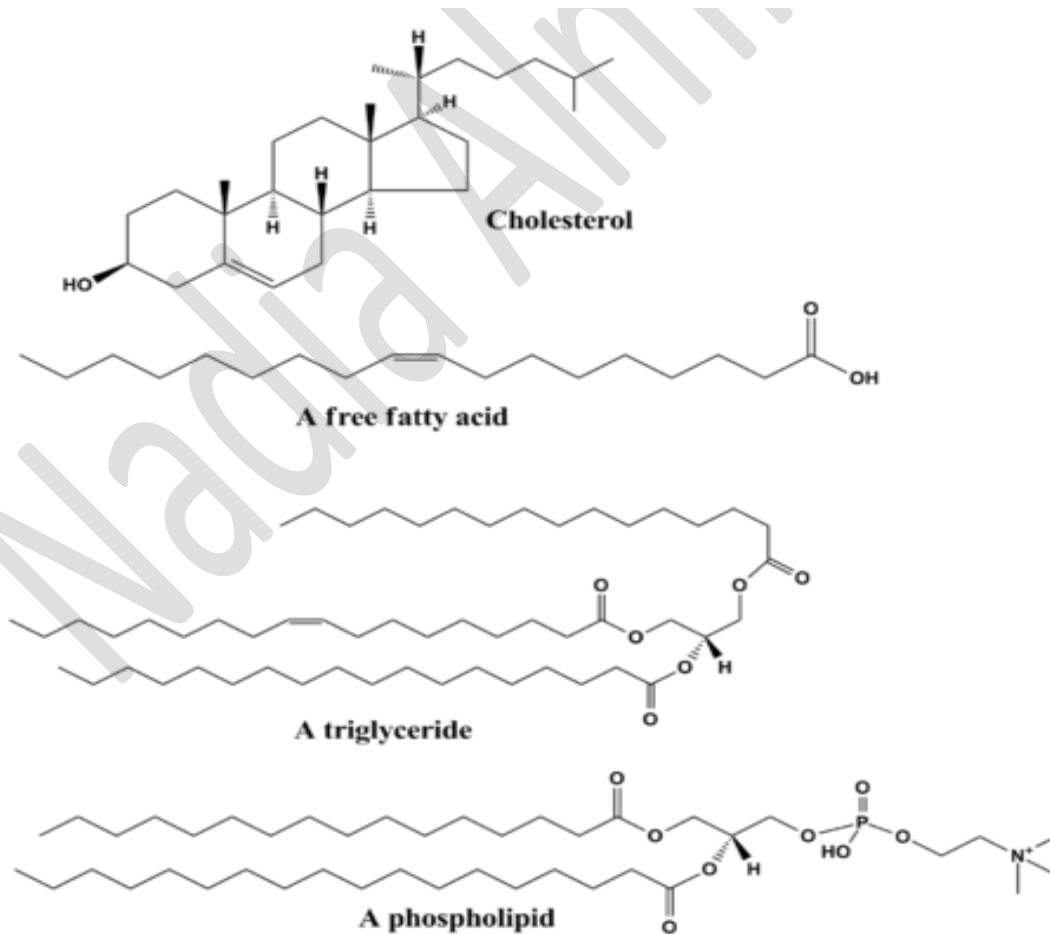
E. Neutral lipids: are those which carry no charges and include:

- 1. Neutral fats (acylglycerols).
- 2. Cholesterol and cholesteryl esters.



The functions of lipids include storing energy, signaling, and acting as structural components of cell membranes. Lipids have applications in the cosmetic and food industries as well as in nanotechnology. Scientists sometimes broadly define lipids as hydrophobic or amphiphilic small molecules; the amphiphilic nature of some lipids allows them to form structures such as vesicles, multilamellar/unilamellar liposomes, or membranes in an aqueous environment.

Lipids also encompass molecules such as fatty acids and their derivatives (including tri-, di-, monoglycerides, and phospholipids), as well as other sterol-containing metabolites such as cholesterol. Although humans and other mammals use various biosynthetic pathways both to break down and to synthesize lipids, some essential lipids can't be made this way and must be obtained from the diet.



Structures of some common lipids.

Membrane lipid

A **membrane lipid** is a compound which belongs to a group of (structurally similar to fats and oils) which forms the double-layered surface of all cells (lipid bilayer). The three major classes of membrane lipids are phospholipids, glycolipids, and cholesterol. Lipids are amphiphilic: they have one end that is soluble in water ('polar') and an ending that is soluble in fat ('nonpolar'). By forming a double layer with the polar ends pointing outwards and the nonpolar ends pointing inwards membrane lipids can form a 'lipid bilayer' which keeps the watery interior of the cell separate from the watery exterior. The arrangements of lipids and various proteins, acting as receptors and channel pores in the membrane, control the entry and exit of other molecules and ions as part of the cell's metabolism.

Dr. Nadia Matter AL-Mhana

2018-2019