BIOMOLECULES

A biomolecule or biological molecule is any molecule that is present in living organisms, including large macromolecules such as proteins, carbohydrates, lipids, and nucleic acids, as well as small molecules such as primary metabolites, secondary metabolites, and natural products. A more general name for this class of material is biological materials. Most biomolecules are organic compounds, and just four elements oxygen, carbon, hydrogen, and nitrogen make up 96% of the human body's mass. But many other elements, such as the various biometals, are present in small amounts.

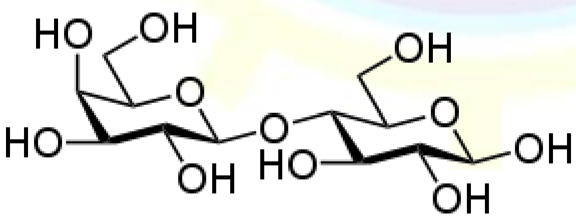
‘Carbohydrates are defined as 'Polyhydroxy aldehydes or ketones and their derivatives'.

Saccharide

Monosaccharides are the simplest form of carbohydrates with only one simple sugar. They essentially contain an aldehyde or ketone group in their structure.The presence of an aldehyde group in a monosaccharide is indicated by the prefix aldo-. Similarly, a ketone group is denoted by the prefix keto-. Examples of monosaccharides are the hexoses glucose, fructose, and galactose and pentoses, ribose, and deoxyribose

Disaccharides are formed when two monosaccharides, or two single simple sugars, form a bond with removal of water. They can be hydrolyzed to yield their saccharin building blocks by boiling with dilute acid or reacting them with appropriate enzymes. Examples of disaccharides include sucrose, maltose, and lactose.

Polysaccharides are polymerized monosaccharides, or complex carbohydrates. They have multiple simple sugars. Examples are starch, cellulose, and glycogen. They are generally large and often have a complex branched connectivity. Because of their size, polysaccharides are not water-soluble, but their many hydroxy groups become hydrated individually when exposed to water, and some polysaccharides form thick colloidal dispersions when heated in water. Shorter polysaccharides, with 3 - 10 monomers, are called oligosaccharides.



Lactose is a disaccharide found in milk. It consists of a molecule of D-galactose and a molecule of D-glucose bonded by beta-1-4 glycosidic linkage. It has a formula of $C_{12}H_{22}O_{11}$.

Application

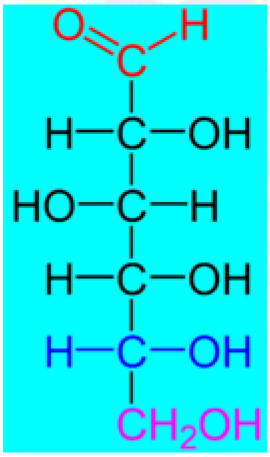
Carbohydrates perform numerous roles in living organisms. Polysaccharides serve for the storage of energy (e.g. starch and glycogen) and as structural components (e.g. cellulose in plants and chitin in arthropods). The 5-carbon monosaccharide ribose is an important component of coenzymes (e.g. ATP, FAD and NAD) and the backbone of the genetic molecule known as RNA. The related deoxyribose is a component of DNA. Saccharides and their derivatives include many other important biomolecules that play key roles in the immune system, fertilization, preventing pathogenesis, blood clotting, and developement. In food science and in many informal contexts, the term carbohydrate often means any food that is particularly rich in the complex carbohydrate starch (such as cereals, bread and pasta) or simple carbohydrates, such as sugar (found in candy, jams, and desserts).

Structure

The open-chain form of a monosaccharide often coexists with a closed ring form where the aldehyde/ketone carbonyl group carbon (C=O) and hydroxyl group (–OH) react forming a hemiacetal with a new C–O–C bridge.

Monosaccharides can be linked together into what are called polysaccharides (or oligosaccharides) in a large variety of ways. Many carbohydrates contain one or more modified monosaccharide units that have had one or more groups replaced or removed. For example, deoxyribose, a component of DNA, is a modified version of ribose; chitin is composed of repeating units of N-acetyl glucosamine, a nitrogen-containing form of glucose.

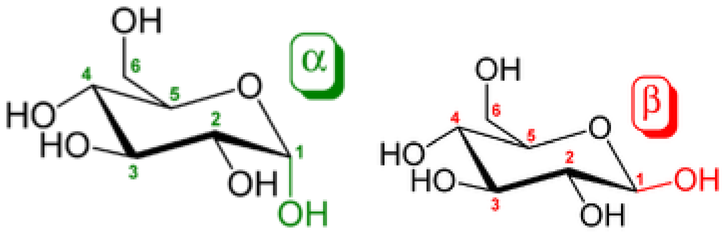
Monosaccharide



D-glucose is an aldohexose with the formula $(C \bullet H_2O)_6$. The red atoms highlight the aldehyde group and the blue atoms highlight the asymmetric center furthest from the aldehyde; because this -OH is on the right of the Fischer projection, this is a D sugar.

Monosaccharides are the simplest carbohydrates in that they cannot be hydrolyzed to smaller carbohydrates. They are aldehydes or ketones with two or more hydroxyl groups. The general chemical formula of an unmodified monosaccharide is $(C \bullet H_2O)$ n, literally a "carbon hydrate." Monosaccharides are important fuel molecules as well as building blocks for nucleic acids. The smallest monosaccharides, for which n=3, are dihydroxyacetone and D- and L-glyceraldehydes.

Classification of monosaccharides

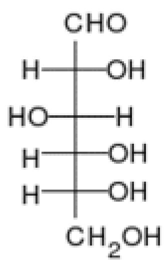


The α and β anomers of glucose. Note the position of the hydroxyl group (red or green) on the anomeric carbon relative to the CH2OH group bound to carbon 5: they either have identical absolute configurations (R,R or S,S) (α), or opposite absolute configurations (R,S or S,R) (β).

Monosaccharides are classified according to three different characteristics: the placement of its carbonyl group, the number of carbon atoms it contains, and its chiral handedness. If the carbonyl group is an aldehyde, the monosaccharide is an aldose; if the carbonyl group is a ketone, the monosaccharide is a ketose. Monosaccharides with three carbon atoms are called trioses, those with four are called tetroses, five are called pentoses, six are hexoses, and so on. These two systems of classification are often combined. For example, glucose is an aldohexose(a six-carbon aldehyde), ribose is an aldopentose (a five-carbon aldehyde), and fructose is a ketohexose (a six-carbon ketone).

Each carbon atom bearing a hydroxyl group (-OH), with the exception of the first and last carbons, are asymmetric, making them stereo centers with two possible configurations each (R or S). Because of this asymmetry, a number of isomers may exist for any given monosaccharide formula. Using Le Bel-van't Hoff rule, the aldohexose D-glucose, for example, has the formula $(C•H_2O)_6$, of which four of its six carbons atoms are stereogenic, making D-glucose one of 24=16 possible stereoisomers. In the case of glyceraldehydes, an aldotriose, there is one pair of possible stereoisomers, which are enantiomers and epimers. 1, 3-dihydroxyacetone, the ketose corresponding to the aldose glyceraldehydes, is a symmetric molecule with no stereo centers. The assignment of D or L is made according to the orientation of the asymmetric carbon furthest from the carbonyl group: in a standard Fischer projection if the hydroxyl group is on the right the molecule is a D sugar, otherwise it is an L sugar. The "D-" and "L-" prefixes should not be confused with "d-" or "l-", which indicate the direction that the sugar rotates plane polarized light. This usage of "d-" and "l-" is no longer followed in carbohydrate chemistry.

Ring-straight chain isomerism



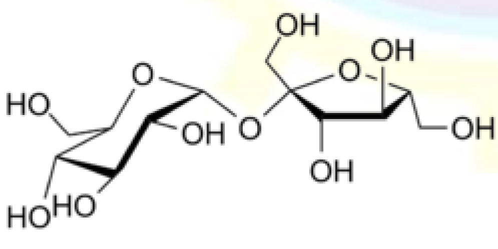
Glucose can exist in both a straight-chain and ring form.

The aldehyde or ketone group of a straight-chain monosaccharide will react reversibly with a hydroxyl group on a different carbon atom to form a hemiacetal or hemiketal, forming a heterocyclic ring with an oxygen bridge between two carbon atoms. Rings with five and six atoms are called furanose and pyranose forms, respectively, and exist in equilibrium with the straight-chain form.
During the conversion from straight-chain form to the cyclic form, the carbon atom containing the carbonyl oxygen, called the anomeric carbon, becomes a stereogenic center with two possible configurations: The oxygen atom may take a position either above or below the plane of the ring. The resulting possible pair of stereoisomers is called anomers. In the αanomer, the -OH substituent on the anomeric carbon rests on the opposite side (trans) of the ring from the CH_2OH side branch. The alternative form, in which the CH_2OH substituent and the anomeric hydroxyl are on the same side (cis) of the plane of the ring, is called the β anomer.

Use in living organisms

Monosaccharides are the major source of fuel for metabolism, being used both as an energy source (glucose being the most important in nature) and in biosynthesis. In many animals, including humans, this storage form is glycogen, especially in liver and muscle cells. In plants, starch is used for the same purpose. The most abundant carbohydrate, cellulose, is a structural component of the cell wall of plants and many forms of algae. Ribose is a component of RNA. Deoxyribose is a component of DNA. Lyxose is a component of lyxoflavin found in the human heart. Ribulose and xylulose occur in the pentose phosphate pathway. Galactose, a component of milk sugar lactose, is found in galactolipids in plant cell membranes and in glycoproteins in many tissues. Mannose occurs in human metabolism, especially in the glycosylation of certain proteins. Fructose, or fruit sugar, is found in many plants and in humans, it is metabolized in the liver, absorbed directly into the intestines during digestion, and found in semen. Trehalose, a major sugar of insects, is rapidly hydrolyzed into two glucose molecules to support continuous flight.

Disaccharides

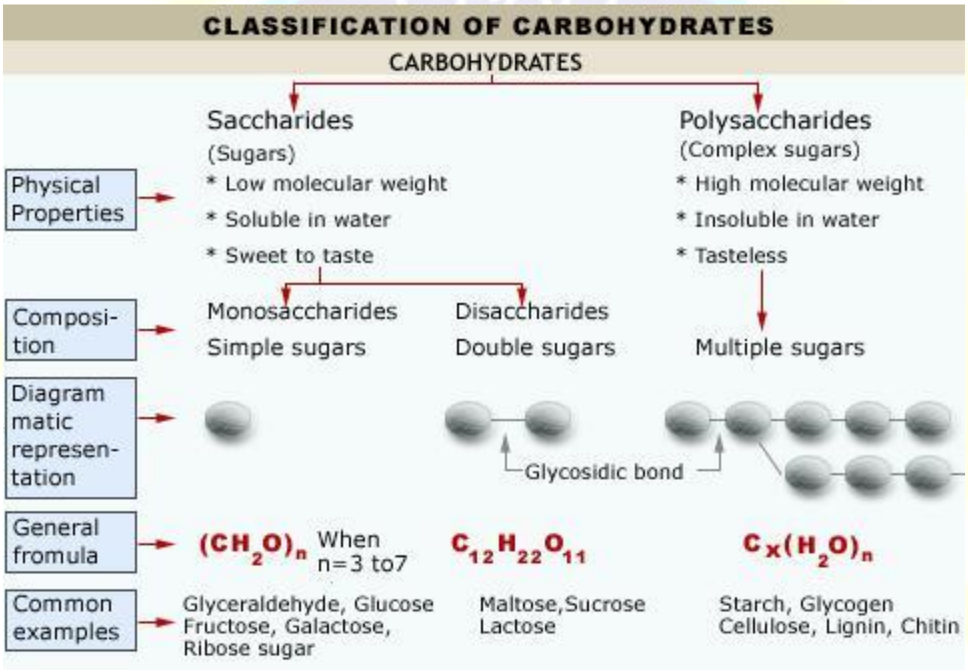


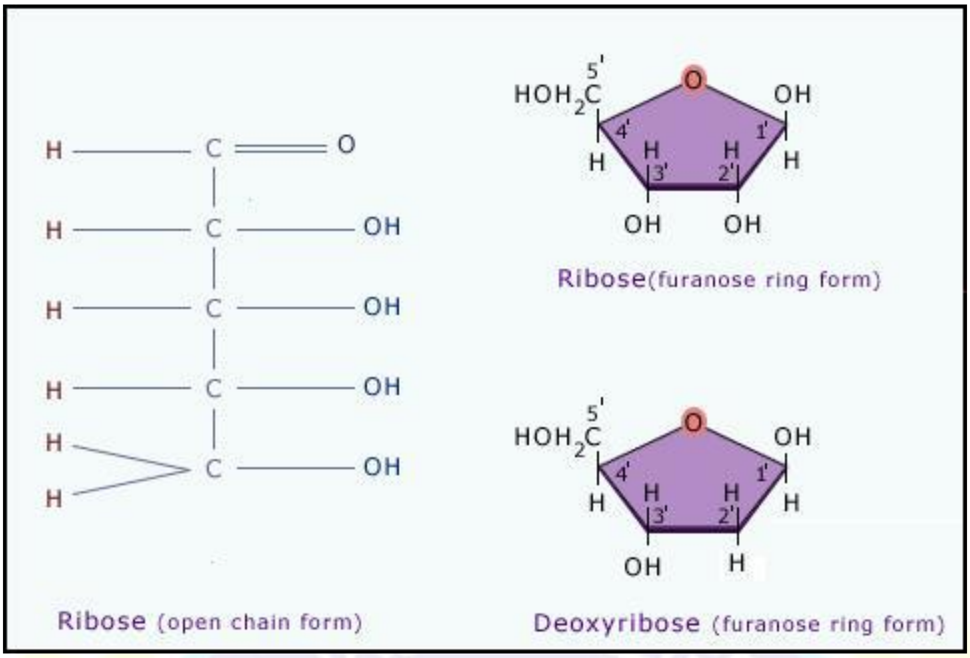
Sucrose, also known as table sugar, is a common disaccharide. It is composed of two monosaccharides: D-glucose (left) and D-fructose (right).
Two joined monosaccharides are called a disaccharide and these are the simplest polysaccharides. Examples include sucrose and lactose. They are composed of two monosaccharide units bound together by a covalent bond known as a glycosidic linkage formed via a dehydration reaction, resulting in the loss of a hydrogen atom from one monosaccharide and a hydroxyl group from the other. The formula of unmodified

disaccharides is $C_{12}H_{22}O_{11}$. Although there are numerous kinds of disaccharides, a handful of disaccharides are particularly notable.

- Its monosaccharides: glucose and fructose
- Their ring types: glucose is a pyranose and fructose is a furanose
- How they are linked together: the oxygen on carbon number 1 (C_1) of α-D-glucose is linked to the C_2 of D-fructose.
- The -oside suffix indicates that the anomeric carbon of both monosaccharides participates in the glycosidic bond.

Lactose, a disaccharide composed of one D-galactose molecule and one D-glucose molecule, occurs naturally in mammalian milk. The systematic name for lactose is O-β-D-galactopyranosyl-(1→4)-D-glucopyranose. Other notable disaccharides include maltose (two D-glucoses linked α-1,4) and cellulobiose (two D-glucoses linked β-1,4). Disaccharides can be classified into two types: reducing and non-reducing disaccharides. If the functional group is present in bonding with another sugar unit, it is called a reducing disaccharide or biose.





Structure of pentose sugar.

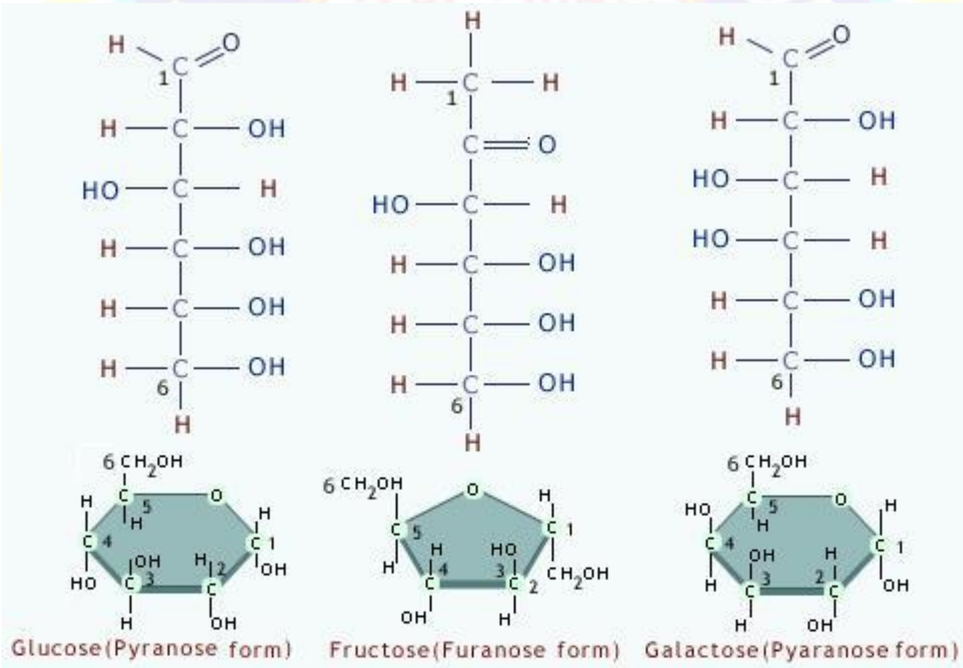
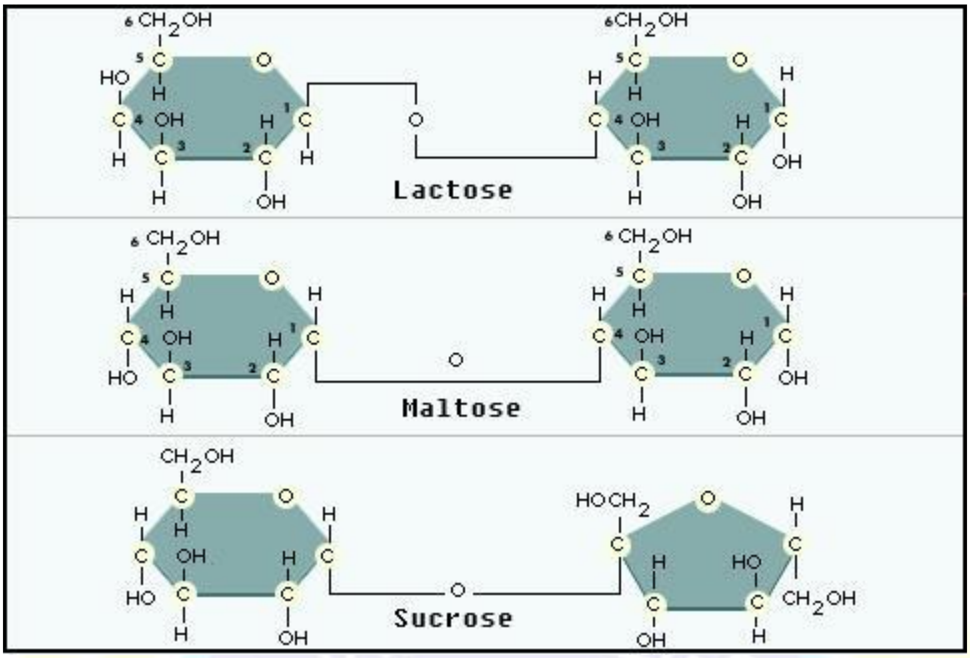


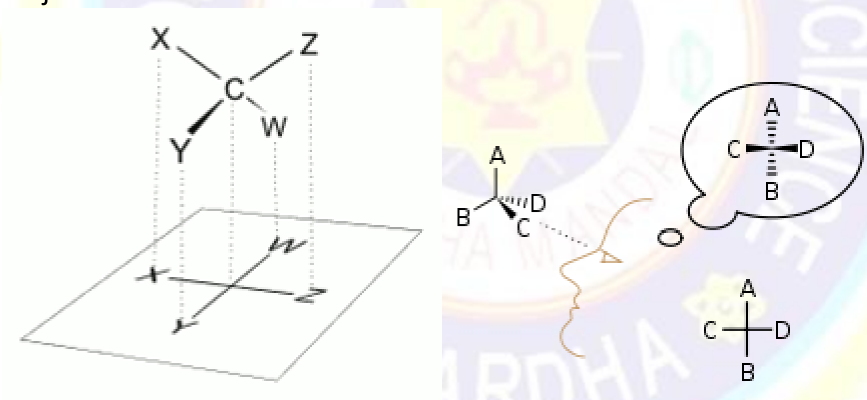
fig. - **Open Chain and Ring Forms of three Hexoses**



Structure of Dissacharides.

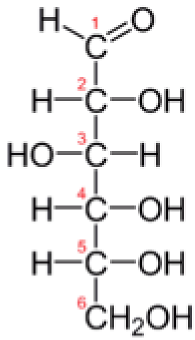
Fischer projection

Projection of a tetrahedral molecule onto a planar surface.



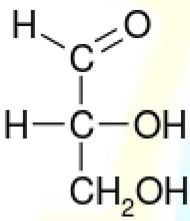
The Fischer projection, devised by Hermann Emil Fischer in 1891, is a two-dimensional representation of a three-dimensional organic molecule by projection. Fischer projections were originally proposed for the depiction of carbohydrates and used by chemists, particularly in organic chemistry and biochemistry. The use of Fischer projections in non-carbohydrates is discouraged, as such drawings are ambiguous when confused with other types of drawing.

Convention



D- Glucose chain

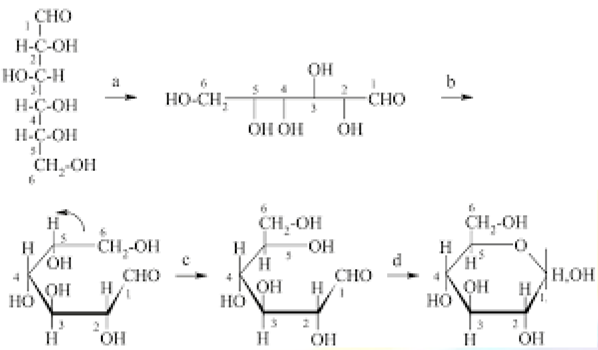
All nonterminal bonds are depicted as horizontal or vertical lines. The carbon chain is depicted vertically, with carbon atoms represented by the center of crossing lines. The orientation of the carbon chain is so that the C_1 carbon is at the top.In an aldose, the carbon of the aldehyde group is C_1; in a ketose the carbon of the ketone group has the lowest possible number (usually C_2).

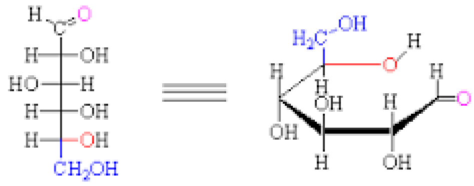


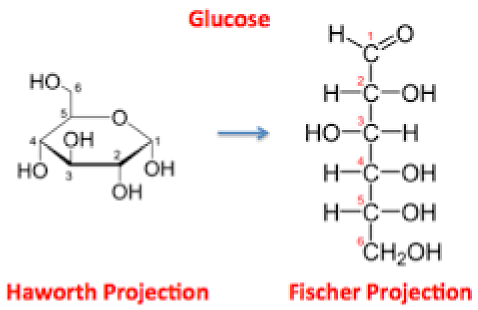
Fischer projection of D-Glyceraldehyde

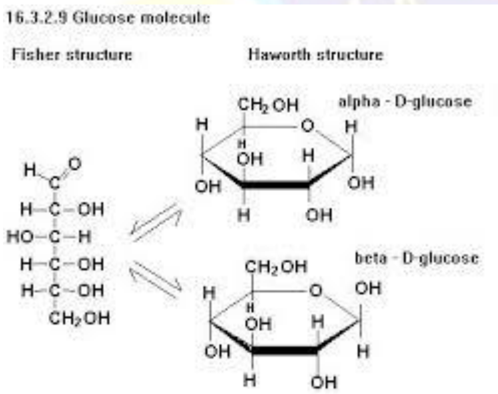
A Fischer projection is used to differentiate between L- and D- molecules. On a Fischer projection, the penultimate (next-to-last) carbon of D sugars are depicted with hydrogen on the left and hydroxyl on the right. L sugars will be shown with the hydrogen on the right and the hydroxyl on the left.
In a Fischer projection, all horizontal bonds project toward the viewer, while vertical bonds project away from the viewer. Therefore, a Fischer projection cannot be rotated by 90° or 270° in the plane of the page or the screen, as the orientation of bonds relative to one another can change, converting a molecule to its enantiomer. However, any rotation of 180° doesn't change the molecule's representation. Swapping two pairs of groups attached to the central carbon atom still represents the same molecule as was represented by the original Fischer projection.
Usage
Fischer projections are most commonly used in biochemistry and organic chemistry to represent monosaccharides, but can also be used for amino acids or for other organic molecules. Since Fischer projections depict the stereochemistry (three-dimensional structure) of a molecule, they are very useful for differentiating between enantiomers of chiral molecules.
Other systems
Haworth projections are a related chemical notation used to represent sugars in ring form. The groups on the right hand side of a Fischer projection are equivalent to those below the plane of the ring in Haworth projections. Fischer projections should not be confused with

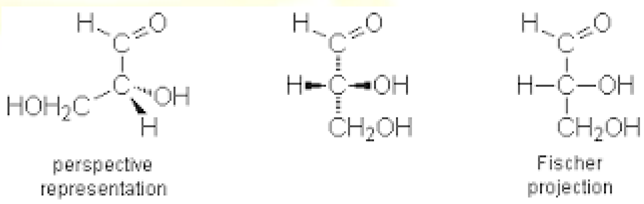
Lewis structures, which do not contain any information about three dimensional geometry. Newman projections are normally used to represent the stereochemistry of alkanes.











Protein

Any of a group of complex organic macromolecules that contain carbon, hydrogen, oxygen, nitrogen, and usually sulfur and are composed of one or more chains of amino acids.

Proteins are fundamental components of all living cells and include many substances, such as enzymes, hormones, and antibodies, that are necessary for the proper functioning of an organism. They are essential in the diet of animals for the growth and repair of tissue and can be obtained from foods such as meat, fish, eggs, milk, and legumes.

Protein structure

The particular series of amino acids that form a protein is known as that protein's primary structure. This sequence is determined by the genetic makeup of the individual. It specifies the order of side-chain groups along the linear polypeptide "backbone". Proteins have two types of well-classified, frequently occurring elements of local structure defined by a particular pattern of hydrogen bonds along the backbone: alpha helix and beta sheet. Their number and arrangement is called the secondary structure of the protein. Hemoglobin contains only helices, natural silk is formed of beta pleated sheets, and many enzymes have a pattern of alternating helices and beta-strands. The secondary-structure elements are connected by "loop" or "coil" regions of non-repetitive conformation, which are sometimes quite mobile or disordered but usually adopt a well-defined, stable arrangement.

The overall, compact, 3D structure of a protein is termed its tertiary structure or its "fold". It is formed as result of various attractive forces like hydrogen bonding, disulfide bridges, hydrophobic interactions, hydrophilic interactions, van der Waals force etc.

When two or more polypeptide chains (either of identical or of different sequence) cluster to form a protein, quaternary structure of protein is formed. Quaternary structure is an attribute of polymeric (same-sequence chains) or heteromeric (different-sequence chains) proteins like hemoglobin, which consists of two "alpha" and two "beta" polypeptide chains

Amino Acids and Proteins

Proteins are long chains of amino acids. Amino acids are the building blocks of protein. For example, the amino acids are like the links in a chain. The chain itself represents the protein molecule. Protein chains are then twisted and folded together in specific ways to create certain molecules.

Classification of Proteins

Based on Conformation

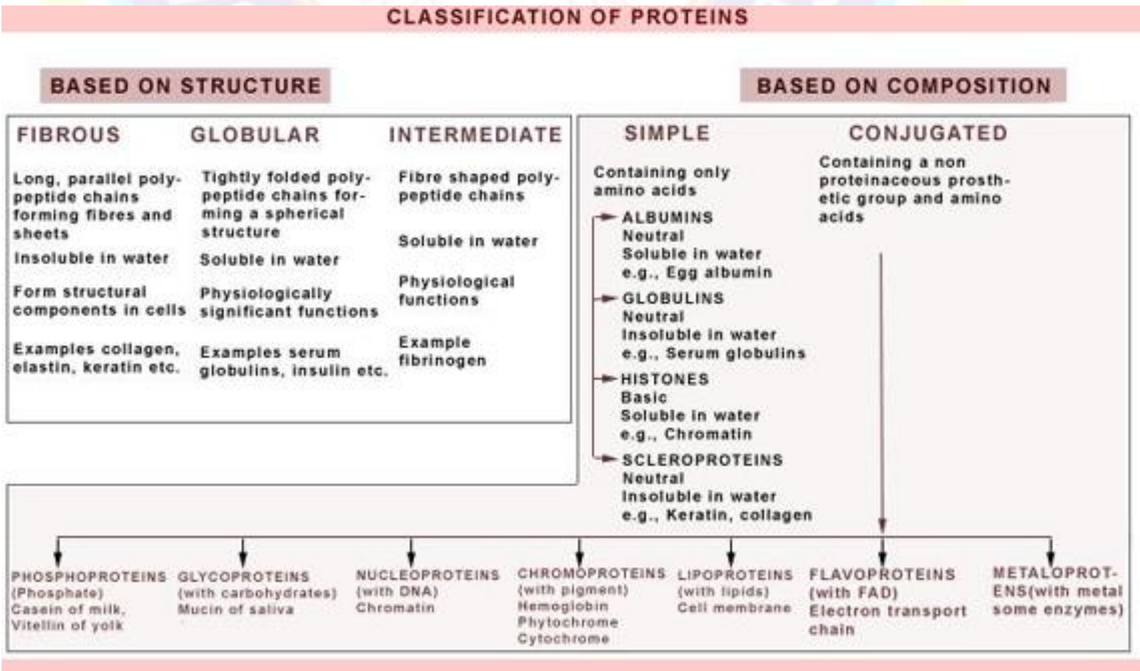
Fibrous Insoluble in H_2O	Globular Soluble in H_2O
•α-Keratin •β-Keratin •Collagen	•Myoglobin •Hemoglobin •Lysozyme •Ribonuclease •Chymotrypsin •Cytochrome-c •Lactate dehydrogenase •subtilisin

Based on Composition

Simple	Conjugated	Derived
•Albumin •Globulin •Glutalins •Prolamins •Protamines •Histones •Scleroproteins	•Nucleoprotein •Lipoprotein •Phosphoprotein •Metalloprotein •Glycoprotein •Flavoprotein •Hemoprotein •chromoproteins	•Protiose •Peptones •Small peptides •Fibrin •Metaproteins •Coagulated proteins

Based on Nature of

Acidic	Basic
•Blood proteins	•Histones



Protein classification based on chemical composition

On the basis of their chemical composition, proteins may be divided into two classes: simple and complex.

Simple proteins

Also known as homoproteins, they are made up of only amino acids. Examples are plasma albumin, collagen, and keratin.

Conjugated proteins

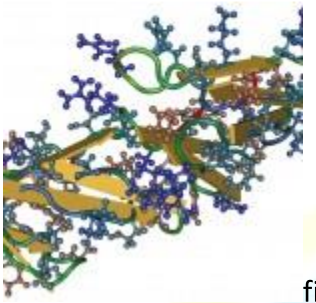


fig.Humanfibronectin

Sometimes also called heteroproteins, they contain in their structure a non-protein portion. Three examples are glycoproteins, chromoproteins, and phosphoproteins.

Glycoproteins

They are proteins that covalently bind one or more carbohydrate units to the polypeptide backbone.

Typically, the branches consist of not more than 15-20 carbohydrate units, Examples of glycoproteins are:

glycophorin, the best known among erythrocyte membrane glycoproteins;

fibronectin, that anchors cells to the extracellular matrix through interactions on one side with collagen or other fibrous proteins, while on the other side with cell membranes;

all blood plasma proteins, except albumin;

immunoglobulins or antibodies.

Chromoproteins

They are proteins that contain colored prosthetic groups.

Typical examples are:

hemoglobin and myoglobin, which bind, respectively, one and four heme groups;

chlorophylls, which bind a porphyrin ring with a magnesium atom at its centre;

rhodopsins, which bind retinal.

Phosphoproteins

They are proteins that bind phosphoric acid to serine and threonine residues.

Generally, they have a structural function, such as tooth dentin, or reserve function, such as milk caseins (alpha, beta, gamma and delta), and egg yolk phosvitin.

Protein classification based on shape

On the basis of their shape, proteins may be divided into two classes: fibrous and globular.

Fibrous proteins

fig.Collagen

They have primarily mechanical and structural functions, providing support to the cells as well as the whole organism.

These proteins are insoluble in water as they contain, both internally and on their surface, many hydrophobic amino acids. The presence on their surface of hydrophobic amino acids facilitates their packaging into very complex supramolecular structures.

Fibroin

It is produced by spiders and insects. An example is that produced by the silkworm, Bombyxmori.

•**Collagen** The term "collagen" indicates not a single protein but a family of structurally related proteins (at least 29 different types), which constitute the main protein component of connective tissue They are found in different tissues and organs, such as tendons and the organic matrix of bone, where they are present in very high percentages, but also in cartilage and in the cornea of the eye.

α-Keratins

They constitute almost the entire dry weight of nails, claws, beak, hooves, horns, hair, wool, and a large part of the outer layer of the skin.

The different stiffness and flexibility of these structures is a consequence of the number of disulfide bonds that contribute, together with other binding forces , to stabilize the protein structure.

Elastin

This protein provides elasticity to the skin and blood vessels, a consequence of its random coiled structure, that differs from the structures of the α-keratins and collagens.

Globular proteins

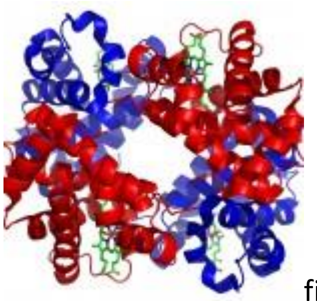


fig.Haemoglobin

Most of the proteins belong to this class.
They have a compact and more or less spherical structure, more complex than fibrous proteins.They are generally soluble in water but can also be found inserted into biological membranes (transmembrane proteins), thus in a hydrophobic environment.
Unlike fibrous proteins, that have structural and mechanical functions, they act as:

- enzymes;
- hormones;
- membrane transporters and receptors;
- transporters of triglycerides, fatty acids and oxygen in the blood;
- immunoglobulins or antibodies;
- grain and legume storage proteins.

Examples of globular proteins are myoglobin, hemoglobin, and cytochrome c.
At the intestinal level, most of the globular proteins of animal origin are hydrolyzed almost entirely to amino acids.
Protein classification based on biological functions
The multitude of functions that proteins perform is the consequence of both the folding of the polypeptide chain, therefore of their three-dimensional structure, and the presence of many different functional groups in the amino acid side chains, such as thiols, alcohols, thioethers, carboxamides, carboxylic acids and different basic groups.
From the functional point of view, they may be divided into several groups.

- **Enzymes (biochemical catalysts).**

In living organisms, almost all reactions are catalyzed by specific proteins called enzymes. They have a high catalytic power, increasing the rate of the reaction in which they are involved at least by factor 106
Examples are:
hemoglobin, that carries oxygen from the alveolar blood vessels to tissue capillaries; transferrin, which carries iron in the blood; proteins of plasma lipoproteins, macromolecular complexes of proteins and lipids responsible for the transport of triglycerides, which are otherwise insoluble in water;
albumin, that carries free fatty acids, bilirubin, thyroid hormones, and certain medications such as aspirin and penicillin, in the blood.Many of these proteins also play a protective role, since the bound molecules, such as fatty acids, may be harmful for the organism when present in free form.

- **Storage proteins**

Examples are:

ferritin, that stores iron intracellularly in a non-toxic form;
milk caseins, that act as a reserve of amino acids for the milk;
egg yolk phosvitin, that contains high amounts of phosphorus;
prolamins and glutelins, the storage proteins of cereals.
•**Mechanical support**

Proteins have a pivotal role in the stabilization of many structures. Examples are α-keratins, collagen and elastin. The same cytoskeletal system, the scaffold of the cell, is made of proteins.

•They generate movement.

They are responsible, among others, for:

the contraction of the muscle fibers (of which myosin is the main component);

the propulsion of spermatozoa and microorganisms with flagella;

the separation of chromosomes during mitosis.

Amino acids Amino acids contain both amino and carboxylic acid functional groups. Modified amino acids are sometimes observed in proteins; this is usually the result of enzymatic modification after translation (protein synthesis). For example, phosphorylation of serine by kinases and dephosphorylation by phosphatases is an important control mechanism in the cell cycle. Only two amino acids other than the standard twenty are known to be incorporated into proteins during translation, in certain organisms:

All enzymes are proteins, but not all proteins are enzymes

Proteins are the building blocks of all living organisms. Humans, animals, plants and microorganisms are all made up of proteins. Every part of the human body is built of proteins. Proteins constitute about 80% of the dry weight of muscle, 70% of the dry weight of skin and 90% of the dry weight of blood. Proteins can be split into two groups: structural proteins and biologically-active proteins. Structural proteins are the main constituents of our bodies e.g. collagen, which is found in bones, tendons and ligaments, and keratin, the protein of nails, hair and feathers. Biologically-active proteins catalyze biochemical reactions in cells. These are the enzymes at the heart of Novozymes' business.

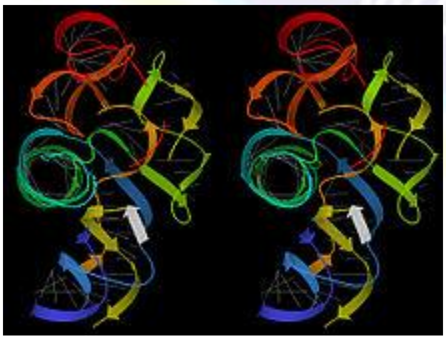
Apoenzymes An apoenzyme is the protein without any small-molecule cofactors, substrates, or inhibitors bound. It is often important as an inactive storage, transport, or secretory form of a protein. Apoenzymes becomes active enzymes on addition of a cofactor. Cofactors can be either inorganic (e.g., metal ions and iron-sulfur clusters) or organic compounds, (e.g., flavin and heme). Organic cofactors can be either prosthetic groups, which are tightly bound to an enzyme, or coenzymes, which are released from the enzyme's active site during the reaction.

Isoenzymes Isoenzymes, or isozymes, are multiple forms of an enzyme. They are either products of different genes,. They may either be produced in different organs or cell types to perform the same function, or several isoenzymes may be produced in the same cell type under differential regulation to suit the needs of changing development or environment. LDH (lactate dehydrogenase) has multiple isozymes, while fetal hemoglobin is an example of a developmentally regulated isoform of a non-enzymatic protein. The relative levels of isoenzymes in blood can be used to diagnose problems in the organ of secretion.

Nucleosides and nucleotides

Nucleosides are molecules formed by attaching a nucleobase to a ribose or deoxyribose ring. Examples of these include cytidine (C), uridine (U), adenosine (A), guanosine (G), thymidine (T) and inosine (I).Both DNA and RNA are polymers, consisting of long, linear molecules assembled by polymerase enzymes from repeating structural units, or monomers, of mononucleotides. DNA uses the deoxynucleotides C, G, A, and T, while RNA uses the ribonucleotides (which have an extra hydroxyl(OH) group on the pentose ring) C, G, A, and U. Each nucleotide is made of an acyclic nitrogenous base, a pentose and one to three phosphate groups. They contain carbon, nitrogen, oxygen, hydrogen and phosphorus. They serve as sources of chemical energy (adenosine triphosphate and guanosine triphosphate)

DNA and RNA structure DNA structure is dominated by the well-known double helix formed by Watson-Crick base-pairing of C with G and A with T. This is known as B-form DNA, basis of reliable genetic information storage. DNA can sometimes occur as single strands (often needing to be stabilized by single-strand binding proteins) or as A-form or Z-form helices, and occasionally in more complex 3D structures such as the crossover at Holliday junctions during DNA replication.



RNA, in contrast, forms large and complex 3D tertiary structures reminiscent of proteins, as well as the loose single strands with locally folded regions that constitute messenger RNA molecules.

Lipids

Lipids (oleaginous) are chiefly fatty acid esters, and are the basic building blocks of biological membranes. Another biological role is energy storage (e.g., triglycerides). Most lipids consist of a polar or hydrophilic head (typically glycerol) and one to three nonpolar or hydrophobic fatty acid tails, and therefore they are amphiphilic. Fatty acids consist of unbranched chains of carbon atoms that are connected by single bonds alone (saturated fatty acids) or by both single and double bonds (unsaturated fatty acids). The chains are usually 14-24 carbon groups long, but it is always an even number.

For lipids present in biological membranes, the hydrophilic head is from one of three classes:

•Glycolipids, whose heads contain an oligosaccharide with 1-15 saccharide residues.

•Phospholipids, whose heads contain a positively charged group that is linked to the tail by a negatively charged phosphate group.

•Sterols, whose heads contain a planar steroid ring, for example, cholesterol.

Other lipids include prostaglandins and leukotrienes which are both 20-carbon fatty acyl units synthesized from arachidonic acid. They are also known as fatty acids