Carbohydrates and Derivatives

Carbohydrates are important biological macromolecules that consist of carbon, hydrogen, and oxygen in a 1:2:1 ratio. Carbohydrates are organic compounds organized in the form of aldehydes or ketones with multiple hydroxyl groups coming off the carbon chain. Carbohydrates are the most abundant organic compounds in living organisms. Their major function in living systems is the storage and transport of energy. They can also have structural, informational, recognition, and protective functions. Monosaccharides, the simplest carbohydrate units, are commonly known as simple sugars. Chains of more than one sugar are called oligosaccharides.

Carbohydrate derivatives are sugar molecules that have been modified with substituents other than hydroxyl groups. Examples include glycosylamines, sugar phosphates, and sugar acetates. Most sugar derivatives occur naturally and have important biological functions. For instance, chondroitin sulfate is an important structural component of cartilage and provides much of its resistance to compression.

Single units of carbohydrates called **[monosaccharides](https://en.wikibooks.org/wiki/Structural_Biochemistry/Carbohydrates/Monosaccharides%22%20%5Co%20%22Structural%20Biochemistry/Carbohydrates/Monosaccharides)** may undergo various reactions to form **carbohydrate derivatives**. Derivatives in case of carbohydrates often means modification of sugar molecules by addition substituents other than hydroxyl group. Amino sugars, acidic sugars, deoxy sugars, sugar alcohols, glycosylamines, and sugar phosphates are examples of carbohydrate derivatives. After modification, a transformed molecule of sugar resembles structure of a sugar and an added substituent; however, it is not considered as sugar anymore because its function and characteristics has changed. For instance, sugar alcohols still have sweet taste, but are not completely absorbed by the human body and, therefore, the impact of sugar alcohols on blood sugar is less and they provide fewer calories per gram. Thus, some sugar alcohols are widely used as sugar replacement in diet and health-oriented foods especially for individuals with diabetes. Most sugar derivatives occur naturally and have important biological functions. For instance, amino sugar heparin occurs in intracellular granules of mast cells that line arterial walls and, when released, inhibits blood clotting. Glycosylamine adenosine is an important part of DNA and RNA structure. Also, due to wide application of sugar derivatives in different areas many of them are commercially synthesized.

## Glucose Family



beta-D-Glucose



alpha-D-Glucose-6-Phosphate



alpha-D-Glucosamine



N-Acetylmuramic Acid



D-Gluconic Acid

**The Glucose Family** are [monosaccharides](https://en.wikibooks.org/wiki/Structural_Biochemistry/Carbohydrates/Monosaccharides%22%20%5Co%20%22Structural%20Biochemistry/Carbohydrates/Monosaccharides) with functional groups replacing the hydroxyl group at the C-2 carbon or the C-6 group. Each sugar modification has a prominent effect in metabolism.

**β-D-Glucose**- This carbohydrate derivative plays a crucial role in metabolism. It is the main source of energy which is starts the process of cellular respiration. It is produced through photosynthesis and is often used in food products. It’s the most common carbohydrate and also circulates through the blood. It is known as blood sugar and can be converted into starch by the body. It is also used in blood tests for diabetes.

**β-D-Glucose 6 Phosphate**- Plays an important role in glycolysis. It is the final product after glucose is broken down and converted into the energy. The addition of the phosphate group gives the sugar a negative charge which prevents sugars from easily crossing lipid membranes. At elevated levels, it can inhibit brain hexokinase. It can be converted into starch or glycogen where it is stored in the liver and muscles. It plays an important role in blood glucose levels. Low levels can lead to Glucose-6-phosphate dehydrogenase deficiency, but the disease is hereditary. The disease leads to breakdown of red blood cells when exposed to certain environments.

**β-D-Glucosamine**- This is also an amino sugar that is very important in the formation of lipids and proteins. This can also form chitin in exoskeletons of insects as well as cell walls of plants. One of its common uses is for osteoarthritis. It helps rebuild cartilage and is used in veterinary medicine. Another of its uses is in helping with joint function and connective tissue. It also helps in body regulation and functions with β-D-Glucose 6 Phosphate in the body.

**N-Acetyl- β-D-Glucosamine**- This sugar is essential for optimal health and function in the body. It aids in cell communication. It also plays a role in how the immune system reacts with HIV and tumors. This also plays a role in osteoarthritis and helps in cartilage formation. It has been shown to play a role in nerve functioning for learning in mammals. This molecule has multiple uses such as limiting cholesterol absorption and decreases insulin secretion. Some receptors have been found in the thyroid to transport iodine proteins. It is found in multiple glands of the body and plays some role in the organ’s function. Muramic Acid-This sugar is a main component of bacteria cell walls and it is a derivative of peptidoglycan. It is used in gas chromatography for laboratory experiments.

**N-Acetylmuramic Acid**- This is also found in peptidoglycans of bacterial cell walls. It is a the product after N-acetylglucosamine that has been condensed with lactic acid. In bacteria, phosphophoenolpyruvate adds the lactyl group to C3 of N-acetylglucosamine. Beta-lactams compete for binding with transpeptidases, enzymes that catalyze the formation bonds between N-acetylmuramic acid-based peptide chains. Chlamydia lacks N-acetylmuramic acid in its cell walls which is the reason why penicillin does not treat the disease.

**β-D-Glucuronate**-This molecule is a highly polar molecule. It is used to increase solubility of some drugs. It is incorporated into proteoglycans and then combined with steroid hormones. This molecule forms to help make compounds more soluble for excretion. Bilirubin is one of the main molecules that this molecule makes soluble. This compound is very useful in clearing drugs from the body and making them soluble so that drugs can be processed through the body.

**β-D-Gluconate** – This is used as an alkalinizing agent for fluid therapy. It can be used in cleaning products because it dissolves mineral deposits. An alkaline solution will aid in dissolving the minerals faster. It can slowly be metabolized into bicarbonate, but the effects are longer lasting. It is an acidic sugar that occurs naturally in plants, honey, and fruits. It can be prepared through fermentation of glucose as well. When combined with calcium, it can form a gel to treat burns that are caused by hydrofluoric acid.

## Amino Sugars



Galactosamine



Alpha-D-glucosamine



Sialic acid (beta-N-Acetylneuraminic Acid.svg)

**Amino sugars** are generally known as [monosaccharide](https://en.wikibooks.org/wiki/Structural_Biochemistry/Carbohydrates/Monosaccharides) carbohydrate sugars that have replaced an -NH2 amine group with the 2'-carbon hydroxyl substituent. The most abundant amino sugar is one of the oldest and most abundant organic compounds on Earth. More than 60 amino sugars are known, many of them having been isolated and identified only recently as components of antibiotics. Examples of amino sugars include:

* [Galactosamine](https://en.wikibooks.org/w/index.php?title=Galactosamine&action=edit&redlink=1)
* [Glucosamine](https://en.wikibooks.org/w/index.php?title=Glucosamine&action=edit&redlink=1)

**Galactosamine**, for example, is one of eight essential amino acids that function in cell to cell interaction. Though research on galactosamine has just begun, research has shown that it may help those with joint inflammations. Lacking in galactosamine may even be one of the factors related to heart disease. Also, it may also function as a toxin leading to liver failure. In addition, galactosamine may also function as one of the sugars composing the follicle stimulating hormone (FSH) and the luteinizing hormone (LH), both of which are needed in the reproductive processes of the human body. Sources of galactosamine include bovine (which includes both cattle and oxen), red algae and shark meat.

**Glucosamine**, contrary to galactosamine is a very popular and relatively well-known amino sugar that our bodies use to produce glycoconjugates like glycosylated lipids and proteins. Glucosamine has a structural role in composing the hard exoskeleton of chitins, such as a variety of arachnids, crustaceans, and insects. Our bodies can obtain glucosamine from external sources such as the fermentation of different grains, like wheat and rice and barley, and like galactosamine, from bovine and shark. As far as its effect on bodily functions, glucosamine's precursor, glucosaminoglycans are major segments involved in joint cartilage, and thus can help in the treatment of osteoporosis, or osteoarthritis.

**Muramic acid** is an amino [sugar acid](https://en.wikipedia.org/wiki/Sugar_acid). In terms of chemical composition, it is the [ether](https://en.wikipedia.org/wiki/Ether) of [lactic acid](https://en.wikipedia.org/wiki/Lactic_acid) and [glucosamine](https://en.wikipedia.org/wiki/Glucosamine). It occurs naturally as [*N*-acetylmuramic acid](https://en.wikipedia.org/wiki/N-Acetylmuramic_acid) in [peptidoglycan](https://en.wikipedia.org/wiki/Peptidoglycan%22%20%5Co%20%22Peptidoglycan), whose primary function is a structural component of many typical bacterial [cell walls](https://en.wikipedia.org/wiki/Cell_wall).