Glucose (Glc), a monosaccharide (or simple sugar), is an important carbohydrate in biology. The living cell uses it as a source of energy and metabolic intermediate. Glucose is one of the main products of photosynthesis and starts cellular respiration in both prokaryotes and eukaryotes. The name comes from the Greek word *glykys* (γλυκύς), meaning "sweet", plus the suffix "-ose" which denotes a sugar.

Two stereoisomers of the aldohexose sugars are known as glucose, only one of which (D-glucose) is biologically active. This form (D-glucose) is often referred to as **dextrose monohydrate**, or, especially in the food industry, simply **dextrose** (from *dextrorotatory glucose*[1]). This article deals with the D-form of glucose. The mirror-image of the molecule, L-glucose, cannot be metabolized by cells in the biochemical process known as glycolysis.

Contents

[hide]

[edit] Structure

Glucose ($C_6H_{12}O_6$) contains six carbon atoms, one of which is part of an aldehyde group, and is therefore referred to as an aldohexose. In solution, the glucose molecule can exist in an open-chain (acyclic) form and a ring (cyclic) form (in equilibrium). The cyclic form is the result of a covalent bond between the aldehyde C atom and the C-5 hydroxyl group to form a six-membered cyclic hemiacetal. At pH 7 the cyclic form is predominant. In the solid phase, glucose assumes the cyclic form. Because the ring contains five carbon atoms and one oxygen atom, which resembles the structure of pyran, the cyclic form of glucose is also referred to as glucopyranose. In this ring, each carbon is linked to a hydroxyl side group with the exception of the fifth atom, which links to a sixth carbon atom outside the ring, forming a CH_2OH group. Glucose is commonly available in the form of a white substance or as a solid crystal. It can also be dissolved in water as an aqueous solution.

[edit] Isomers

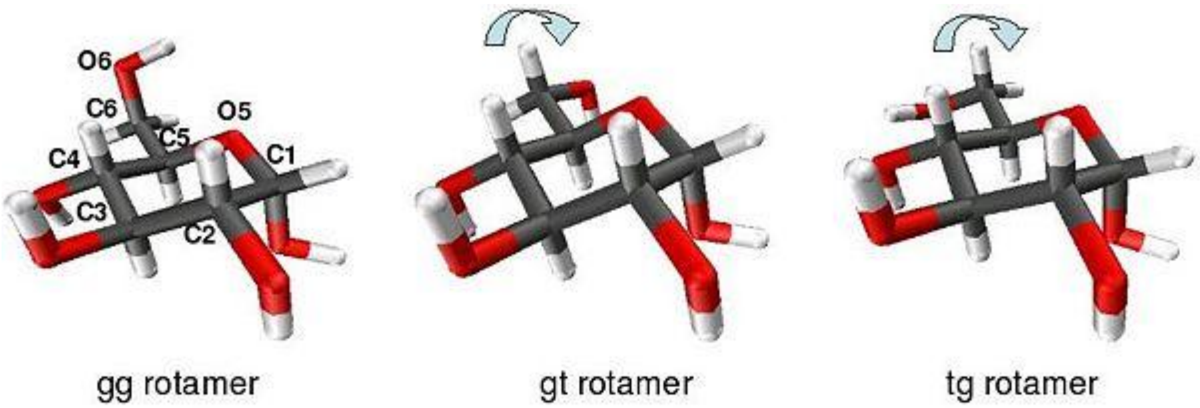
Aldohexose sugars have 4 chiral centers giving $2^4 = 16$ stereoisomers. These are split into two groups, L and D, with 8 sugars in each. Glucose is one of these sugars, and L-glucose and D-glucose are two of the stereoisomers. Only 7 of these are found in living organisms, of which D-glucose (Glu), D-galactose (Gal), and D-mannose (Man) are the most important. These eight isomers (including glucose itself) are related as diastereoisomers and belong to the D series.

An additional asymmetric center at C-1 (called *the anomeric carbon atom*) is created when glucose cyclizes and two ring structures called anomers are formed as *α*-glucose and *β*-glucose. These anomers differ structurally by the relative positioning of the hydroxyl group linked to C-1, and the group at C-6 which is termed the reference carbon. When D-glucose is drawn as a Haworth projection or in the standard chair conformation, the designation *α* means that the hydroxyl group attached to C-1 is positioned trans to the -CH_2OH group at C-5, while *β* means it is cis. Another popular method of distinguishing *α* from *β* is by observing whether the C-1 hydroxyl is below or above the plane of the ring; but this method is an inaccurate definition, and may fail if the glucose ring is drawn upside down or in an alternative chair conformation. The *α* and *β* forms interconvert over a timescale of hours in aqueous solution, to a final stable ratio of *α*:*β* 36:64, in a process called *mutarotation*.[2]

The Fischer projection of the chain form of D-glucose	The chain form of D-glucose	*α*-D-glucopyranose	*β*-D-glucopyranose
Chain form: ball-and-stick model	Chain form: space-filling model	*α*-D-glucopyranose	*β*-D-glucopyranose

[edit] Rotamers

Within the cyclic form of glucose, rotation may occur around the O6-C6-C5-O5 torsion angle, termed the ω-angle, to form three rotamer conformations as shown in the diagram below. Referring to the orientations of the ω-angle and the O6-C6-C5-C4 angle the three stable staggered rotamer conformations are termed *gauche*-*gauche* (gg), *gauche*-*trans* (gt) and *trans*-*gauche* (tg). For methyl *α*-D-glucopyranose at equilibrium the ratio of molecules in each rotamer conformation is reported as 57:38:5 gg:gt:tg.[3] This tendency for the ω-angle to prefer to adopt a *gauche* conformation is attributed to the gauche effect.



Rotamer conformations of *α*-D-glucopyranose

[edit] Properties and energy content

The Gibbs free energy of formation of solid glucose is -909 kJ/mol and the enthalpy of formation is -1273 kJ/mol. The heat of combustion (with liquid water in the product) is about 2803 kJ/mol, or 3.72 kcal per gram. The ΔG (change of Gibbs free energy) for this combustion is about -2880 kJ/mol.

Upon heating, glucose, like any carbohydrate, will undergo pyrolysis (carbonization) yielding steam and a char consisting mostly of carbon. This reaction is exothermic, releasing about 0.237 kcal per gram.

[edit] Production

[edit] Natural

1. Glucose is one of the products of photosynthesis in plants and some prokaryotes.
2. In animals and fungi, glucose is the result of the breakdown of glycogen, a process known as glycogenolysis. In plants the breakdown substrate is starch.
3. In animals, glucose is synthesized in the liver and kidneys from non-carbohydrate intermediates, such as pyruvate and glycerol, by a process known as gluconeogenesis.

[edit] Commercial

Glucose is produced commercially via the enzymatic hydrolysis of starch. Many crops can be used as the source of starch. Maize, rice, wheat, potato, cassava, arrowroot, and sago are all used in various parts of the world. In the United States, cornstarch (from maize) is used almost exclusively.

This enzymatic process has several stages. In the gelatinization stage, a slurry of starch is heated to 105 °C, and the enzyme, α-amylase, is added. In the liquefaction stage, the mixture is held at 95 °C for 2 hours. In the last stage, known as "saccharification", the partially hydrolyzed starch is completely hydrolyzed to glucose using the glucoamylase enzyme from the fungus *Aspergillus niger*. Typical reaction conditions are pH 4.0–4.5, 60 °C, and a carbohydrate concentration of 30–35% by weight. Under these conditions, starch can be converted to glucose at 96–97% glucose, "glucose syrup" over 1–4 days.[4] In some variations on this process, the liquefaction stage is carried out at 130 °C or even hotter.[*citation needed*] This heat treatment improves the solubility of starch in water, yielding a more concentrated syrup, but deactivates the enzyme, and fresh enzyme must be added to the mixture after each heating. Higher glucose yields can be obtained using more dilute solutions, but this approach requires larger reactors and processing a greater volume of water, and is not generally economical. ultimately, the resulting glucose solution is then purified by filtration and concentrated in a multiple-effect evaporator. Solid D-glucose is then produced by repeated crystallizations.

Glucose

Glucose tablets

[edit] Function

We can speculate on the reasons why glucose, and not another monosaccharide such as fructose (Fru), is so widely used in evolution, the ecosystem, and metabolism. Glucose can form from formaldehyde under abiotic conditions, so it may well have been available to primitive biochemical systems. Probably more important to advanced life is the low tendency of glucose, by comparison to other hexose sugars, to non-specifically react with the amino groups of proteins. This reaction (glycation) reduces or destroys the function of many enzymes. The low rate of glycation is due to glucose's preference for the less reactive cyclic isomer. Nevertheless, many of the long-term complications of diabetes (e.g., blindness, kidney failure, and peripheral neuropathy) are probably due to the glycation of proteins or lipids. In contrast, enzyme-regulated addition of glucose to proteins by glycosylation is often essential to their function.

[edit] As an energy source

Glucose is a ubiquitous fuel in biology. It is used as an energy source in most organisms, from bacteria to humans. Use of glucose may be by either aerobic or anaerobic respiration (fermentation). Carbohydrates are the human body's key source of energy, through aerobic respiration, providing approximately 3.75 kilocalories (16 kilojoules) of food energy per gram.[5] Breakdown of carbohydrates (e.g. starch) yields mono- and disaccharides, most of which is glucose. Through glycolysis and later in the reactions of the Citric acid cycle (TCAC), glucose is oxidized to eventually form CO_2 and water, yielding energy, mostly in the form of ATP. The insulin reaction, and other mechanisms, regulate the concentration of glucose in the blood. A high fasting blood sugar level is an indication of prediabetic and diabetic conditions.

Glucose is a primary source of energy for the brain, and hence its availability influences psychological processes. When glucose is low, psychological processes requiring mental effort (e.g., self-control, effortful decision-making) are impaired.[6][7][8][9]

[edit] Glucose in glycolysis

Use of glucose as an energy source in cells is via aerobic or anaerobic respiration. Both of these start with the early steps of the glycolysis metabolic pathway. The first step of this is the phosphorylation of glucose by hexokinase to prepare it for later breakdown to provide energy.

α-D-Glucose	Hexokinase	α-D-Glucose-6-phosphate

ATP ADP

Compound C00031 at KEGG Pathway Database. Enzyme 2.7.1.1 at KEGG Pathway Database. Compound C00668 at KEGG Pathway Database. Reaction R01786 at KEGG Pathway Database.

The major reason for the immediate phosphorylation of glucose by a hexokinase is to prevent diffusion out of the cell. The phosphorylation adds a charged phosphate group so the glucose 6-phosphate cannot easily cross the cell membrane. Irreversible first steps of a metabolic pathway are common for regulatory purposes.

[edit] As a precursor

Glucose is critical in the production of proteins and in lipid metabolism. Also, in plants and most animals, it is a precursor for vitamin C (ascorbic acid) production. It is modified for use in these processes by the glycolysis pathway.

Glucose is used as a precursor for the synthesis of several important substances. Starch, cellulose, and glycogen ("animal starch") are common glucose polymers (polysaccharides). Lactose, the predominant sugar in milk, is a glucose-galactose disaccharide. In sucrose, another important disaccharide, glucose is joined to fructose. These synthesis processes also rely on the phosphorylation of glucose through the first step of glycolysis.

[edit] Sources and absorption

All major dietary carbohydrates contain glucose, either as their only building block, as in starch and glycogen, or together with another monosaccharide, as in sucrose and lactose. In the lumen of the duodenum and small intestine, the oligo- and polysaccharides are broken down to monosaccharides by the pancreatic and intestinal glycosidases. Glucose is then transported across the apical membrane of the enterocytes by SLC5A1, and later across their basal membrane by SLC2A2.[10] Some of the glucose goes directly toward fueling brain cells and erythrocytes, while the rest makes its way to the liver and muscles, where it is stored as glycogen, and to fat cells, where it can be used to power reactions which synthesize some fats. Glycogen is the body's auxiliary energy source, tapped and converted back into glucose when there is need for energy.

[edit] See also

- Blood glucose or Blood Sugar
- HbA1c
- DMF (potential glucose-based biofuel)
- Glycation
- Glycosylation
- Photosynthesis
- Fructose

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Glycolysis Metabolic Pathway

Glucose	Hexokinase	Glucose-6-phosphate	Glucose-6-phosphate isomerase	Fructose 6-phosphate	6-phosphofructokinase	Fructose 1,6-bisphosphate	Fructose bisphosphate aldolase	Dihydroxyacetone phosphate		Glyceraldehyde 3-phosphate	Triose phosphate isomerase	Glyceraldehyde 3-phosphate	Glyceraldehyde-3-phosphate dehydrogenase
	ATP ADP				ATP ADP								$NAD^+ + P_i$ $NADH + H^+$
									-		**2**		
													NAD^+ NADH

									+ P_i	+ H^+
1,3-Bisphosphoglycerate	Phosphoglycerate kinase	3-Phosphoglycerate	Phosphoglycerate mutase	2-Phosphoglycerate	Phosphopyruvate hydratase(Enolase)	Phosphoenolpyruvate	Pyruvate kinase	Pyruvate	Pyruvate dehydrogenase	Acetyl-CoA
	ADP ATP				H_2O		ADP ATP		CoA + NAD^+ NADH + H^+ + CO_2	
2	2		2		2		2		2	
	ADP ATP				H_2O					

[edit] References