Carbohydrates

Carbohydrates are one of the main macronutrients. They provide an essential source of energy. They are mainly found in plants, where they are manufactured by photosynthesis.

Photosynthesis

Photosynthesis is the process by which green plants use sunlight to make sugar (glucose) from carbon dioxide and water.

How photosynthesis occurs

Plant roots absorb water (H_2O) from the soil.

Leaves take in carbon dioxide (CO_2) from the air.

Chlorophyll (green pigment) in leaves absorbs energy from the sun.

Result

Glucose (sugar) ($C_6H_{12}O_6$) is formed.

Oxygen (O_2) is released into the air.

Equation for photosynthesis

light energy

$6CO_2 + 6H_2O$ — $C_6H_{12}O_6 + 6O_2$

chlorophyll

Carbon + dioxide water — glucose + oxygen

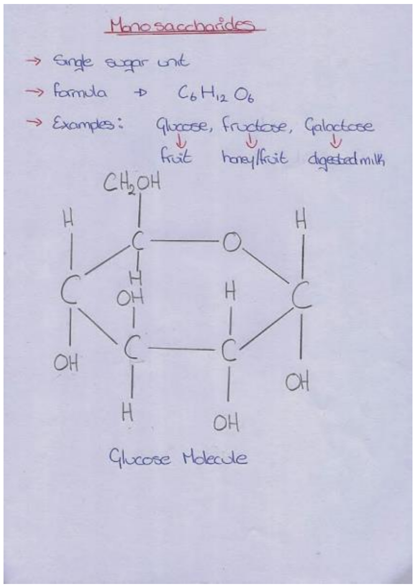
Elemental composition of carbohydrates

Carbohydrates are made up of three elements: carbon (C), hydrogen (H) and oxygen (O).

Monosaccharides

Structure	Chemical formula	Examples	Sources
A simple sugar that contains one simple sugar unit. It is the smallest unit of a carbohydrate.	$C_6H_{12}O_6$	Glucose Fructose Galactose	Fruit Fruit and honey Digested milk

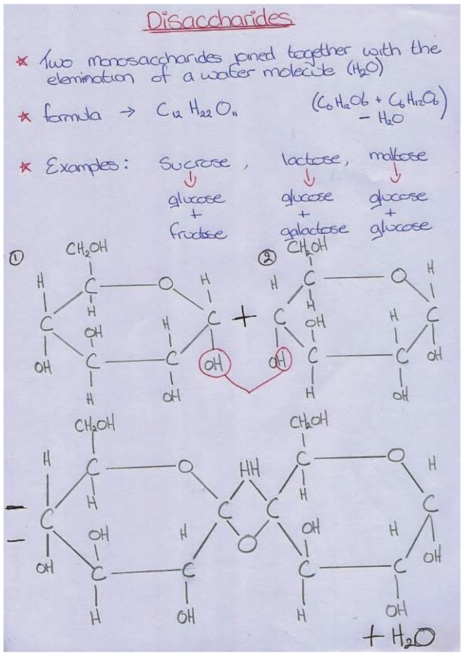
Chemical structure



Disaccharides

Structure	Chemical formula	Examples	Sources
Formed when two monosaccharides join, resulting in the loss of a water (H2O) molecule (condensation reaction).	C12H22O11	Maltose (glucose + glucose) Sucrose (glucose + fructose) Lactose (glucose + galactose)	Barley Table sugar Milk

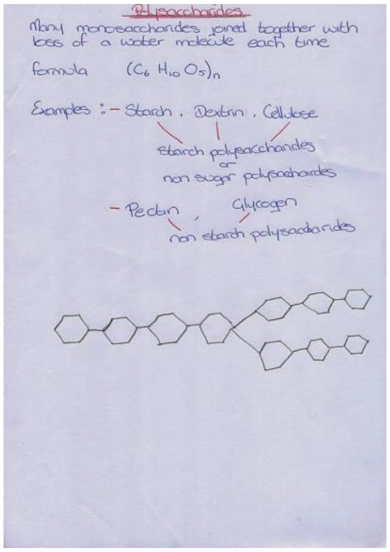
Chemical structure



Polysaccharides

Structure	Chemical formula	Examples	Sources
Formed when three or more monosaccharides join together, resulting in the loss of a water (H_2O) molecule with each new link (condensation reaction). Chains can be straight or branched.	$(C_6H_{10}O_5)_n$ (n refers to the number of monosaccharides joined together)	Starch Pectin Glycogen Gums Cellulose (dietary fibre)	Cereals and potatoes Fruit Meat Plants and seaweed Skins of fruit and vegetables Nuts

Chemical structure



Properties of sugar

Solubility

Sugar is a white crystalline compound. It is soluble in water. A syrup is formed when a large amount of sugar is dissolved in a small amount of water.

Culinary application: used as a preservative in canned fruit, e.g., canned peaches.

Sweetness

All sugars are sweet and give an appetising flavour to food. Some sugars are much sweeter than others. This is measured on a point scale of sweetness. For example, fructose has the highest sweetness rating and lactose has the lowest.

Culinary application: shortbread and cupcakes.

Sweetness table

Sugar	Sweetness
Fructose	170%
Sucrose	100%
Glucose	75%
Lactose	15%

Ability to assist aeration

When sugar is whisked with egg aeration occurs. The sugar helps to denature the egg protein, causing it to unfold and entrap air bubbles. Whisking also creates heat that begins to set the egg albumin. This forms a temporary foam, which will collapse after a while unless it is heated to coagulate and set as a permanent foam.

Culinary application: meringues and sponges.

Maillard reaction

The maillard reaction is the non-enzymic browning of food due to a reaction between certain amino acids and sugars under dry heat. It produces an attractive brown colour and a crust with an appetising flavour.

Culinary application: shortbread biscuits, roast potatoes and roast meat.

Caramelisation

On heating, sugar melts and caramelises. This occurs over ten gradual stages, between 104°C and 177°C. Caramelisation normally occurs at 160°C, resulting in an attractive brown colour and a sweet taste. If overheated (above 177°C), caramel will carbonise or burn.

Culinary application: crème caramel and caramel squares.

Crystallisation

When a liquid has dissolved as much sugar as it can, it is saturated. If more sugar is added, crystals of sugar form in the solution and solidify when cooled.

Culinary application: confectionery and fudge.

Hydrolysis

Hydrolysis (the reverse of the condensation reaction) occurs during digestion. Water and enzymes split disaccharides into two monosaccharides, e.g., lactose into glucose and galactose.

Inversion

Inversion occurs when a liquid sucrose solution is heated in the presence of an acid or enzyme, causing the sucrose (disaccharide) to split in glucose and fructose (monosaccharides). This is known as an invert sugar, and it is sweeter than sucrose.

Culinary application: jam-making. Inversion results in a smooth jam, as invert sugars dissolve easily, preventing sugar crystals from forming.

Properties of starch

Solubility

Starch is a white non-crystalline powder. It is insoluble in cold water.

Flavour

Strach is not sweet in flavour.

Hygroscopy

Starch has the ability to absorb moisture from the air. This can cause uncovered foods, e.g., biscuits, to soften and lose crunch.

Culinary application: helps to keep cakes moist and prevents them from drying out.

Gelatinisation

When starch is combined with liquid and heated to 55-70°C the grains swell, burst and absorb the liquid around them, increasing the viscosity. As the temperature increases (above 85°C) it becomes even more viscous and forms a sol. When the mixture cools, water molecules become trapped, resulting in a gel.

Culinary application: moist heat – roux sauce, lemon curd; dry heat – popcorn and pastry.

Hydrolysis

Hydrolysis (the reverse of the condensation reaction) occurs during digestion. Water and enzymes split starch (polysaccharide) into the disaccharide maltose.

Dextrinisation

When starch foods are dry-heated, short-chained polysaccharides called dextrins are formed. On further heating these combine to form pyrodextrins. This causes a colour change on the surface of the food, resulting in an attractive brown appearance.

Culinary application: the browning of bread to make toast.

Properties of non-starch polysaccharides

Cellulose/dietary fibre

Cellulose/dietary fibre is insoluble in water. It can't be digested by the body, but it absorbs water as it passes through the intestinal tract and helps stimulate peristalsis. This is beneficial to the body as it speeds up the passage of food and waste, preventing bowel disorders, e.g., constipation.

Gums

Gums are soluble in water. They have the ability to absorb large amounts of water to form a thick gel with a firm texture.

Culinary application: salad dressings and ice cream.

Pectin

Pectin is naturally present in plant cells and the cell walls of fruit and vegetables. It is used as a setting agent, as it has the ability to absorb water to form a gel. It is only present in fruits when they are ripe. In underripe fruits it is in the form of protopectin, and in overripe fruits it becomes pectic acid, neither of which can set as they can't absorb water. For pectin to be extracted it needs heat and acid, e.g., lemon juice.

Culinary application: jam-making.

Effects of heat on carbohydrates

Dry heat	Dextrinisation, e.g., toasting bread. Caramelisation, e.g., crème caramel. Maillard reaction, e.g., roast beef.
Moist heat	Syrup formation, e.g., tinned peaches. Gelatinisation, e.g., white sauce. Cellulose softens, e.g., potatoes. Pectin extraction, e.g., jam.

Biological functions of carbohydrates

Carbohydrates supply the body with heat and energy. This helps to keep the body at 37°C and provides energy for all activities.

Carbohydrates have a protein-sparing function. By consuming a sufficient amount of carbohydrates, proteins can fulfil their primary function of growth and repair of cells, rather than being used to produce energy.

Cellulose/dietary fibre absorbs water as it passes through the intestinal tract and helps to stimulate peristalsis. This is beneficial to the body as it speeds up the passage of food and waste, preventing bowel disorders, e.g., constipation.

Excess carbohydrate intake is converted to glycogen and stored in the liver and muscles as a long-term energy reserve. They may also be to fat and stored as adipose tissue under the skin, which insulates the body and acts as another energy reserve.

Recommended Daily Allowance (RDA)/ Reference Intake (RI)

The carbohydrate requirement of an individual depends on their activity level. On average, adults need approximately 260 g of carbohydrates per day, of which sugars should only account for only 90 g. It is also recommended that people consume 25-35 g of cellulose/dietary fibre each day.

Energy value of carbohydrates

1 g of carbohydrates provides 4 kcal of energy (17 kJ).

Associated dietary disorders

Dietary disorders occur when we eat too many sugary and starchy foods and too little cellulose/dietary fibre. Too much sugar and starch can lead to obesity, type 2 diabetes and dental cavities. Too little cellulose/dietary fibre can lead to bowel disorders.

Digestion of carbohydrates

During digestion water and enzymes break carbohydrate chains into monosaccharides. This process is called hydrolysis.

Mouth: food is chewed into small pieces by the teeth. The salivary glands secrete saliva containing the enzyme salivary amylase, which breaks down starch into maltose.

Pancreas: secretes pancreatic juice containing the enzyme amylase into the duodenum (the first part small intestine). This continues to break down starch into maltose.

Small intestine: the ileum (final section of the small intestine) secretes intestinal juice containing:

The enzyme maltase, which breaks down maltose into glucose.

The enzyme sucrase, which breaks down sucrose into glucose and galactose.

The monosaccharides glucose, fructose and galactose are now ready to be absorbed and utilised by the body.

Organ or gland	Secretion	Enzymes	Substrate	Product
Salivary glands (mouth)	Saliva	Salivary amylase	Starch	Maltose
Pancreas	Pancreatic juice	Amylase	Starch	Maltose
Small intestine (ileum)	Intestinal juice	Maltase Sucrase Lactase	Maltose Sucrose Lactose	Glucose Glucose and fructose Glucose and galactose

Absorption and utilisation of carbohydrates

After digestion the monosaccharides glucose, fructose and galactose are ready to be absorbed by the small intestine. They pass through the wall of the villi and into the bloodstream.

Next the hepatic portal vein transports the monosaccharides to the liver via the bloodstream.

In the liver, fructose and galactose are converted to glucose. The glucose is then:

Oxidised to produce heat and energy.

Converted to glycogen and stored in the liver and mucles as a long-term energy reserve.

Excess glucose is converted to fat and stored as adipose tissue under the skin, insulating the body and acting as an energy reserve.