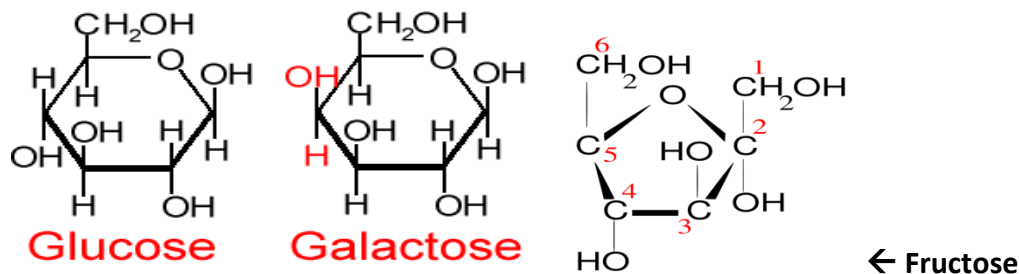


Chemistry of Carbohydrates

Carbohydrates have ring structures.

Carbohydrates have alcohol functional groups (C-OH) and ether functional groups (C-O-C)



The molecules above all have the same chemical formula: $C_6H_{12}O_6$

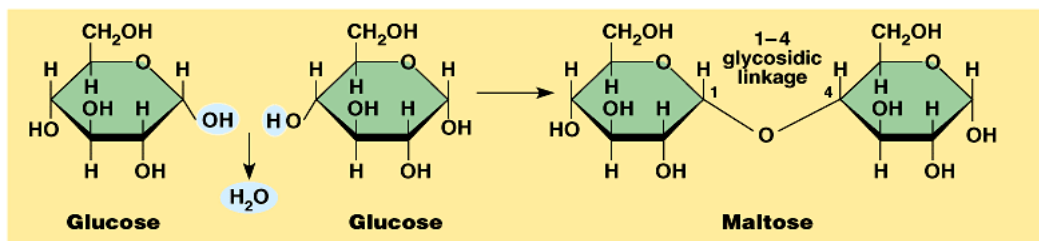
But they all taste different and metabolize differently, because they have different structures.

Molecules with the same formula and different structures are isomers.

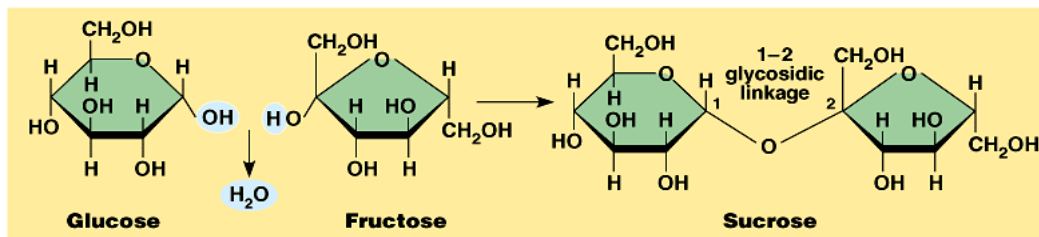
Monosaccharides: Sugars that are single rings, like the ones above. Different disaccharide isomers taste different and can be metabolized differently. (example: fructose is very sweet and is only metabolized in the liver; glucose is less sweet and can be metabolized anywhere) (formula of most monosaccharides is $C_6H_{12}O_6$)

Disaccharides: Sugars made up of two rings connected together; the connection between sugars is an ether functional group.

- Below are some examples of disaccharides. Notice that sucrose is a combination of one glucose molecule and one fructose molecule.
- Our bodies are able to quickly separate the sugar rings and metabolize them individually.
- Disaccharides can have a different taste than the individual single rings they're made up of. For example, maltose below has somewhat of a bitter taste, while glucose has a slightly sweet taste.
- The formula of most disaccharides is $C_{12}H_{22}O_{11}$ – this is a bit less than double of $C_6H_{12}O_6$ because a water molecule is lost during the combination reaction.



(a) Dehydration synthesis of maltose



(b) Dehydration synthesis of sucrose

Biological Function of Carbohydrates: Provides short term energy (energy content = 4 Cal/g)

- Body doesn't store carbohydrates
 - BUT you can convert carbs to fat
- Body doesn't need carbohydrates to build cells

Types of Carbohydrates

Fiber:

Fiber is a carbohydrate that we cannot digest – yet it is an essential nutrient.

Energy value of fiber = zero Calories per gram

- **Soluble fiber:** slows down digestion; delays emptying of stomach (feel full longer) ; improves cholesterol; helps reduce insulin response and improves insulin sensitivity (helps avoid diabetes)
- **Insoluble fiber:** makes food travels faster through gut – makes you feel satiated sooner; prevents constipation; found in whole grains and vegetables.
 - Processing of food destroys insoluble fiber – this is one reason processed foods are less healthy.
- Most people should try to eat 25-40 grams of fiber per day.

Starch / Complex carbohydrates

- Polymers of many sugar rings connected together with ether linkages
- Digests a bit slower
- Breaks down to glucose
- Found in bread, pasta, rice, potatoes, etc
- Most starchy foods are not very nutrient rich, but it's at least not actively bad for you.

Glucose

- The most common sugar in nature
- Any cell in any organism on earth can metabolize glucose
- Your liver can safely handle any amount of glucose
- Starch breaks down to glucose

Lactose (milk sugar)

- Converted to glucose in cells, so its health / nutrition impact is similar to glucose and starch
 - Lactose is lumped into "sugars" on food labels, but it digests differently than fructose/sucrose.
- Causes issues for people who are lactose intolerant; their cells do not produce much lactase enzyme

Fructose / Sucrose (the simple version here... see next page for more details)

- The sweetest tasting sugar
- Unhealthy sugar: over time, too much contributes to diabetes, high blood pressure, obesity, heart disease
- Only metabolized by the liver – too much sugar at once causes bad things to happen in the liver.
- Eating small amounts is fine
- Eating it with fiber is okay - this is why fruit is healthy but juice is bad for you. Fiber makes you absorb sugar more slowly so that the liver can keep up with metabolizing it.

Sucrose, Fructose (the more complicated version)

- Sucrose is a 50/50 combination of glucose and fructose (it's a two ring sugar, a disaccharide)
- High Fructose Corn Syrup is also about 50% fructose and 50% glucose
- It doesn't matter if you eat cane sugar, organic sugar, high fructose corn syrup, etc. It's the same stuff.
- **Only the liver** can metabolize fructose (unlike glucose, which can be metabolized in any cell)
- Big fructose dose in liver → liver can't keep up → liver converts 30% or so of it to fat.
 - Fat in the liver is BAD
 - Makes the liver sick (causes insulin resistance – that is BAD)
 - Leads to muscle insulin resistance (leads to diabetes)
 - Contributes to hepatitis (liver inflammation)
 - Leads to bad cholesterol – leads to heart problems
- Increases uric acid in liver – leads to hypertension (high blood pressure)
- Insulin resistance leads to higher insulin levels
 - Leads to higher blood pressure
 - Causes more fat production
 - Leads to leptin resistance
 - Means your brain thinks it's starving even when you eat a lot
 - Brain reacts by reducing your metabolism
 - Brain reacts by making you less motivated to move around
 - Makes you feel depressed
- Fructose is a chronic toxin, but not an acute toxin. This means that over time it can have toxic effects, but it has no toxic effects in the short term. Fructose causes most of the same chronic toxicity problems (described above) as alcohol.
- Sugar (unlike salt or fat) can be considered to be addictive. This is a controversial view, but some evidence exists to support it. Addiction is clinically characterized by bingeing, withdrawal, craving, addiction transfer.