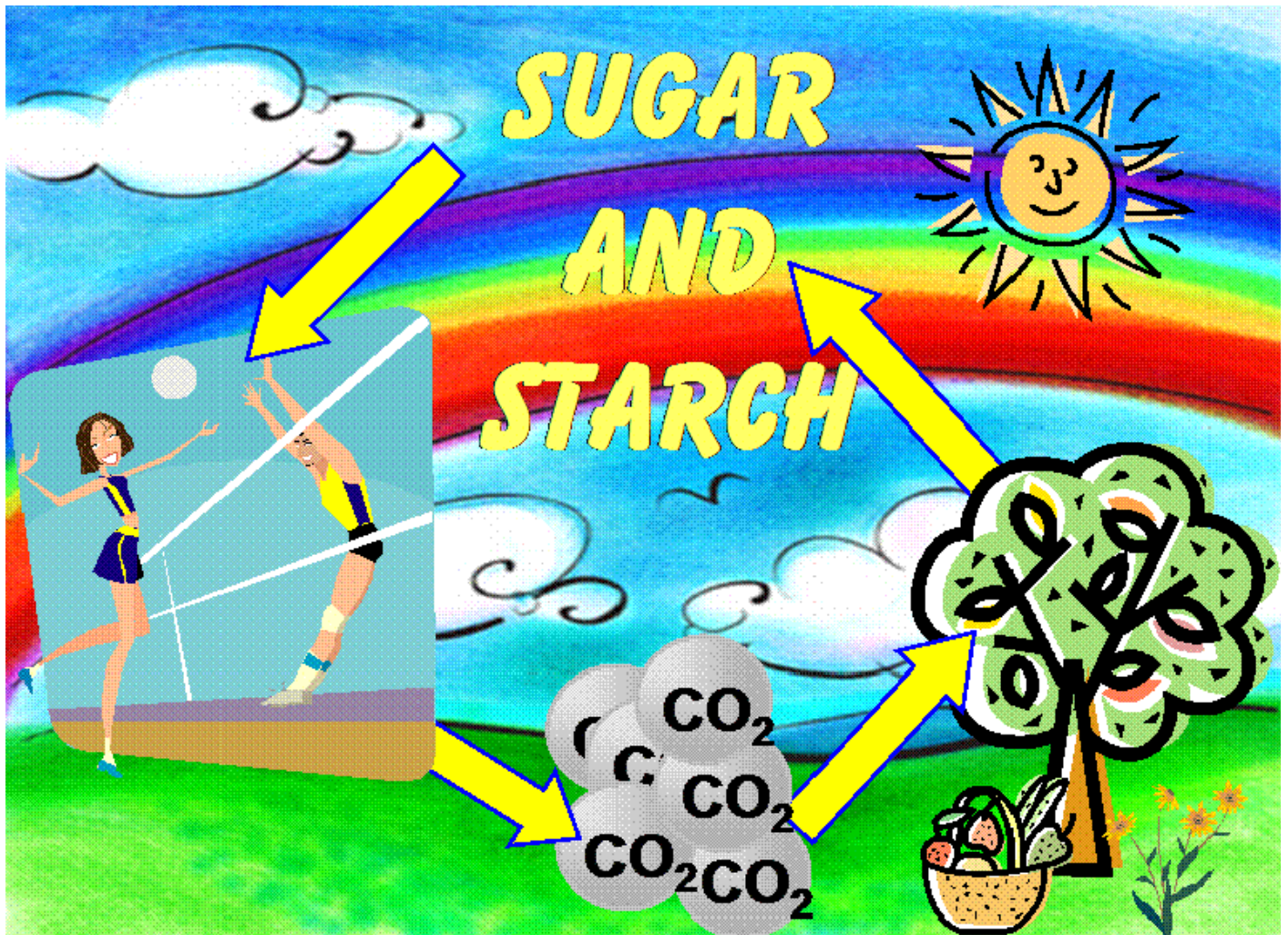


# Sugars 4 Kids



Sugars and starch = Renewable Energy!

***After you have worked with "sugars 4 kids" you will know:***

- 1. Which sugars are found in our food.***
- 2. How they are taken up and used in our bodies.***
- 3. Why some of us get tummy aches from milk (and too much candy!).***
- 4. Why we cannot eat grass.***

## **It's a sugary world!**

Bread, potatoes for dinner, logs in the fireplace, fuel for your emotions, a page in your favorite book, frosting on the cake, the green crest of the hill, an apple's dripping juice, coke, grass, the wooden boat, a horse's hay, the bee cube filled with honey, milk, a winner's driving energy, oak trees, rice for the world's masses. It's all made from sugar. Sweet sugar, rigid sugar, no-taste sugar, flowing sugar, sugar crystals, sugar! One sugar is the basis for all of this. The same sugar that flows in your blood. The sugar that drives your thoughts and pushes the runner faster and faster.

That sugar is GLUCOSE, bound or free. Bound so that you can digest it. Bound so that you cannot digest it. GLUCOSE! It covers the land. It powers the fish of the sea. All plants live of it. All animals survive on it. GLUCOSE, probably the most common carbon substance in the world! GLUCOSE, the foundation of life! GLUCOSE, the core of cellulose and, therefore, of trees and flowers and grass.

GLUCOSE, that sugar bound in huge numbers in plants and animals as reserve energy. GLUCOSE, half of the sugar in milk and table sugar. GLUCOSE, the basis for our genetic development through hundreds of thousands of years. One of the three simple digestible sugars and the only one in large quantities throughout time.

## What are sugars?

Let's look at that stuff we usually mean when we speak about sugar. You know, that stuff we have on the table, pour out on breakfast cereal, that we dump up in coffee and tea and which is found in cakes and cookies and many of the soft drinks we like so well. Scientists call it sucrose. It is a combination of two

smaller sugars known as glucose and fructose. Sucrose is one of the two sugars commonly found in our food.



The second common sugar is found in milk. This is lactose or "milk sugar". Lactose is a combination of glucose and another small sugar, called galactose.

There is a third common sugar too, known as maltose which actually is not found in the food we eat.

Maltose is made of two glucose molecules. We make it ourselves from starch when we eat bread, potatoes and other starch-containing foods.

Starch is a long chain of glucose molecules. It is broken down in the intestines to maltose, a disaccharide or "double sugar" made up of two molecules of glucose.

Once again. The sugar we usually eat is sucrose. Those who drink fresh milk get lactose too. These are "double sugars", that is, they are made up of two smaller sugars linked together by a chemical bond. In addition we consume lesser amounts of two small sugars; glucose and fructose. These are found in fruit, the exact amounts being dependent upon how ripe the fruits are. For example, an apple contains around six grams of fructose and something like three grams of glucose. Honey is a rich source of fructose, being made up of about 40 % fructose and 50% glucose. During the past decade a combination of glucose and fructose, called HFCS or "high fructose corn syrup" has been used to replace some of the sucrose in soft drinks. This is an approximately 50/50 mixture of these two small sugars.

**We can summarize all of this in a table:**

Sugars in our food			
	"Single" Sugars*	"Double" Sugars**	Complex Sugars***
Fruits, fruit juices, jam, syrup, soft drinks	Glucose, fructose	Sucrose	-
Honey	Glucose, fructose	-	-
Cereal, potatoes, pasta, macaroni, rice, bread, sweetened cereals, baked goods	-	Sucrose (table sugar)	Starch
Milk	-	Lactose (milk sugar)	-
Fiber in food, grass, trees	-	-	Cellulose

\* Monosaccharides, \*\* Disaccharides, \*\*\* Polysaccharides.

The three small sugars (single sugars or monosaccharides) have the same basic components (six carbon atoms, twelve hydrogen atoms and six oxygen atoms).

The differences between them lie in the ways these are assembled. Those "little"

differences determine how your body handles these sugars. We will just use simple icons for these here in Sugars-4-Kids,

but if you want to see the exact structures you



can [click here](#). The differing structures of these sugars also influence their taste. We are used to sucrose and experience its taste as "normally sweet". Glucose is experienced as less sweet than sucrose while fructose is "very sweet".

The "double" sugars or disaccharides are made by combining two "single" sugars with a strong and stable chemical bond. All of the digestible disaccharides have one glucose element bound to another of the "single" sugars.

**Sucrose = glucose + fructose.**

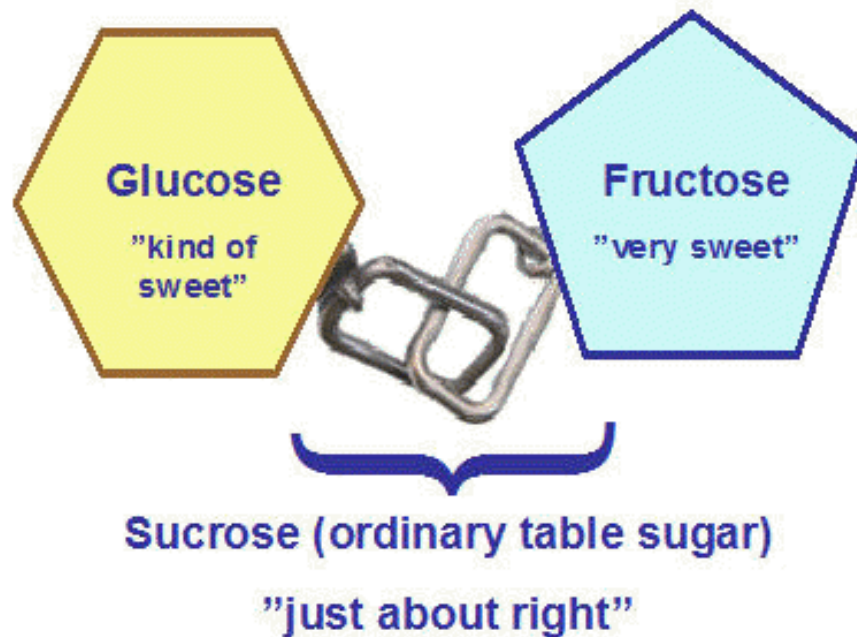
**Lactose = glucose + galactose.**

**Maltose = glucose + glucose.**

Polysaccharides or complex sugars are long chains of glucose bound together chemically. Some of these are digestible (starch) while others are not (cellulose as in wood!). Once again: in spite of the huge differences in character between these materials, they all are built up from the same basic element, GLUCOSE. More about this further on.

# What does sucrose (usual table sugar) look like?

Table sugar is a “double sugar”, a disaccharide, a combination of one glucose molecule and one fructose molecule, strongly linked together through a chemical bond. That link is very stable and sucrose does not break down when boiled or

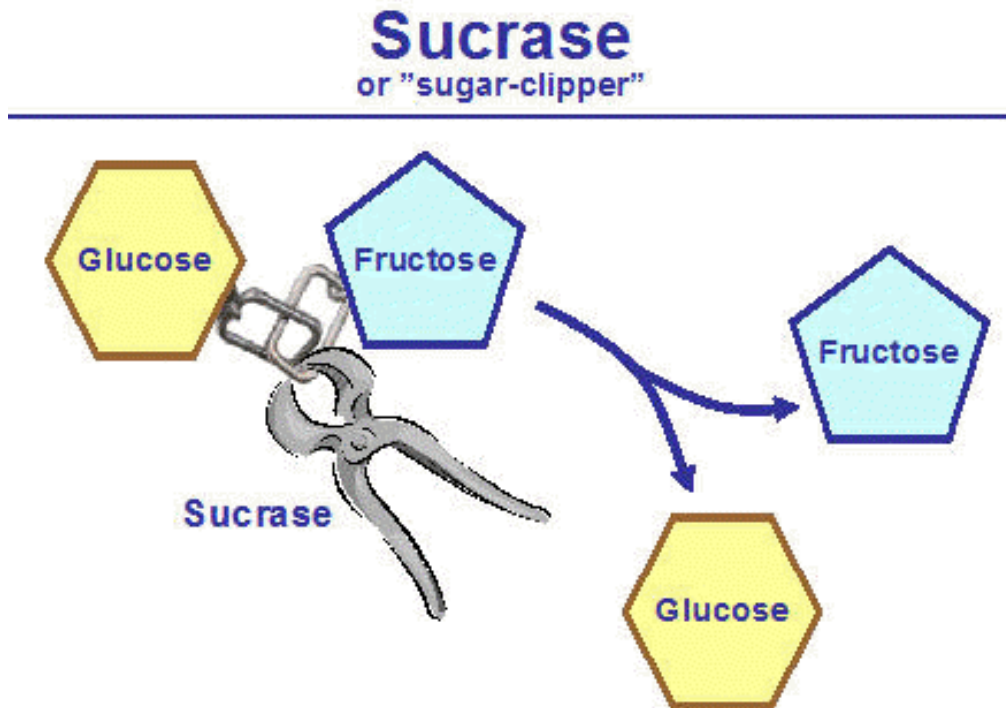


baked. That brings up another interesting problem when we talk about sugars. Disaccharides are not taken up in our bodies! They must be broken down to the individual small sugars before they can go over the cell membranes in the intestines. Even the small sugars cannot of themselves cross from the gut to the circulation. There are special transporters in the intestine that carry these from the digested material in our gut into our bodies.

Well, if the bond between the small sugars is so strong, how do we split sucrose into its two simple sugars? We use enzymes!

Enzymes are very specialized proteins designed to greatly speed-up specific reactions. They are responsible for driving forward the many and complex reactions in our bodies. Enzymes get their forms from codes found in our genes that have been inherited in an endless chain starting from our very early ancestors. When we speak of "very early ancestors" we do NOT refer to "cavemen" but to animals that lived "up in the trees" and who nourished themselves largely by eating fruit. Our metabolism is based on eating sugars and starch, not meat. Many of our body's organs "burn" only sugar!

Now, back to sucrose-eating. When that table sugar reaches the beginning of the small intestine it meets an enzyme called "sucrase". This is a protein formed



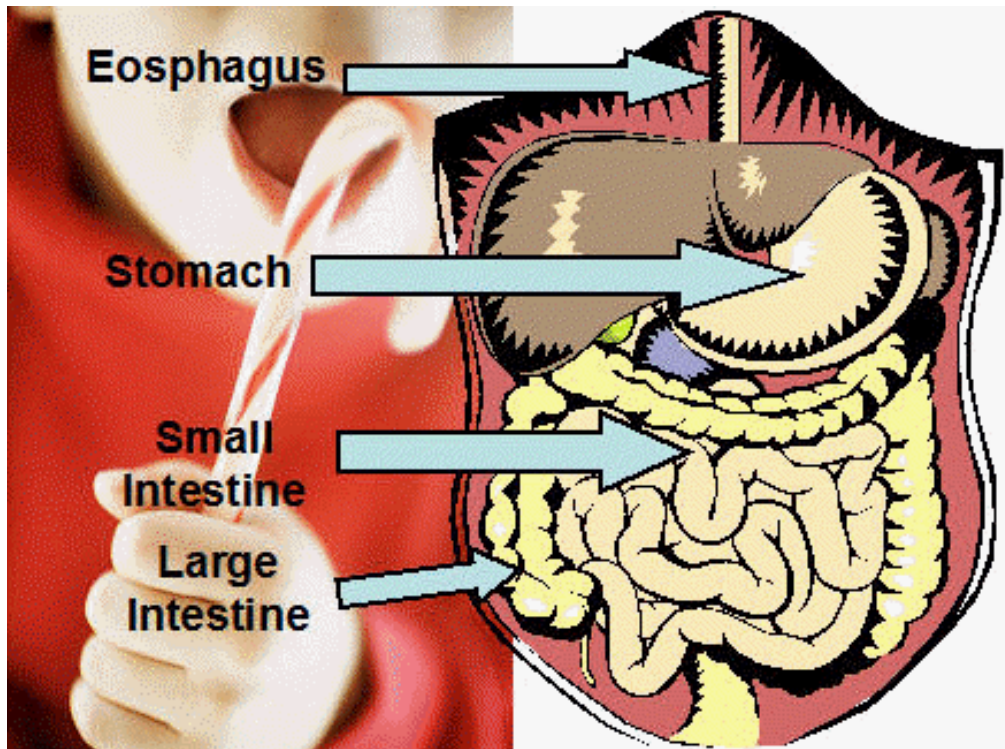
on the inside of the intestine. It recognizes sucrose and splits the "chain" or bond

between glucose and fructose. This "sugar-clipper" is specially designed to fit the link between glucose and fructose in sucrose alone. It does not attack other sugars.

The small sugars released by sucrase can then be taken up by transport systems in the small intestine's wall and are moved to the circulation. Once in the blood they are carried to all of the body's tissues and are used to supply energy.

## Jens eats candy.

We can look at a drawing of the intestines to get a more detailed description of the uptake process. Here is "little Jens", about to devour a candy stick. Which organs are going to be involved in handling the sugar in that candy?

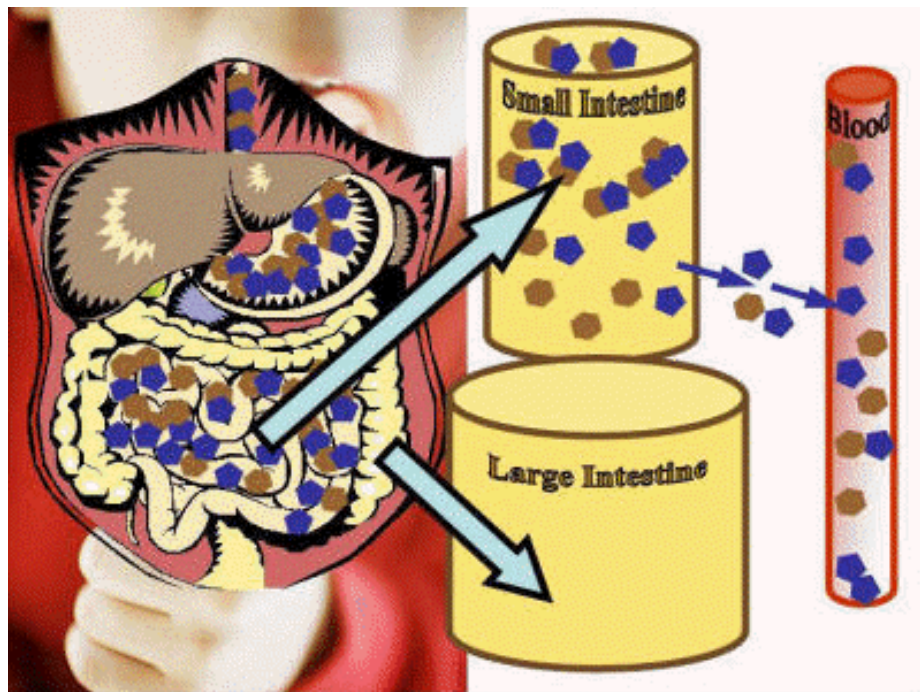


Four major organs are involved here. The esophagus is "just" a tube connecting the mouth and stomach. The sugars from that candy are not altered until they

enter the small intestine. Here they are split into glucose and fructose and are then taken up over the small intestine's membranes and end up in the circulation.

## Go now to the next figure for details.

There are several points that you should note here:



1. Disaccharides ("double sugars") like sucrose are not split before entering the small intestine. Sugars are not digested in the stomach. Enzymes that split disaccharides are only found in the upper reaches of the small intestine (called the duodenum). No transport of sugars to the blood can occur before enzymes split them.
2. The released small sugars (glucose and fructose in the case of sucrose) are absorbed in the small intestine. They do NOT reach

the large intestine. This is quite important for us! They are then sent to the blood stream and distributed through the body.

## The small and large intestines.

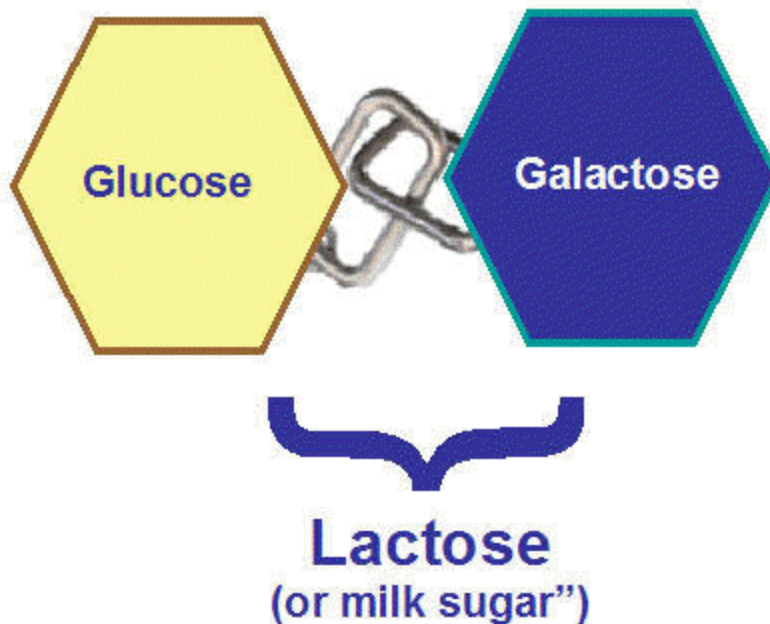
There are great differences in the functions of these two organs. Digestion of food and uptake of released nutrients is the major function of the small intestine. Here food is processed and sent further to the blood and distributed to the rest of the body.

The large intestine is concerned with cleaning up the leftovers, taking up water from digested food and getting wastes ready to send to the toilet. A really important difference is that the large intestine is packed with bacteria. These are usually kindly and helpful, and aid in cleaning up leftovers from the food we eat.

**Let us look at an example of what can happen if sugars go into the large intestine.**

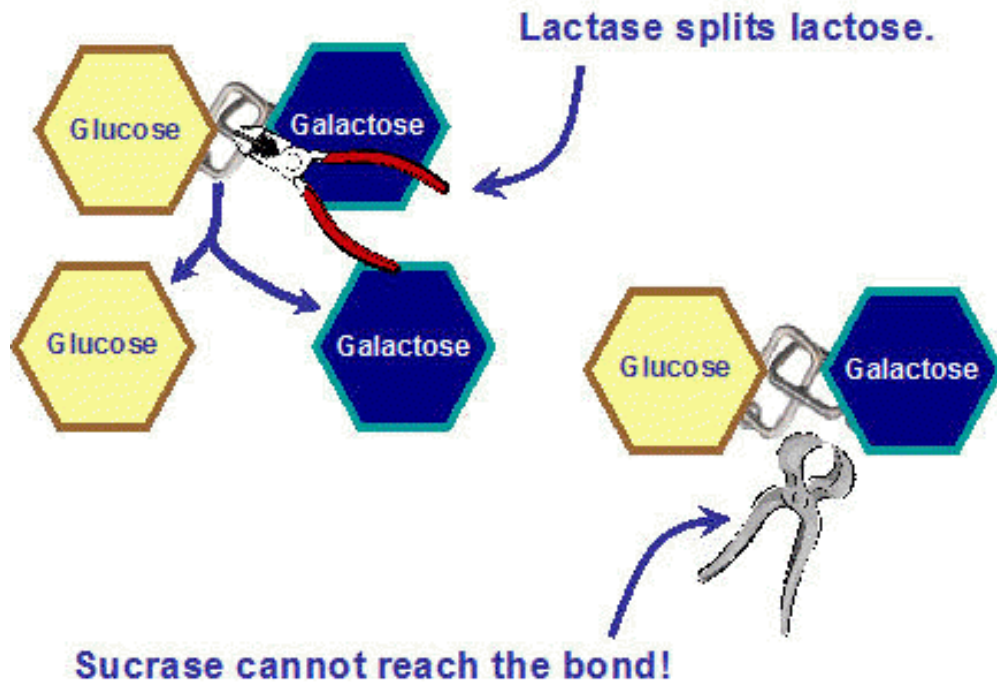
**(or "I get a tummy ache from milk").**

Milk sugar or lactose is also a disaccharide, being made up of one glucose molecule coupled to a galactose molecule. These are bound by a strong



chemical bond. However, The link between these two small sugars is unlike that we saw in table sugar. It lies buried and partially hidden between the glucose and galactose molecules. We must have a dyed-in-the-wool specialized enzyme to split lactose and break that link. The enzyme is called lactase. It manages to release the glucose and galactose from lactose but does not attack other sugars.

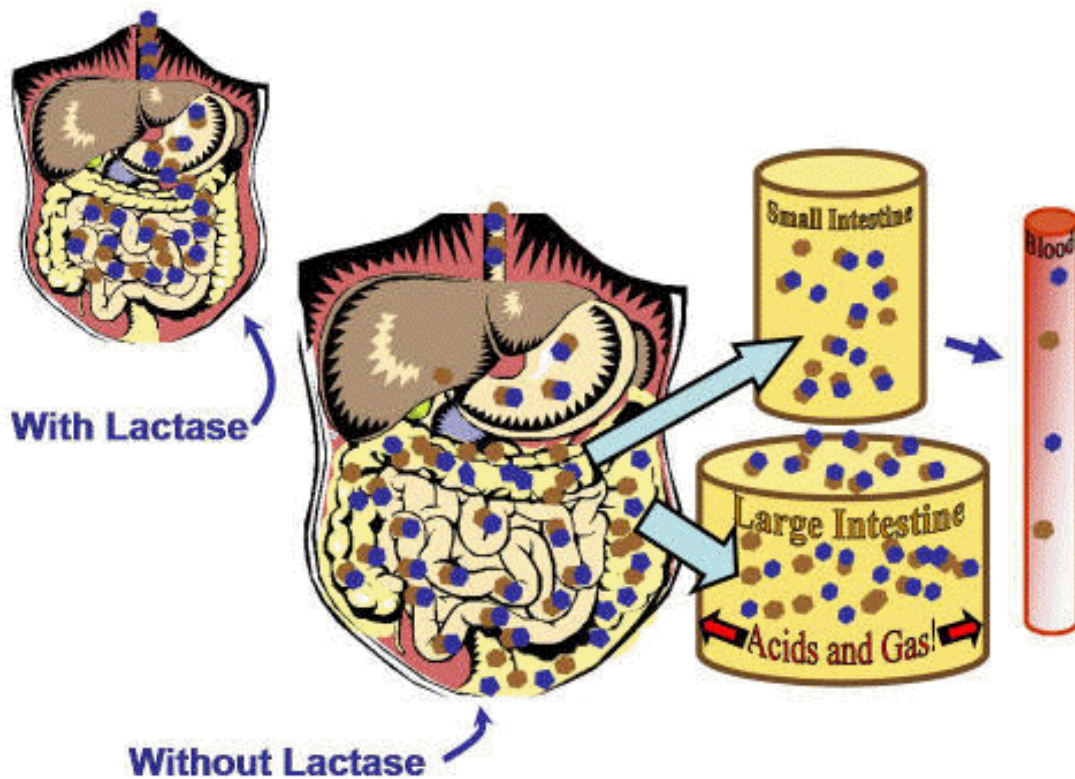
Lactase is an enzyme that almost all of us are born with. Production of this enzyme continues in the small intestine during our first three to five years of life. After that, lactase production stops up. Most of us continue through a long life



without lactase production. We still have sucrase (the table sugar splitting enzyme), but this cannot break the sugar link in milk sugar.

## What happens when we (I am one of them) milk-intolerant people drink milk?

If we look at the next figure we can see that, in the presence of lactase, sugar digestion and uptake goes just about as with sucrose and sucrose. The disaccharide is split in the small intestine and the two small sugars are taken up there. They do not reach the large intestine. Everything is OK as long as you have lactase.



**But, what about those of us who have little or no lactase?**

Those un-split lactose molecules continue to the large intestine. Here they meet our kindly and very active bacteria. They split the lactose and make acids and lots of GAS. You can see from the drawing that the large intestine becomes swollen and full. OUI! That hurts!

The bottom line here is that normally, sugars do not reach the large intestine. When they do, discomfort will result since bacteria split and ferment all of the usual sugars. This leads to accumulation of water and bulk in the large intestine. At the same time there is a lot of gas produced. The result is pain and diarrhea.

All sugars have the same effect if they come to the large intestine. Kids who eat too much candy or drink a lot of cola when they have a "stomach ache" often experience diarrhea and an increased tummy ache. Too much table sugar (sucrose) has the same effect as milk sugar (lactose) in people without lactase.

## **Some adults do drink milk.**

Scandinavians and several tribes in Africa have experienced genetic mutations which keep the gene responsible for lactase production active throughout life. Most adults in Norway, Sweden and Denmark can drink milk without problems. In other areas, particularly Asia and most of Africa, grownups usually do not tolerate fresh milk. World-wide, more than 50% of all adults experience milk-intolerance.

This does not mean that older people cannot drink milk products. We simply let yeast or bacteria digest the milk for us. Culture milk, sour cream and yoghurt are examples of milk products that people who lack lactase can consume without problems. Here the lactose is split during preparation of the milk products before we consume them.

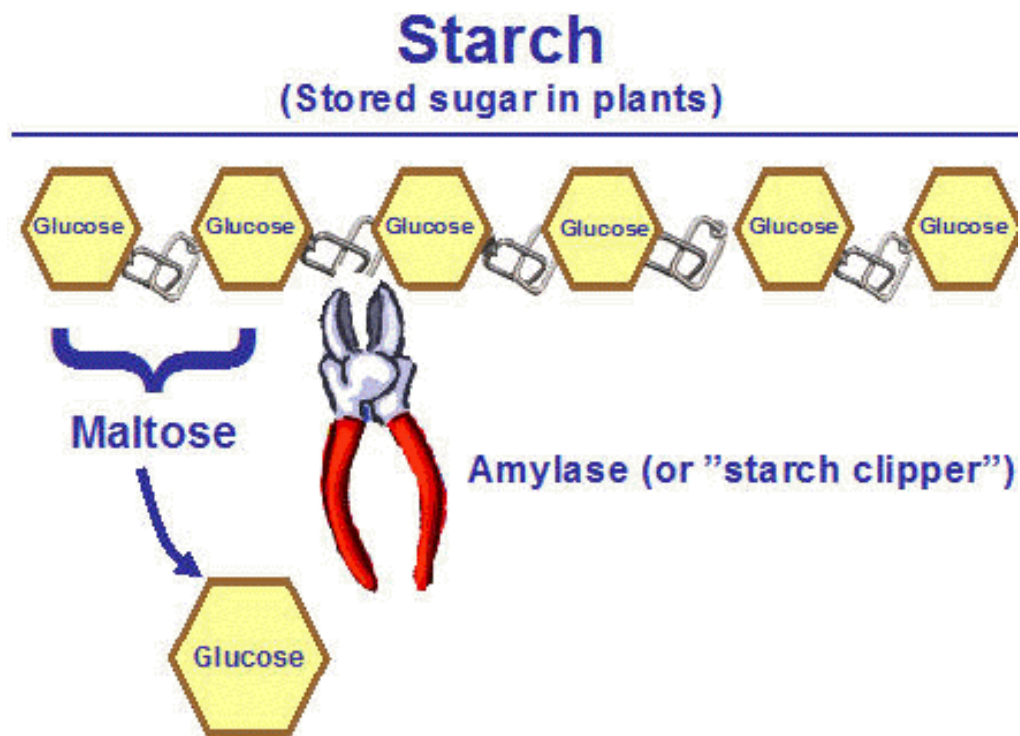
# Starch.

Plants have two ways to store sugars.

**1.** They can make the "single" and "double" sugars discussed above. These are stored in fruits and can be picked and eaten by animals who wander by. This is a good way for a plant that is "stuck in the soil" to get its seeds spread around in the neighborhood. The disadvantage is that fruits are large, wet (read juicy) and rot easily. They are nice for the community but do not help to provide energy to seeds that are to become new plants.

**2.** What about a form of sugar that does not dissolve in water, is stable over long periods of time without refrigeration and is so compact that it can be packed in small seeds. Enter starch! This is a pure chain of glucose molecules (or a polysaccharide) and has all of the characteristics that a plant could ask for. It is easily stored in seeds and roots and quickly split to a simple sugar when energy is needed. We have taken advantage of this and developed plants that produce large seeds that we use to make flour and which are the basis for all baking. Much of the world's population live on rice, another seed crop containing starch. Root crops such as potatoes also are "storage bins" of starch.

Let's look a little closer at starch. As you can see in the next figure, starch is just a simple chain of glucose molecules, linked together by a chemical bond. We have an enzyme that can split that link, called amylase. It is produced in the pancreas and flows into the small intestine in the same area where we find sucrose and lactase. Amylase clips off glucose groups "two and two". This



gives the maltose that I mentioned earlier. Another enzyme, maltase, rapidly cleaves this "double sugar" and sets loose glucose from starch in the small intestine.

So, starch is an excellent source of sugar for us. But, it is not sweet, it is dry and not particularly "good to eat" as it comes from plants. However, breakfast food, breads, spaghetti and cakes made from flour are delicious!

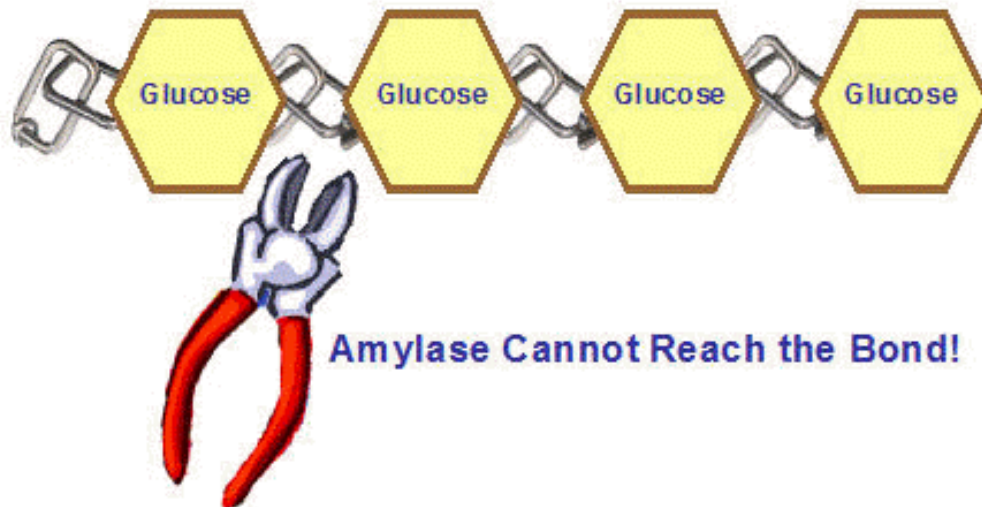
# Why can't I eat grass?

Grass and leaves, pine needles and wood; all are made largely of sugar. But, you cannot smell it, taste it or digest it. That must be a strange sugar! Well, it is not, really. The stuff is called cellulose and is almost identical to starch. It is made entirely of glucose.

Let's look at this. The only real difference between starch and cellulose is the placing of the link between the glucose groups in the chain. While starch has what we call alpha bonds that hang below the sugar elements, cellulose has beta

## Cellulose

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bonds. These are buried behind the glucose groups. The "starch-splitting" enzyme amylase cannot reach in between the glucose groups in cellulose and clip them up. We have no intestinal enzyme that can do this for us, so cellulose just passed through our digestive system without being split.

Well, we need a little roughage (or fiber) to keep things going down there, so cellulose in fiber and in small amounts is not wasted on us, but nourishment is it not!

By the way, cows and horses and even termites do not have their own enzymes to split cellulose either. They have extra stomachs where bacteria do that job for them. These "bugs" have cellulose-splitting enzymes and they digest all that grass and wood. The glucose produced is then used by the animals.

## **Here is a check list over all those enzymes:**

**Sucrase splits sucrose to glucose and fructose.**

**Lactase splits lactose to glucose and galactose.**

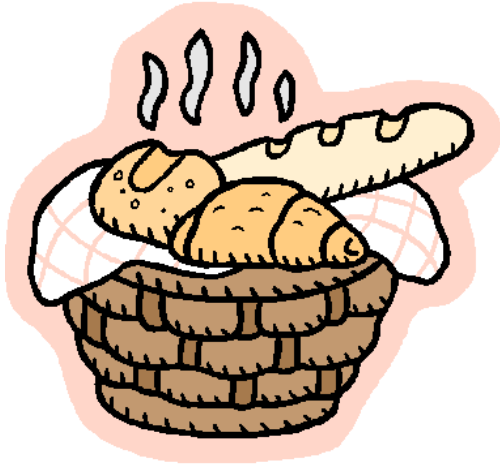
**Amylase splits starch to maltose.**

**Maltase splits maltose to 2 glucose molecules.**

**Nothing splits cellulose in animals. Bacteria do this for them.**

# Are sugars good food?

"Eat low GI food"! "LowCarb diets cure overweight"! "Eat fat"! "Watch out for sugar bombs"! The daily press is full of articles telling us what to eat. Is there anything in these claims? Is bread really "bad food"? Are potatoes really safe? Do we need to eat sugars at all?



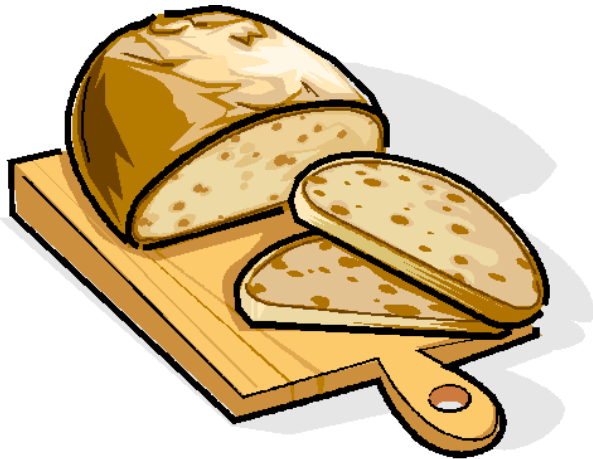
The answers are really quite simple. Our genetic makeup seems to say that we should eat a good portion of sugars and starch daily. We must use carbohydrates to supply the energy needed to drive our bodies. Our brain, the retina of the eye and red blood cells have glucose as their only energy source.

In spite of this, we can survive quite well without eating sugars and starch. We can make glucose ourselves! For example, people can survive for a long time just by eating pemmican, a mixture of lean meat (proteins) and fat. A Norwegian explorer, Helmer Hansen, gave some striking examples of this in his book about the "Gjøa" expedition under leadership of Roald Amundsen. He wrote: "they (the Eskimos) valued only meat. Coffee made them sick, candy and chocolate were too sweet for their taste. They did not like bread. They ate a little of our food after staying with us for a while, but their stomachs did not tolerate this. They were "cured" by eating meat so rotten that even the dogs would not have it". Nevertheless, everybody (even Eskimos) must have a stable supply of sugar in their blood. Our brains are completely dependent on blood sugar. Neither fats nor proteins can be used by the brain! Hard work uses almost only sugar for energy.

You can choose not to eat sugar. That's OK. But then your liver has to make sugar for you. It can convert the meat you eat to sugar! And, if you just do not eat you will use your own body's muscles as a source of blood sugar. No sugar, no life!

# So, which carbohydrates should we eat?

This puzzle is also easy to answer. While we can choose among an almost endless variation in



the protein or fatty components of our diet, the choice of carbohydrates is quite limited. Regardless of which food we choose, there are basically only three energy-giving carbohydrates that we can digest; starch, sucrose and lactose. And, of course, a little fructose and glucose from fruits.

The secret is choosing food that satisfies our appetite and gives enough energy for growth and work. At the same time we should not eat too much. Too much food =

overweight! The best carbohydrate-rich foods are whole-grain breads (thick slices!), cooked and baked potatoes, rice, corn and pasta. Things that satisfy your appetite and that take time to eat. Your body needs that time to find out that your hunger is satisfied! Good food is bulky and takes time to devour! "Fast-food", candy and especially soft drinks give us too much food too fast. It is far too easy to take in that "extra food" with those choices.

# And, which foods shouldn't we eat so much of?

That's easy. Candy, soft drinks, ice cream, syrup on pancakes... Sure, they taste good but too much food too fast is not good for us. Remember, many of the illnesses that are common among adults follow overweight. And, overweight is VERY difficult to be quit.



# What about table sugar?

Table sugar (sucrose) is merely a combination of **glucose and fructose** while milk sugar (lactose) is made up of glucose and galactose. Starch and glycogen (animal starch) are simply glucose polymers. Glucose is the only breakdown product of these huge molecules. **NO OTHER CARBOHYDRATES CAN BE DIGESTED AND ABSORBED BY HUMANS!** All the "others" wind

up in the large intestine as energy sources for bacteria. If more than five grams daily end up there the result is often "explosive" diarrhea.



What happens if you eat more table sugar than you can absorb? Ask a kid who has eaten too much candy! Eating more sugar than one can digest and take up in the small intestine leads to "stomach pain" when it is carried to the large intestine. The bacteria in the large intestine take over with generation of lots of gas as a result.

## We are not used to eating a lot of fructose:

Limited amounts of fructose are found in many fruits. Honey is super-sweet, containing about 40% fructose and 30% glucose. It used to be a scarce but real treat in earlier years.

We have "always" eaten some fructose, but not nearly as much as we do today. Fruit and especially honey were certainly delicacies in the past. Even bears crave sweets and let themselves get stung while they steal honey.

Fructose became a major energy source with development of the sugar industry and has been a key dietary component for less than 200 years. Table sugar (sucrose) has now been partially replaced by a new and inexpensive sweetener. This is called "high fructose corn syrup" or

"HFCS". This is made from corn starch. This starch is chemically split to glucose and some of this is then converted to fructose. These simple sugars are then blended in an approximately 50-50 mixture. HFCS is an inexpensive replacement for sucrose and is used to make ice cream and soda pop. In the USA, sucrose consumption has been reduced during the past decade or two by replacing it with inexpensive HFCS. However, HFCS is a form for sugar! The total sugar consumption in the USA has increased because of the use of high fructose corn syrup. Total sugar consumption in the USA is now close to 60 kg per person per year.

## Each sugar has its own metabolism.

Our body is driven by energy from fats and glucose. However, some important tissues, namely the brain and blood cells, can only use glucose as their energy source. A stable blood sugar level is an absolute requirement for good health. Blood sugar (or glucose) comes from starch, from proteins and from the sugar we consume. In addition, we store a kind of starch (called glycogen) in our liver and this helps to stabilize blood sugar levels.

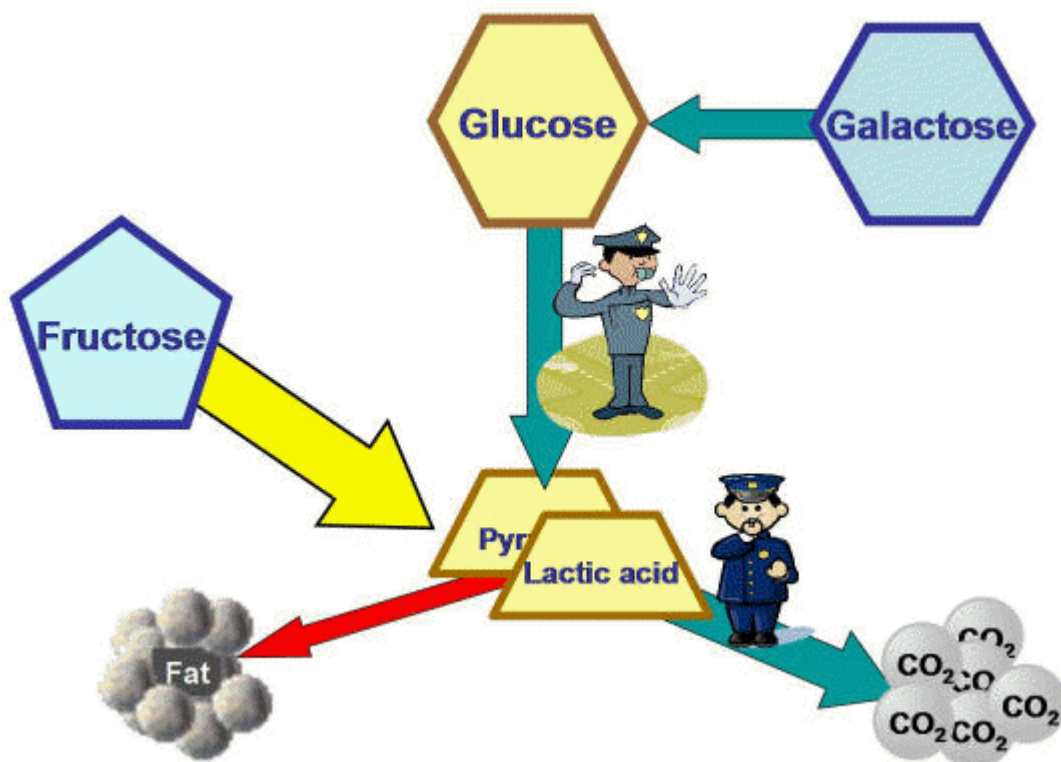
Around 25 % of the energy in our modern diet comes from table sugar, and half of that is fructose. This is a new situation. Earlier, most of the "sugar" we used came from digestion of starch and our own production of sugar from proteins.

Now, most of us utilize fructose quite well; too well in fact. The problem with fructose is that fructose metabolism goes twice as rapidly as that of glucose. There are no major control posts in fructose metabolism. This is in contrast to glucose metabolism. Glucose "burning" is carefully adjusted to replace energy that is used in work and play. If a muscle doesn't work it will not use glucose. When the muscle begins to work, it begins to use glucose. Fuel consumption is linked to work when we talk about glucose! But that is not the case for fructose. If it comes to the liver it will be used! Even if we do not need its energy.

# Look at the next drawing.

Let's take up glucose first. It begins its metabolism by being split to two smaller compounds, pyruvic and lactic acids. That pathway is controlled so that use of glucose balances the need for energy. We have a "controller" who coordinates traffic on that pathway. Those two small acids are then "burned" or oxidized to  $\text{CO}_2$ . Once again, we see that we have a "controller" here that makes sure that the supply of and demand for energy are balanced.

These processes are very carefully controlled by various hormones. As long as we do not take in excess glucose over time, little fat is made from this sugar.



The same pathway is used by galactose. This sugar must be converted to glucose before it can be "burned". Therefore, we have good control over metabolism of milk sugar.

Fructose metabolism, on the other hand, goes very quickly and without "controllers". And, when production of the small acids from fructose exceeds their use (burning to carbon dioxide), they

are converted to fat. Fructose is a very good source for too many calories and may well be fattening.

Perhaps even more important is the fact that, unlike glucose, fructose does not cause release of the hormone insulin from the pancreas. Now, insulin has many functions and one of these is to dampen appetite. That means that half of the sugar we eat gives no "satisfied" signal to the brain. As we all know, we can drink a lot of soda pop without feeling full.

Can it be that fructose is to blame for the rapid increase in overweight seen during the past twenty years?

Fructose has been suggested to be a good replacement for table sugar as a sweetening agent. After all, it tastes two to three times as sweet as sucrose (table sugar). So, they say, "we can have just as sweet food with much less sugar if we use fructose".

There are two things that are wrong with this.

**1.** While it is quite true that fructose is sweeter than table sugar (sucrose) this applies only to cold fructose. If you warm it up in tea or coffee or bake it in a cake it changes form. The sweet "5-ring" characteristic for fructose changes to a "6-ring" when fructose is warmed up. That "6-ring" is not sweeter than sucrose! So, coffee, tea and cakes sweetened with fructose need to have just as much fructose as usual sugar to taste "sweet enough".

**2.** That metabolism bit is important. We seem to make more fat out of fructose than other sugars. People who drink a lot of soda pop and often eat candy tend to be overweight. They often have increased fat levels in their blood. This is thought to lead to development of high blood pressure and to heart disease. Fructose may be a natural food for us, but at much lower levels than those we experience today. Over-eating fructose lie back of the marked increase in heart disease and diabetes we see around the world today.

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