# CARBOHYDRATES

## What are carbohydrates?

**Carbohydrates** are the most abundant class of organic compounds made up of carbon, hydrogen and oxygen. They are a major food source and a key form of energy for most organisms. Most organic matter on earth is made up of carbohydrates because they are involved in so many aspects of life, such as:

- Energy fuels, stores, and metabolic intermediaries
- Ribose and deoxyribose sugars are part of the structural framework of RNA and DNA
- Protective membranes for organisms and cells
- Main structural support for plants - cellulose (a type of carbohydrate) makes up most of plant cell walls
- Carbohydrates are linked to many proteins and lipids (fats), where they are vitally involved in cell interactions

Carbohydrates are formed in plants as a result of photosynthesis which happens in 2 phases:

a. **The light dependent reaction:** The sunlight energy is absorbed by chlorophyll and converted to chemical energy
b. **The light independent reaction:** The so called Calvin Cycle where the products of the light dependent reaction are taken and turned into sugars, starches and cellulose, all of which are types of carbohydrates.

Also known as **saccharides**, carbohydrates may be classified into 2 groups according to their structure: **simple** and **complex.**

1. **Simple carbohydrates** include: **monosaccharides** or single sugar molecules and **disaccharides** two sugar molecules that have joined together. In general, they are both commonly referred to as "**sugars**". **Monosaccharides,** are the simplest carbohydrates in that they cannot be broken down into smaller carbohydrates. This is the smallest possible sugar unit. Two joined monosaccharides are called a **disaccharide** and these are the simplest polysaccharides (complex carbohydrates).

Simple carbohydrates include:

- **Glucose** (dextrose)
- **Fructose** (found in fruits)
- **Galactose** (found in milk products)
- **Ribose**

Double carbohydrates include:

- **Lactose** (found in dairy =glucose+glactose)
- **Maltose** (vegetables and beer)
- **Sucrose** (table sugar = glucose + fructose) also sometimes called **saccharose**
- **Honey**

2. **Complex carbohydrate** include: **oligosaccharides** and **polysaccharides** are comprised of many sugar molecules, which are all connected. The distinction between the two is based upon the number of monosaccharide units present in the chain. **Oligosaccharides** typically contain between three and ten monosaccharide units and **polysaccharides** contain greater than ten monosaccharide units. Complex carbohydrates, often referred to as "**starchy**" foods, include starch and fibre.. These long chain carbohydrates, as we call them, take some time to be broken down into monosaccharides and therefore take time to enter into the bloodstream. This is very important issue for our health (in the insulin regulation) which I will talk about later in this chapter.

Complex carbohydrates include:

- **Legumes**
- **Starchy vegetables**
- **Whole-grain breads and cereals**

Three main types of polysaccharides - **storage**, **structural** and **bacterial.**

**Storage Polysaccharides**

Polysaccharides may act as **food stores** in plants in the form of **starch**, or food stores in humans and other animals in the form of **glycogen**. Starches are not water soluble. Humans and animals digest them by hydrolysis - our bodies have **amylases**, an enzyme, which breaks them down. Rich sources of starches for humans include potatoes, rice and wheat.

**Structural Polysaccharides**

Polysaccharides also have **structural roles** in the plant cell wall in the form of **cellulose** or **pectin**, and the tough outer skeleton of insects in the form of **chitin**. Cellulose is the structural constituent of plants. Fibre or cellulose is not digestible by humans however needed by the digestive system to eliminate waste and toxins and as such are essential. Some animals, such as termites, can digest cellulose because their gut has a type of bacteria that has an enzyme which breaks down cellulose. Chitin, a polysaccharide, is one of the most abundant natural materials in the world. Microorganisms, such as bacteria and fungi secrete chitinases, which over time can break down chitin. Chitin is the main component of fungi cell walls, the exoskeletons (hard outer shell/skin) of arthropods, such as crabs, lobsters, ants, beetles, and butterflies. Chitin is also the main component of the beaks of squid and octopuses.

**Bacterial polysaccharides**

They are polysaccharides that are found in bacteria. Pathogenic (illness causing) bacteria often produce a thick layer of mucous-like polysaccharide which cloaks the bacteria from the host's immune system. In other words, human's immune system will less likely attack the bacteria because the polysaccharide layer masks its pathogenic properties. *Escherichia coli*, for example, produces hundreds of different polysaccharides.

## What is the role of carbohydrates?

**CARBOHYDRATES SUPPLY ENERGY**

The primary function of carbohydrates is to provide **energy** for the body. They are body's preferred energy source. Fat is body's $2^{nd}$ source of energy. Proteins can also be used for energy however they are the last resource.

Our bodies need a constant supply of energy to function properly. The carbohydrates are not essential to our body as fat and proteins can be used as a source of energy instead. However, they are important for the correct working of our brain, heart and nervous, digestive and immune systems and lack of carbohydrates in the diet can cause tiredness or fatigue, poor mental function and lack of endurance and stamina.

So how do we get energy from carbohydrates? For that we need to look at the digestive system. What happens once we eat carbohydrates.

A very important fact to know is that carbohydrates are **pre-digested** in the mouth. This is where they are first broken down mechanically by our teeth but also chemically by **amylase**, an enzyme secreted by our salivary glands. It is therefore terribly important to chew the carbohydrates for at least 35 times. (On average we chew between 5-7 times!). As carbohydrates are digested and broken down by amylase, they are converted into **glucose** (blood sugar). Glucose then travels through the blood stream looking for individual cells that need energy. For glucose to get into the cells it needs **insulin**, a hormone secreted by pancreas gland. Insulin is the key to open the cell door for glucose without which it is not able to enter. It is also central to regulating carbohydrate and fat metabolism in the body causing cells in the liver, muscle, and fat tissue to take up glucose from the blood, storing it as glycogen in the liver and muscle.

Once inside the cell, glucose binds with oxygen turning it into **ATP** molecule. When energy is needed the bond between the phosphates in the ATP is broken and energy is produced. ATP is the molecule that allows quick and easy access to energy when needed by cell's organelles. This process of making energy in the cell is also called ''cell respiration"" process.

Today, most people, when they think of carbohydrates, think in terms of **calories**, the measurement for the energy content in the food. They believe that eating carbohydrates alone will give them energy. This is completely false. Carbohydrates **alone** cannot adequately supply our energy needs, as we **must** have our carbohydrates **in combination** with proteins, water, vitamins, minerals, fats, in order for them to be used by our cells. This equally means that a diet of **refined foods** or simple carbohydrates (refined sugar, rice, flour and other – ie. foods that have all the vitamins and minerals taken out) **will not** nourish adequately one's body as it is deprived of other nutriments and is part of the reason why so many of us feel "**tired**" nowadays. Carbohydrates must be obtained in combination with the other essential food factors to be truly useful in the overall energy production and nutrition of the organism.

## EXCESS OF CARBS AND TODAY HEALT PROBLEMS

In our modern diet today we generally consume far more sugar than we actually need and our modern sedentary lifestyle has no use for such an ample amount of energy. Body's regulation process allows for about 1 tea-spoon of sugar in the blood at one time. So what happens with all that excess? Our bodies are indeed amazing intelligent machines with a rather defined set of rules within. Should there be a large amount of glucose in a body at one time, and is not needed immediately, it will be stored in one's liver and muscles as **glycogen**, which is the **stored form of glucose**.

The liver, however, has its maximum capacity of glycogen. Should the reserves not be regularly used up and emptied, we then find ourselves with too much glycogen, or stored glucose, and the body therefore converts this to stored adipose tissue, **fat**. The preferred place for storage of this kind of fat will be the in the areas around the abdomen and hips, which is a visual indicator for people that have the problem with excess sugar consumption and are already or about to be insulin resistant.

Once we find ourselves with an excess of glucose in the blood, our brain sends a message to the beta cells in pancreas to produce large quantities **insulin**. Insulin is central to regulating carbohydrate and fat metabolism in the body causing cells in the liver, muscle, and fat tissue to take up glucose from the blood, storing it as glycogen in the liver and muscle. It is provided within the body in a constant proportion to remove excess glucose from the blood, which otherwise would be toxic.

When insulin has finished its job of feeding cells with glucose or storing it, blood glucose levels fall below a certain level and alpha cells in pancreas start secreting glucagon. Glucagon has an effect opposite to that of insulin. It raises blood glucose by causing the liver to convert stored glycogen into glucose, which is then released directly into the bloodstream.

This phenomenon is called glycogenolysis and it enables one to maintain normal blood sugar levels during a fast or when body is not being well nourished. Practically the entire fat store of the body can be used up without detriment to health.

Glycogen also sends a signal to the brain that the sugar level in the blood is too low and the brain triggers of the hunger response but more so the craving for carbohydrates. We then find ourselves with a terrible urge to eat something sweet and consequently bring again a high level of glucose into our system at once. This the beginning of the viscous circle, of sugar addition, that our body will perform over and over again, on a daily basis and that we today call **Hyperglycaemia**. We find that a large number of people as actually hyperglycaemic without even realising it, but what is more frightening is that a very high number of kids today suffer from this syndrome which a precedent to type 2 Diabetes.

In short - insulin and glucagon help maintain regular levels of blood glucose for our cells, especially our brain cells. Insulin brings excess blood glucose levels down, while glucagon brings levels back up when they are too low.

Pancreas, on the other hand, has a limited bank of insulin for a lifetime. If blood glucose levels are rising too rapidly (by consuming refined foods and simple carbohydrates) and too often we get it trained to produce large quantities of insulin on a daily basis. Not only we find ourselves with more and more glycogen, or fat, being stored in our body and therefore obesity problem, but after a few years it will start to deliver insufficient insulin or faulty insulin or not respond properly to insulin's "absorb blood energy and store" instruction. The cells will require a higher level of insulin to react - we call this I**nsulin Resistance (IR).** Insulin resistance leads to **Hypertension** (high blood pressure), high blood fat levels **(triglycerides)**, **low** levels of good cholesterol **(HDL), weight gain** (obesity) and other diseases. All these illnesses, together with insulin resistance, are called **Metabolic Syndrome**. Eventually, the beta cells in the pancreas wear out - because they have had to produce lots of insulin for many years - insulin production drops and eventually packs in altogether and we get **type 2 Diabetes**.

These four modern dysfunctions: **Insulin Resistance, Obesity, Metabolic Syndrome and Type 2 Diabetes** are therefore all directly linked to excess sugar consumption or excess consumption of simple carbohydrates.

**THE GLYCEMIC INDEX AND GLUCEMIC LOAD**

One more important factor with Carbohydrates is their **Glycemic Index** or **GI**. The glycemic index is a measure of how fast a carbohydrate raises one's blood sugar once eaten compared to pure glucose. Glucose taken as a benchmark has a GI of 100. Carbohydrates that break down quickly during digestion and release glucose rapidly into the bloodstream have a high GI; carbohydrates that break down more slowly, releasing glucose more gradually into the bloodstream, have a low GI.

Foods with high GI cause the blood sugar level to shoot up very high and therefore the blood sugar level crash is also more important which causes a feeling of strong hunger, lethargy and cravings for foods with again high GI or stimulants such as coffee or cigarettes. Glycemic index is closely related to the simple and complex carbohydrates. Simple carbohydrates, refined, processed, milled, ground, puffed etc foods have a high GI. Complex carbohydrates, wholegrain, fruits and vegetables in general have much lower GI's.

GI values are commonly interpreted as follows:

| **Classification** | **GI** | **Examples** |
|---|---|---|
| Low GI | <55 | most fruits and vegetables, legumes/pulses, whole grains, nuts, |
| Medium GI | 56–69 | whole wheat products, basmati rice |
| High GI | > 70 | white bread, most white rices, corn flakes, extruded breakfast cereals, glucose, maltose |

The **Glycemic Load** or **GL** is a measurement of carbohydrate content in food based on their glycemic index (GI) and a portion size of 100g. Glycemic load or GL combines both the quality and quantity of carbohydrate in one number. It is the best way to predict blood glucose values of different types and amounts of food. The formula is: GL = GI x the amount of available carbohydrate in a 100g serving.

GL is in fact a weighted GI value. For example, watermelon has a high GI – but watermelon does not actually contain much carbohydrate, so the glycemic effect of eating it (and therefore its GL) is actually relatively low.

A GL greater than 20 is considered high, a GL of 11-19 is considered medium, and a GL of 10 or less is considered low. Foods that have a low GL almost always have a low GI. Foods with an intermediate or high range GL range from a very low to very high GI.

GI and GL are important measurements for maintaining a low and durable sugar levels in our blood and avoiding being in that vicious circle of **hyperglycemia** we spoke about earlier.

For more detailed table of GI's and GL measurements of foods please refer to the tables in the back of the book.