Topic 1 Fundamentals of nutrition

Concept: Principles of nutrition, physiology and health

1.1 Macronutrients

Nutrition Understanding

Macronutrients are a category of nutrients that are needed in large amounts daily and provide us with energy. They are measured in grams (g). There are three types of macronutrients: carbohydrates, proteins and lipids (fats). Each macronutrient provides us with a different amount of energy and has a differing role within cells and the body. Carbohydrates and proteins provide us with 16.7 kJ/g, whereas lipids are more energy dense containing 37.7 kJ/g.

Alcohol is another molecule that provides us with energy but it is considered a toxin because it causes harm to the body's cells. Alcohol is more energy dense than carbohydrates and proteins, providing 29.3 kJ/g.

Figure 1.1.1: A variety of macronutrients.

Did you know?

Every day our body is constantly replacing cells and growing new ones. Our red blood cells have a life cycle of 120 days and approximately two million are replaced every second. Furthermore, the lining of our intestines is replaced every three to five days. Our body needs nourishment to replace these cells and the food we eat provides us with the energy and nutrients we need to replace them. However, it is not true that all of our body's cells are replaced every seven years. This is a misconception and there are some cells that are never replaced, such as particular types of brain cells. For more information, including how nuclear testing has allowed us to determine how frequently cells are replaced, please watch the following video:

Helpful online resources

SciShow: Do You Really Have a New Body Every 7 Years?

https://www.youtube.com/watch?v=ZCiuMomjVx0

Helpful online resources

FuseSchool - Global Education: Balanced Diet

https://www.youtube.com/watch?v=NqV1Ig4_nfI

1.2 Carbohydrates

Nutrition Understanding

Carbohydrates are very important molecules that help fuel our daily activities. Our brains cannot function without a carbohydrate known as glucose and require approximately 130 grams per day to function effectively. Every second, our brain is making roughly ten trillion calculations and requires glucose to fuel this activity. Our brain cannot store glucose and obtains it from our blood supply. It is therefore essential that we consume sufficient carbohydrates throughout each day to provide our brain with enough glucose so that we can function normally and learn efficiently.

Carbohydrates are made up of three elements of the Periodic Table: **C**arbon, **H**ydrogen and **O**xygen. For this reason, carbohydrates are generally abbreviated as **CHO**. There are many different types of carbohydrates and they are split into two categories: **simple carbohydrates** and **complex carbohydrates**.

Did you know?

Potatoes are a common food source that provides us with a rich source of starch (complex carbohydrates) and are easily accessible. The potato crop has an interesting past and is often credited with supporting population growth throughout history. Potatoes were also widely utilised by the Allies during World War II. Watch the video below to find out more about the role of the potato in modern history.

Helpful online resources

TED-Ed: History through the eyes of the potato–Leo Bear-McGuinness

https://www.youtube.com/watch?v=xROmDsULcLE

Simple carbohydrates

Simple carbohydrates consist of one or two units of sugar (saccharide). There are six important simple carbohydrates. Three of these are **monosaccharides** that consist of one unit of sugar (‘mono’ means one). The remaining three are **disaccharides** that consist of two units of sugar (‘di’ means two). Food items are rarely made up of one single monosaccharide or disaccharide and generally contain varying combinations of them. Simple carbohydrates are easily absorbed by the body and can cause increased spikes in blood sugar levels. Simple carbohydrates have less nutritional value to the body than complex carbohydrates and excess intake has been linked to many diseases, including obesity, diabetes, cardiovascular disease, brain degenerative diseases, and many more.

Monosaccharides

The three monosaccharides consist of the same number and type of atoms (six carbon atoms, 12 hydrogen atoms and six oxygen atoms), but they are arranged slightly differently. The difference in their arrangement contributes to the difference in their sweetness; for example, fructose is the sweetest of the simple sugars. The three monosaccharides are **glucose**, **fructose**, and **galactose**.

Glucose is generally sourced from the conversion of more complex carbohydrates but small amounts can be naturally found in some fruits, vegetables and honey. It can also be found as an additive in processed food items. **Fructose** is naturally found in fruits, vegetables and honey. It can also be sourced through the breakdown of the disaccharide sucrose. **Galactose** is sourced from milk through the digestion of the disaccharide lactose.

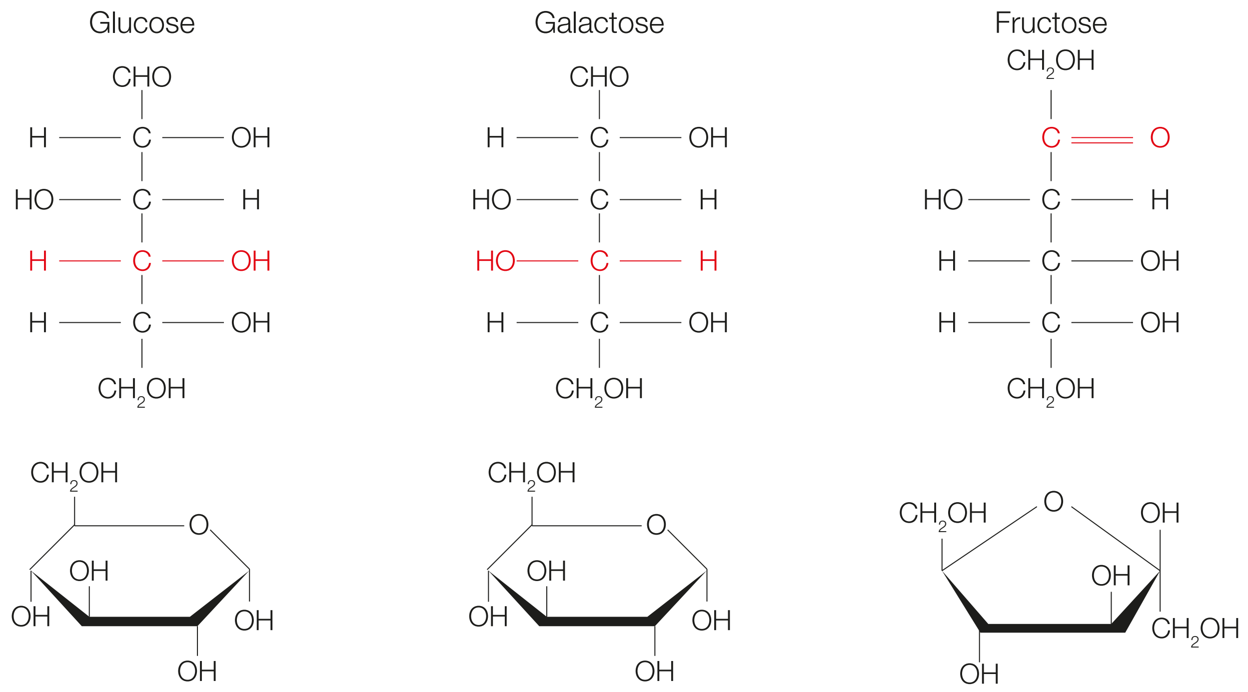

Figure 1.2.1: The molecular structures of the monosaccharides glucose, galactose and fructose.

Disaccharides

Disaccharides are made up of **two** of the monosaccharides mentioned above. See diagram below:

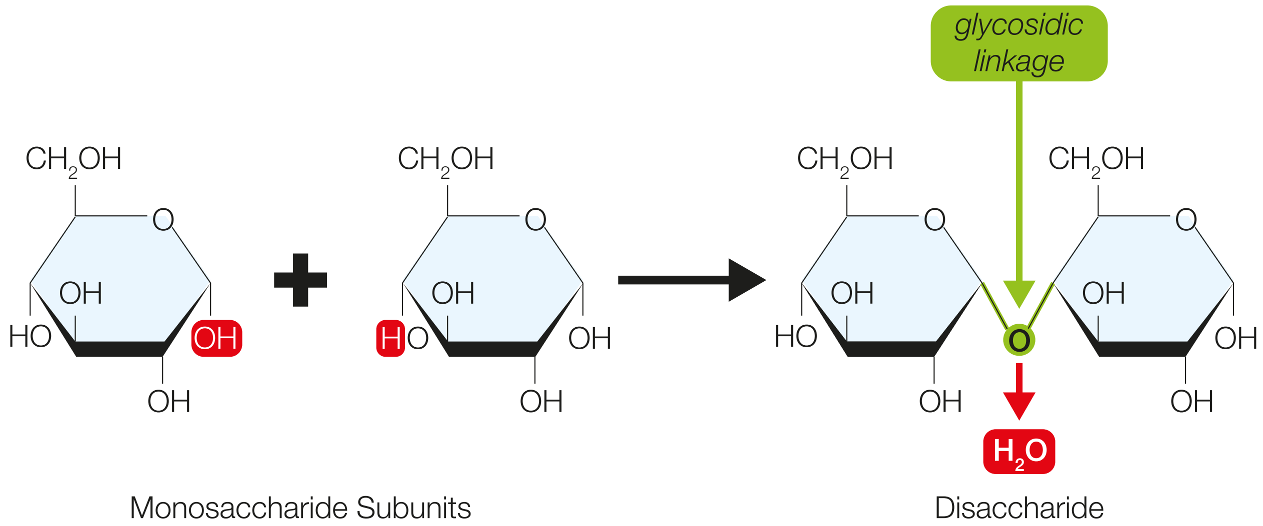

Figure 1.2.2: The formation of a disaccharide from two monosaccharides.

There are three important disaccharides: **sucrose**, **lactose** and **maltose**. Disaccharides cannot be absorbed in the small intestine (they are too big) and require processing in the intestines. Only monosaccharides can be absorbed across the small intestine into the blood. Each of the three disaccharides are broken down into their monosaccharides by a specific enzyme (protein). However, some people can't produce enough of the required enzyme and this can result in complications. An example of this is individuals who are **lactose intolerant**. These individuals cannot produce enough of the enzyme lactase so they cannot break the lactose in milk down into its two monosaccharides.

The combination of monosaccharides that make up disaccharides, enzymes to digest them and sources of disaccharides are highlighted in Table 1.2.1 on the next page:

Table 1.2.1: The monosaccharides that make up the three disaccharides and their sources.

Disaccharide	Combination of monosaccharides	Enzyme required to digest into monosaccharides	Sources of disaccharide
Sucrose	Glucose + Fructose	Sucrase	Naturally found in different types of sugar such as cane sugar and brown sugar. This is the most common disaccharide and is commonly known as 'table sugar'.
Lactose	Glucose + Galactose	Lactase	Naturally found in milk and dairy products.
Maltose	Glucose + Glucose	Maltase	The main source of maltose is breakfast cereals, but it is also found in seeds and beer.

Complex carbohydrates

Complex carbohydrates consist of three or more monosaccharide subunits bound together to form chains (see Figure 1.2.3). There are two types of complex carbohydrates:

- **oligosaccharides** that contain three to 10 monosaccharide units ('oligo' means few); and
- **polysaccharides** that contain greater than 10 monosaccharide units, with some containing thousands ('poly' means many).

Oligosaccharides are found in legumes and prebiotics (such as kombucha and kimchi). Oligosaccharides help absorb some minerals and are fermented by bacteria in the intestines, producing short chain fatty acids that nourish our intestines (protecting it from inflammation). This will be explored further in Topic 3: Digestion, malabsorption and the microbiome.

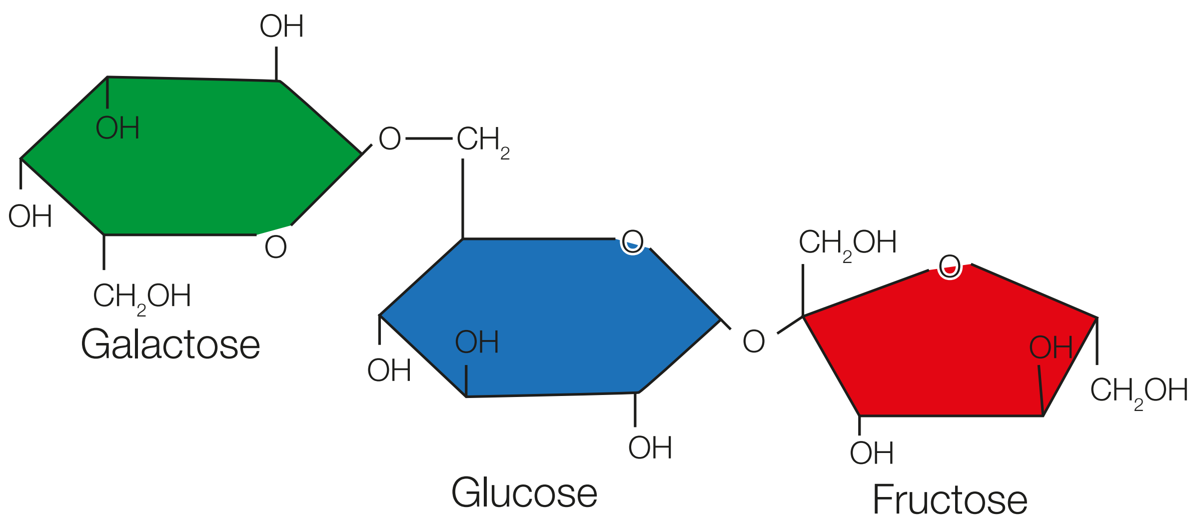

Figure 1.2.3: The structure of an Oligosaccharide: Raffinose, consisting of three singular sugar units.

There are three major types of polysaccharides: **glycogen**, **starch** and **fibre**.

Glycogen is an **energy** storage molecule in **animals**. The majority of glycogen is stored in the **liver**, with smaller amounts stored in **skeletal muscles**. Glycogen in the skeletal muscles can be broken down to provide muscles with glucose for respiration (to produce energy). The glycogen in the liver can be broken down to release glucose into the blood, providing other types of cells (and muscles when needed) with glucose. Glycogen is a highly branched molecule, which makes it easier for enzymes to break down.

Starch is the **energy** storage molecule in **plants**. Starch is also a highly branched polysaccharide, which means it is easier for the body to digest. However, starch consists of different types of branches to glycogen. Starch is found in plant sources such as grains, vegetables, seeds, etc.

Cellulose is an important **structural** polysaccharide in **plant** cells. It is also known as insoluble **fibre**. Cellulose makes up the cell wall of plant cells and aids in maintaining cell shape and protects the cell. When we eat plant-based foods, we also consume cellulose. Humans cannot digest cellulose because we do not have the enzymes required to break the bonds between monosaccharides. This is because cellulose has a different arrangement of glucose molecules to glycogen and starch.

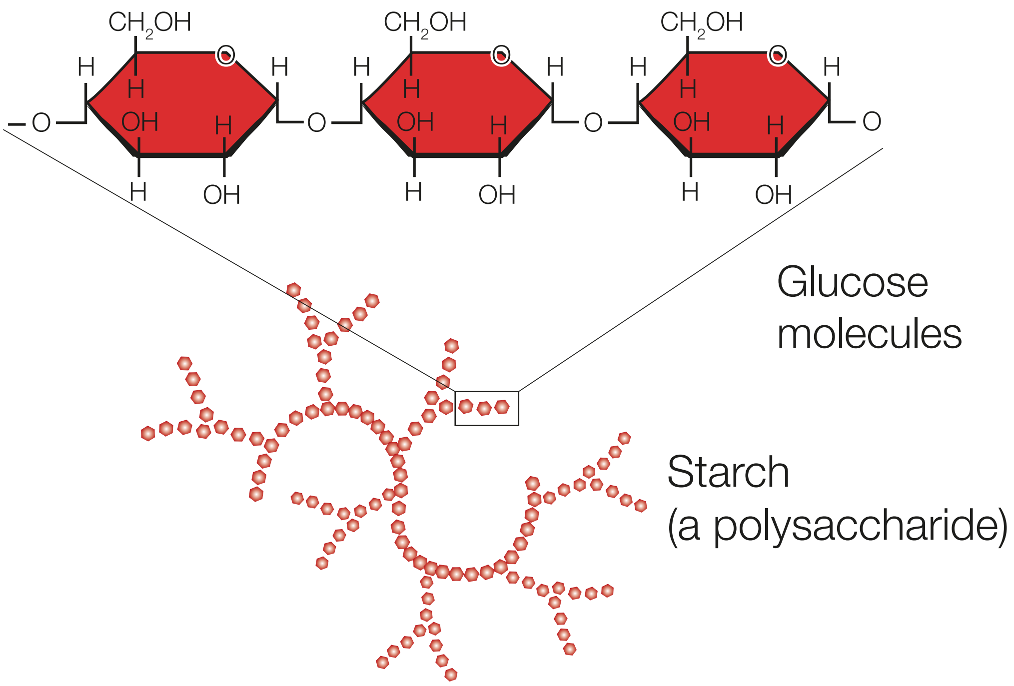

Figure 1.2.4: The structure a Polysaccharide, Starch consisting of many singular sugar units.

Each of the hexagons in the molecules in Figure 1.2.4 represent a glucose molecule. The bonds between these glucose molecules in starch and glycogen can be broken down to isolate glucose molecules so they can be released into the blood for other cells to access when the body requires energy.

Helpful online resources

Free Animated Education: What are Carbohydrates? What are its different Types?

https://www.youtube.com/watch?v=IJUwdIups9o

Did you know?

Cruciferous vegetables, such as broccoli, contain compounds called glucosinolates and in a different area of the cell there is an enzyme called myrosinase. Chopping, blending or chewing cruciferous vegetables breaks the plants cell walls and allows myrosinase and glucosinolate to react and produce isothiocyanates (ITCs). Some studies have demonstrated that ITCs could possibly remove cancer inducing chemicals from the body. Scientists in China have discovered the ideal way to cook broccoli to release the most ITCs. Their study revealed that it is best to chop broccoli up as small as possible (they chopped it into 2mm cubes) and leave it for 90 minutes before lightly cooking (stir fry). This method produced the highest amount of sulforaphane (an ITC) because there was more time for the chemical reaction to occur. In reality, we often don't have the time to pre-chop broccoli into tiny pieces and leave it for 90 minutes prior to cooking. However, we can easily implement greater chewing of cruciferous vegetables to increase the release of ITCs from our food.

The study has also resulted in a couple of new fads. Firstly, it resulted in increased sales of powdered 'broccoli' pills. Sales increased due to advertising claims that they have anti-cancer benefits (this might be true, but this can be achieved by regularly including cruciferous vegetables in the diet). Due to this research, broccoli lattes have also started to become an option at cafes. Broccoli stems are processed into powder and mixed into people's lattes to consume some greens with their morning coffee with the added benefit of extra phytonutrients such as ITCs.

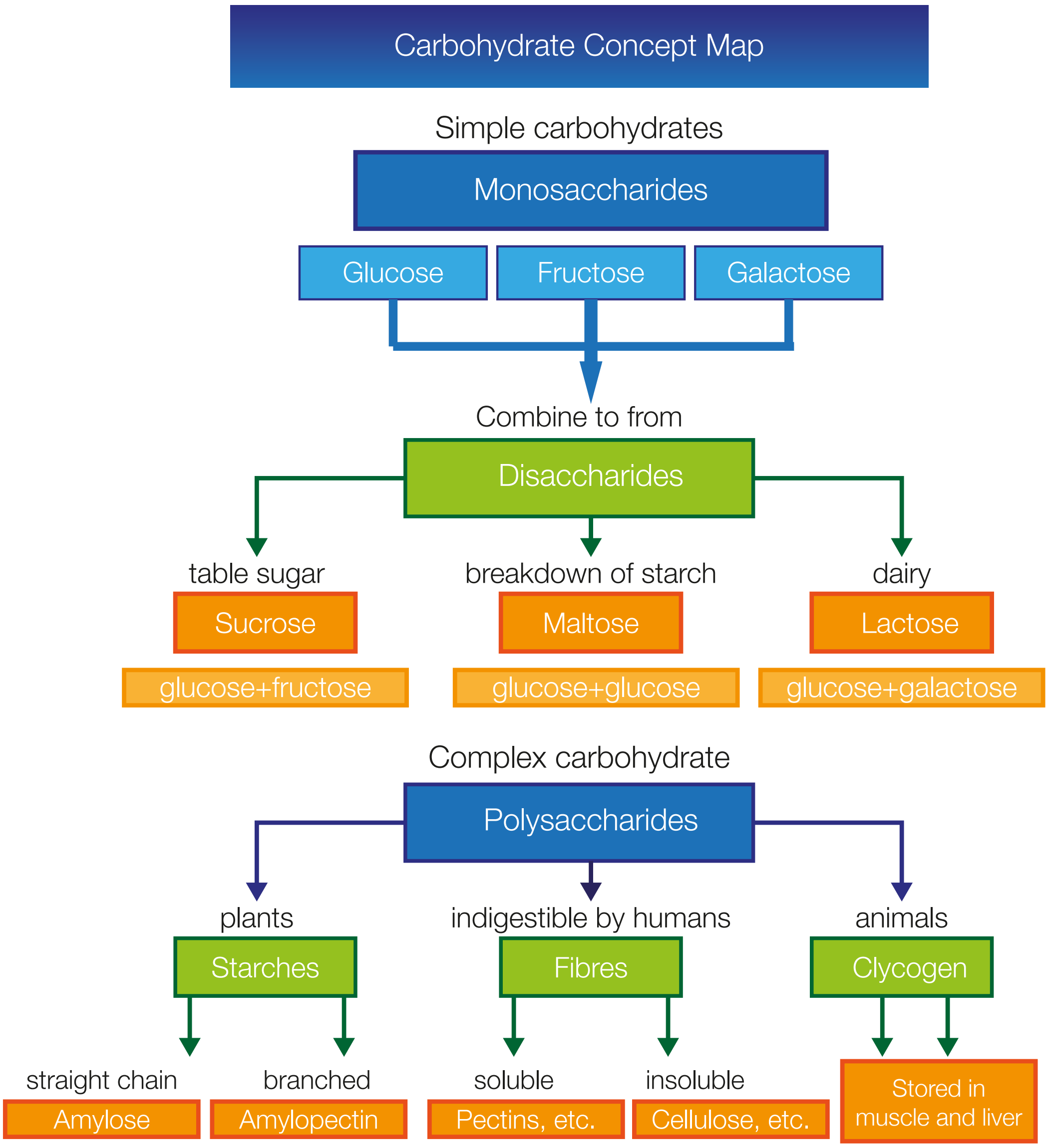

Figure 1.2.5: A summary concept map of the simple and complex carbohydrates.

Dietary fibre

Dietary fibre is found in **plant-based products** such as fruit, vegetables, legumes, and whole grains. Fibre is **not** found in animal products such as meat and cheese. Dietary fibre is found in the structural parts of plant such as their cell walls, stems, seeds and skins. Fibres are complex carbohydrates that consist of many repeating monosaccharide units bound together. Unlike glycogen and starch, the human body does not contain the necessary enzymes to break the bonds between the repeating monosaccharides of fibre. This means that they progress through the intestines without being digested and releasing energy. Dietary fibre is generally broken down into two categories: **soluble** and **insoluble** fibre. Most plant-based foods contain a mixture of both types of fibre, but they generally contain more of one type than the other.

Soluble fibre

Soluble fibre dissolves in water easily forming a **gel-like substance**. A good way to think about this is thinking about what happens when you make porridge. The oats absorb the water and form a more gel-like, mushy porridge. This is because oats are high in soluble fibre. As the soluble fibre dissolves in water, it also results in the gel-like substance expanding. This is because it is retaining water as well. Foods that contain a lot of soluble fibre expand in the stomach, taking up more space, which makes us **feel fuller**. Therefore, eating foods high in soluble fibre can prevent us from overeating and **reduce the risk of weight gain**. Because our bodies do not contain the enzymes to break down soluble fibre, the gel-like soluble fibre also **slows digestion**. This means that the absorption of nutrients in the intestines is also slowed down. In particular, it takes longer for the sugar in our meal to be absorbed and this prevents large spikes in blood sugar and **lowers the risk of developing type 2 diabetes**. Soluble fibre also **reduces the risk of cardiovascular disease** because it binds with cholesterol in the intestines, which means the cholesterol cannot be absorbed and is removed from the body with the soluble fibre in the stool. This can lower blood cholesterol levels.

Soluble fibre cannot be digested by humans, but the good bacteria in our intestines can easily ferment it, obtaining nutrition for themselves and releasing short chain free-fatty acids that provide us with small amounts of energy. It is estimated that soluble fibre provides our body with approximately 8 kJ of energy per gram.

As mentioned above, soluble fibre is commonly found in **oats**; however, it is also found in **legumes**, **psyllium**, **barley** and **fruits containing pectin such as berries, apples and citrus fruits**. To increase soluble fibre in one's diet, it is easy to add a legume such as lentils to your everyday meals (e.g. pasta).

Grains – oats

Fruits – especially berries, citrus, apples and pears (pectin)

Legumes – lentils, peas, beans

Vegetables – particularly Brussels sprouts, broccoli, potato and carrots

Others – psyllium husks

Figure 1.2.6: Some examples of foods that are rich in soluble fibre.

Insoluble fibre

Insoluble fibre does not dissolve in water and therefore does not form a gel-like substance. In contrast to the porridge example for soluble fibre, placing a food high in insoluble fibre, such as pure wheat or celery, in water will not result in a gel-like substance. Insoluble fibre is also less readily fermented by bacteria in the large intestine and very little (if any) energy is extracted from insoluble fibre for human use.

Because insoluble fibre is indigestible, it **provides bulk** and sits in the intestines and binds to other waste products that need to be excreted. This facilitates the processing of waste and increases the gastrointestinal tract movement **preventing constipation**. In doing so, this also reduces the risk of inflammation of the intestinal lining and blockages of the intestines. Insoluble fibre can promote intestinal health by reducing the risk of small pouches forming at weak points in the intestines resulting in **diverticular disease** and could also reduce the risk of intestinal cancer. As it is indigestible it also takes up space in the stomach and intestines, making us feel fuller and preventing overeating, whilst providing the body with no energy.

Insoluble fibre is commonly found in **grains** such as **wheat**, bran, **nuts**, seeds, brown rice and **vegetables such as celery**. Insoluble fibre such as **cellulose** is found in high amounts in the skin of fruits and vegetables. Cellulose makes up the cells walls of plant cells (animal cells do not contain cell walls and therefore do not provide cellulose when eaten). An easy way to increase insoluble fibre is to make sure that you don't peel your fruits/vegetables and instead eat them whole (where appropriate). This is also one reason why it is better to consume fruits instead of fruit juice because fruit juice has lost the majority of its beneficial fibre. You can also include 30g of nuts to your diet daily to increase insoluble fibre.

Grains - mixed grain or wholemeal bread, whole wheat pasta, brown rice, corn

Outer skins - vegetables and fruits

Legumes - kidney beans, chickpeas

Nuts & seeds

Figure 1.2.7: Some examples of foods that are rich in insoluble fibre.

Helpful online resources

WebMD: What's the Difference Between Soluble and Insoluble Fiber?

https://www.youtube.com/watch?v=zFoD3F-nlec

Free Animated Education: Dietary Fibre: The Most Important Nutrient? Best Fiber Foods?

https://www.youtube.com/watch?v=_qo5Bllt1_M

Functions of fibre in the body

A summary of the main functions of fibre are listed below:

- Because fibre is very tough it can increase chewing, stimulating greater saliva release, promoting healthier gums and teeth.
- Both types of fibre (but especially soluble fibre) slow down the emptying of the stomach into the intestines. This makes us feel fuller for longer and reduces the likelihood of us overeating (whilst providing very little energy because we cannot break it down).
- Because digestion is slowed down, this also results in a slower absorption of nutrients and reduces the likelihood of blood glucose spikes and, in turn, the risk of developing type 2 diabetes.
- Soluble fibre helps reduce blood cholesterol levels by binding to cholesterol, preventing its absorption and facilitating its excretion from the body.
- Insoluble fibre also results in the softening of stools (preventing constipation), which also reduces the likeliness of straining when emptying the bowels. This reduces the risk of developing diverticular disease and cancer.

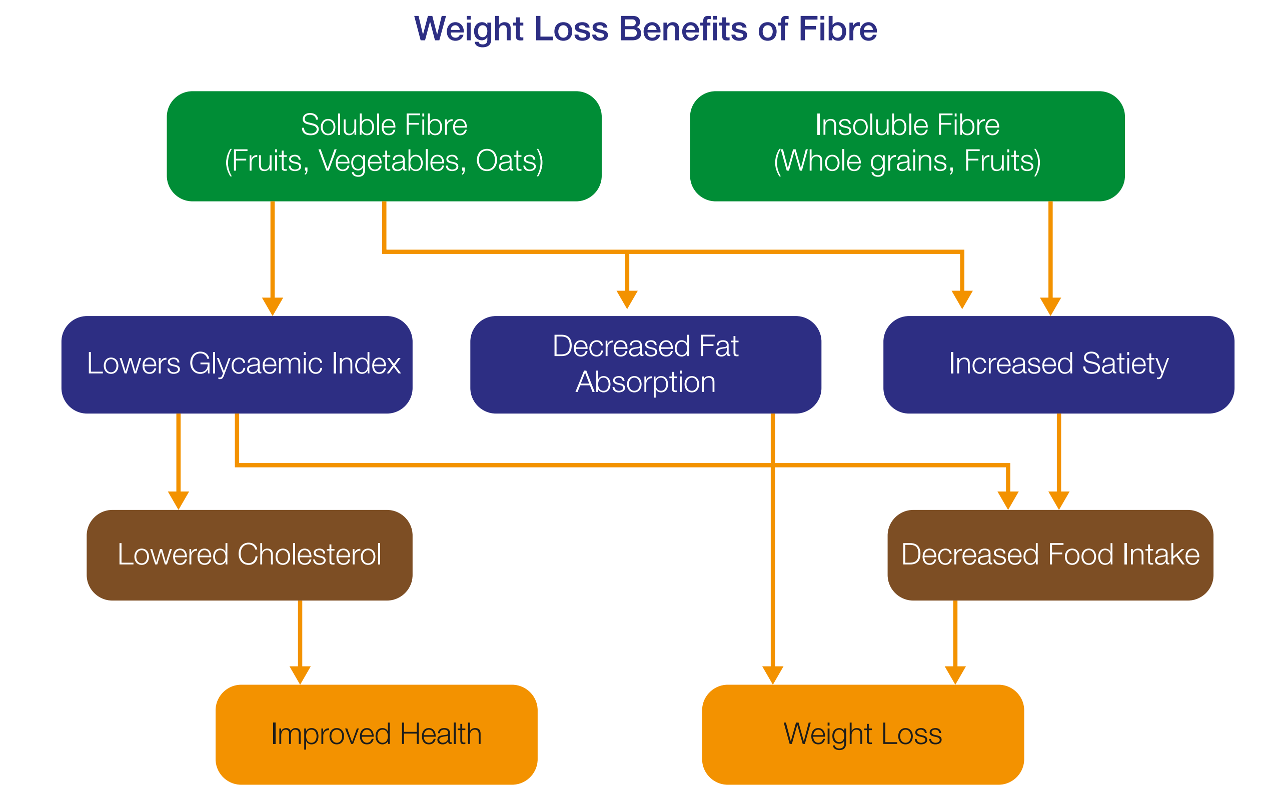

Figure 1.2.8: A flow diagram summarising how both forms of fibre can contribute to increased weight loss and health outcomes.

Functions of carbohydrates

Energy provision

The **primary function** of carbohydrates is to provide **energy**. Carbohydrates provide us with **16.7kJ/g**. This means that for every gram of carbohydrate we consume, it provides us with 16.7kJ of energy. The average recommended amount of energy an adult should consume per day is 8700kJ, but the energy requirements of each individual differs. This energy **fuels our activities** throughout the day, such as movement, repairing wounds, growing, thinking, etc. As glucose is the **primary source of energy for our brains**, consuming carbohydrates also **prevents us from getting headaches and feeling tired and irritable**.

When we eat simple and complex carbohydrates, they are digested by enzymes in the digestive system into their simplest form: monosaccharides. These monosaccharides are absorbed into the blood and directed to the liver. The liver is an important organ in the metabolism of carbohydrates.

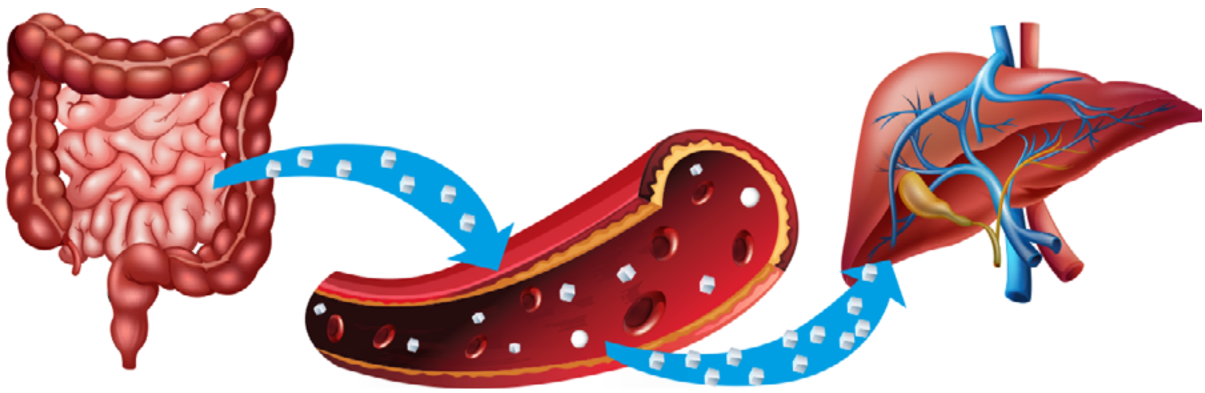

Figure 1.2.9: Glucose is absorbed through the small intestine and carried by blood to the liver.

Depending on the body's needs at a given time, three different outcomes can occur after glucose is absorbed into the blood:

1. **The glucose is used:** if the body's cells require glucose, then the glucose is released back into the bloodstream so that cells can access it and use it for immediate energy. Under normal circumstances, approximately 70% of glucose is redirected back into the blood for other cells to use and muscle cells to store.
2. **The glucose is converted to glycogen:** if the body has excess glucose, then the liver converts the glucose to glycogen (long chains of glucose) and stores it for when it is needed in the future. The liver stores approximately 4,200kJ of glycogen which equates to approximately four hours' worth of glucose supply for the average human. The liver stores approximately a quarter of the body's total glycogen. The skeletal muscles store the rest.

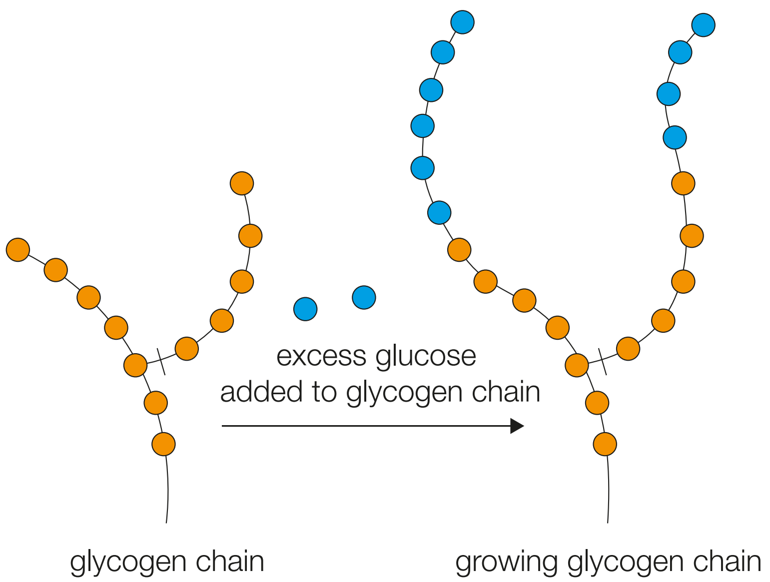

Figure 1.2.10: Excess glucose molecules being stored as glycogen in the liver. Each circle represents a glucose molecule (monosaccharide). When there is an excess of monosaccharides, they are bound together to be stored as the polysaccharide glycogen in the liver.

3. **The glucose is converted to fats:** if the glycogen stores in the liver and muscles are full, then the glucose is converted to fats and stored in adipose tissue (fat tissue).

Did you know?

Sugary drinks such as juices and soft drinks are a large contributor to gaining weight. When a sugary drink is consumed, the 'liquid sugar' is generally not registered by the brain and doesn't make us feel full. Because the kilojoules are not registered, it is likely that extra kilojoules are consumed through extra food. This can lead to an excess carbohydrate intake and result in the sugar being converted to fats.

Cellular communication

Carbohydrates also play important roles in **cellular communication and recognition**. The cell membrane contains short chains of carbohydrates that are bound to a protein (glycoprotein) or the phospholipid membrane (glycolipid). These receptor molecules recognise other cells and recognise **hormones** that are sent from another area of the body to communicate a specific message to a particular cell (e.g. when the hormone insulin communicates with skeletal muscle cells to take up excess glucose in the blood).

Protects protein from being used for energy

For an average person consuming 8,700kJ per day, between 3,915 to 5,655kJ is required from carbohydrate intake (or 230 to 333g of carbohydrates). It is important to remember that we need to consume carbohydrates daily to fuel our activities, especially the activity of our brain that relies on glucose. If we do not consume enough carbohydrates, our body activates different processes to obtain it. One example of this is muscle degradation. This means that our **muscles break down so that the protein can be converted to glucose to fuel our brain**. In doing so, this lowers our basal metabolic rate. This is discussed further in Topic 9.1.

Summary of carbohydrate functions

Carbohydrates:

- are an immediate energy source providing 16.7 kJ/g;
- are the primary fuel for the brain and nervous system;
- can be stored as glycogen for times when the body is carbohydrate deficient;
- supply dietary fibre to regulate bowel movements and slow digestion;
- make up structural components of cell membranes (carbohydrate receptors) and allow communication;
- protect protein from being used as a primary energy source;
- prevent headaches and fatigue; and
- allow a person to participate in activities requiring energy.

Carbohydrate recommended dietary intake

The Acceptable Macronutrient Distribution Range for carbohydrates (AMDR), recommends that **45% to 65%** of daily kilojoules (energy) come from **carbohydrates**. However, as highlighted throughout this topic not all carbohydrates are created equal. It is recommended that these carbohydrates are obtained from sources that they occur naturally in, such as fruits, vegetables, grains, milk etc. It is also recommended that only **10% to 15%** of the daily carbohydrate intake should come from **simple sugars**. Simple sugars do occur naturally, but they are often added to processed foods. The amount of added sugars in processed foods might surprise you. Some jars of pasta sauce contain more sugar than a 50g packet of M&Ms. Our diet should also include fibre. It is recommended that **women consume 25g and males consume 30g of dietary fibre per day.**

Deficiency of carbohydrates

When people have **deficient carbohydrate consumption** their glycogen reserves are used up first. However, once the glycogen reserves are low, the body needs to ensure it has an ongoing supply of glucose to supply to the brain and nervous tissues. The protein that makes up our muscles can be broken down and converted into glucose molecules. This results in reduced muscle mass. This is why athletes eat before and after workouts. Athletes want to provide their body with carbohydrate fuel and reduce the risk of their muscles being broken down to fuel their body (see Topic 9: Sports nutrition for more information). There is also another emergency energy backup supply for the brain. When the brain's energy needs cannot be met by carbohydrates alone, the liver can convert fats into **ketone bodies**. The brain can also use these ketone bodies for energy, but it prefers glucose as its energy source. This is the theory behind the **ketogenic diet.** Reduce the intake of carbohydrates so the body uses fat (ketone bodies) to fuel the brain instead of carbohydrate. However, this diet can result in reduced cognitive function and other side effects that will be explored in Topic 5: Food trends.

Generally, if someone is **carbohydrate deficient,** they experience **symptoms** such as **headaches, weakness, irritability, inability to exercise** and **even fainting**. Carbohydrates are a major energy source for the body and a lack of them results in people feeling lethargic. The brain primarily uses glucose for its daily processes and without energy it makes sense that there are side effects such as headaches and irritability.

Excess of carbohydrates

When **carbohydrates** are consumed in **excessive amounts**, the excess can be stored as fat and could result in **obesity**. This can also contribute to other health implications such as **type 2 diabetes**, hypertension and cardiovascular disease. Furthermore, excessive consumption of carbohydrates also increases the risk of developing **dental caries** (tooth decay). This is because bacteria in the mouth ferment the sugar in the mouth producing acid as a bi-product. This acid can erode tooth enamel leading to dental caries.

Figure 1.2.11: The comparison of a healthy tooth compared with progressive tooth decay and a cavity.

Figure 1.2.12: An image of dental caries.

Helpful online resources

TedEd: How do carbohydrates impact your health–Richard J. Wood

https://www.youtube.com/watch?v=wxzc_2c6GMg

Osmosis: Carbohydrates & sugars–biochemistry

https://www.youtube.com/watch?v=jQi84TnstI4

FreeMedEducation: What causes tooth decay?

https://www.youtube.com/watch?v=BE_h4bTdcdQ