How your body works

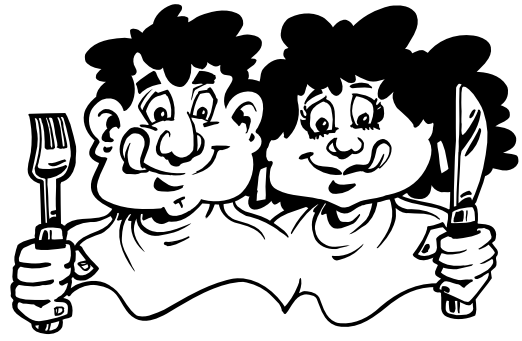
It is important to understand how the body works in order to understand the difference in the way it works when you have diabetes. If you are not familiar with medical terms, or not interested in learning them, you can skip the terms in brackets. You do not need to know them to understand what is being said.

The three most important things making up the food we eat are sugar or starch (carbohydrates), fat and protein. When we eat, the digestion of starch (long chains of sugar, see page 203) begins immediately in the mouth with the help of a special enzyme (saliva amylase). An enzyme is a protein compound that breaks the bonds holding chemicals together. The food collects in the stomach, where it is mixed and broken down by the acidic gastric juice. The stomach then empties this mixture, a little at a time, into the small intestine through the lower opening of the stomach (pylorus, see illustration on page 21 and 64).

Phases in glucose metabolism

① **Storing at meals:**
During a meal and for the following 2-3 hours glucose from the meal will be used as fuel by the cells. At the same time the stores of glycogen (glucose in long chains, see picture on page 203) fat and protein are rebuilt.

② **Fasting between meals**
After 3-5 hours the carbohydrate content of the meal is consumed and the blood glucose level starts to decrease. The glycogen stores in the liver will then be broken down to maintain a constant blood glucose level. The glucose produced in this way will be used by the brain while the body uses free fatty acids from fat tissue for its fuel.



As soon as you see food your mouth will water and your body will begin to prepare to digest it.

Once the food is in the small intestine, it will be broken down even more by digestive enzymes from the pancreas and suspended in bile produced by the liver. If you eat sugar (for example, if you have hypoglycaemia, see page 60) it cannot be absorbed into the blood until it has entered the small intestine. A study on adults indicates that glucose cannot be absorbed from the mouth (oral cavity) [321] or from the stomach.[277] In this sense the emptying rate of the stomach will have a considerable impact on how quickly the sugar you eat enters the bloodstream and increases your blood glucose level (see page 203).

The carbohydrates we eat are broken down into the simple sugars (mono-saccharides), glucose (dextrose, grape-sugar), fructose (fruit sugar) and galactose. Fructose must first be transformed into glucose in the liver before it can affect your blood glucose level. Food proteins are broken down into amino acids, and fat into very tiny droplets (known as chylomicrons, and composed mainly of triglycerides). Simple sugars and proteins are absorbed directly into the blood while the fat droplets are absorbed into the lymph system and enter the bloodstream through the lymph vessels.

How insulin works

① Insulin opens the door for glucose to enter the cells.

② It stimulates the storing of glucose in the liver (as glycogen).

③ It stimulates the development of fat from excess carbohydrates.

④ And it stimulates the development of protein compounds in the body.

The venous blood draining the stomach and intestines passes through the liver before reaching the rest of the body. A large amount of glucose will be absorbed by the liver with the help of insulin, and then stored as a reservoir as glycogen (see page 32). These stores can be used between meals, during the night, and when a person is starving. Only glucose that is not absorbed by the liver can reach the peripheral bloodstream (reaching all over the body), and it is through this that glucose is delivered to the rest of the body. This glucose can be measured by a finger prick or a blood test from the vein.

The muscles can also store a certain amount of glucose as glycogen. Whereas the glycogen store in the liver can be used to raise the blood glucose level, the store in the muscles can only be used by the muscles themselves during exercise. The body's ability to store glucose is very limited. The glycogen stores are only sufficient for 24 hours without food for an adult and 12 hours for a child.[699]

The glucose content of the blood is surprisingly constant during both day and night in a person without diabetes (approximately 4-7 mmol/l, 70-120 mg/d). In adults, this blood glucose level corresponds to only about two lumps of sugar. If you think about it this way, you won't find it surprising that even a small amount of sugar, a few sweets for example, can disturb the balance of glucose in the body of a person with diabetes.

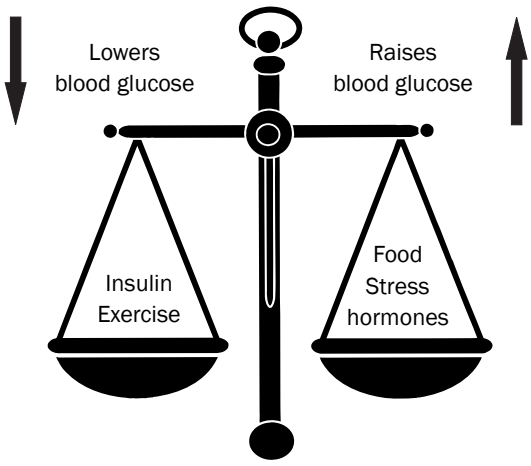
The smallest building blocks in your body are called cells. All the cells in our body need glucose to function well. With the help of oxygen, glucose is broken down into carbon dioxide, water and the vital energy to make cells work throughout the body (see "A healthy cell" on page 24).

Insulin

Many of the different things your body does are controlled by hormones. Hormones act through the blood and work like keys, "opening doors" to different functions in the body. Insulin is a hormone that is produced in the pancreas in special types of cells called beta cells. The beta cells are found in a part of the pancreas known as "the Islets of Langerhans" which also contain alpha cells producing the hormone glucagon (see picture on page 23). Other hormones are also produced by the islets, and help the islet cells to communicate with each other. The pancreas has another very important function. It produces enzymes to help you digest your food. This part works quite well, even in a person with diabetes.

The reason that insulin is so important is that it acts as the key that "opens the door" for glucose to enter the cells. As soon as you see or smell food, signals are delivered to the beta cells to increase insulin production.[253] Once the food has gone into your stomach and intestine, other special hormones send more signals to the beta cells to continue increasing their insulin production.

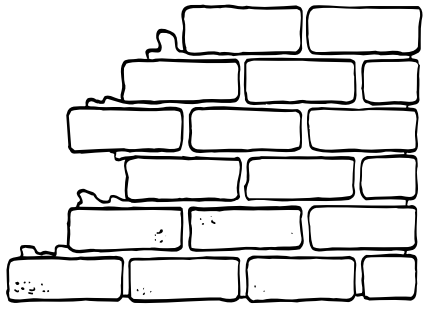
The beta cells contain an inbuilt "blood glucose meter" that registers when the level of glucose in your blood goes up and responds by sending the correct amount of insulin into your bloodstream. When a person without diabetes eats food, the insulin concentration in their blood increases rapidly (see figure on page 22) to take



The blood glucose in your body is controlled by many different actions that balance each other to achieve an as even a level as possible throughout the day.

care of the glucose coming from the food, transporting it into the cells. This person's blood glucose level will normally not rise more than 1-2 mmol/l (20-25 mg/dl) after a meal.[253]

Insulin follows the bloodstream to the different cells of the body, sticking to the cell surface in special insulin receptors. This makes it possible for glucose to travel through the cell wall made permeable to glucose. Insulin causes certain proteins inside the cell to come to the cell surface, collect glucose and then release it inside the cell. In this way, the blood glucose level is kept at a constant level.



All the organs in the body are built of cells, which are like the bricks in a house. Each organ contains specialized cells to enable it to perform its function, so there are identifiable kidney cells, liver cells and muscle cells.

Not all cells require insulin to transport glucose into their interior. There are "insulin independent" cells that absorb glucose in direct proportion to the blood glucose level. Cells like this can be found in the brain cells, nerve fibres, retina, kidneys and adrenal glands, as well as in the blood vessels and the red blood cells.

It may seem illogical that certain cells can absorb glucose without insulin. However, in a situation where there is not enough glucose in the body, the insulin production will be stopped, reserving the glucose for the most important organs. If you have diabetes and your blood glucose level is high, the cells that don't need insulin will absorb large amounts of glucose. In the long run this will poison the cells, making those organs susceptible to long-term damage from having diabetes.

The body needs a small amount of insulin, even between meals and during the night, to accommodate the glucose coming from the liver (see page 32). This is often referred to as the "basal insulin level" to distinguish between the need for insulin in the background between mealtimes, and the "boluses" of insulin needed to accommodate the eating of meals or snacks. Around 40-50% of the total amount of insulin produced by a person without diabetes, over any 24 hour period, will be secreted as basal insulin between meals.[86]

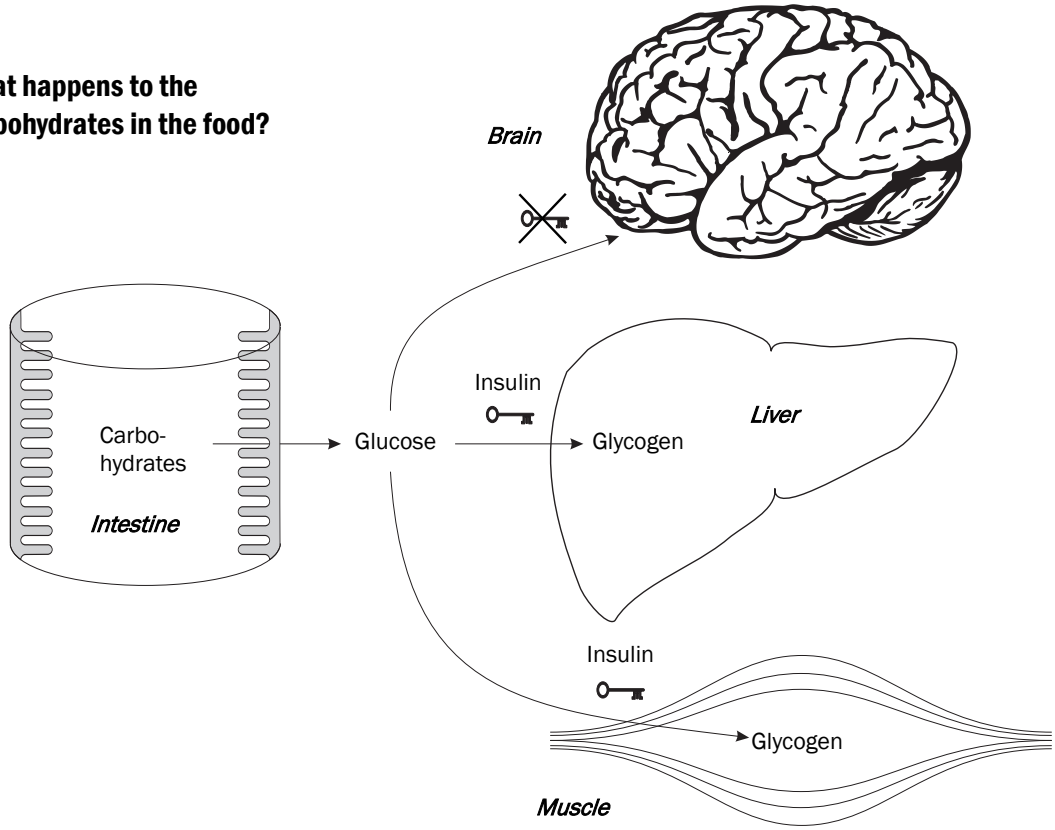
A large amount of carbohydrate from a meal will be stored in the liver (as glycogen, see page 32). If you eat more than you need, the excess carbohydrate is transformed into fat and stored in the fat tissue. The human body has an almost unlimited ability to store fat, so fat left over from a meal is stored in the same way. Proteins (amino acids) from the meal can be used by different body tissues. There is no specific way of storing amino acids. The liver can produce glucose from amino acids, for example, if you haven't eaten for some time. But this means that the body tissues themselves are broken down since the body has no way of storing amino acids.

Your body doesn't realize it has diabetes

When you read about how your body functions if you have diabetes, remember that it always "thinks" and reacts as if it did not really have diabetes, that is to say, as if the insulin production was still working as well as it should. Your body doesn't understand why things go wrong when you become insulin deficient, because it doesn't realize what has happened. On the other hand your brain can help you by thinking through what will happen when your insulin production stops working. It is very important therefore that you remember to stop and think about how your body reacts in particular situations, why it reacts like this, and how you can influence these reactions.

Your insulin doses will vary from day to day since you rarely conduct your life in the same way from one day to another. If you did not have diabetes, your beta cells would make automatic adjustments for this. But now it is up to you to notice how your body reacts on different days, and how much insulin you need in different situations.

What happens to the carbohydrates in the food?



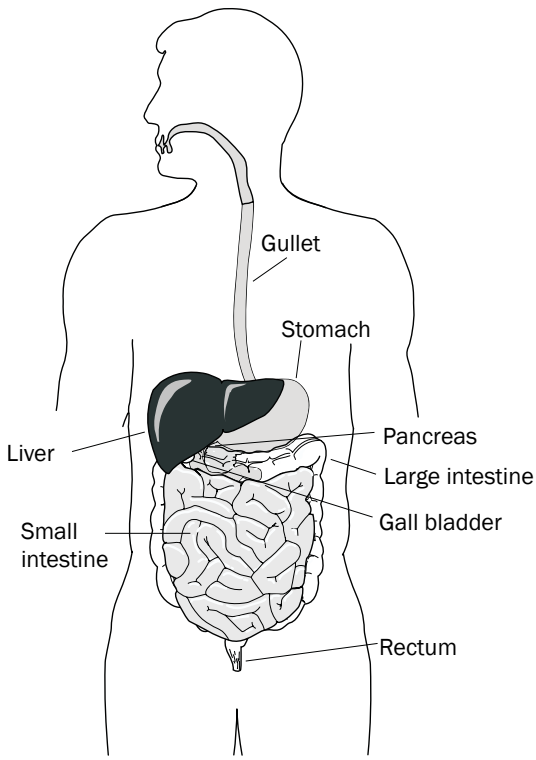
The complex carbohydrates in food are broken down to simple sugars in the intestine. Glucose is absorbed into the bloodstream and stored as glycogen in the liver and muscles. The key hormone insulin is needed to transport glucose into the cells of these organs. The brain cannot store glucose, so it has to depend upon a regular supply if it is to function well. The nervous system and some other cells (for example, those in the eyes and kidneys) can take up glucose without the help of insulin. There are advantages to this in the short term as the nervous system will not experience a lack of glucose, even if no insulin is present. However, in the long term, there are disadvantages for a person with diabetes, as the nervous system will be exposed to high levels of glucose inside the cells when the blood glucose level is high.

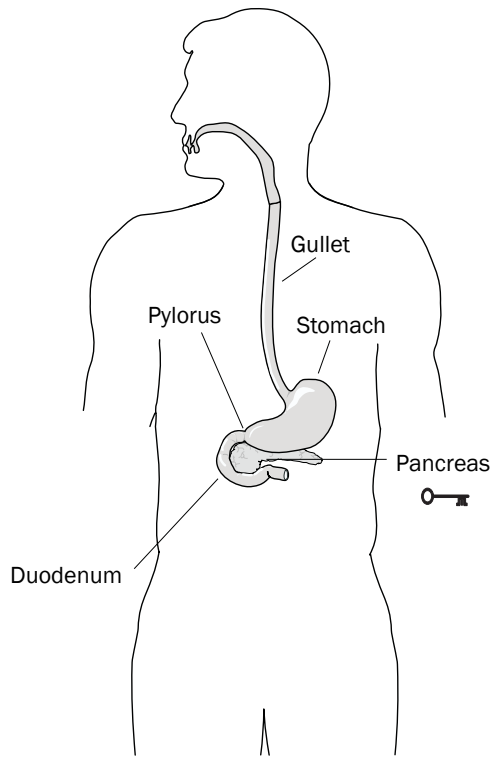
The anatomy of your body

When you eat, the food passes from your mouth through your gullet on its way down to your stomach. Sugar can not be absorbed into your blood until the food has passed the lower opening of your stomach (pylorus) and entered the intestine. In the intestine, it will be digested by enzymes from your pancreas and intestinal lining.

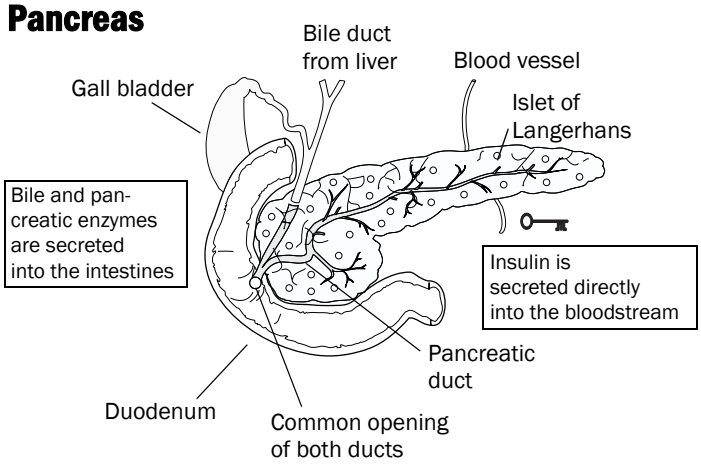
The small intestine is very long (3-5 metres or 9-15 feet in an adult) and is folded or coiled in order to fit comfortably inside your abdominal cavity or tummy. The first part of the small intestine, the duodenum, is 25-30 cm (10-12 inches) long.

After leaving the small intestine, the food passes into the large intestine (or colon) which is approximately 1½ metres (4-5 feet) long. The large intestine passes around the abdominal cavity before entering the rectum.





Pancreas

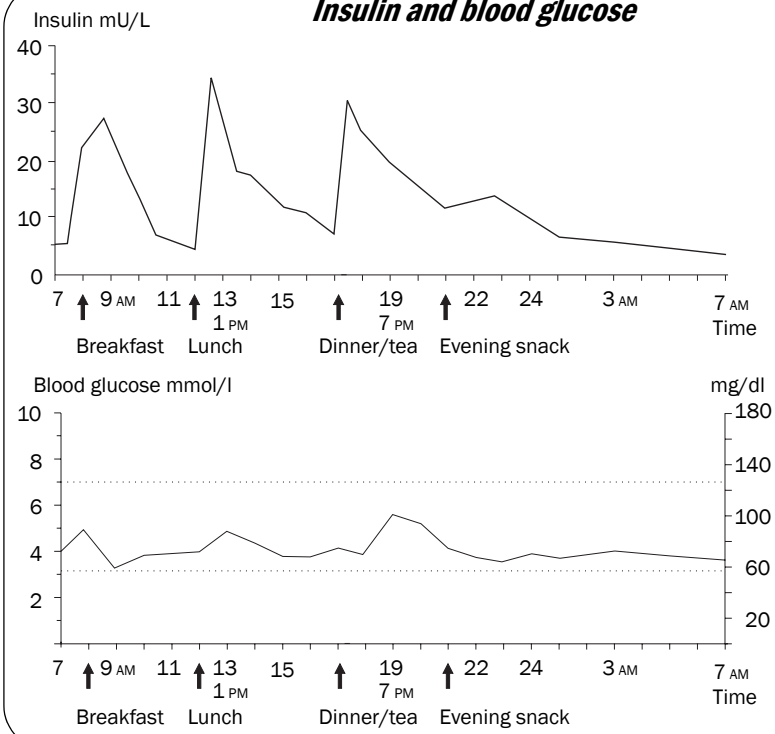


"I am now your pancreas but one day, when you are older and learn to take care of yourself, your brain will become your pancreas."

The mother of Maria de Alva, former president of IDF (International Diabetes Federation).

Your pancreas is about the size of the palm of your hand. It is positioned under the left rib cage in the back of the abdominal cavity, close to the stomach. The pancreas has two main functions: it produces enzymes which help you digest food, and it produces insulin which helps control blood sugar. The digestive enzymes from the pancreas reach the intestine through the pancreatic duct. This drains into the duodenum together with the duct from the liver and gall bladder. There are approximately one million islets of Langerhans in the pancreas. Insulin produced in the beta cells of the islets is secreted directly into the small blood vessels passing through the pancreas.

Insulin and blood glucose



A person without diabetes

If a person doesn't have diabetes, the insulin concentration in the blood will increase rapidly after a meal.[576] When the glucose in the food is absorbed from the intestine, and the blood glucose has returned to normal levels, the insulin level will drop back to baseline once again. However, the insulin level will never go right down, as a low level of basal insulin is needed to take account of the glucose coming from the reserve stores in the liver between meals and during the night.

The resulting blood glucose level will be very stable in a person without diabetes as this graph illustrates.[519] The normal blood glucose level is between about 4 and 7 mmol/l (70-120 mg/dl.)