The Homeostatic control of Glucose in blood by the hormones Insulin and Glucagon

Cellular Respiration vs. Ventilation

Cellular Respiration is the process whereby the mitochondria in a cell react **Glucose** and **Oxygen** together to provide **ENERGY** for the cell. *Without energy, a cell would die within seconds*! From the point of view of Biology, the *by-products* of cellular respiration are **Carbon Dioxide** and **Water** and it is **ENERGY** that is the main product. Please remember this next equation for your 'A' Level exams.

	Glucose	+	**Oxygen**	—>	**ENERGY**	+	**Carbon Dioxide**	+	**Water**
	$C_6H_{12}O_6$	+	$6O_2$	—>	**ENERGY**	+	$6CO_2$	+	$6H_2O$
Stoichiometric Ratio	1		6				6		6

The human body therefore consumes literally **BILLIONS** of molecules of **Glucose** and **BILLIONS** of molecules of **Oxygen** EVERY SINGLE SECOND. If the cells in a human body do not get enough of Oxygen and enough of Glucose then the person dies within seconds – and if the person gets an **insufficient** amount of either, then something has gone seriously wrong with his/her body. If the cells of a human being do not get enough **Glucose** then it is usually because something has gone wrong with the homeostatic balance of **insulin** in his/her body. This medical condition is called Diabetes – and there are two types of Diabetes. We will look at Diabetes in this Section (B11).

DIABETES

Step 1, The production of Glucose

Glucose, $C_6H_{12}O_6$, is a monosaccharide sugar molecule and it is the **MAIN** sugar molecule in blood (and, although there are small amounts of other sugars such as fructose and sucrose and lactose in the bloodstream, at GCSE Level we shall ignore them). Glucose is produced (mainly) by the breakdown of carbohydrates by digestion in the intestines. The Glucose is then absorbed into the bloodstream through the walls of the intestines and it is then circulated to every part of the body for delivery to every cell in the body (so that it can be reacted with Oxygen by the mitochondria in cells to produce energy). OK that is how Glucose is produced – but HOW does it get from the bloodstream into a cell?

One part of the answer to that question is that it gets into the cell by *"facilitated diffusion"* (which is what Diana has asked me about in the last few days), but that does not explain the reason **why** it crosses the phospho-lipid bi-layer cell membrane. Why does it just not waltz past cells and ignore them. Why does it take the trouble to go up to carrier proteins and say to them

> *"please Mr Carrier Protein, would you be so kind as to carry me across the cell membrane because there are lots of mitochondria in the cell who need me (and also Oxygen) to create energy and it is important that I get to the mitochondria quickly otherwise the cell will die".*

and that is where the hormone INSULIN comes in![1]

I do not usually use baby language in my Notes for you, but I have just done so because by making the language more dramatic it highlights the interplay between Glucose and the carrier protein involved in facilitated diffusion – and it is rather important that you understand the fundamentally important life-dependent drama that is unfolding zillions of times per second in your body. In fact if you multiply what is going on in each cell by the number of cells in your body (and there are TRILLIONS of cells in a human body) then there an almost **UNBELIEVEABLY** large (10^n) number of such transactions occurring every spilt second in your body.

[1] Insulin will activate the **Gl**ucose **T**ransporter (GLUT 4), but you do **not** need to know about GLUT4 at GCSE Level.

OK let us get back to understanding the sequence of events that is unfolding. We have now understood how and why glucose is present in the bloodstream and how and why Insulin is present in the bloodstream (Insulin being the molecule that triggers the entry of Glucose into a cell by means of a carrier protein called a **Glu**cose **T**ransporter, GLUT[2]), but although I have told you that every cell needs Glucose, I have as yet not told you that too much Glucose in the bloodstream is just as damaging as too little Glucose (and now are you beginning to understand why **homeostatic balance** is so important).

Too much Glucose in the body could, over a period of time, severely damage your heart, your eyes (you could go blind), your feet (you may have to have your feet amputated/cut off), and your kidneys (you will have renal failure).

….. and at this point the penny about Biological Homeostasis will finally drop! In any body (animal or plant) *Homeostasis* is of massive importance. Too little of anything will result in damage or death, and too much will equally result in damage or death. Insulin is needed to trigger the carriage of Glucose across a cell membrane – but too much of it will cause a problem in the body (**Hypoglycaemia**) just as much as too little insulin will cause a problem (**Diabetes**).

Step 2, The production of Insulin

Healthline at https://www.healthline.com/health/diabetes/insulin-and-glucagon says that during digestion, foods that contain carbohydrates are converted into glucose. Most of this glucose is sent into the bloodstream, causing a rise in blood glucose levels. **This increase in blood glucose signals the pancreas to produce insulin** *(and at GCSE Level you are not required to know the workings of the triggering mechanisms)* and the insulin tells cells throughout the body to **take in glucose from the bloodstream**. Some cells convert the glucose into energy immediately, while other cells (e.g. those in the liver and in the muscles), store excess glucose as **glycogen** and the body then uses this glycogen as fuel *between* meals.

As glucose moves into cells, the levels of glucose in the bloodstream thus goes down – and please remember that this Section of GCSE Biology is all about understanding the importance of and the achievement of homeostasis in an organism.

The sequence described thus far has been

- Food is digested in the intestines to produce Glucose
- Glucose travels across the walls of the intestines into the bloodstream
- Blood vessels carry the glucose to every cell in the body
- The concentration of Glucose in the bloodstream causes Insulin to be produced by the Pancreas
- Insulin then triggers carrier proteins called Glucose Transporters to transport Glucose molecules across the phopsho-lipid bi-layer of the cell membrane into the cell by a process called facilitated diffusion
- Once in the cell, mitochondria react Glucose and Oxygen together to form the **ENERGY** that cells need to stay alive.
- Insulin is thus crucial to the carriage of Glucose across a cell membrane
- There are two diseases associated with Diabetes viz.
  - **Type 1** Diabetes which is an auto-immune problem, and
  - **Type 2** Diabetes which is an Insulin production problem.

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[2] Wikipedia says that **Glucose transporters** are a wide group of membrane proteins that facilitate the transport of glucose across the plasma membrane by process known as facilitated diffusion. The GLUT or SLC2A (SLC = **S**o**l**ute **C**arrier protein) are a family of carrier proteins that is found in most mammalian cells. 14 GLUTS are encoded by human genome. GLUT is a type of **uniporter** transporter carrier protein. It is not a channel protein.

Type 1 Diabetes (10% of those people who have Diabetes have Type 1 Diabetes)
Please watch the nice little video at https://www.diabetes.org.uk/type-1-diabetes

Here the body attacks and kills the cells in the Pancreas that produce Insulin. Thus hardly any Insulin is produced by the body. This is an *autoimmune disease*, and it has nothing to with eating the wrong sort of food/or being overweight/etc.

The intestines keep producing Glucose but the Glucose cannot get into cells because there is hardly any Insulin in the bloodstream, therefore someone with Type 1 Diabetes has to urinate frequently to get rid of the unused and the potentially harmful **excess** Glucose. Urination rids the body of the excess Glucose, but urination also removes Water from the body. Someone with Type 1 Diabetes therefore suffers from extreme **thirst**; but much more importantly, the cells in that person cannot produce energy and the person suffers from **extreme tiredness**.

In order to get energy, the body has to break down the fat stored in the body, and the person with Type 1 Diabetes will lose a lot of weight.

Type 2 Diabetes: (and 90% of those who have Diabetes have Type 2 Diabetes)
Please watch the nice little video at https://www.youtube.com/watch?v=4SZGM_E5cLI

In Type 2 Diabetes either the body cannot produce enough insulin or else the Insulin that is produced cannot do its job properly

- possibly because the person is overweight and fat prevents the Glucose Transporters from working properly, or
- for some reason or other, the Insulin does not do its job and does not get Glucose into the cells.

For GCSE Level purposes, all that you need to know is that **Type 1** occurs as the result of an auto-immune disease whereby the Pancreatic cells that produce Insulin are attacked and either killed or disabled, and that in **Type 2 Diabetes** Insulin is produced but in insufficient quantities, or for some reason the Insulin that is produced cannot do its job properly.

You are also required to know that Insulin and a hormone called **Glucagon** work together.

Healthline says that Insulin and Glucagon are both hormones that help regulate the levels of blood glucose in the body. They work together to balance blood sugar levels, keeping them in the narrow range that the body requires. During digestion, foods that contain carbohydrates are converted into glucose. Most of this glucose is sent into the bloodstream, causing a rise in blood glucose levels. This increase in blood glucose signals the pancreas to produce insulin and the insulin tells cells throughout the body to take in glucose from the bloodstream. As the glucose moves into cells, blood glucose levels go down. Some cells use the glucose as energy. Other cells, such as cells in the liver and muscles, store excess glucose as a substance called **glycogen**. The body uses glycogen for fuel between meals.

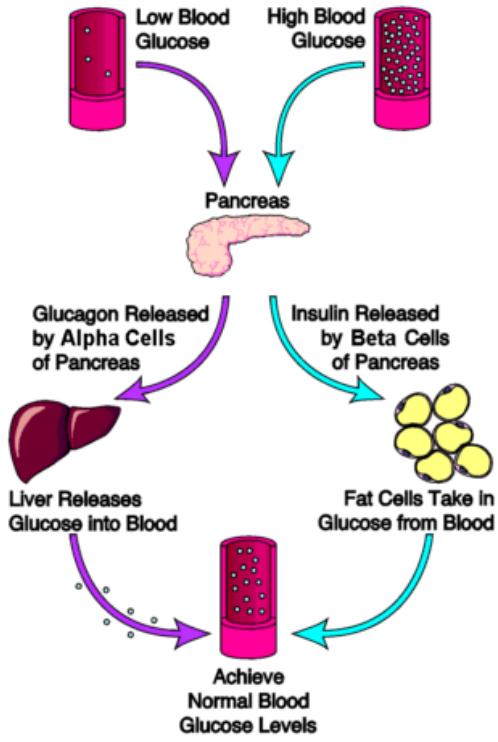
How Glucagon works
Glucagon works to counterbalance the actions of insulin. About four to six hours after eating, the glucose levels in blood decrease, thus triggering the pancreas to produce glucagon. This hormone signals the liver and muscle cells to change the stored glycogen back into glucose. These cells then release the glucose into your bloodstream so your that cells can use it for the creation of energy.

This is called a **negative feedback loop** and keeps blood sugar levels from dipping too low, ensuring that that body has a steady supply of energy.

Term	Definition
glucose	sugar that travels through the blood to provide a constituent of fuel in cells
insulin	a hormone that tells cells either to take glucose from the blood or to store it for later use
glycogen	a substance made from glucose that is stored in the liver and in muscle cells to be used later
glucagon	a hormone that tells cells in the liver and muscles to convert glycogen into glucose and release it into the bloodstream
pancreas	an organ in the abdomen that makes and releases insulin and glucagon.

Level of glucose in the blood is too **LOW**

Level of glucose in the blood is too **HIGH**



Low blood glucose levels tell the Pancreas to secrete *glucagon*, and glucagon causes fat and muscle cells in the liver to convert glycogen back into glucose – **and thus levels of glucose in the blood are INCREASED back to the level required for homeostasis.**

High blood glucose levels tell the Pancreas to **INCREASE** the amount of insulin being secreted, and fat cells then absorb glucose from the blood and store the glucose as glycogen – **and thus the overly high levels of glucose are REDUCED!**

BBC Bitesize says that

- **Insulin** and **glucagon** interact to produce homeostasis in blood sugar levels (the concentration of glucose in the blood). Glucose is a monosaccharide and is **by far** the most important sugar molecule in the blood stream.
- People with T*ype* 1 *diabetes* don't produce insulin. Type 1 Diabetes is an auto-immune disease. People with T*ype 2 diabetes* do not respond to insulin as well as they should and later in the disease often do not make enough insulin. For a long time it was thought that Type 2 diabetes was a metabolic disorder. This type of disorder occurs when the body's natural chemical processes do not work properly. However, recent research suggests that Type 2 Diabetes may actually be an autoimmune disease. If that is the case, then new treatments and preventive measures may be developed to treat this condition.
- Type 1 diabetes, also known as juvenile diabetes, is thus an autoimmune condition that develops when the immune system attacks insulin-producing cells in the pancreas. This means that the body cannot make enough insulin and causes glucose to build up in the blood. *People with type 1 diabetes therefore have to take insulin every day to manage their condition.*
- Type 2 diabetes is a disease that usually develops over time. This condition is often referred to as adult-onset diabetes, *but it can affect children*. In people with type 2 diabetes, the body cannot produce enough insulin and certain **cells become resistant to its effects**. This means that those cells are unable to take in and store glucose. Instead, glucose remains in the blood. *Type 2 diabetes develops most often in people who are overweight and who live a sedentary lifestyle.*