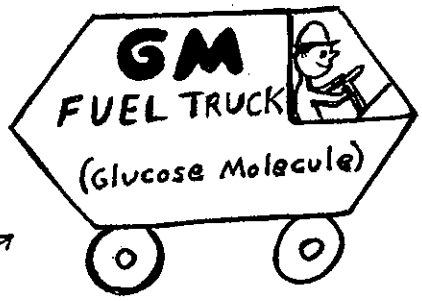
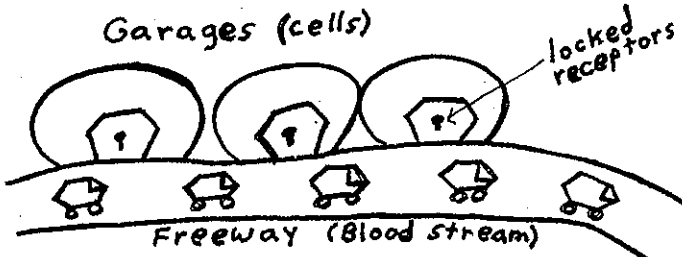
The Wonders of Modern Science Department:
Understanding Blood Sugar, Insulin, and Diabetes

All carbohydrates in the diet (except fiber) are either broken down to glucose and absorbed in the intestine, or they are absorbed as other monosaccharides (fructose or galactose) and converted to glucose in the liver.



The glucose circulates around in the blood (the blood vessels make up the **freeway** system) to be taken up by tissues and used as fuel or stored for later. Here is a close-up of a Glucose Molecule. As you can see, it is actually a tiny **fuel truck.**

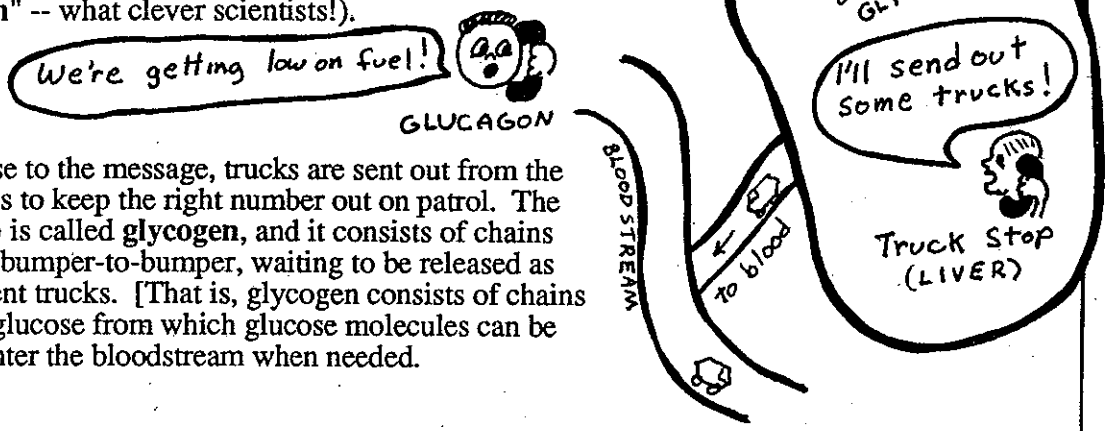


Under a microscope, you can see that the cells of the body are all equipped with garage doors that are perfectly shaped to receive the fuel delivery. Also notice that each door has a **lock** on it. (The doors with locks are **receptors** on the cell membrane.)

The fuel trucks have a lot of trouble getting into the cell through the garage door without a **key**. Fortunately, there is an agency in the body that counts the number of trucks entering the freeway, and it sends a message to a **key factory**, ordering the delivery of just the right number of keys to let the trucks into the cells. The key factory is the **pancreas**, and the keys are molecules of **insulin.**

(Not all of the trucks enter the cells; some have to patrol the freeway in case there is an emergency need for fuel energy.)

There is also a truck-stop in the liver, so that when the number of trucks on the freeway gets too low (**hypoglycemia**), an ageney reports the shortage by way of a hormone messenger that says that "glucose is gone" (so they called the messenger "**glucagon**" -- what clever scientists!).



In response to the message, trucks are sent out from the truck-stops to keep the right number out on patrol. The truck-stop is called **glycogen**, and it consists of chains of trucks, bumper-to-bumper, waiting to be released as independent trucks. [That is, glycogen consists of chains of stored glucose from which glucose molecules can be freed to enter the bloodstream when needed.

[Don't you just hate how all of these glucose-related words look and sound nearly identical?! The only way to deal with it is to look carefully at each word: often in the foreign language known only to scientists, there are clues to the meaning. For examle, "gen" means "to make" or "to begin", as in words like genesis or generate. "Glyco**gen**" was so-named because it is used to **gen**erate glucose; that is, it makes glucose available from an internal source, when a dietary source of glucose is not available.]

Anyway, the two hormones insulin and glucagon work together in this way to allow the absorbed glucose to enter the cells of the body, while maintaining the required minimum amount of glucose circulating in the blood.

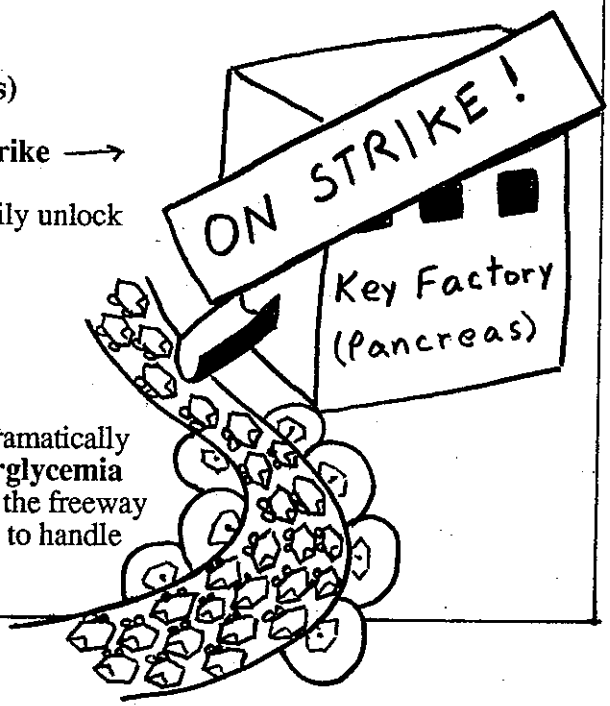
How all this applies to Diabetes:

There are several types of diabetes. The most common are Type I and Type II.

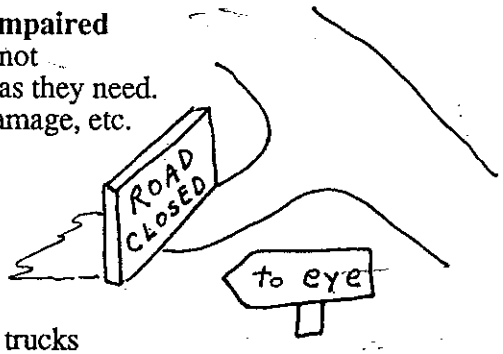
Type I Diabetes (Insulin-Dependent Diabetes)

In this type of diabetes, the **key factory is on strike** → so keys are not produced (**the pancreas stops producing insulin**). The fuel trucks cannot easily unlock the garage doors (**receptors**) to enter the cells.

The number of trucks on the freeway increases dramatically because they have nowhere to go. This is **hyperglycemia** (high blood sugar), and it can be very harmful to the freeway system (**blood vessels**), which was not designed to handle so many trucks. →

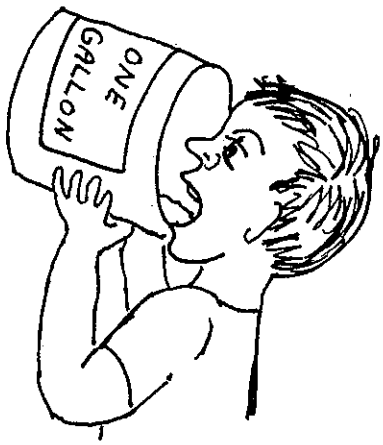


Some parts of the freeway may have to be closed (**impaired circulation**), which means that certain tissues will not receive as many shipments of oxygen and nutrients as they need. This can lead to blindness, kidney damage, nerve damage, etc.



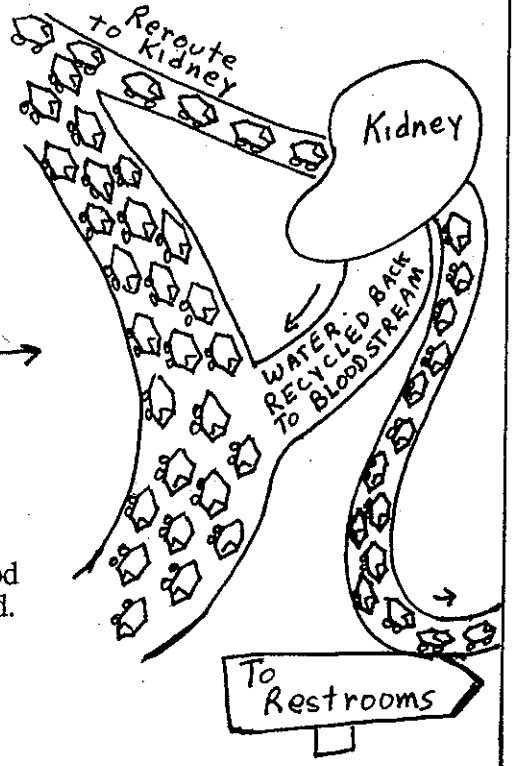
A monitoring agency in the brain notices how many trucks are on the freeway and signals the person that the ratio of trucks to blood volume is disturbed. The sensation caused by this signal is **thirst**, so the person with high blood sugar will want to drink large amounts of fluid.

The scientific term for this is **polydipsia**, a word you do not need to learn, but which is good practice in decoding scientific words: [poly = many; dips = thirst, from the Greek word "dipsesis." (You can remember it by thinking of dips of a ladle at a punch bowl or dipping a bucket at a well.)]



All this fluid results in more urine being produced, a condition called (you guessed it!) **polyuria** . . . another word you do not need to know.

When the blood sugar is so high, the kidney starts to try to help by diverting some trucks from the blood stream and excreting them in the urine. Normally glucose is <u>not</u> excreted in the urine, but the kidneys are smart and they sense that this is an emergency situation.



Testing for **sugar in the urine**, then, is a marker for uncontrolled diabetes, but it tells us nothing until the blood sugar level is high enough to cross the kidney's threshold. That is why **blood sugar testing** with a drop of blood from a finger prick is a much more valuable monitoring tool; it can tell exactly what the level of blood sugar is at any moment, normal, high, or low.

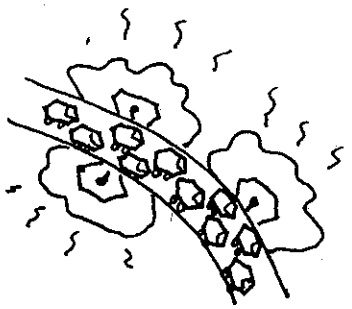
In the text, it was described how an early test for diabetes was "sweet tasting urine." Whose job was it to test for that?!

Advertisement for a Lab Tech job in Ancient Greece:

> Help Wanted -- Inquire within. Must have adverturous spirit.

A related phenomenon helps in diagnosing diabetes in children: all that fluid they thirstily drink often results in episodes of bed-wetting, and the sheets feel very sticky because of the high sugar content of the urine.

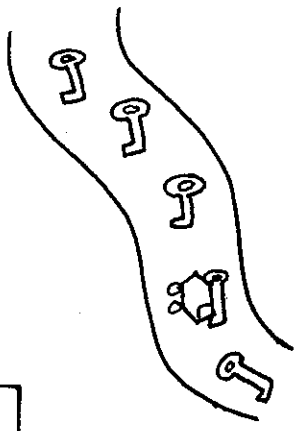
Back to the cells: Since so much fuel is lost in the urine, and the fuel trucks parked outside the cell cannot get in, the cells begin to starve. This is like living in Minnesota in the winter and running out of fuel . . . you begin to burn the furniture to stay alive. →



Important cell materials may be destroyed in an effort to get enough energy for the cell to keep working. The person also feels weak and starved, and loses weight.

The solution? The person with Type I Diabetes needs to **import some keys** (take **insulin injections**) from outside the body. But since a set number of keys are imported, it becomes important for the person to control the number of trucks taken in.

Too many keys in relation to trucks can make blood sugar dangerously <u>low</u>; too many trucks in relation to the number of keys imported will result in damaging <u>high</u> blood sugar. →

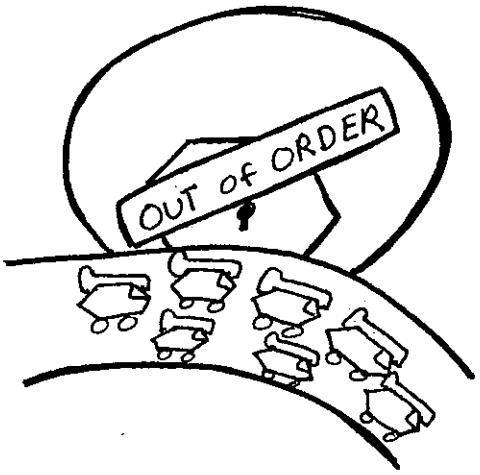


That is why people with this condition follow a **meal plan** that provides a certain amount of carbohydrate, timed to coincide with taking their insulin shots. Protein and fat are also measured to be sure that calories, total fat, and protein intake are adequate but not excessive, since these factors can also affect health.

> Today's Meal Plan: 8 a.m.
>
> Inject two keys; take in two trucks.

How is Type II Diabetes different from Type I?

Type II Diabetes is by far the most common form of diabetes. People with Type II diabetes usually produce normal or even high numbers of keys (**insulin**), but the glucose fuel trucks still cannot enter the cell because the **locks are broken** (the **receptors** are not working properly).



This is why Type II is called **"non-insulin-dependent diabetes"**; people with this kind are not dependent on taking shots of insulin for survival.

The effects on the body (thirst, excessive urination, damage to blood vessels, etc.) are the same as in Type I, but they may not be as immediately noticeable or severe because not all of the locks are broken and some trucks get into the cells.

Losing weight seems to have the effect of **fixing the locks** (reactivating or increasing the number of receptors), so if a person with Type II diabetes is overweight, this is an important part of treatment.

Some people with Type II diabetes are not overweight, however, and controlling their blood sugar problem can be more complex. It may be that this group actually has a different type of diabetes altogether, but we do not yet know enough about it to label it differently.

Exercise also helps glucose enter the cell in both Type I and Type II diabetes. For people with Type I, then, the amount and timing of exercise must be planned along with meals and insulin injections. Extra carbohydrate will be needed during exercise to avoid low blood sugar, since both insulin and exercise will be putting glucose into the cells and out of the blood.

For people with Type II diabetes, exercise has the happy result of repairing lock function, (normalizing blood sugar control), so high blood sugar can decrease as glucose can better enter the cells. Since they do not have to worry about imported keys (insulin), the problem of exercise-induced dangerously low blood sugar is not the same as in Type I.

Other differences between Type I and Type II are:

the age at which each type of diabetes typically develops
Childhood is most common for Type I; older adulthood for Type II.

the genetic pattern of inheritance
There are genetic factors in both, but they work differently.

and association with other risk factors
In Type II, a person with a genetic risk of diabetes will be more likely to develop it if overweight; there is no such pattern seen in Type I.

"Different Types of Diabetes" Mnemonic:

Here's a way to remember which type of diabetes is which . . . "**more** or less":

The "Less" Kind of Diabetes	The "More" Kind of Diabetes
Type I (one is less than two)	**Type II** (two is more than one)
insulin dependent (name has less letters)	**non-insulin dependent** (name has more letters)
usually childhood onset (age at onset is less)	**usually adult onset** (age at onset is more)
10% of people with diabetes have this kind (number who have it is less)	**90% of people with diabetes have this kind** (number who have it is more)
likely to weigh less than ideal at time of diagnosis	**likely to weigh more than ideal at time of diagnosis**
weight loss/exercise less able to correct basic metabolic problem (still can't make insulin/keys)	**weight loss/exercise more able to correct basic metabolic problem** (improves function of receptors/locks)

"Hyper/Hypo" Mnemonic

The prefixes "**hyper-**" and "**hypo-**" look close enough alike to be confusing, although their meanings are the **exact opposites** of each other.

Examples:
Hyperglycemia means "high blood sugar" and **hypo**glycemia means "low blood sugar."
Hyperactive means a "high rate of activity"; **hypo**active means a "low level of activity."
Hypertension means "high blood pressure"; **hypo**tension means "low blood pressure."

They can also mean "over" and "under", as in "**hyper**sensitive" (overly sensitive) and "**hypo**dermic" (under the skin).

You get the idea, but how can you remember which is which?

Think of the one with the R in it (hypeR) as "Raised";
Think of the one with the O (hypO) as Ø (as in zero or low)