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> Carbohydrates
> **Starch**   **Sucrose**
>   **Glucose**
> Uptake to blood   Glycemic index
>   **Blood sugar**
> **Insulin**   **Obesity**
>   Metabolic syndrom
> **Diabetes**   **Atherosclerosis**

Low CARB and GI
Prevent Obesity and Diabetes

International short version of original report in Swedish

Carbohydrates are currently recognized as the primary cause of epidemic obesity and diabetes. The great challenge is to apply biochemical knowledge to urgent preventive dietary changes.

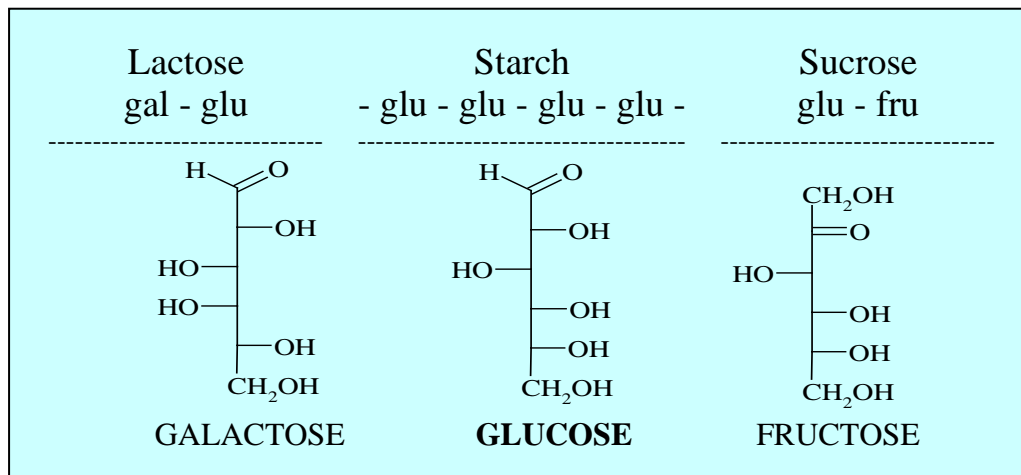Related report: Cardiovascular impact of Sugar and Fat
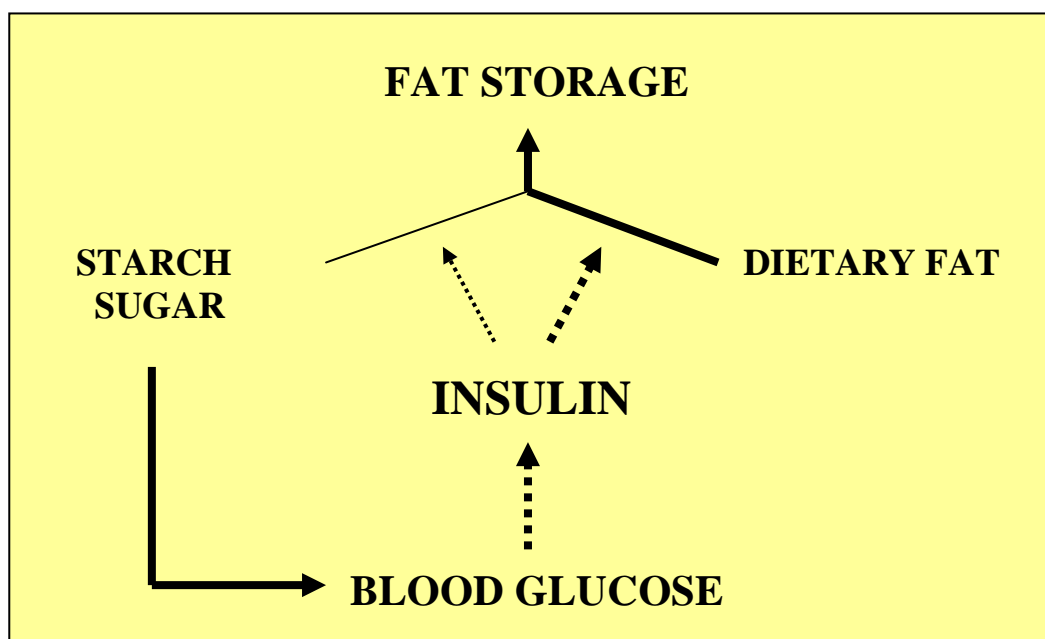
Basic Biochemistry

The major biochemical causes of excessive obesity and diabetes 2 are presently widely known. Extensive literature can be searched using the keywords on the front page. The important question now is how to convert increasingly accepted basic knowledge to sound changes of diet.

Biochemistry: Biochemical links from diet to obesity and diabetes are shown above. Dietary carbohydrates are commonly known as carbs. Rapidly digested fast carbs raise blood sugar stimulating increased secretion of insulin. Insulin promotes storage of fat. Repeated supply of fast carbs causes insulin resistance with permanently raised blood insulin and increased storage of fat. Continued abuse of fast carbs results in persistently high blood glucose defining diabetes.

Misleading dietary advice: Excess body fat normally originates mainly from dietary fat although fast carbs cause storage of the fat. Statistical studies may therefore falsely conclude that decreased intake of fat or caloric restrictions are efficient means against obesity. Resulting dietary advice has misled people and health care for decades because of ignorance of basic biochemistry.

Informed opinion: Focus on sugar and the GI concept for many years has made clear that fast carbs cause obesity and diabetes. This short review hopefully adds to an improved biochemical understanding in support of urgent action.

Lactose
gal - glu

Starch
- glu - glu - glu - glu -

Sucrose
glu - fru

```
   H   O              H   O             CH2OH
    \ //               \ //            ═ O
     ──OH               ──OH
HO──                HO──            HO──
HO──                     ──OH            ──OH
     ──OH                ──OH            ──OH
   CH2OH              CH2OH           CH2OH
 GALACTOSE          GLUCOSE          FRUCTOSE
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Sugar and Carbohydrates

Carbohydrates include monosaccharides with one, disaccharides with two and polysaccharides with several sugar units. Monosaccharides are often illustrated as non-cyclic but exist mainly as cyclic equilibrium structures. Their names may be shortened if convenient to the first three letters.

Glucose: The main sugar in metabolism and for energy supply is glucose. It is also known as grape sugar and occurs naturally in berries and fruits. In recent years, glucose produced from starch increasingly replaces ordinary sugar.

Starch: The most important dietary polysaccharide is starch. It is composed of more or less branched chains of glucose units. Digestion decomposes starch to glucose which is absorbed into the blood. The main types of starch are amylose with straight glucose chains and amylopectin with a more branched structure.

Fructose: Fructose occurs naturally in fruits and berries in varying proportions relative to glucose. Fructose and glucose are the major components in honey. Fructose has a higher sweetness than table sugar at low temperature.

Sucrose: This disaccharide is the common table sugar derived from sugar cane or sugar beet. The structure consists of a glucose unit linked to a fructose unit. Enzymatic digestion releases glucose and fructose for uptake to blood. Sucrose has a higher sweetness than glucose.

Lactose: Milk sugar or lactose is an important component in milk and many dairy products. Lactose is split by the enzyme lactase to galactose and glucose on digestion. Lack of this enzyme results in lactose intolerance.
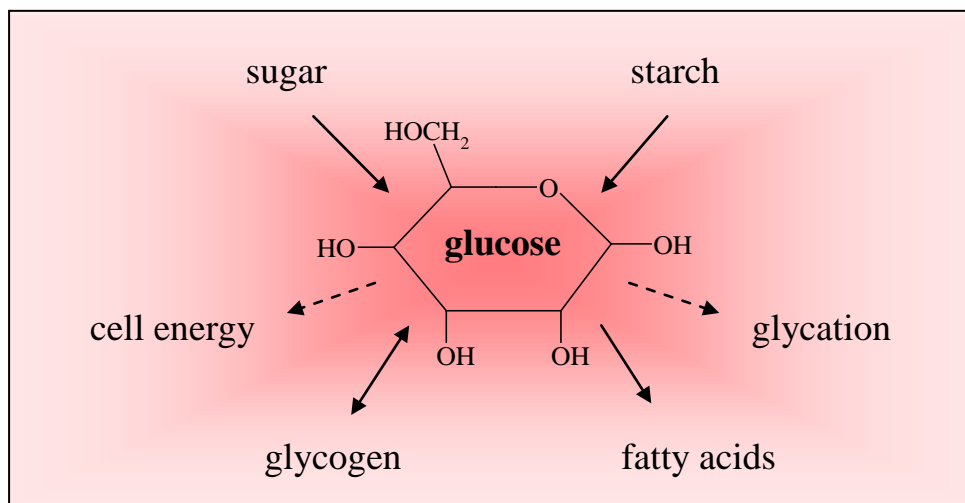
Blood sugar and Insulin

Blood glucose has a key role in the utilization of carbohydrates as an energy source. The figure shows the normal cyclic structure of glucose. Disorders related to blood glucose and its regulation by insulin cause the severe increase of several threats to health.

Glucose uptake: Starch is digested by enzymes to glucose which is absorbed through the intestinal wall and carried by blood directly to the liver. Metabolic reactions occur in the liver, but glucose bypasses into the main bloodstream. Blood glucose levels are regulated hormonally to 4-5 mmol / l, but often rise as much as 50 % within one hour after meals. Glucose is a vital source of energy for the brain. Normally the brain uses more than 100 g of glucose per day. If the need is not covered by starch and sugar from the diet, glucose can be formed from protein but also from the glycerol component of fats.

Insulin: The hormone insulin from the pancreas regulates active glucose uptake to cells via receptors on the cell surface. Approximately 2000 kcal energy as the polysaccharide glycogen can be stored in the muscles and in the liver. Excess glucose is converted to fat. Insulin increases storage of dietary fats in fat cells. Diets increasing blood glucose and insulin levels are a major cause of obesity. Elevated blood glucose also increases the destructive reactions between glucose and proteins known as glycation.

Energy: In the cell glucose can provide energy by the metabolic degradation reactions of glycolysis linked to the citric acid cycle and to the mitochondrial respiratory chain. Physical activity stimulates storage and use of glycogen and may improve regulation of blood glucose.

> **High blood glucose**
> **Insulin resistance**
> **Obesity**
> **Diabetes type 2**
> **Atherosclerosis**
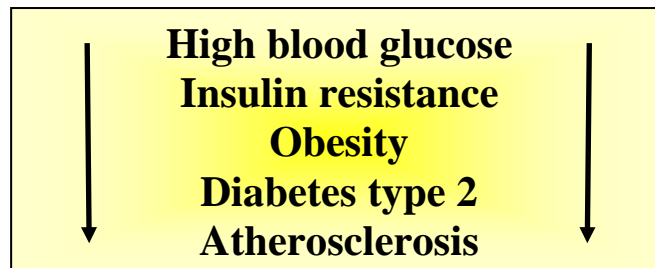
Obesity and Diabetes

Diet-dependent obesity and diabetes are emerging as major national threats to health in the U.S. followed by other parts of the world.
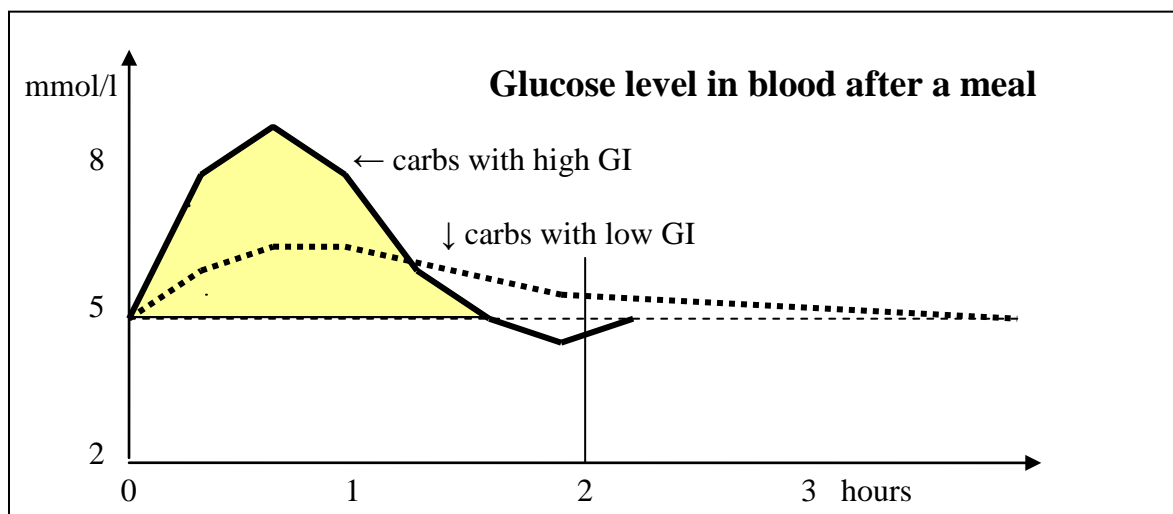
High insulin: A basic problem is elevated short-time and average insulin levels in the blood. These arise as a result of carbs that rapidly increase blood glucose. Most types of cells resist high intake of glucose from blood, and more insulin is then needed to decrease blood glucose. Conditions with elevated average insulin are termed insulin resistance.

Obesity: Body weight is often thought of as regulated by the balance between energy intake with the diet and energy consumption by the life processes and physical activity. Focus should now shift to insulin-driven obesity. High insulin levels due to fast carbs that quickly raise blood glucose levels cause continuous fat accumulation from dietary fats and to some extent from carbohydrates. The problem is almost impossible to master unless the diet is changed so that insulin levels are kept low. The basic individual and national strategy against epidemic obesity must therefore rely on a lowered intake of fast carbs.

Diabetes: A long-term high glucose load with resulting insulin resistance may also induce permanently increased concentrations of blood glucose. This defines diabetes. In the long run the strained production of insulin may decrease.

Blood glucose: Glucose levels can be measured fairly easily. Fasting values in the morning are critical. An indicator of average levels of blood glucose over about a month is HbA1c reflecting the proportion of hemoglobin glycated by reaction with glucose. Glycation also harms lipoproteins explaining why high blood glucose increases atherosclerosis and myocardial infarction.

Diet and obesity: To prevent obesity and diabetes an early removal of fast diet carbs is important. Insulin resistance causes obesity because insulin effectively stores dietary fat. Obesity itself is not a primary cause of diabetes, contrary to a popular belief.

Glucose level in blood after a meal

mmol/l

8 ← carbs with high GI

↓ carbs with low GI

5

2

0   1   2   3   hours

GI as Glucose Index

The effect of specific foods on blood glucose levels can be measured providing an index known as GI. All values of GI should be related to equal amounts of different foods. Unfortunately, the old concept denoted glycemic index must be recalculated to obtain such useful GI values.

Diagram: The solid curve shows how blood glucose typically rises after intake of sugar, bread and other foods that easily produce glucose. The increased level of glucose stimulates release of insulin that rapidly lowers glucose down to or below normal levels. The dotted curve shows the lower and more prolonged elevation of glucose typical of slowly digested carbohydrates.

Meaning of GI: Values of GI are based on measured blood levels of glucose during two hours after ingestion of the food to be studied. The area between the concentration curve and the base level of glucose is determined. The area for glucose (dextrose) is set to 100 as a reference.

Applications: Health problems like diabetes and obesity depend on high blood glucose and insulin levels and consequently primarily on food. A basic rule is to avoid carbohydrates with high GI. An extensive literature with GI tables is now available but condensed knowledge is often helpful.

Things to consider: A complete meal slows down digestion and lowers blood glucose response. Soft drinks and sweets between the meals are worse. Physical activity often improves the use of blood glucose for restoring glycogen. Inactive people have particular reasons to avoid foods with high GI.

GI – Index of blood glucose response
(per weight of food, index 100 for glucose)

GI (per weight) = GI (glycemic index; per 50 g of carbs) x share of carbs

Food	GI (per weight) =		GI (glyc. index)	x share of carbs
Glucose (grape sugar)	**100**		100	1.0
Sucrose (table sugar)	**70**	High!	70	1.0
Fructose (fruit sugar)	**20**		20	1.0
White bread	**35**	High!	70	0.5
Wholegrain bread	**25**		60	0.4
Pasta	30		45	(0.7)
two shares of water	**10**			0.25
Rice	40		55	(0.7)
two shares of water	**15**			0.25
Oatmeal	30		60	(0.5)
two shares of water	**10**	Low!		0.2
Cornflakes	**70**	High!	85	0.8
Potato, boiled	**12**		60	0.2
Potato, baked	**25**	High!	90	0.3
French fries	**25**	High!	80	0.3
Soybeans	**2**	Low!	20	0.1
Green peas	**4**	Low!	40	0.1
Carrots	**3**	Low!	40	0.07
Banana	**12**		60	0.2
Water melon	**7**		70	0.1
Apple	**4**	Low!	40	0.1
Orange	**4**	Low!	40	0.1

- Approximate figures are given because the values are affected by the composition of the meal and a number of other factors. Concomitant intake of proteins, fats and fiber-rich, acidic, compact and other slowly digested foods lowers GI and decreases blood glucose response.

- It is important to ensure that comparisons are based on the same amount of foods. The table illustrates how old high GI values referring to *glycemic index* may mislead particularly for fruit, legumes and vegetables but also for boiled potatoes. Per weight comparisons may also take added water into account as illustrated in the table.

Avoid	*Avoid*
rapidly digested starch:	*added sugar:*
white bread	**soft drinks**
heated potato	**sweets**
sticky rice	**ice-cream**
quick pasta	**cakes**

Carbs and GI

The impact of carbs and blood glucose on health makes adequate comparisons of foods important. The GI table illustrates several aspects.

Adequate use of GI: Ingredients in foods are declared on the packages referring to 100 g. The same principle should apply to GI. Adequate comparisons of foods can then be made as illustrated for those listed in the table. Glucose with GI 100 is used as a logical reference for the impact of foods on blood glucose.

Misleading use of GI: The old concept glycemic index refers to an amount of food equivalent to 50 g of digested carbohydrates. This implicates a misleading comparison of 100 g of bread with about 500 g of apples or carrots. Tabulated data of glycemic index can be corrected for the proportion of digested carbs in the food. The correction factor is 1.0 for glucose, about 0.5 for bread and about 0.1 for apples and carrots with only about 10 % digestible carbs.

Sugar: Cane sugar, sucrose, is digested into glucose and fructose and increases blood glucose efficiently but not as much as glucose syrup with glucose only. Foods with added and often hidden sugar can provide much glucose and the content of sugar should be clearly labeled. Soft drinks with about 10 % of sugar are major dangers because they are easily consumed in high amounts.

Starch: Starch is a more complicated danger than sugar. White bread provides almost the same blood glucose response as sugar, but the amount consumed is often several times larger. Common starchy foods are rice, pasta and potatoes. The water content after cooking may be considered. Both heating and grinding facilitates the digestive release of glucose from starch.

Fruits and vegetables: For most fruits and legumes GI and the proportions of sugars and starch are low relative to the high content of many nutrients, fibers and antioxidants. These foods are normally healthy choices.