

# Carbohydrate - Glucose Metabolism

AusDBF - eLearning Modules

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# Carbohydrate - Glucose Metabolism

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Carbohydrate - Glucose Metabolism.**

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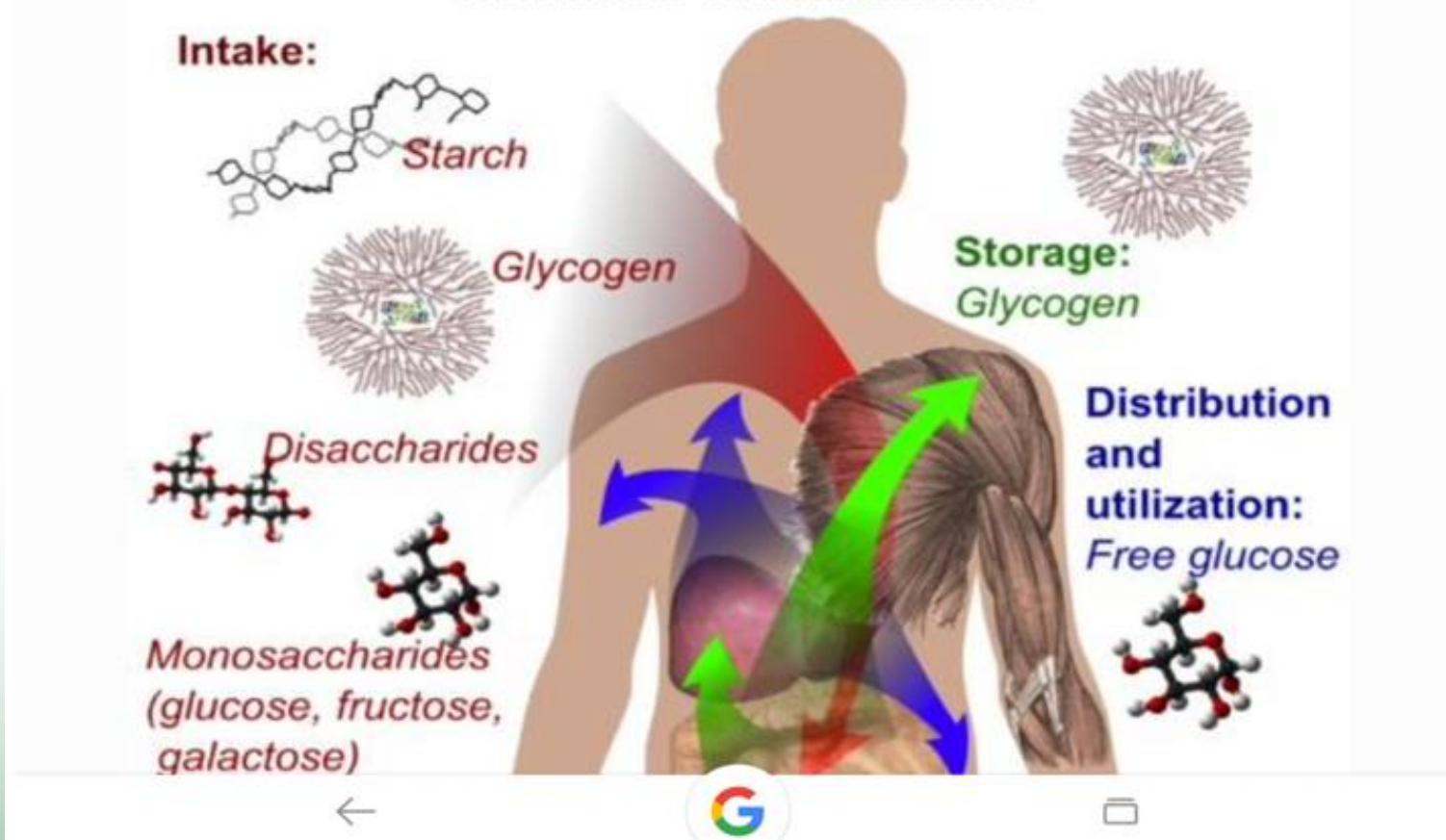
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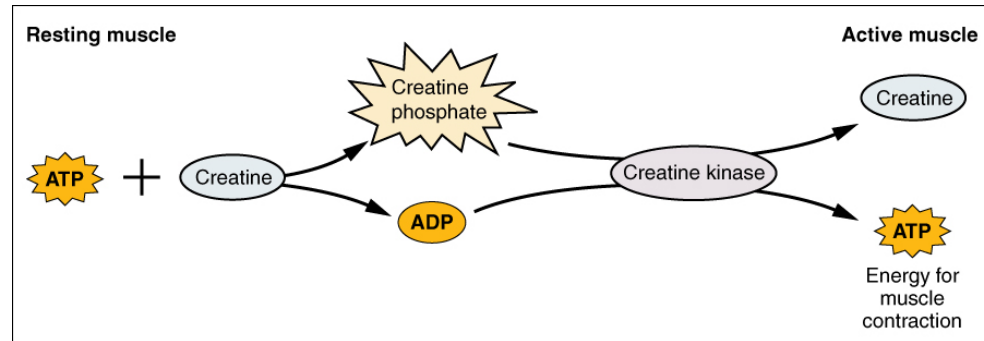
# Glucose metabolism



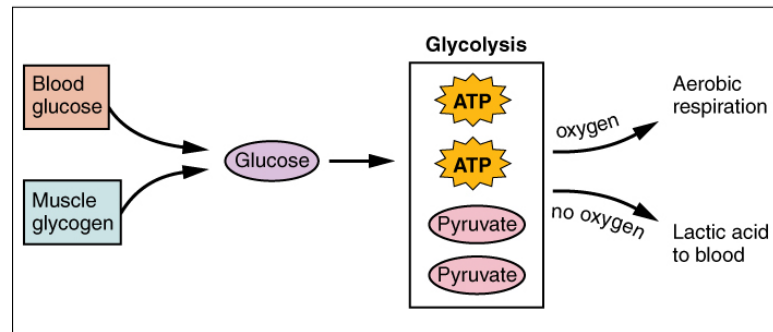
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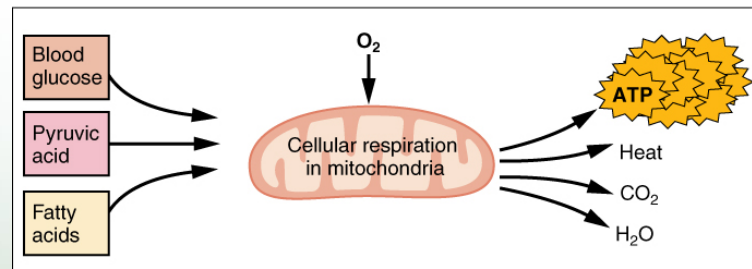
# Pathways of the three Energy Systems



(a)



(b)



(c)

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# Carbohydrate Metabolism

**Carbohydrate metabolism** includes the biochemical processes responsible for the metabolic formation, breakdown, and conversion of carbohydrates in living organisms.

As humans, we consume a variety of carbohydrates.

Digestion breaks down complex carbohydrates into a few simple monomers (monosaccharides) for metabolism:

- ✓ glucose,
- ✓ fructose
- ✓ galactose.

Glucose constitutes about 80% of these, and is the primary structure that is distributed to cells in the tissues, where it is broken down or stored as glycogen.

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# Carbohydrate Metabolism .....

In aerobic respiration, the main form of cellular respiration used by humans, glucose and oxygen are metabolised to release energy, with carbon dioxide and water as by products.

Most of the fructose and galactose travel to the liver, where they can be converted to glucose.

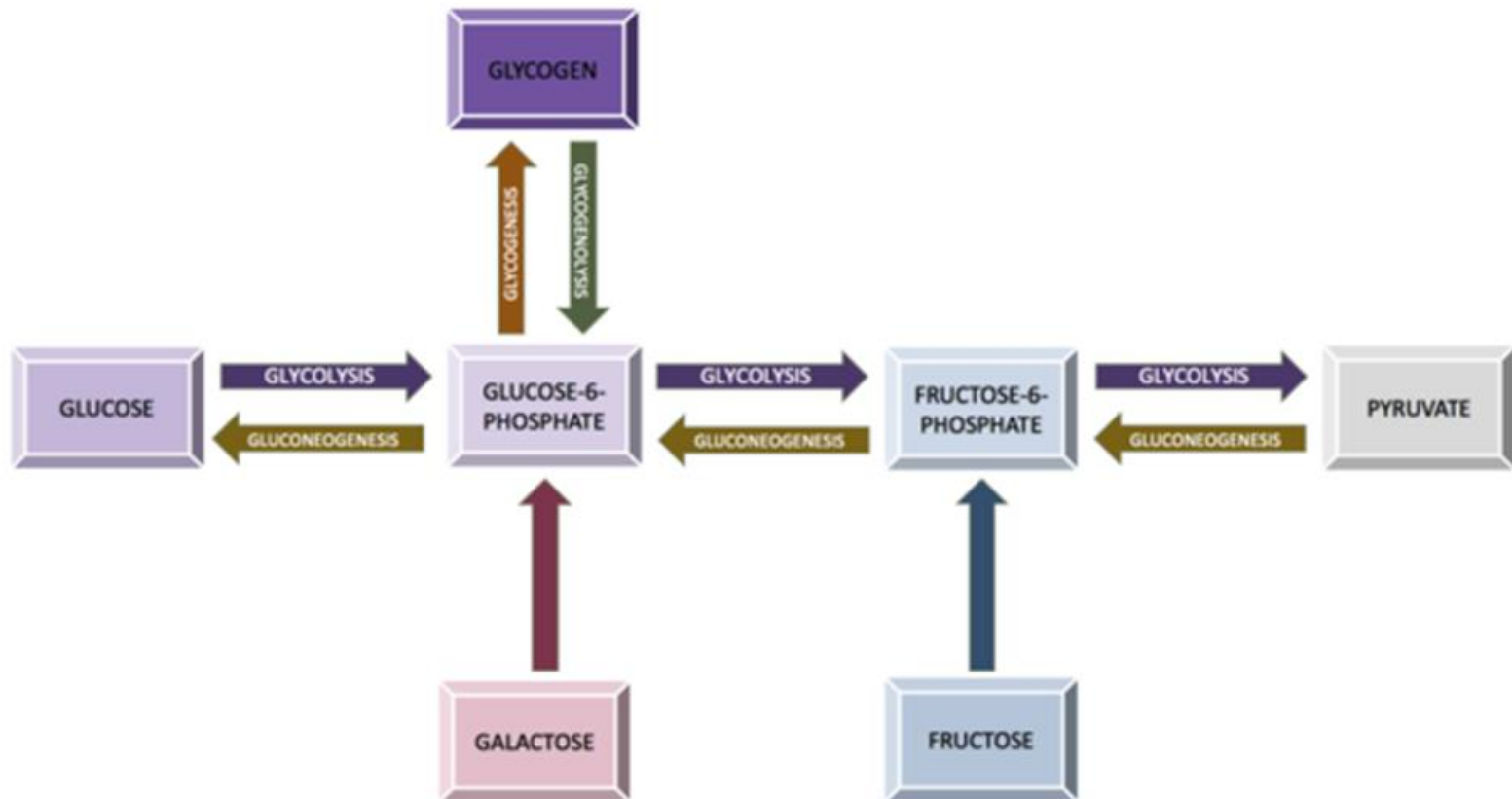
Some simple carbohydrates have their own enzymatic oxidation pathways, as do a few of the more complex carbohydrates.

The disaccharide lactose, for instance, requires the enzyme lactase to be broken into its monosaccharide components, glucose and galactose.

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# Metabolic Pathways



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# GLYCOLYSIS

**GLYCOLYSIS** is the process of breaking down a glucose molecule into two pyruvate molecules, while storing energy released during this process as ATP and NADH.

Glycolysis is commonly divided into two phases.

The **first phase** requires the breakdown of two ATP molecules.

During the **second phase**, chemical energy from the intermediates is transferred into ATP and NADH.

The breakdown of one molecule of glucose results in two molecules of pyruvate, which can be further oxidized to access more energy in later processes.

Nearly all organisms that break down glucose utilise glycolysis. Glucose regulation and use are the primary categories in which these pathways differ between organisms.

In some tissues and organisms, glycolysis is the sole method of energy production. This pathway is common to both anaerobic and aerobic respiration.

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# Glycogenolysis

**GLYCOGENOLYSIS** refers to the breakdown of glycogen.

In the liver, muscles, and the kidney, this process occurs to provide glucose when necessary.

A single glucose molecule is cleaved from a branch of glycogen, and is transformed into glucose-1-phosphate during this process.

This molecule can then be converted to glucose-6-phosphate, an intermediate in the glycolysis pathway and then progress through glycolysis.

Glycolysis only requires the input of one molecule of ATP when the glucose originates in glycogen.

Alternatively, glucose-6-phosphate can be converted back into glucose in the liver and the kidneys, allowing it to raise blood glucose levels if necessary.

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# Glycogenolysis

**GLUCAGON** in the liver stimulates glycogenolysis when the blood glucose is lowered, known as **hypoglycaemia**.

The glycogen in the liver can function as a backup source of glucose between meals.

Adrenaline stimulates the breakdown of glycogen in the skeletal muscle during exercise.

In the muscles, glycogen ensures a rapidly accessible energy source for movement.

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# Gluconeogenesis

**GLUCONEOGENESIS** - is the reverse process of glycolysis.

The liver is the primary location of gluconeogenesis, but some also occurs in the kidney

It involves the conversion of non-carbohydrate molecules into glucose.

The non-carbohydrate molecules that are converted in this pathway include pyruvate, lactate, glycerol, alanine, and glutamine.

This process occurs when there is a lowered amount of glucose.

This pathway is regulated by multiple different molecules.

Glucagon, adrenocorticotrophic hormone, and ATP encourage gluconeogenesis.

Gluconeogenesis is inhibited by AMP (adenosine monophosphate), ADP, and insulin.

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# Glycogenesis

**GLYCOGENESIS** refers to the process of synthesizing glycogen.

In humans, excess glucose is converted to glycogen via this process.

Glycogen is a highly branched structure, consisting of glucose, in the form of glucose-6-phosphate, linked together.

The branching of glycogen increases its solubility, and allows for a higher number of glucose molecules to be accessible for breakdown.

Glycogenesis occurs primarily in the liver, skeletal muscles, and kidney.

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# Pentose phosphate pathway

The pentose phosphate pathway is an alternative method of oxidizing glucose.

It occurs in the liver, adipose tissue, adrenal cortex, testis, milk glands, phagocyte cells, and red blood cells.

It produces products that are used in other cell processes, while reducing NADP to NADPH.

This pathway is regulated through changes in the activity of glucose-6-phosphate dehydrogenase

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# Fructose metabolism

Fructose must undergo certain extra steps in order to enter the glycolysis pathway.

Enzymes located in certain tissues can add a phosphate group to fructose.

This phosphorylation creates fructose-6-phosphate, an intermediate in the glycolysis pathway that can be broken down directly in those tissues.

This pathway occurs in the muscles, adipose tissue, and kidney.

In the liver, enzymes produce fructose-1-phosphate, which enters the glycolysis pathway and is later cleaved into glyceraldehyde and dihydroxyacetone phosphate

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# Galactose metabolism

Lactose, or milk sugar, consists of one molecule of glucose and one molecule of galactose.

After separation from glucose, galactose travels to the liver for conversion to glucose.

Galactokinase uses one molecule of ATP to phosphorylate galactose.

The phosphorylated galactose is then converted to glucose-1-phosphate, and then eventually glucose-6-phosphate, which can be broken down in glycolysis.

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# Energy production

Many steps of carbohydrate metabolism allow the cells to access energy and store it more transiently in ATP.

The cofactors NAD<sup>+</sup> and FAD are sometimes reduced during this process to form NADH and FADH<sub>2</sub>, which drive the creation of ATP in other processes.

A molecule of NADH can produce 1.5–2.5 molecules of ATP, whereas a molecule of FADH<sub>2</sub> yields 1.5 molecules of ATP.

**NADH** (*nicotinamide adenine dinucleotide*)

Formed when NAD<sup>+</sup> picks up Hydrogen (H)

The chemical occurs naturally in the body and plays a role in many chemical processes that generates energy.

**FAD** (*flavin adenine dinucleotide*) gets reduced to NAHD in the Krebs cycle and glycolysis.

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# Carbohydrates as storage

Carbohydrates are typically stored as long polymers of glucose molecules with glycosidic bonds for structural support (e.g. chitin, cellulose) or for energy storage (e.g. glycogen, starch).

However, the strong affinity of most carbohydrates for water makes storage of large quantities of carbohydrates inefficient due to the large molecular weight of the solvated water-carbohydrate complex.

In most organisms, excess carbohydrates are regularly catabolised to form acetyl-CoA, which is a feed stock for the fatty acid synthesis pathway; fatty acids, triglycerides, and other lipids are commonly used for long-term energy storage.

The hydrophobic character of lipids makes them a much more compact form of energy storage than hydrophilic carbohydrates.

However, animals, including humans, lack the necessary enzymatic machinery and so do not synthesize glucose from lipids (with a few exceptions, e.g. glycerol)

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## Some medical issues affected by Carbohydrate Metabolism

- Diabetes mellitus
- Lactose intolerance
- Fructose malabsorption
- Galactosemia
- Glycogen storage disease

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Please **turn up your volume** then click on the URL link below to view a short video of about Carbohydrate – Glucose Metabolism.

When the video is completed please return and go to the next slide in this presentation.

<https://youtu.be/Dtm7QmkJV9U>

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