CHAPTER-III

CARBOHYDRATE METABOLISM

GYCOLYSIS

Glycolysis (from *glycose*, an older termfor glucose + *-lysis* degradation) is the metabolic pathway that converts glucose $C_6H_{12}O_6$, into pyruvate, $CH_3COCOO^- + H^+$. The free energy released in this process is used to form the high-energy compounds ATP (adenosine triphosphate) and NADH (reduced nicotinamide adenine dinucleotide).

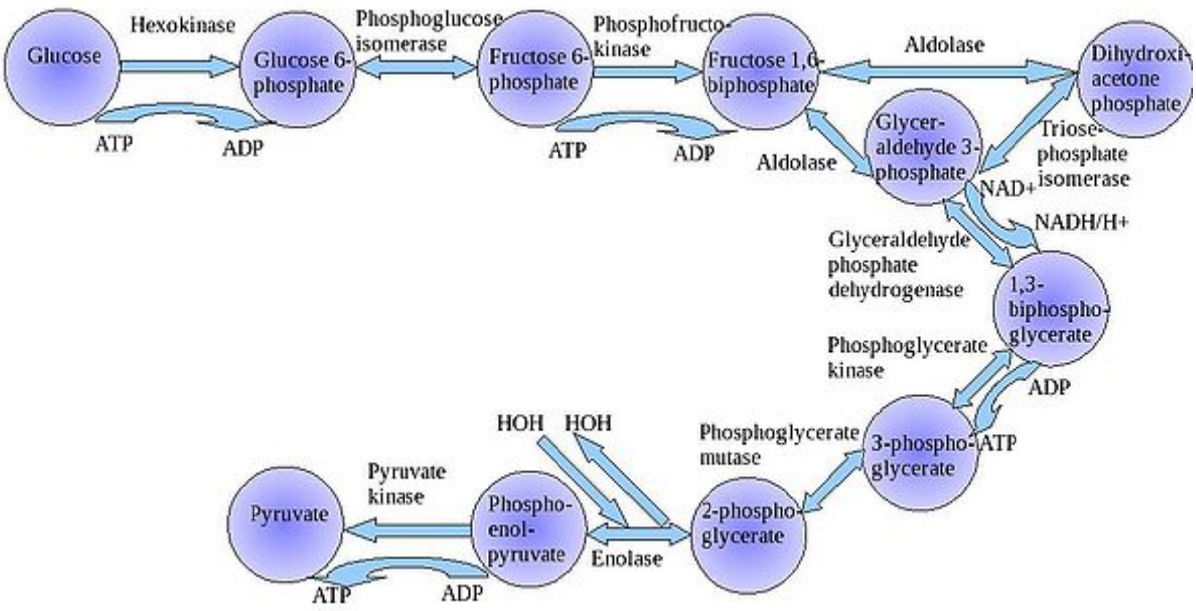
Glycolysis is a definite sequence of ten reactions involving ten intermediate compounds (one of the steps involves two intermediates). The intermediates provide entry points to glycolysis. For example, most monosaccharides, such as fructose, glucose, and galactose, can be converted to one of these intermediates. The intermediates may also be directly useful. For example, the intermediate dihydroxyacetone phosphate (DHAP) is a source of the glycerol that combines with fatty acids to form fat.

It occurs, with variations, in nearly all organisms, both aerobic and anaerobic. The wide occurrence of glycolysis indicates that it is one of the most ancient known metabolic pathways.[3] It occurs in the cytosol of the cell.

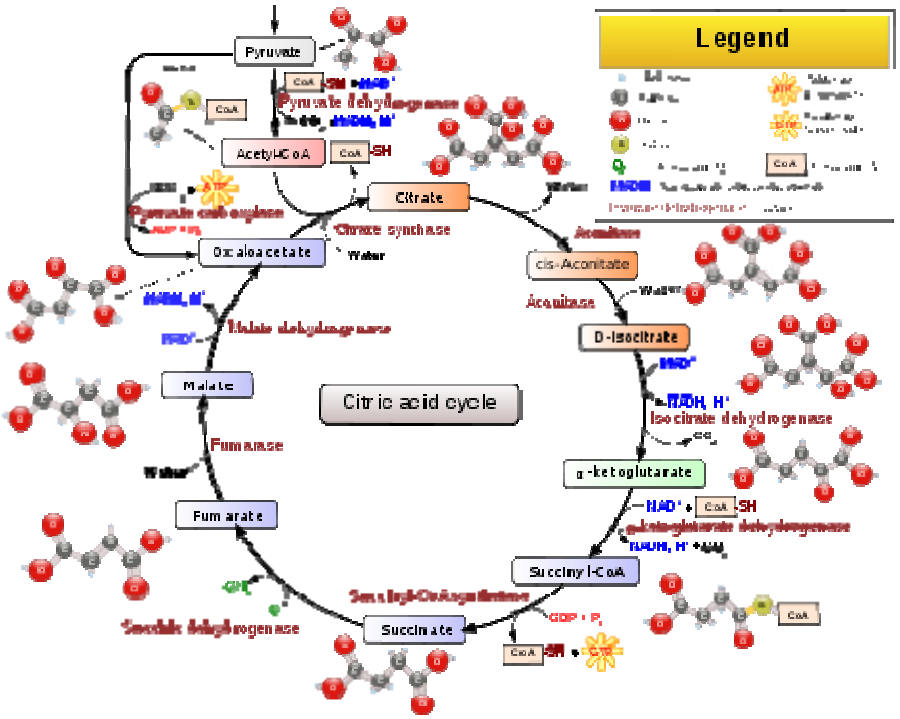
The most common type of glycolysis is the *Embden-Meyerhof pathway (EMP pathway)*, which was first discovered by Gustav Embden, Otto Meyerhof. Glycolysis also refers to other pathways, such as the *Entner–Doudoroff pathway* and various heterofermentative and homofermentative pathways. However, the discussion here will be limited to the Embden-Meyerhof pathway.

The entire glycolysis pathway can be separated into two phases:

1. The Preparatory Phase - in which ATP is consumed and is hence also known as the investment phase
2. The Pay Off Phase - in which ATP is produced.



CITRIC ACID CYCLE



Overview of the citric acid cycle

The **citric acid cycle** — also known as the **tricarboxylic acid cycle** (**TCA cycle**), the **Krebs cycle**, or the **Szent-Györgyi–Krebs cycle** — is a series of chemical reactions used by all aerobic

organisms to generate energy through the oxidization of acetate derived from carbohydrates, fats and proteins into carbon dioxide. In addition, the cycle provides precursors including certain amino acids as well as the reducing agent NADH that is used in numerous biochemical reactions. Its central importance to many biochemical pathways suggests that it was one of the earliest established components of cellular metabolism and may have originated abiogenically.

The name of this metabolic pathway is derived from citric acid (a type of tricarboxylic acid) that is first consumed and then regenerated by this sequence of reactions to complete the cycle. In addition, the cycle consumes acetate (in the form of acetyl-CoA) and water, reduces NAD^+ to NADH, and produces carbon dioxide. The NADH generated by the TCA cycle is fed into the oxidative phosphorylation pathway. The net result of these two closely linked pathways is the oxidation of nutrients to produce usable energy in the form of ATP.

In eukaryotic cells, the citric acid cycle occurs in the matrix of the mitochondrion. Bacteria also use the TCA cycle to generate energy, but since they lack mitochondria, the reaction sequence is performed in the cytosol with the proton gradient for ATP production being across the plasma membrane rather than the inner membrane of the mitochondria.

The components and reactions of the citric acid cycle were established in the 1930s by seminal work from the Nobel laureates Albert Szent-Györgyi and Hans Adolf Krebs.

Pentose phosphate pathway

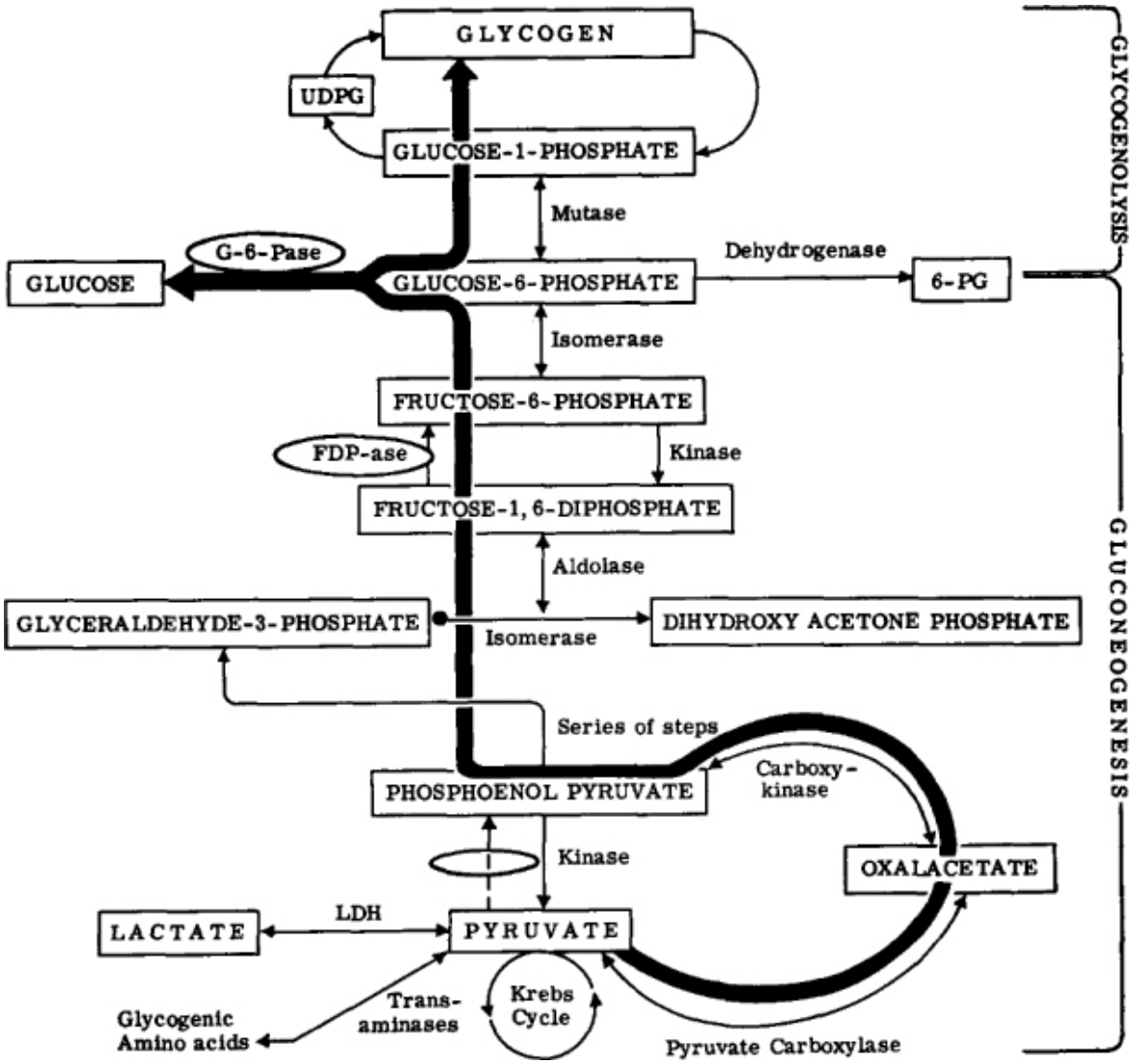
The **pentose phosphate pathway** (also called the **phosphogluconate pathway** and the **hexose monophosphate shunt**) is a process that generates NADPH and pentoses (5-carbon sugars). There are two distinct phases in the pathway. The first is the oxidative phase, in which NADPH is generated, and the second is the non-oxidative synthesis of 5-carbon sugars. This pathway is an alternative to glycolysis. While it does involve oxidation of glucose, its primary role is anabolic rather than catabolic. For most organisms, it takes place in the cytosol; in plants, most steps take place in plastids.

The primary results of the Pathway are:

- The generation of reducing equivalents, in the form of NADPH, used in reductive biosynthesis reactions within cells. (e.g. fatty acid synthesis)
- Production of ribose-5-phosphate (R5P), used in the synthesis of nucleotides and nucleic acids.
- Production of erythrose-4-phosphate (E4P), used in the synthesis of aromatic amino acids


Pentose Phosphate pathway
Glucose-6-P
Oxidative phase
NADP+
NADPH
Glucose-6-phosphate dehydrogenase
6-Phosphoglucono-lactone
H2O
H+
Gluconolactonase
6-Phosphogluconate
NADP+
NADPH
CO2
6-phosphogluconate dehydrogenase
Ribulose-5-phosphate
Non-oxidative phase
Ribulose 5 phosphate Isomerase
Ribulose 5 phosphate 3-Epimerase
Ribose-5-phosphate
Xylulose-5-phosphate
Transketolase
Glyceraldehyde 3-phosphate + Sedoheptulose 7-phosphate
Transaldolase
Fructose 6 phosphate
Erythrose 4 phosphate
Xylulose 5 phosphate
Glycolysis
Transketolase
Glyceraldehyde 3-phosphate
Fructose 6-phosphate
Glycolysis
Glycolysis

Glycogenolysis



Glycogenolysis (also known as "Glycogenlysis") is the break down of glycogen to glucose-1-phosphate and glucose. Glycogen branches are catabolized by the sequential removal of glucose monomers via phosphorolysis, by the enzyme glycogen phosphorylase.

Function

Glycogenolysis takes place in the cells of the muscle and liver tissues in response to hormonal and neural signals. In particular, glycogenolysis plays an important role in the fight-or-flight response and the regulation of glucose levels in the blood.

In myocytes (muscle cells), glycogen degradation serves to provide an immediate source of glucose-6-phosphate for glycolysis, to provide energy for muscle contraction.

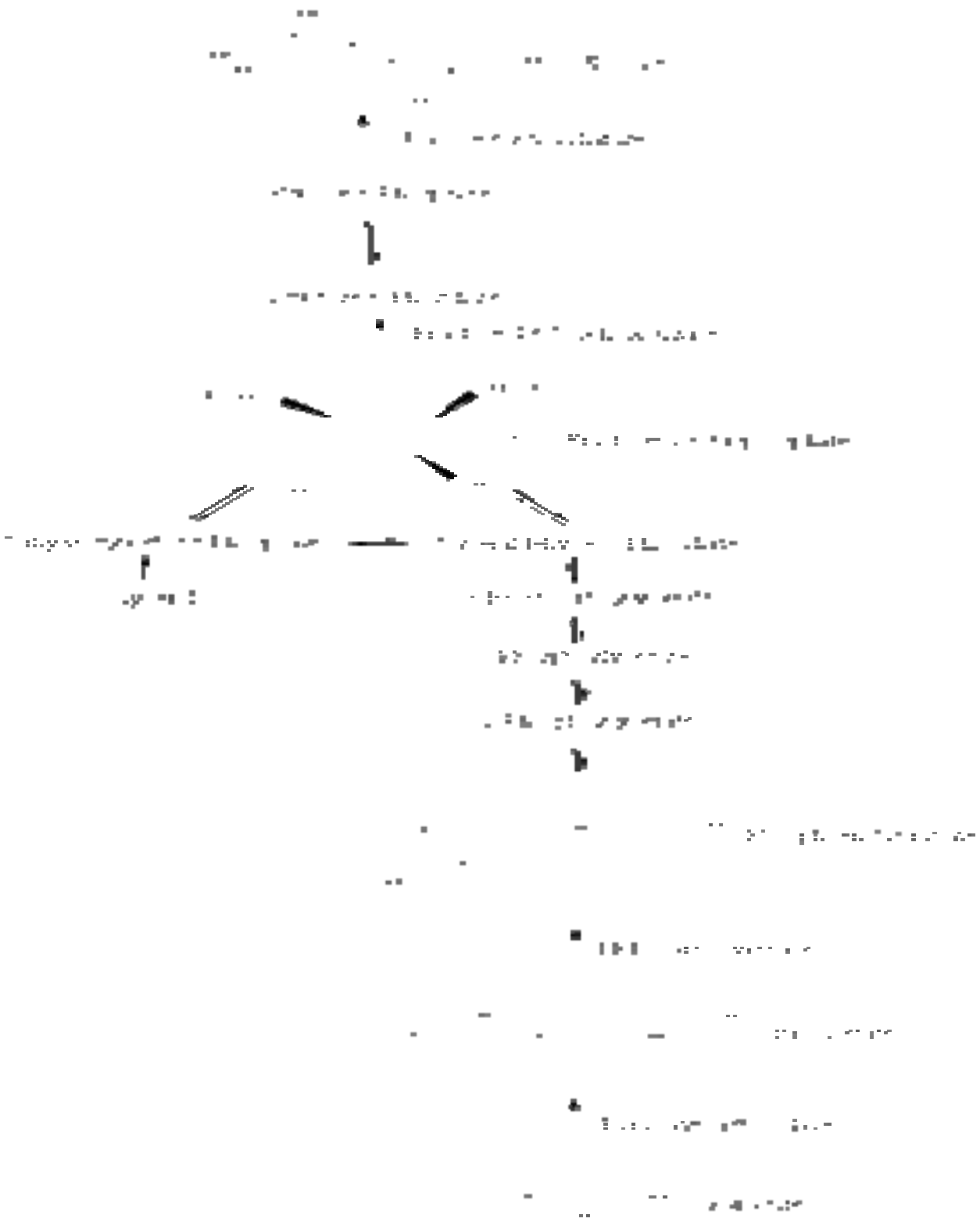
In hepatocytes (liver cells), the main purpose of the breakdown of glycogen is for the release of glucose into the bloodstream for uptake by other cells. The phosphate group of glucose-6-phosphate is removed by the enzyme glucose-6-phosphatase, which is not present in myocytes, and the free glucose exits the cell via GLUT2 facilitated diffusion channels in the hepatocyte cell membrane.

GLUCONEOGENESIS

Gluconeogenesis (abbreviated **GNG**) is a metabolic pathway that results in the generation of glucose from non-carbohydrate carbon substrates such as pyruvate, lactate, glycerol, and glucogenic amino acids.

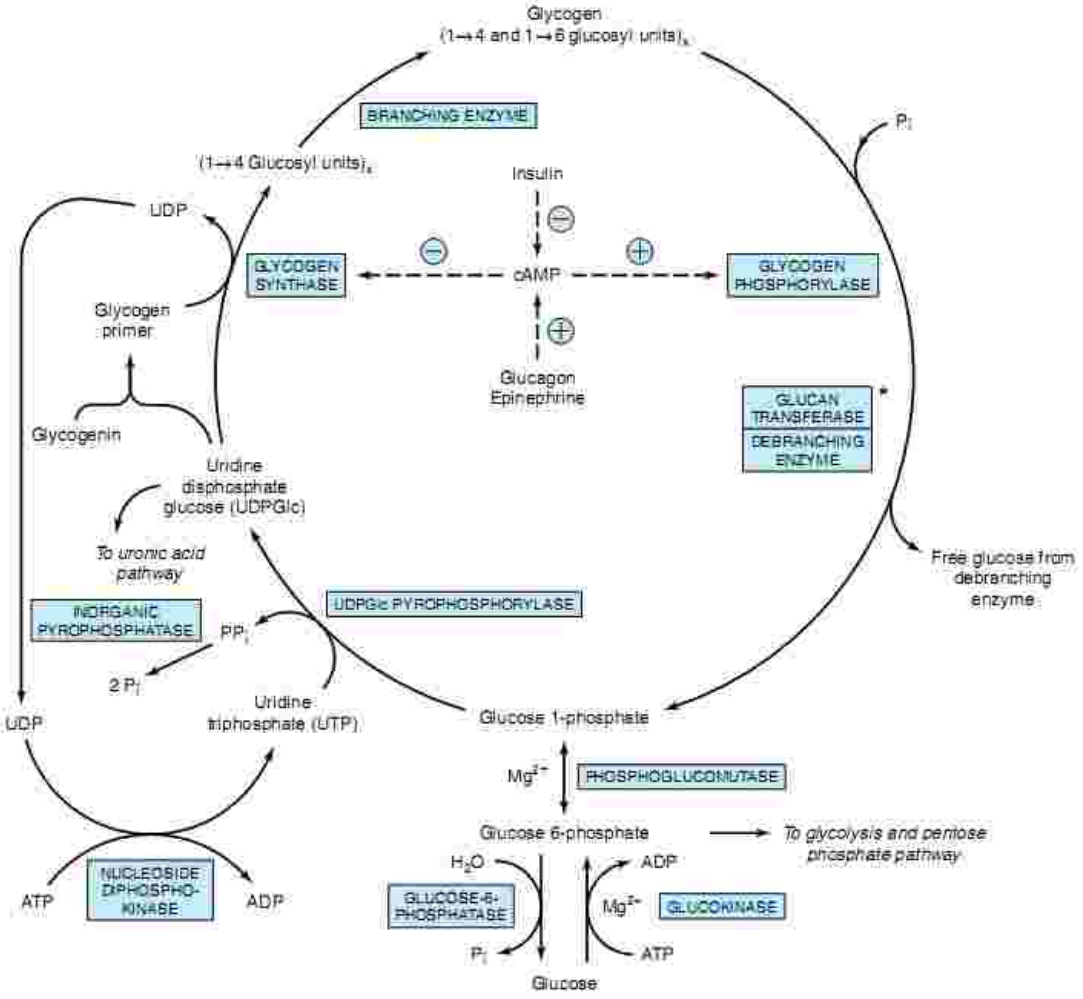
It is one of the two main mechanisms humans and many other animals use to keep blood glucose levels from dropping too low (hypoglycemia). The other means of maintaining blood glucose levels is through the degradation of glycogen (glycogenolysis).

Gluconeogenesis is a ubiquitous process, present in plants, animals, fungi, bacteria, and other microorganisms. In vertebrates, gluconeogenesis takes place mainly in the liver and, to a lesser extent, in the cortex of kidneys. In ruminants, this tends to be a continuous process. In many other animals, the process occurs during periods of fasting, starvation, low-carbohydrate diets, or intense exercise. The process is highly endergonic until ATP or GTP are utilized, effectively making the process exergonic. For example, the pathway leading from pyruvate to glucose-6-phosphate requires 4 molecules of ATP and 2 molecules of GTP. Gluconeogenesis is often associated with ketosis. Gluconeogenesis is also a target of therapy for type II diabetes, such as metformin, which inhibits glucose formation and stimulates glucose uptake by cells. In ruminants, because metabolizable dietary carbohydrates tend to be metabolized by rumen organisms, gluconeogenesis occurs regardless of fasting, low-carbohydrate diets, exercise, etc.



Glycogenesis

Glycogenesis is the process of glycogen synthesis, in which glucose molecules are added to chains of glycogen for storage. This process is activated during rest periods following the Cori cycle, in the liver, and also activated by insulin in response to high glucose levels, for example after a carbohydrate-containing meal.



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