Glycogen Metabolism

Glucose is stored in the liver and muscles as glycogen, a complex polysaccharide consisting of up to thousands of glucose subunits linked together. Glycogenesis refers to the creation of glycogen. First, glucose must first be converted into UDP-glucose. Several molecules of UDP-glucose are then attached to the core protein glycogenin, forming a glycogen primer. Glycogen synthase then adds on additional UDP-glucose subunits, elongating the glycogen chain via creation of -1,4 bonds. Branches are created along the chain by branching enzyme via -1,6 bonds. When the body requires nutrients, glycogenolysis occurs, which breaks glycogen down into free glucose. First, glycogen phosphorylase (along with vitamin B6) removes terminal glycogen residues resulting in the release of glucose-1-phosphate. When branches become too short, they are called “limit dextrins” and must instead be acted on by debranching enzyme. This enzyme facilitates release of glucose from these shortened branches.

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Glycogenesis

Glucose to UDP-Glucose

Glue-bottle to Upside-Down-Pineapple-cake Glue-bottle

Glycogenesis is the conversion of glucose to glycogen. Glucose is first acted upon by glucokinase or hexokinase (depending on the tissue) which attaches a phosphate group, forming glucose-6-phosphate. Following this, phosphoglucomutase moves the phosphate group to the 1’ position forming glucose-1-phosphate. Then, UDP-glucose pyrophosphorylase attaches a UDP group to it, forming UDP-glucose. This is a reversible reaction.

Chain Elongation

UDP-Glucose to Glycogen

Upside-Down-Pineapple-cake Glue-bottle to Glider

UDP-glucose is chained together to form glycogen. Glycogen molecules are huge branched molecules often containing upwards of 20,000 molecules of glucose. First, a small glycogen primer is formed by the enzyme glycogenin. This acts as a nidus for glucose storage. After the formation of the glycogen primer, the enzyme glycogen synthase elongates its branches. This enzyme takes the energy stored in the high-energy bond of UDP-glucose and uses it to elongate the branches. More branches can be added via the branching enzyme.

Glycogenin

Glider-generator

Glycogenin is an enzyme that converts UDP-glucose into a glycogen primer, acting as a core. It does this by attaching up to eight glucose molecules to itself. Once these eight are attached, the glycogen primer is complete and can only be elongated by glycogen synthase or branching enzyme.

Glycogen Synthase

Glider Synthase

Glycogen synthase is an enzyme that adds UDP-glucose subunits onto the growing glycogen molecule. It takes the high-energy bond in UDP-glucose and uses it to attach glucose onto an existing molecule of glycogen. It does this via the creation of -1,4 bonds.

Branching Enzyme

Branch Enzyme

Branching enzyme is an enzyme which catalyzes the addition of branches onto an existing glycogen molecule. It does this via the creation of -1,6 bonds.

Glycogenolysis

Glycogen to Glucose

Glider to Glue

Glycogenolysis is the conversion of glycogen into free glucose. When glucose is required in the body, whether it be to maintain adequate blood glucose levels or to fuel working muscles, it often comes from glycogen stores. A series of reactions are required to liberate glucose from glycogen molecules for use in glycolysis.

Glycogen Phosphorylase + Vitamin B6 Cofactor

Glider Phosphor-P-lace and Viking (B) Bee (6) Sax Crow-flagger

Glycogen phosphorylase is the first enzyme involved in glycogenolysis, and acts on the branches of glycogen. This enzyme adds a phosphate group to the glycogen branch resulting in the liberation of one glucose-1-phosphate. This enzyme requires vitamin B6 as a cofactor. This enzyme is only capable of releasing glucose from the ends of glycogen branches. Once glucose-1-phosphate is produced, phosphoglucomutase will transfer the phosphate group from the 1' position to the 6' position, setting it up to enter glycolysis.

Limit Dextrin

Limit-Desks

Once a branch of glycogen has been shortened enough so only two to four residues remain, the shortened branch is called a "limit dextrin". Glycogen phosphorylase is not capable of acting on glycogen residues in these short branches. Debranching enzyme is instead needed to break these bonds.

Debranching Enzyme

Enzyme Cutting-branches

The shortened four residue "limit dextrin" branches of glycogen are acted upon by debranching enzyme, a special enzyme with two different activities. The first debranching enzyme activity (4-a-D-glucanotransferase) moves three of the glucose subunits from the branch onto the main linkage chain of the glycogen complex. This leaves just one glucose subunit behind as a tiny 'branch', attached to the main linkage by a -1,6 bond. The second debranching enzyme activity (a-1,6-glucosidase) then liberates this remaining residue as free glucose. Deficiency of debranching enzyme is inherited in an autosomal recessive manner known as glycogen storage disease type III (Cori disease, or limit dextrinosis). Limit dextrins accumulate in tissues, especially the liver and muscles, causing damage. A small amount of glycogen is broken down within lysosomes by the enzyme alpha-1,4-glucosidase (acid maltase); a deficiency of this enzyme causes glycogen storage disease type II (Pompe disease).