Dept. of Public Health
Animal Nutrition \ **Theoretical** Assist. Lect. Chalang Madad
2nd stage.1st semester\Lecture 6

Carbohydrates Metabolism

Lactose or milk sugar

It occurs in milk only as a product of mammary gland. Cow's milk contains 4.6 to 4.8 percent lactose. It is not as soluble as sucrose and is less sweet, imparting only a faint sweet taste to milk. On hydrolysis it produces one molecule of glucose and one molecule of galactose.

Maltose or malt sugar

It is produced during the hydrolysis of starch and glycogen by dilute acids or enzymes or during the germination of barley by the action of the enzyme amylase. The barley after germination and drying is known as malt and is used in the manufacture of beer and scotch malt whisky. Maltose is water-soluble but it is not as sweet as sucrose. On hydrolysis it yields two molecules of glucose.

Cellobiose

Cellobiose does not exist naturally as a free sugar, but is the basic repeating unit of cellulose. It is less soluble and less sweet.

Starch

The reserve materials of most plants consist primarily of starch. When this is hydrolyzed with acids or enzymes, it is changed into dextrin, maltose and finally into glucose. In food this exists as a straight chain of glucose units called amylose, mixed with a branched chain structure called amylopectin.

Glycogen

The small amount of carbohydrate reserve in the liver and muscles in the form of glycogen, which is also called ''Animal starch". They form colloidal solutions, which are dextra-rotatory. Glycogen is the main carbohydrate storage product in the animal body and plays an essential role in energy metabolism.

Metabolism

A. Absorbed CH_2O (sugar) is metabolized in three fundamental ways:

1. To be used as an immediate source of energy.
2. To serve as a precursor of liver & muscle glycogen.
3. To serve as a precursor of tissue triglycerides.

B. The metabolic pathways are similar for most animals.

Glucose

1. Glycolysis occurs in the cytoplasm.
2. Phosphorylation to Glu-6-P in the liver and other cells (catalyzed by hexokinase).
3. Isomerization (isomerase), and the second ATP to form Fru-1,6-diP (PFK).
4. Form 2 pyruvate (or 2 lactate in the anaerobic pathway).
5. Pyruvate can enter "mitochondria, then Acetyl-CoA citric acid cycle.
6. Net results - Generation of high-energy bonds during the catabolism of glucose.

Galactose

1. Can be converted to glucose readily in the liver - This ability may be used as a criterion for assessing the hepatic function in the galactose tolerance test.

2. Phosphorylated to Gal-1-P (by galactokinase) in the liver.

3. Converted to Glu-1-P in the liver, which is catalyzed by galactose-1-P uridyl transferase.

- Chicks and people with congenital galactosemia lack this enzyme (also, other enzymes).

- Galactosemia - **(1)** Accumulation of Gal-1-P 6deplete liver inorganic P, **(2)** Can result in the liver failure & mental retardation, & **(3)** Only treatment is a galactose-free diet!

4. Converted to Glu-6-P, and follows oxidative pathways or converted to glucose (by Glu-6-P-tase) in the liver.

Fructose

1. May be phosphorylated to Fru-6-P by hexokinase, but the affinity of this enzyme for fructose is very low vs glucose, ˆnot a major pathway.

2. Phosphorylated to Fru-1-P by fructokinase.

3. Split into triose sugars, and metabolized accordingly.

Conversion of Glucose to Glycogen

A. Most animals consume food in excess of their immediate needs for energy, and an excess is stored as glycogen liver or muscle.

1. Liver - Maintain blood glucose between meals.

2. Muscle - Readily available source of glucose for glycolysis within the muscle.

B. But, the energy stored as carbohydrates or glycogen is very small - e.g., in 70 kg man: Stored carbohydrates = 1,900 Kcal (350g muscle glycogen, 85g liver glycogen, and 20 g glucose in extracellular fluid ECF). vs fat = 140,000 Kcal (80-85% of body fuel supplies stored as fat & the remainder in protein).

C. Glycogenesis & glycogenolysis.

Conversion of Glucose to Fat

A. Again, the storage of sugars as glycogen is rather limited, thus the excess is transformed into fats.

B. Synthesis of fatty acids from glucose.

C. Factors affecting fatty acid synthesis:

1. Insulin: (a) can 8transport of glucose into cells, **(b)** can activate pyruvate dehydrogenase & Acetyl-CoA carboxylase, and **(c)** can inhibit lipolysis.

2. Glucagon - Can inhibit Acetyl-CoA carboxylase and lipogenesis in general.

D. Limiting step - Acetyl-CoA carboxylase, which can be inhibited by Acetyl-CoA, perhaps via negative feedback.

E. Factors affecting Acetyl-CoA.

1. Nutritional status - Inverse relationship between hepatic lipogenesis and serum fatty acids.

2. Dietary lipids can 9 lipogenesis. With > 10% dietary lipids, a little conversion of carbohydrates to fatty acids.

Source of Blood Glucose

1- From Carbohydrates of the Diet:

a. Most carbohydrates in the diet after digestion form glucose, galactose or fructose which are absorbed into the portal vein.

b. In the liver, galactose and fructose are converted to glucose.

2- From Various Glycogenic Compounds:

In the skeletal muscle, glucose is oxidized to lactic acid which is transported by blood to the liver and kidney where glucose is reformed and undergoes oxidation in the tissues via the circulation.

3- From Liver Glycogen by Glycogenosis:

Glucose is formed in the liver from glycogen by phosphorylase and de-branching enzyme and also by glucose-6-phosphatase by the effect of the hormone epinephrine and glucagon.

Glycogenesis (glycogen synthesis) formation of glycogen from glucose.

1. Glycogen is serves as an energy store primarily in muscle and liver, when glucose and ATP are present in relatively high amounts.

2. the excess of insulin promotes the glucose conversion into glycogen for storage in liver and muscle cells.

3. It is stored in the form of granules cytoplasm in the cell.

4. The concentration of glycogen in muscle is low (1-2 % fresh weight) compared to the levels stored in the . liver (up to 8% fresh weight).

5. Glycogen is an energy reserve that can be quickly mobilized to meet a sudden need for glucose.

Glycogenolysis: biochemical breakdown of glycogen to glucose.

Gluconeogenesis: is the process of producing glucose from non-carbohydrate sources.

1. 6 ATP molecules are consumed per molecule of glucose produced.

2. most reactions of the gluconeogenesis take place in the cytoplasm while two reactions occur in the mitochondria.

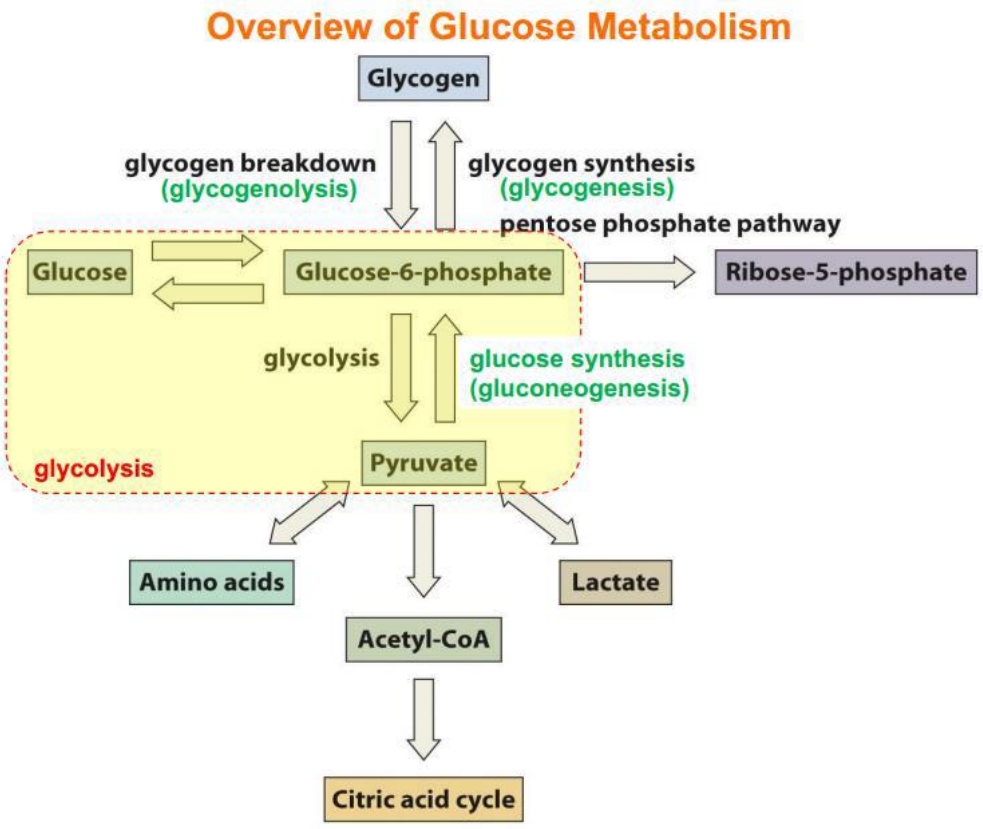
3. It mainly occurs in hepatocytes in liver.

4. The molecules that provide substrates for gluconeogenesis include proteins, lipids and pyruvate.

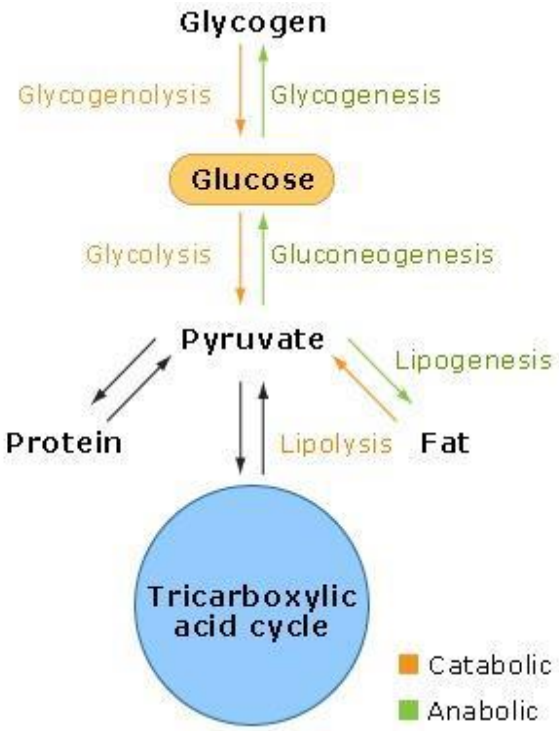
5. Muscle proteins are degraded to form amino acids, These amino acids are called ‘glucogenic amino acids.

6. Pyruvate is produced by glycolysis under anaerobic conditions.

7. glycerol produced during the hydrolysis of fat stores or ingested fats.



Glycogen breakdown



Glucose anabolism