Starvation

Starvation is defined as an absence or inadequacy of exogenous intake and may be partial or complete. The body must survive totally or in part on its internal stores. Starvation initially results in a fall in plasma glucose which triggers a decrease in insulin and an increase in glucagon secretion (a hormone that your pancreas makes to help regulate your blood glucose (sugar) levels. Glucagon increases your blood sugar level and prevents it from dropping too low, whereas insulin, another hormone, decreases blood sugar levels. This halts glycogenesis and starts the process of glycogenolysis. Glycogen is broken down to glucose-1-phosphate and then to glucose which is distributed to the organs that exclusively metabolize glucose . Glycogen storage is sufficient for 24 hours, after which other sources of energy must be utilized.

Glycogenolysis : process by which glycogen, the primary carbohydrate stored in the liver and muscle cells , is broken down into glucose to provide immediate energy and to maintain blood glucose levels during fasting .

Glycogenesis : the formation of glycogen , the primary carbohydrate stored in the liver and muscle cells from glucose . Glycogenesis takes place when blood glucose levels are sufficiently high to allow excess glucose to be stored in liver and muscle cells.

Fatty acid metabolism

Fat is stored as triglyceride in adipose tissue, each triglyceride being composed of three fatty acid chains and a glycerol molecule . Glycerol can be readily converted to DHAP for oxidation in glycolysis or synthesis of glucose in gluconeogenesis.

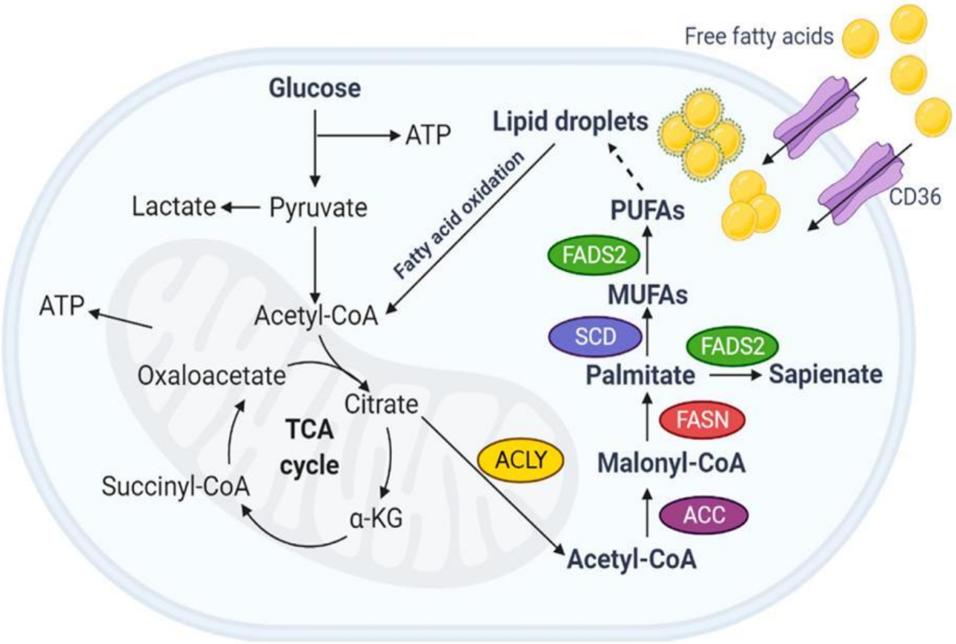
Fatty Acid Oxidation steps

Activation and Transport: In the cytoplasm, fatty acids are activated by conjugating with coenzyme A (CoA) to generate fatty acyl-CoA. Carnitine and the enzyme carnitine palmitoyltransferase I (CPT1) then help transport the fatty acyl-CoA through the mitochondrial membrane.

Beta-Oxidation Steps: Once inside the mitochondria, fatty acyl-CoA undergoes a series of four enzymatic reactions, collectively known as beta-oxidation. In each cycle of beta-oxidation, two carbon units are sequentially removed from the fatty acyl-CoA molecule. These steps include oxidation, hydration, oxidation, and thiolysis, resulting in the generation of acetyl-CoA, NADH, and FADH2.

Acetyl-CoA Utilization: Acetyl-CoA generated during beta-oxidation enters the tricarboxylic acid (TCA) cycle, also known as the Krebs cycle, where it undergoes further oxidation to produce additional NADH, FADH2, and ATP. The NADH and FADH2 molecules subsequently participate in the electron transport chain (ETC) to generate ATP through oxidative phosphorylation.

Regulation: Fatty acid oxidation is tightly regulated by various factors to ensure a balanced energy supply. The key regulatory enzyme (CPT1) , controls the entry of fatty acids into the mitochondria. Hormones such as glucagon and epinephrine stimulate fatty acid oxidation, whereas insulin inhibits it .

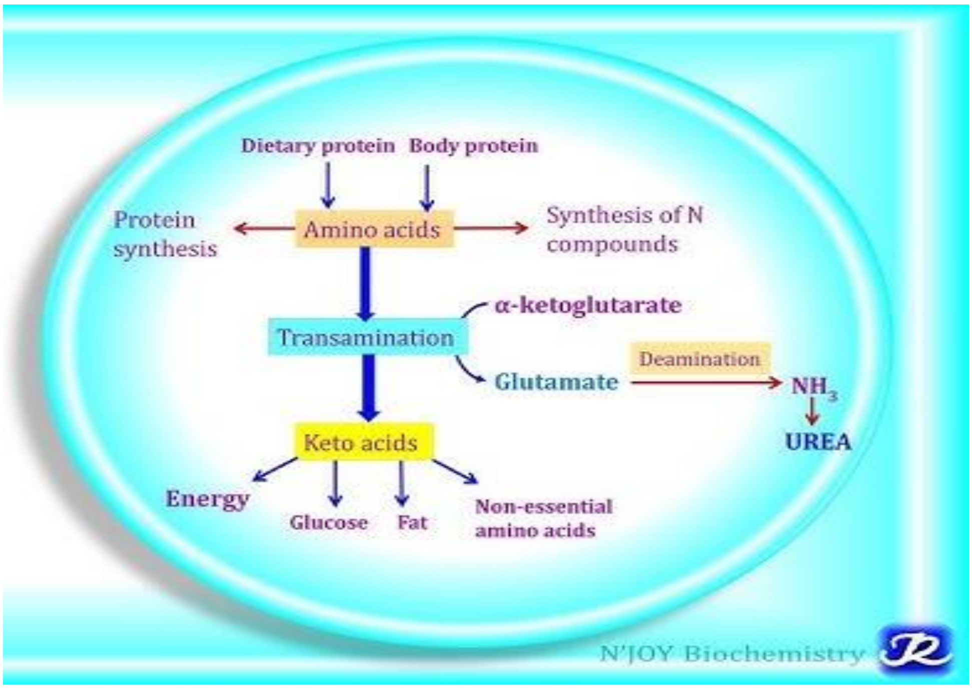


Fatty acid metabolism

Protien metabolism

Protein metabolism occurs in liver , Protein (large molecules consisting of varying combinations of amino acids linked together) is digested and broken down to amino acids which are absorbed into the circulation and taken to cells throughout the body . The liver is the primary site of all amino acid catabolism with the exception of branch-chained amino acid catabolism which occurs in the muscle cells .

They are only used as a source of energy in extreme circumstances. Amino acids consist of carbon, hydrogen, oxygen and an amine group, with some containing sulphur, phosphorous or iron atoms. Branched chain amino acids (such as valine, leucine and isoleucine) are commonly used for energy production. The amino acids undergo transamination and deamination (add or remove of amine group from the molecule to produce urea) and to form keto acids, which can then be broken down to form acetyl coenzyme A , this can be used in the citric acid cycle to produce ATP , or which can used to form glucose , fat and non-essential amino acids .



The Glyoxylate cycle :

The glyoxylate cycle is a variant of the tricarboxylic acid (TCA) cycle and is an anabolic pathway occurring in most protists, plants, bacteria and fungi. The glyoxylate cycle is assumed to be absent in animals and human tissues . The primary function of the glyoxylate cycle is to allow growth when glucose is not available and two-carbon compounds, such as ethanol and acetate, are the only sources of carbon . The glyoxylate cycle shares many metabolic enzymes with TCA cycle , including malate dehydrogenase , citrate synthase, and aconitase . The two decarboxylation steps isocitrate dehydrogenase and α-ketoglutarate dehydrogenase that involve in the TCA cycle are essentially excluded from the glyoxylate cycle. Alternatively, the glyoxylate cycle contains two additional key enzymes: isocitrate lyase and malate synthase . In brief, isocitrate lyase catalyses the breakdown of isocitrate (C_6) into glyoxylate (C_2) and succinate (C_4), Succinate continues through the remaining reactions of the CAC to produce oxaloacetate. Glyoxylate combines with another acetyl-CoA (one acetyl-CoA was used to start the cycle) to create malate (catalyzed by malate synthase). Malate can, in turn, be oxidized to oxaloacetate.

After one turn of the CAC, a single oxaloacetate is produced. Thus, in the CAC, no net production of oxaloacetate is realized. By contrast, at the end of a turn of the glyoxylate cycle, two oxaloacetates are produced, starting with one. The extra oxaloacetate can then be used to make other molecules, including glucose in gluconeogenesis.

Because animals do not run the glyoxylate cycle, they cannot produce glucose from acetyl-CoA in net amounts, but plants and bacteria can. As a result, these organisms can turn acetyl-CoA from fat into glucose, while animals can’t . Each turn of the glyoxylate cycle produces one $FADH_2$ and one NADH instead of the three NADH , one $FADH_2$ and one ATP made in each turn of the CAC.

The Glyoxylate cycle

Photosynthesis

Photosynthesis : is the process in which solar energy is trapped by chlorophyll to convert carbon dioxide and water to produce food in the form of glucose. The manufactured food is utilized for survival by plants and other living things, including humans and animals . Photosynthesis is usually used to refer to oxygenic photosynthesis and anoxygenic photosynthesis .

In oxygenic photosynthesis, H_2O serves as the electron donor to replace the reaction center electron, and oxygen is formed as a by product . In anoxygenic photosynthesis, other reduced molecules like H_2S or thiosulfate may be used as the electron donor; as such, oxygen is not formed as a by product .

OXYGENIC PHOTOSYNTHESIS
VERSUS
ANOXYGENIC PHOTOSYNTHESIS

Oxygenic photosynthesis is the photosynthesis that occurs in plants, algae, and cyanobacteria in which the final electron acceptor is water	Anoxygenic photosynthesis is a form of photosynthesis used by certain bacteria, in which oxygen is not produced
Occurs in plants, algae, and cyanobacteria	Occurs in the green sulfur and nonsulfur bacteria, purple bacteria, heliobacteria and acidobacteria
Both photosystem I and II are used	Only photosystem I is used
Water is the electron source	Hydrogen, hydrogen sulfide or ferrous ions serves as the electron donor
Oxygen is produced during the light reaction	Oxygen is not produced during the light reaction
Chlorophylls are used	Bacteriochlorophylls or chlorophylls are used
ADP serves as the terminal electron acceptor, producing NADPH	NADPH is not produced as the electrons are cycled back to the system
ATP is produced by noncyclic	ATP is produced by cyclic photophosphorylation

Light dependent reaction

Light-dependent reactions happen in the thylakoid membrane of the chloroplast and occur in the presence of sun light . Light-dependent reaction involves four important stages – absorption of light energy, splitting of water molecules, release of oxygen, and formation of energy-carrying molecules – ATP and NADPH

Light - independent reaction (calvin cycle)

The light-independent reactions (Calvin cycle) use stored chemical energy from the light-dependent reactions to fix CO_2 and create a product that can be converted into glucose. The ultimate goal of the light-independent reactions (or Calvin cycle) is to assemble a molecule of glucose Reactions of the Calvin cycle

The Calvin cycle reactions can be divided into three main stages:

1- **Carbon fixation.** A CO_2 combines with a five-carbon acceptor molecule ribulose-1,5-bisphosphate (**RuBP**). This step makes a six-carbon compound that splits into two molecules of a three-carbon compound, 3-phosphoglyceric acid (3-PGA).
2- **Reduction.** In the second stage, ATP and NADPH are used to convert the 3-PGA molecules into molecules of a three-carbon sugar, glyceraldehyde-3-phosphate (**G3P**).
3- **Regeneration.** Some G3P molecules go to make glucose, while others must be recycled to regenerate the RuBP acceptor. Regeneration requires ATP and involves a complex network of reactions

Summary of Calvin cycle reactants and products

Three turns of the Calvin cycle are needed to make one G3P molecule that can exit the cycle and go towards making glucose. Let’s summarize the quantities of key molecules that enter and exit the Calvin cycle as one net G3P is made. In three turns of the Calvin cycle:

- **Carbon.** $3CO_2$ combine with 3 RuBP acceptors, making 6 molecules of glyceraldehyde-3-phosphate (G3P).
- 1 G3P molecule exits the cycle and goes towards making glucose.
- 5 G3P molecules are recycled, regenerating 3 RuBP acceptor molecules.
- **ATP.** 9 ATP are converted to 9 ADP (6 during the fixation step , 3 during the regeneration step).
- **NADPH**. 6 NADPH are converted to 6 $NADP^+$ (during the reduction step).