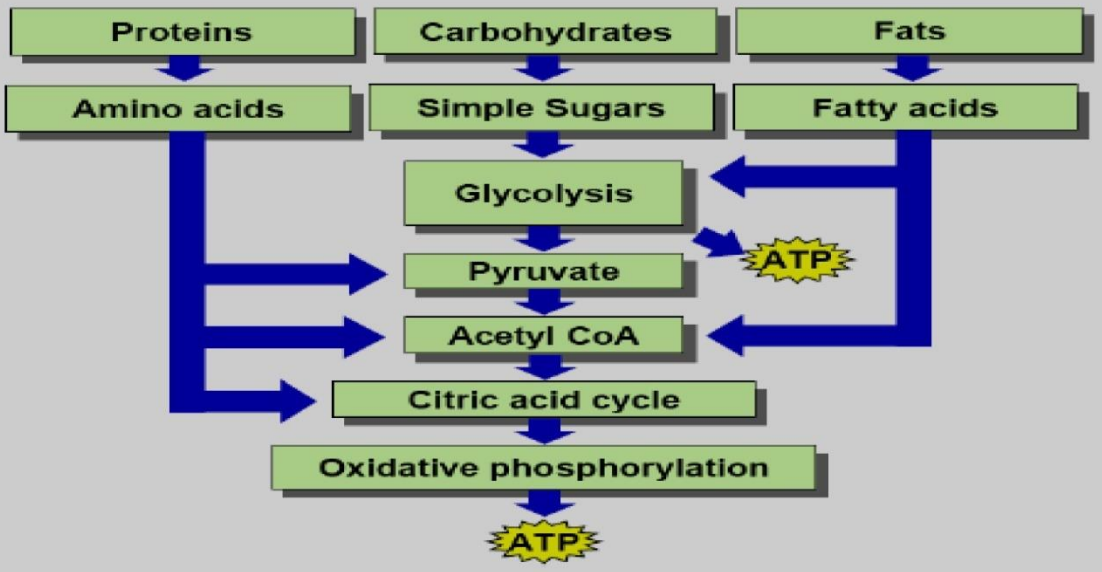
METABOLISM

What is Metabolism?

- The chemical processes that occur within a living organism in order to maintain life.
- The **liver** is the primary site for metabolism. **Liver** contains the necessary enzymes for metabolism of drugs and other xenobiotics.
- A **xenobiotic** is a chemical substance found within an organism that is not naturally produced or expected to be present within the organism
- These enzymes induce two metabolism pathways: Phase I (functional reactions) and Phase II (biosynthetic reactions) metabolism.

Energy Metabolism



Types of Metabolism

It can be divided into two types:-

- **Anabolism**: Process for union of smaller into larger molecules or metabolism of tissue formation.

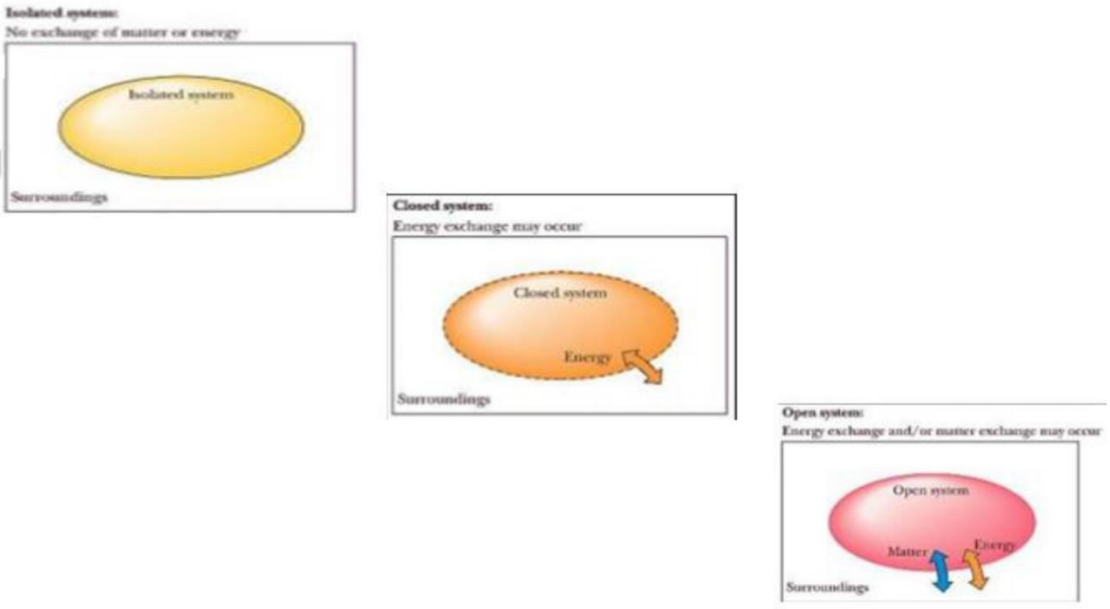
- **Catabolism**: process of tissue breakdown obviously is primarily concerned with the splitting of the larger protoplasmic molecules into the smaller ones.

Basic Thermodynamic Concept

- Thermodynamic is the flow of heat in the system.
- System:- That portion of the universe with which we are concerned.
- Surroundings:- Includes everything else in the universe.

Nature of the system

1. Isolated- cannot exchange energy or matter.
2. Closed- can exchange energy but not matter.
3. Open – can exchange energy and/or matter.



Quantities Describing Energetics of Biochemical Reaction

- Enthalpy (H):- heat content of a reacting system, which depends on the types and numbers of bonds in the reactants and products of a reaction.
- Entropy (S):- a measure of disorder or randomness in the system. It represents energy dispersion and is determined by entropies of final and initial states, not on the path followed from one state to another.
- Gibbs free energy(G):- a function that describes the amount of energy that can be used to do work in a system.

$$G = H - TS \text{ or } \Delta G = H - T\Delta S$$

+ΔG means the process is endergonic.
−ΔG means the process is exergonic.

$$aA + bB \rightleftharpoons cC + dD \quad (1)$$

$$Q' = \frac{[C]^c[D]^d}{[A]^a[B]^b} \quad (2a) \qquad K'_{eq} = \frac{[C]^c_{eq}[D]^d_{eq}}{[A]^a_{eq}[B]^b_{eq}} \quad (2b)$$

$$\Delta G' = \Delta G^{\circ\prime} + RT\ln Q' = \Delta G^{\circ\prime} + RT\ln\left(\frac{[C]^c[D]^d}{[A]^a[B]^b}\right) \quad (3)$$

At equilibrium, $\Delta G' = 0$ and $Q' = K'_{eq}$, so

$$\Delta G^{\circ\prime} = -RT\ln K'_{eq} \quad (4)$$

$$\Delta G = \Delta G^{\circ} + RT\ln\frac{[C]^c.[D]^d}{[A]^a.[B]^b}$$

- ΔG: Maximal work under these conditions
- ΔG°: Maximal work under standard conditions
- $\frac{[C]^c.[D]^d}{[A]^a.[B]^b}$: Activities defining these conditions

Laws of Thermodynamics

- **First Law** :- "The total energy of an isolated system is conserved." or in simple words we can say that "total amount of energy in the universe remains constant, although it may change from one form to other."
- **Second Law**:- "System tends to proceed from ordered (low entropy) states to disordered (high entropy) state."
- The entropy of the system and surrounding is unchanged by reversible process.
- All naturally occurring process proceed toward equilibrium.

Biological Perspective

- In living cells, thermodynamic changes are essential for biological functions such as growth, reproduction, photosynthesis and respiration.

- Light →Chemical : photosynthesis.
- Chemical →Chemical : cellular respiration.
- Chemical→ Electrical : Nervous system.
- Chemical→ Mechanical : Muscles.

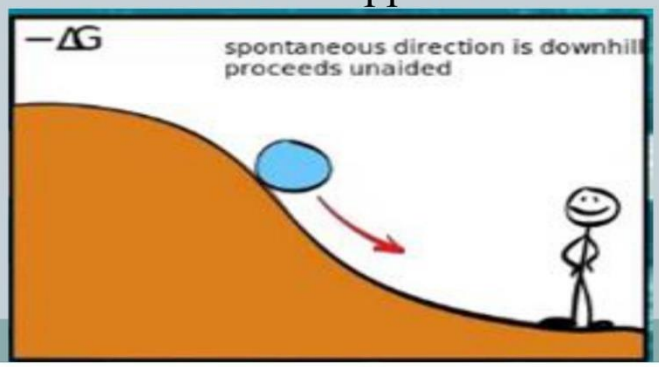
Two types of biochemical reactions

Exergonic reaction (catabolic reactions)	Endergonic reaction (Anabolic reactions)
ΔG is negative	ΔG is positive
ΔH is less than zero	ΔH is greater than zero
Increase in stability	Decrease in stability
Spontaneous	Non-spontaneous
Movement towards equilibrium	Movement away from equilibrium
Coupled to ATP formation	Coupled to ATP utilization
Catabolism	Anabolism

SPONTANEITY

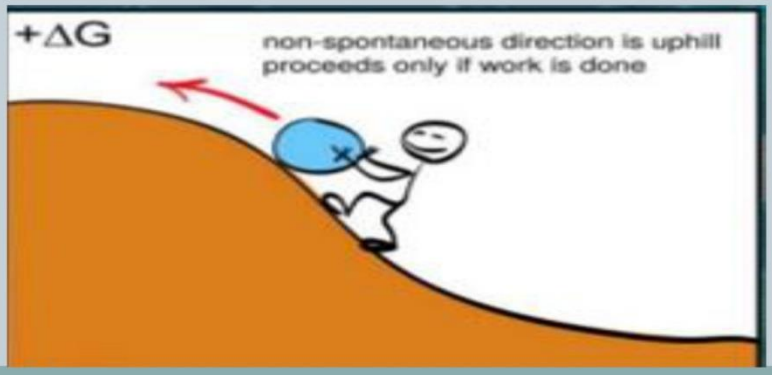
Spontaneous Reaction

- A chemical reaction which favors formation of products from the reactants, at the conditions under which reaction takes place is called spontaneous reaction.
- The tendency or phenomenon by which following process takes place is called Spontaneity.
- It is a type of process which does not need application of energy to take place.



Non Spontaneous Process

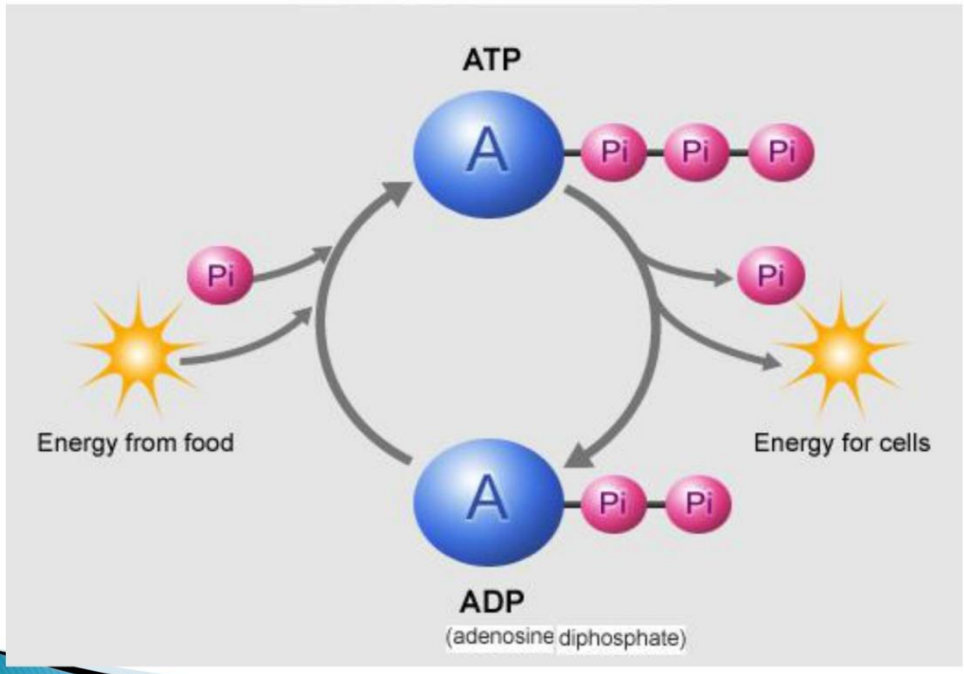
- It is a type of process which needs the use of energy to make it happen.
- It is one which occurs without outside intervention.



ATP- An Energy Currency

What is ATP energy?

- Adenosine triphosphate (**ATP**), **energy**-carrying molecule found in the cells of all living things. It captures chemical **energy** obtained from the breakdown of food molecules and releases it to fuel other cellular processes.
- Its main **role** is to provide energy. Energy released is used for metabolism in the cell.
- **ATP** is called as the **universal energy currency** because the cell stores **energy** in the form of **ATP**. It is the major molecule and all the organisms and cells utilize the **energy** in both catabolic and anabolic processes in the form of **ATP**.



Why is ATP used as energy currency?

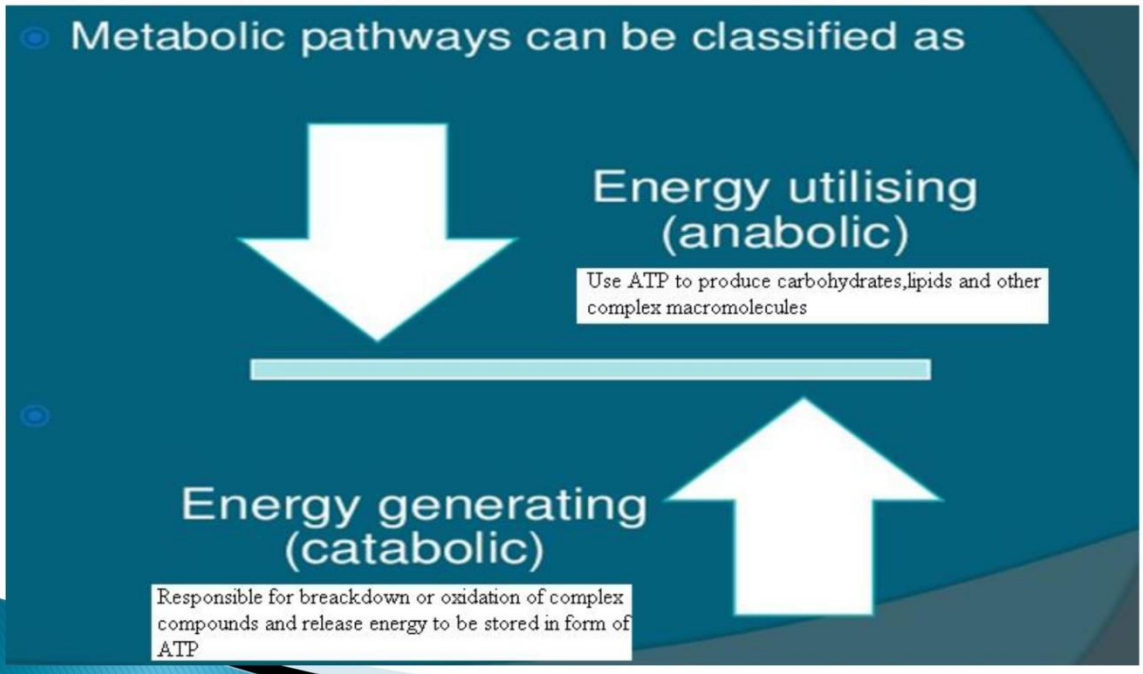
- **ATP** can be **used** to store **energy** for future reactions or be withdrawn to pay for reactions when **energy** is required by the cell.
- When one phosphate group is removed by breaking a phosphoanhydride bond in a process called hydrolysis, **energy** is released, and **ATP** is converted to adenosine diphosphate (ADP).
- Hydrolysis of one gram mole of **ATP releases** about 470 kJ of useful **energy**; hydrolysis of a single **ATP** molecule, about 10^{-19} J. A solution with a **concentration** of **1** mol/L is said to be **1 molar**, commonly designated as **1 M**.

Metabolic Pathways

What is Metabolic Pathway?

- **Metabolic pathway** is a linked series of chemical reactions occurring within a cell.
- The reactants, products, and intermediates of an enzymatic reaction are known as metabolites, which are modified by a sequence of chemical reactions catalyzed by enzymes.

Classification



What is the Difference Between Synthesis and Biosynthesis?

Synthesis	Biosynthesis
Synthesis refers to the formation of macromolecules from small molecules artificially.	Biosynthesis refers to the formation of larger organic compounds from small molecules within a living organism.
Synthesis is artificial and chemical.	Biosynthesis is biological and catalyzed by enzymes.
Polymers Synthesis can result in polymers which are organic or non-organic.	Biosynthesis is biological and catalyzed by enzymes.
Synthesis occurs outside living organisms.	Biosynthesis occurs within a living organism.

Pathways for Biological Systems

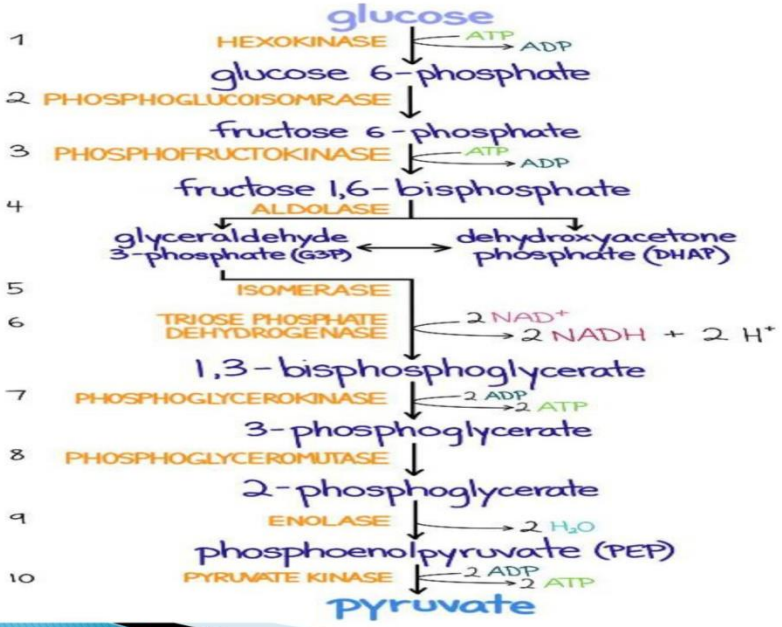
- Respiration (Oxidation or Breakdown of Glucose to Co_2 and H_2O).
- Photosynthesis (Synthesis of Glucose from Co_2 and H_2O).

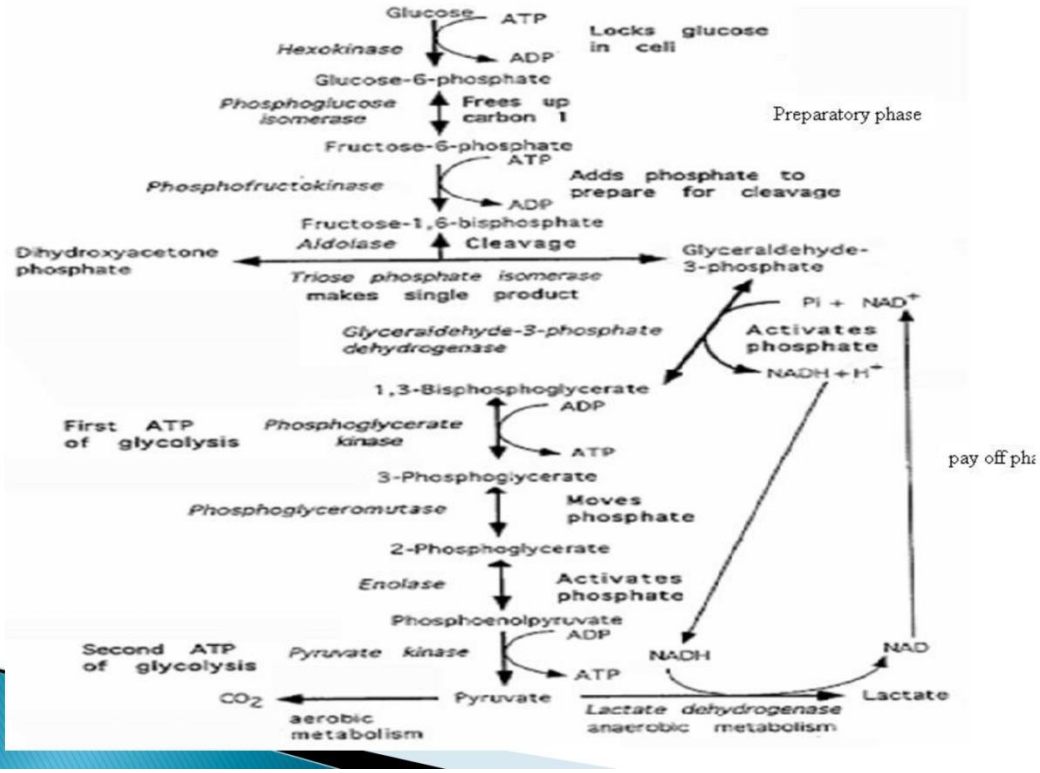
Respiration

Glucose has 3 major fates:

- Stored in form of polysaccharides.
- Oxidized to 3 carbon containing compounds (pyruvate: versatile biological molecule that consists of three carbon atoms and two functional groups - a carboxylate and a ketone group) through glycolysis.
- Oxidized to 5 carbon compound through pentose phosphate pathway.

Glycolysis Pathway

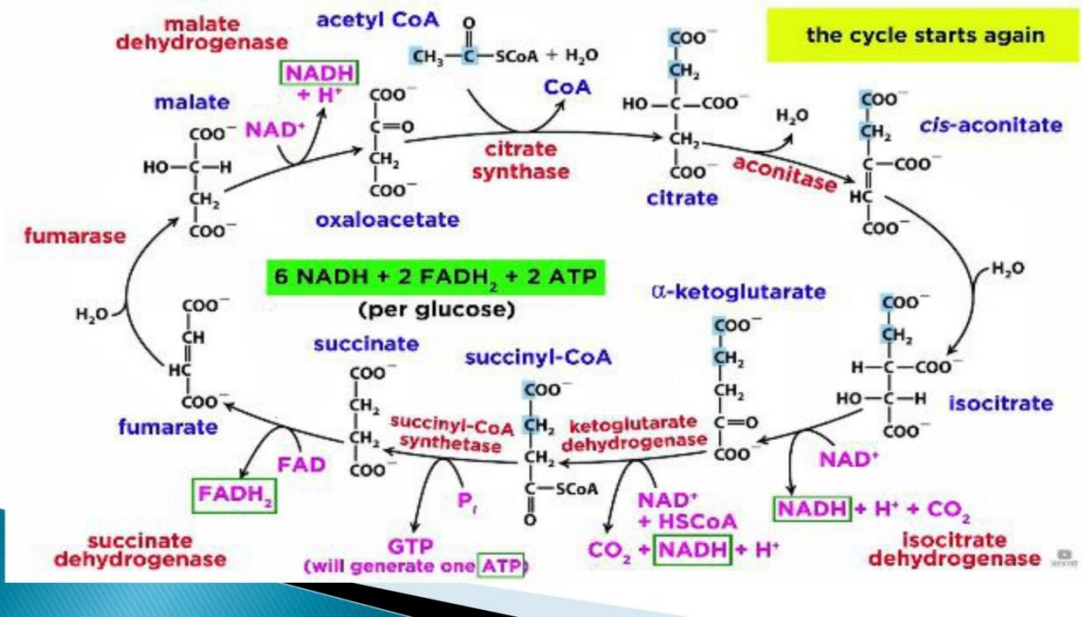




Chemical Transformation

- 6 carbon containing glucose degrades to 3 carbon containing pyruvate.
- ADP (Adenosine diphosphate) gets phosphorylated and converts into ATP with the help of high energy phosphate compounds.
- NADH (nicotinamide adenine dinucleotide(NADH). It plays a key role in energy metabolism by accepting and donating electrons. NADH contributes to oxidation in cell processes like glycolysis to help with the oxidation of **glucose)** produced by NAD due to transfer of hydrogen atoms or electrons.

Citric Acid Cycle/ Kerbs Cycle

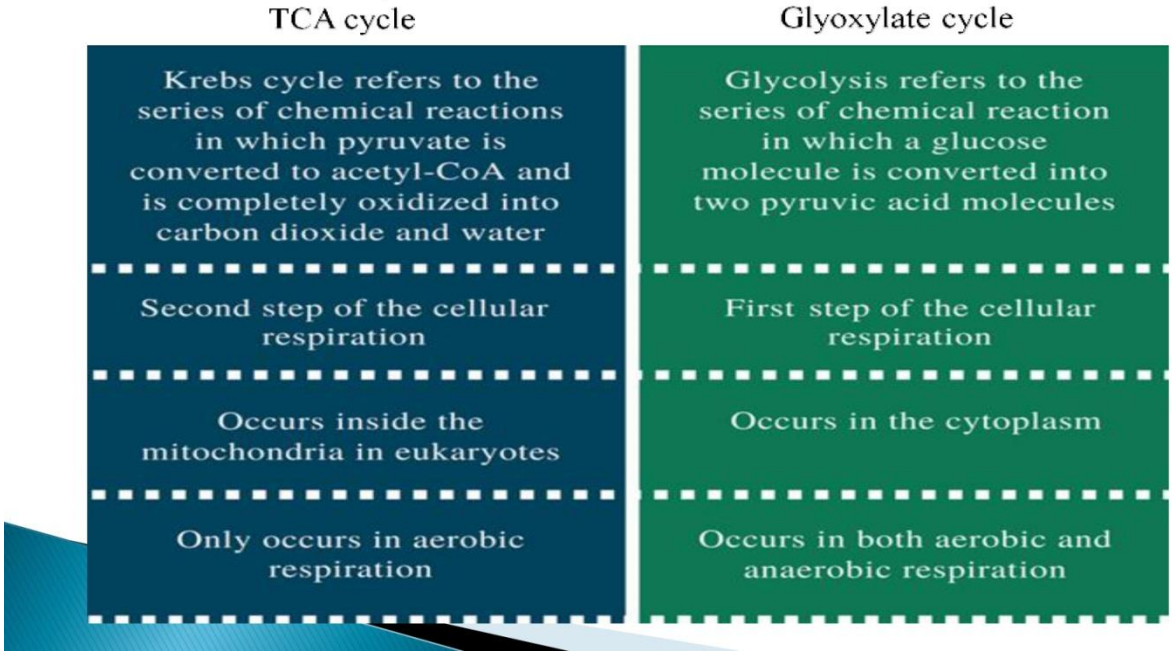


Significance of Kerbs Cycle

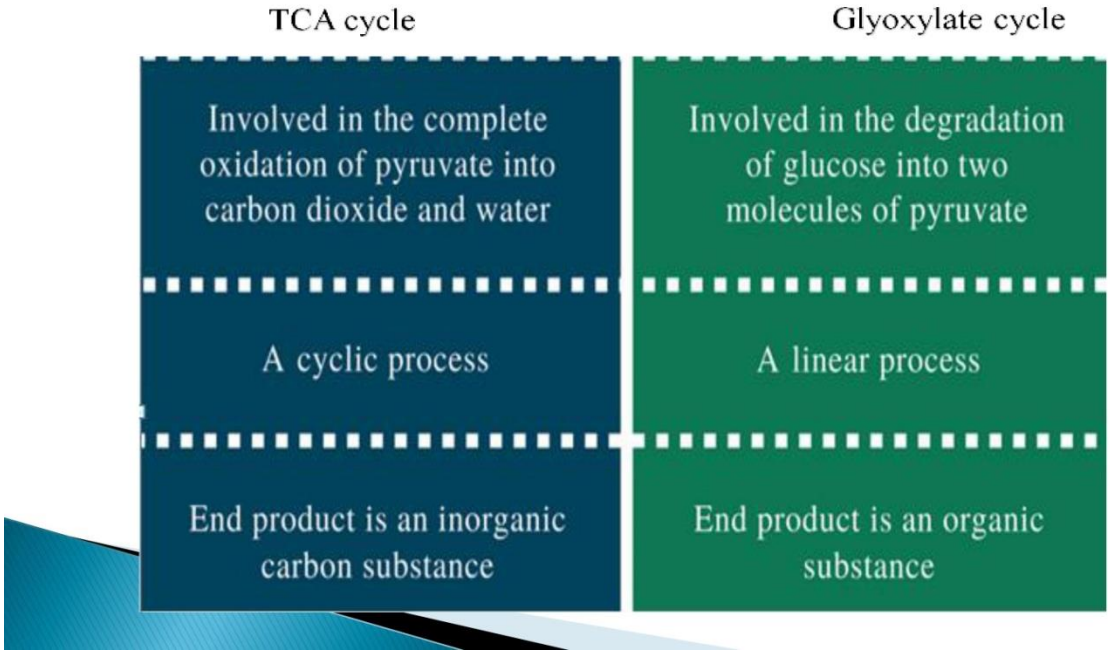
- Intermediate compounds formed during this cycle can be used for synthesis of biomolecules.
- Intermediates likes succinyl CoA (required for the synthesis of hemoglobin and other containing proteins).
- Ketoglutratic acid, pyurvic acid and oxaloacetic acid helps in formation of amino acid sequence.
- It releases plenty of energy as ATP molecule.
- Carbon Skelton formed can be used for growth and maintaining cells.

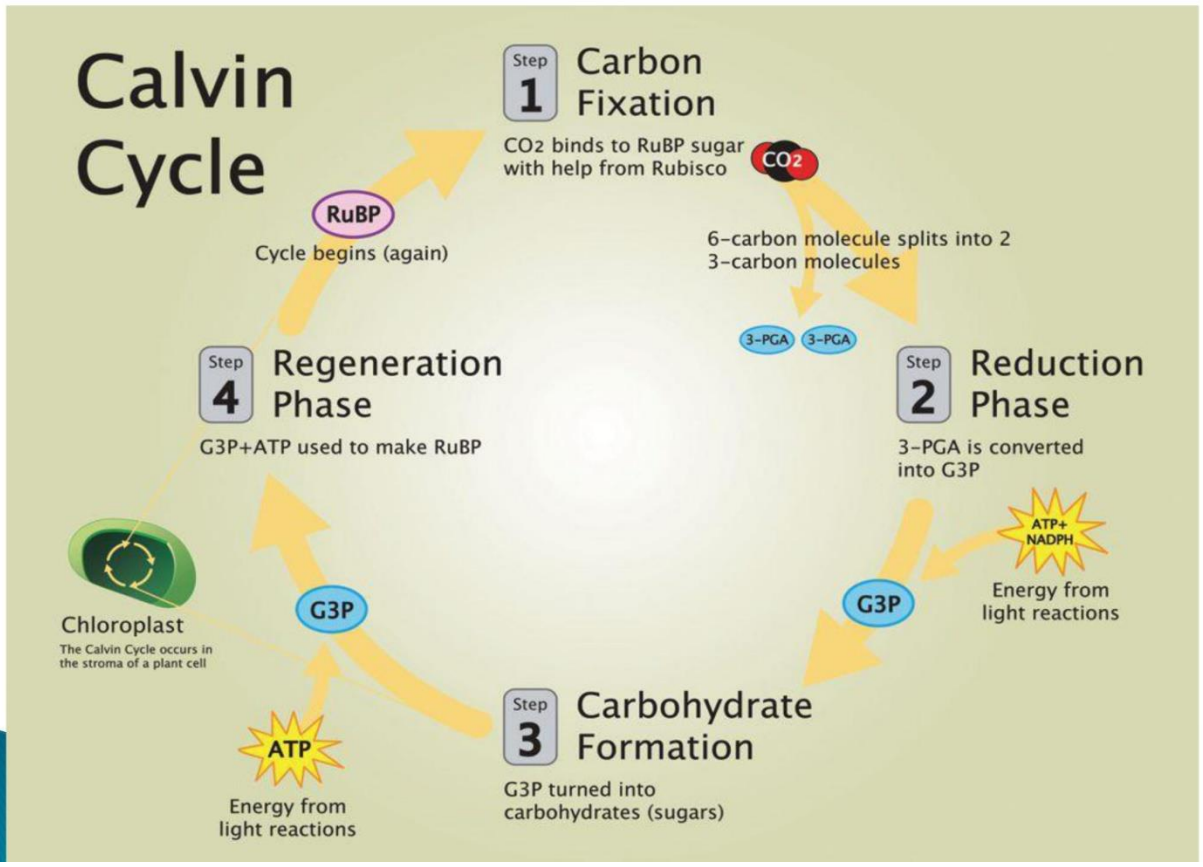
Glyoxylate Cycle

Difference between Glyoxylate cycle and TCA cycle



Difference between Glyoxylate cycle and TCA cycle





Calvin Cycle in Photosynthesis / Dark Reaction