Cellular Metabolism

Metabolic processes – all chemical reactions that occur in the body

Two types of metabolic reactions

Anabolism

- **larger molecules are made from smaller ones**
- **requires energy**

Catabolism

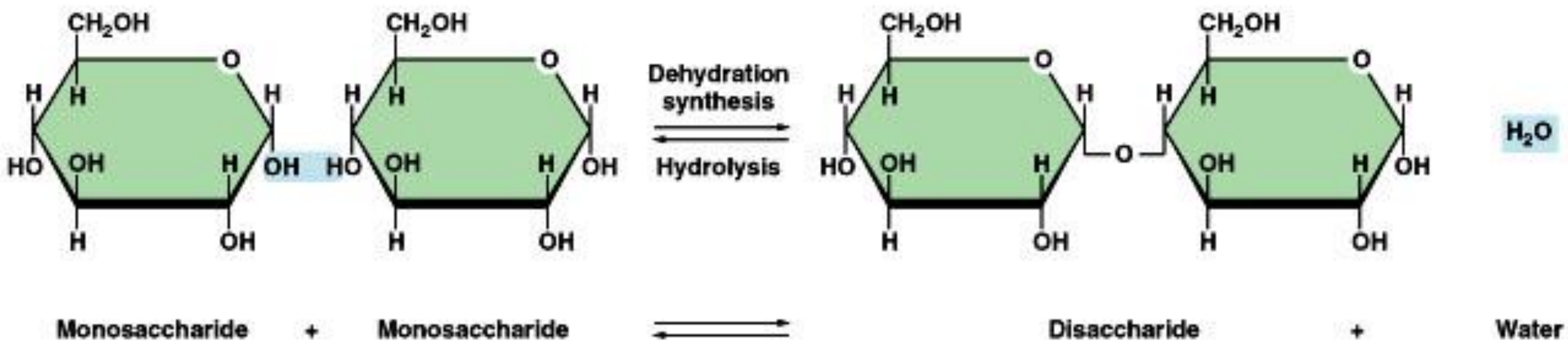
- **larger molecules are broken down into smaller ones**
- **releases energy**

Anabolism

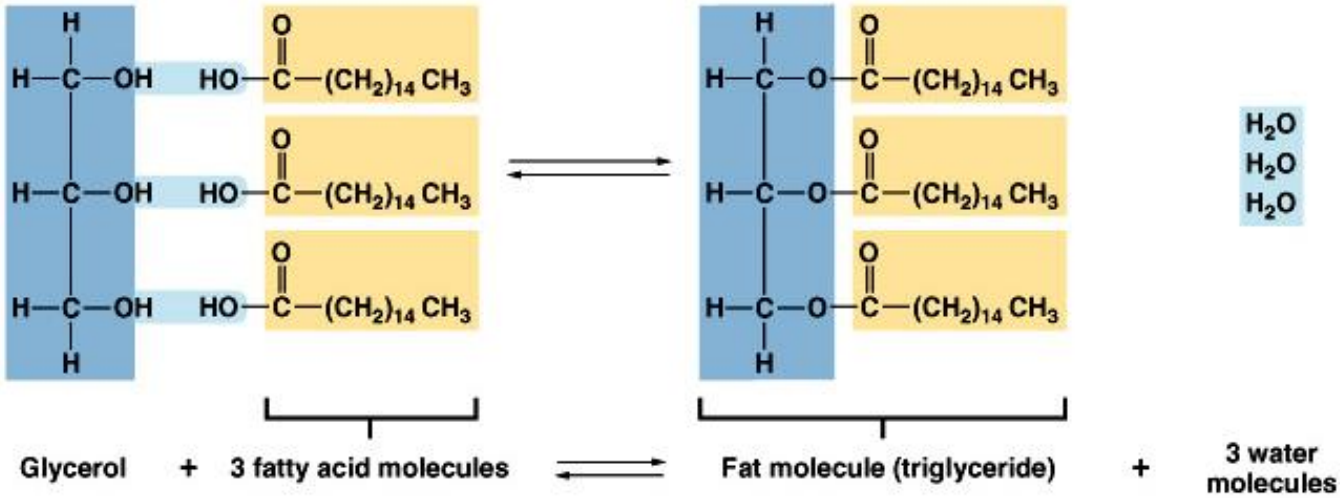
Anabolism provides the materials needed for cellular growth and repair

Dehydration synthesis

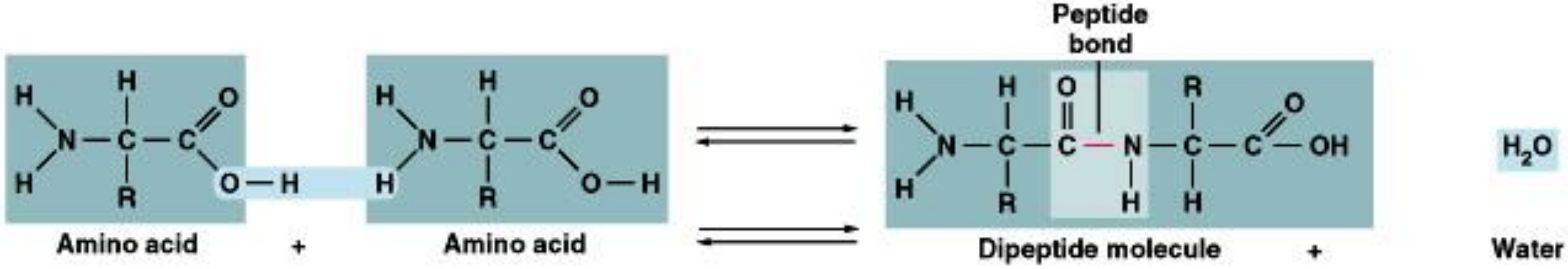
- **type of anabolic process**
- **used to make polysaccharides, triglycerides, and proteins**
- **produces water**



Anabolism



H–C–OH HO–C–(CH2)14 CH3
H2O
H2O
H2O
Glycerol + 3 fatty acid molecules ⇌ Fat molecule (triglyceride) + 3 water molecules



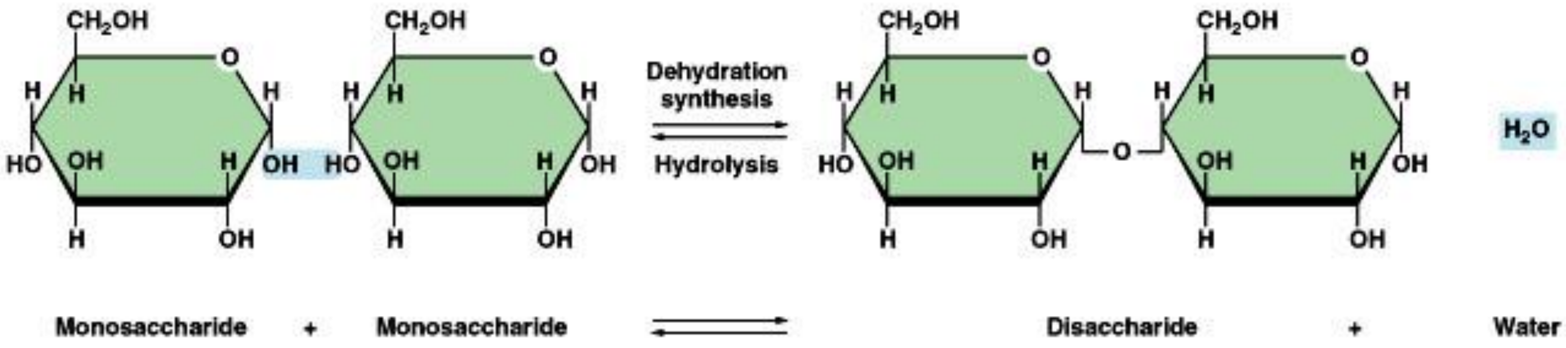
Peptide bond
H2O
Amino acid + Amino acid ⇌ Dipeptide molecule + Water

Catabolism

Catabolism breaks down larger molecules into smaller ones

Hydrolysis

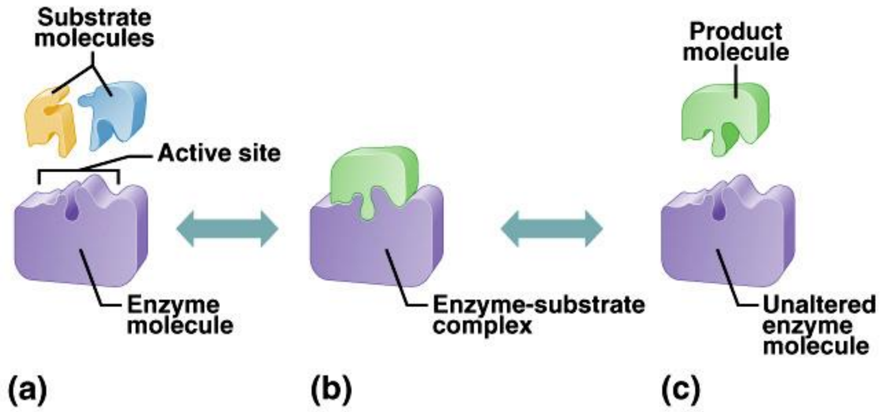
- **a catabolic process**
- **used to decompose carbohydrates, lipids, and proteins**
- **water is used to split the substances**
- **reverse of dehydration synthesis**



Control of Metabolic Reactions

Enzymes

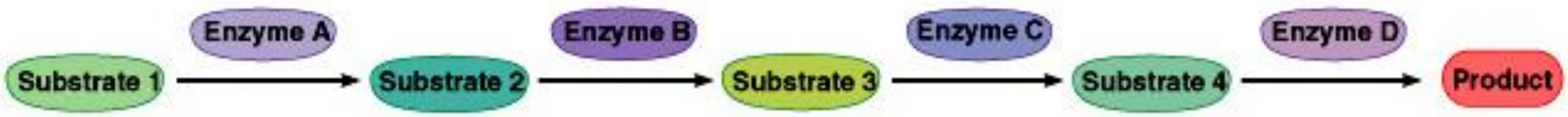
- control rates of metabolic reactions
- lower activation energy needed to start reactions
- most are globular proteins with specific shapes
- not consumed in chemical reactions
- substrate specific
- shape of active site determines substrate



Control of Metabolic Reactions

Metabolic pathways

- series of enzyme-controlled reactions leading to formation of a product
- each new substrate is the product of the previous reaction



Enzyme names commonly

- reflect the substrate
- have the suffix – ase
- sucrase, lactase, protease, lipase

Control of Metabolic Reactions

Cofactors

- make some enzymes active
- non protein component
- ions or coenzymes

Coenzymes

- organic molecules that act as cofactors
- vitamins

Factors that alter enzymes

- heat
- radiation
- electricity
- chemicals
- changes in pH

Cellular Respiration

Occurs in three series of reactions

1. **Glycolysis**
2. **Citric acid cycle**
3. **Electron transport chain**

Produces

- **carbon dioxide**
- **water**
- **ATP (chemical energy)**
- **heat**

Includes

- **anaerobic reactions (without O_2) - produce little ATP**
- **aerobic reactions (requires O_2) - produce most ATP**

Glycolysis

- series of ten reactions
- breaks down glucose into 2 pyruvic acid molecules
- occurs in cytosol
- anaerobic phase of cellular respiration
- yields two ATP molecules per glucose

Summarized by three main events

1. phosphorylation
2. splitting
3. production of NADH and ATP

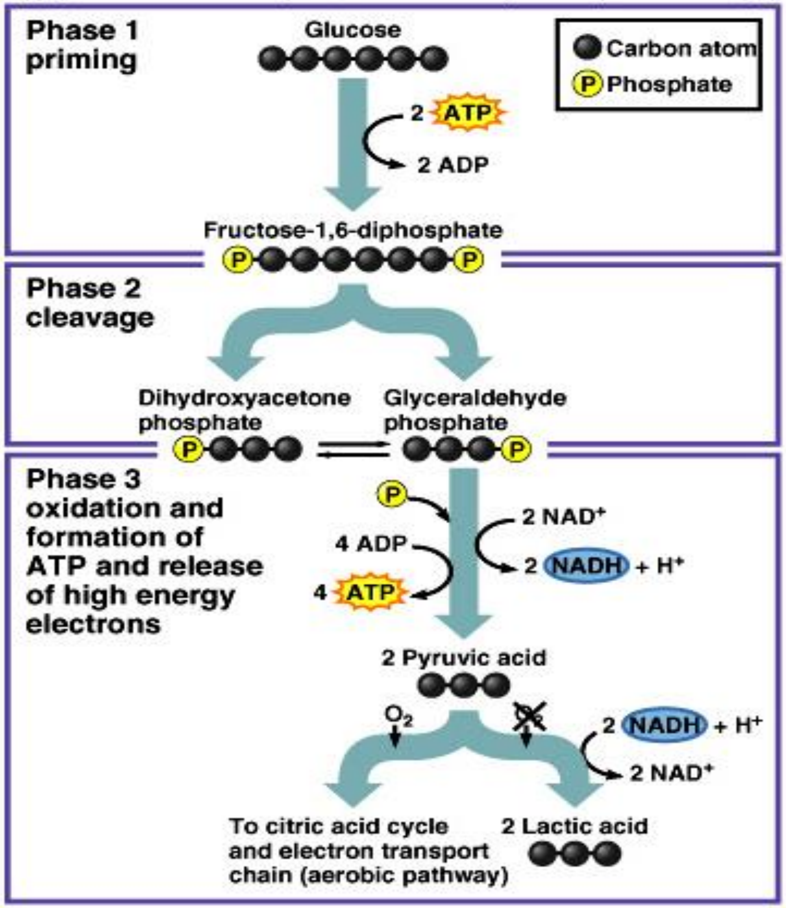
Glycolysis

Event 1 - Phosphorylation

- two phosphates added to glucose
- requires ATP

Event 2 – Splitting (cleavage)

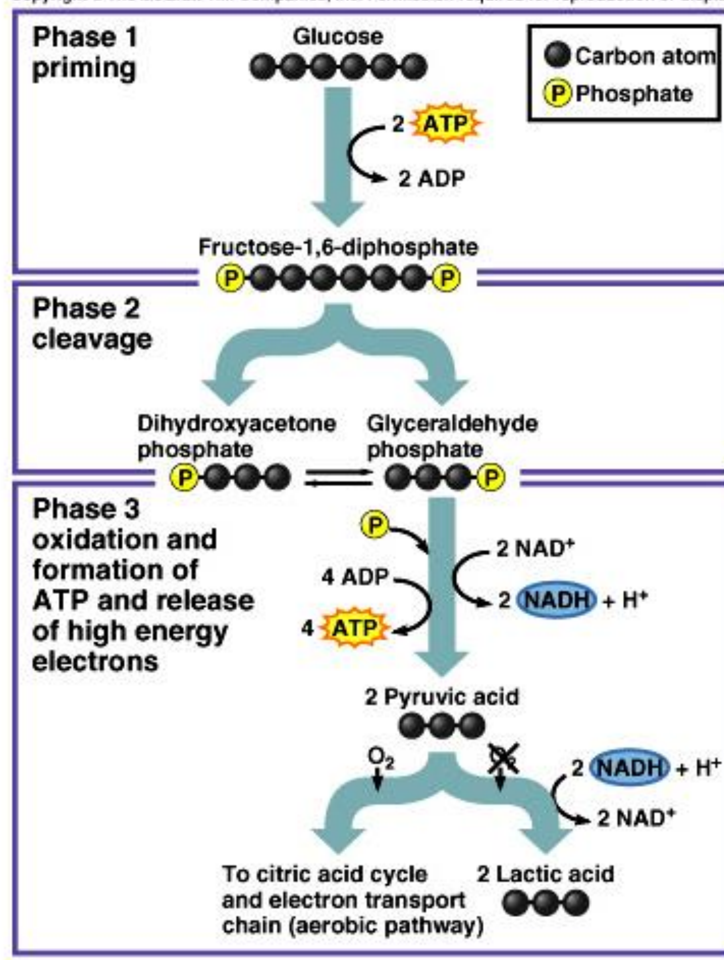
- 6-carbon glucose split into two 3-carbon molecules



Glycolysis

Event 3 – Production of NADH and ATP

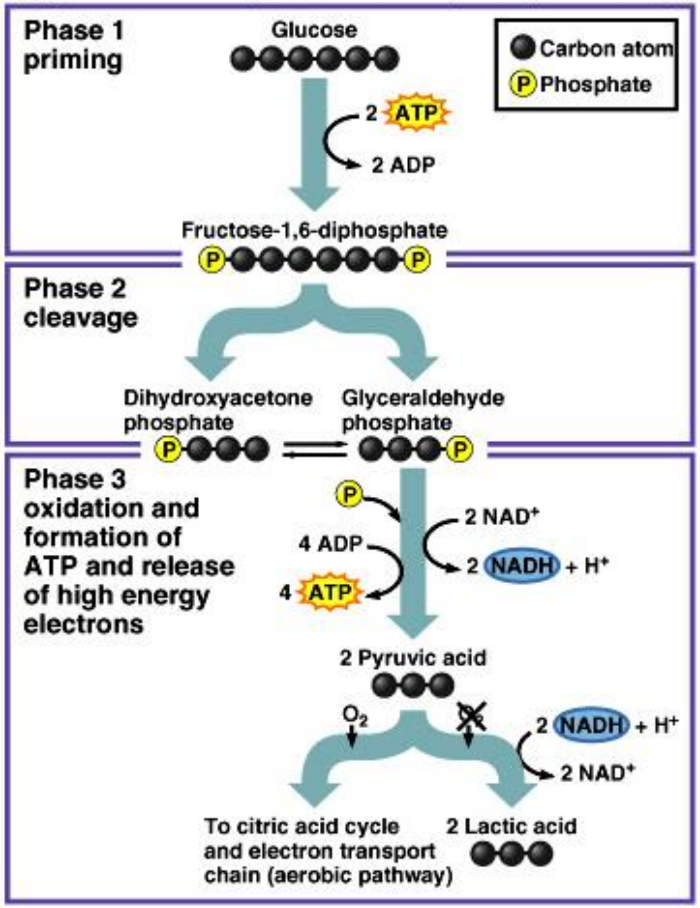
- hydrogen atoms are released
- hydrogen atoms bind to NAD^+ to produce NADH
- NADH delivers hydrogen atoms to electron transport chain if oxygen is available
- ADP is phosphorylated to become ATP
- two molecules of pyruvic acid are produced



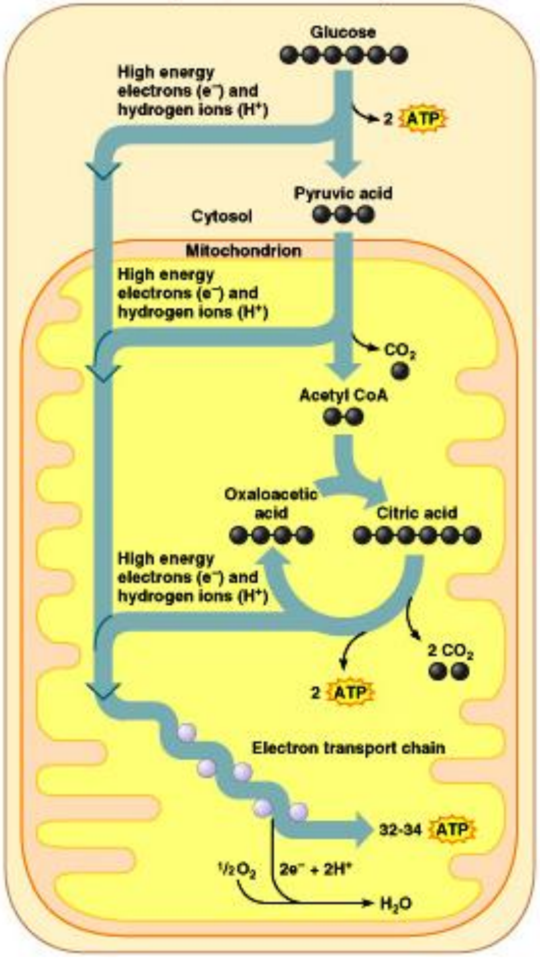
Anaerobic Reactions

If oxygen is not available -

- **electron transport chain cannot accept new electrons from NADH**
- **pyruvic acid is converted to lactic acid**
- **glycolysis is inhibited**
- **ATP production less than in aerobic reactions**



Aerobic Reactions

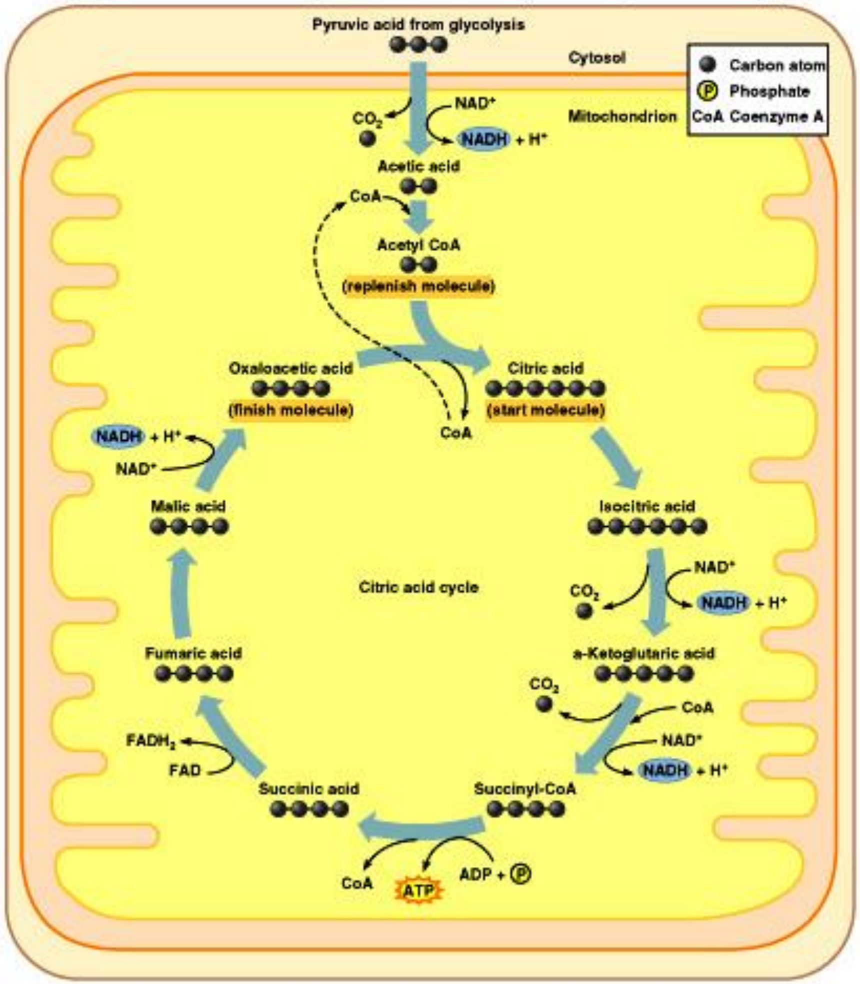


If oxygen is available –

- **pyruvic acid is used to produce acetyl CoA**
- **citric acid cycle begins**
- **electron transport chain functions**
- **carbon dioxide and water are formed**
- **36 molecules of ATP produced per glucose molecule**

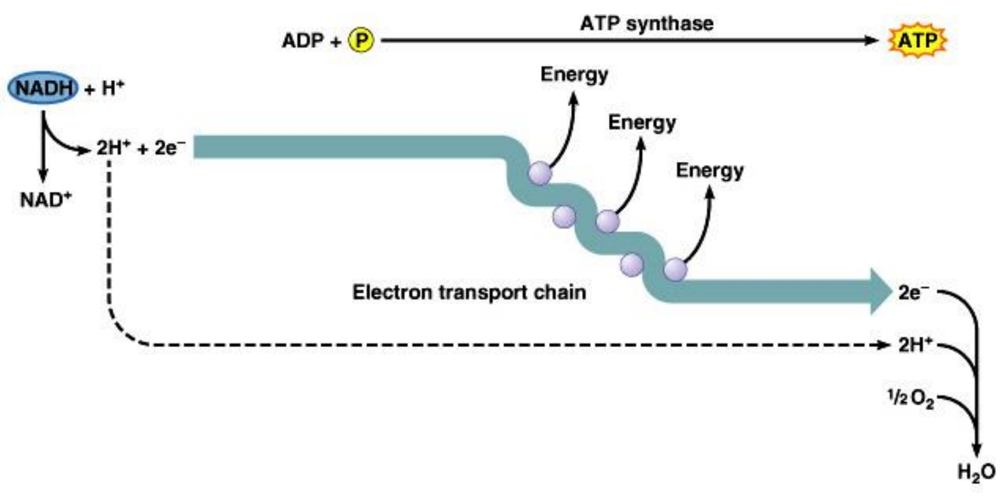
Citric Acid Cycle

- begins when acetyl CoA combines with oxaloacetic acid to produce citric acid
- citric acid is changed into oxaloacetic acid through a series of reactions
- cycle repeats as long as pyruvic acid and oxygen are available
- for each citric acid molecule:
    - one ATP is produced
    - eight hydrogen atoms are transferred to NAD^+ and FAD
    - two CO_2 produced



Electron Transport Chain

- NADH and FADH2 carry electrons to the ETC
- ETC series of electron carriers located in cristae of mitochondria
- energy from electrons transferred to ATP synthase
- ATP synthase catalyzes the phosphorylation of ADP to ATP
- water is formed



Summary of Cellular Respiration

Glycolysis

1 The 6-carbon sugar glucose is broken down into two 3-carbon pyruvic acid molecules with a net gain of 2 ATP and the release of high energy electrons.

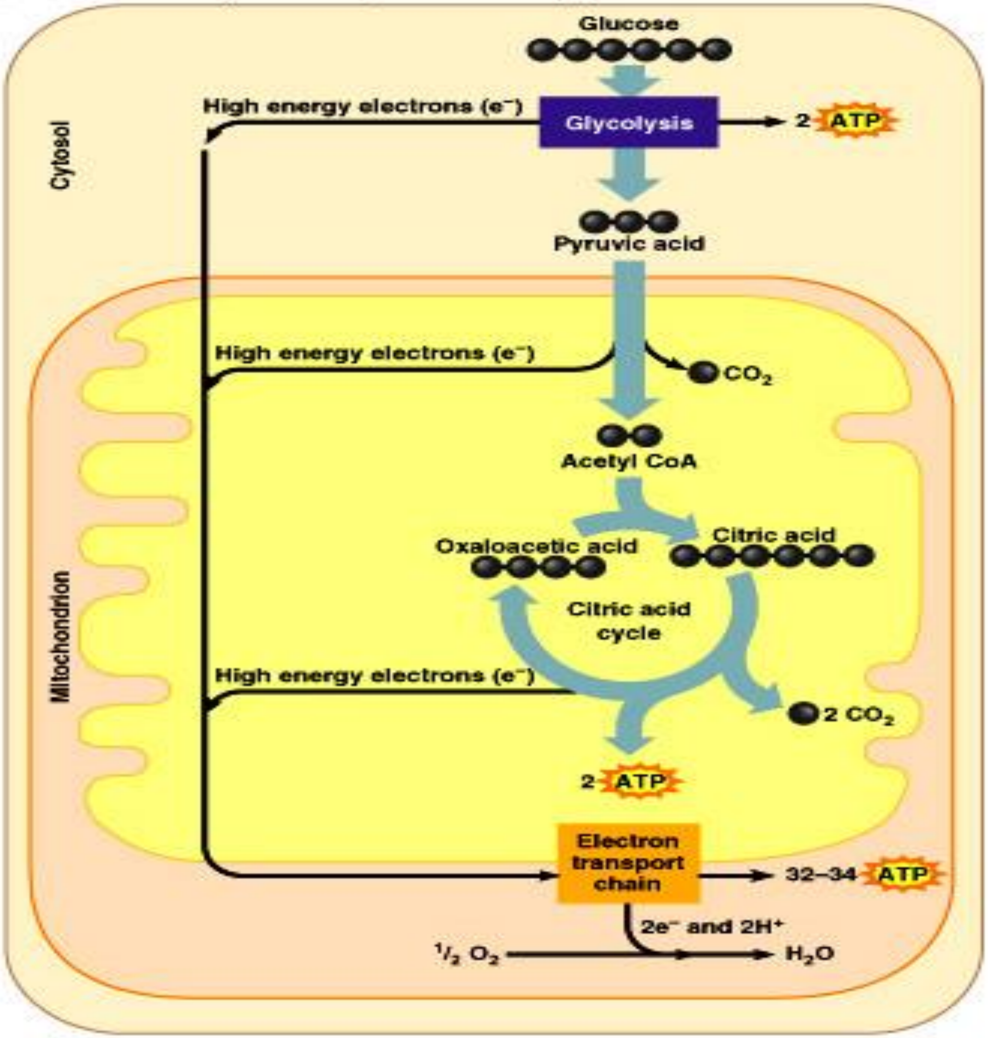
Citric Acid Cycle

2 The 3-carbon pyruvic acids generated by glycolysis enter the mitochondria. Each loses a carbon (generating CO_2) and is combined with a coenzyme to form a 2-carbon acetyl coenzyme A (acetyl CoA). More high energy electrons are released.

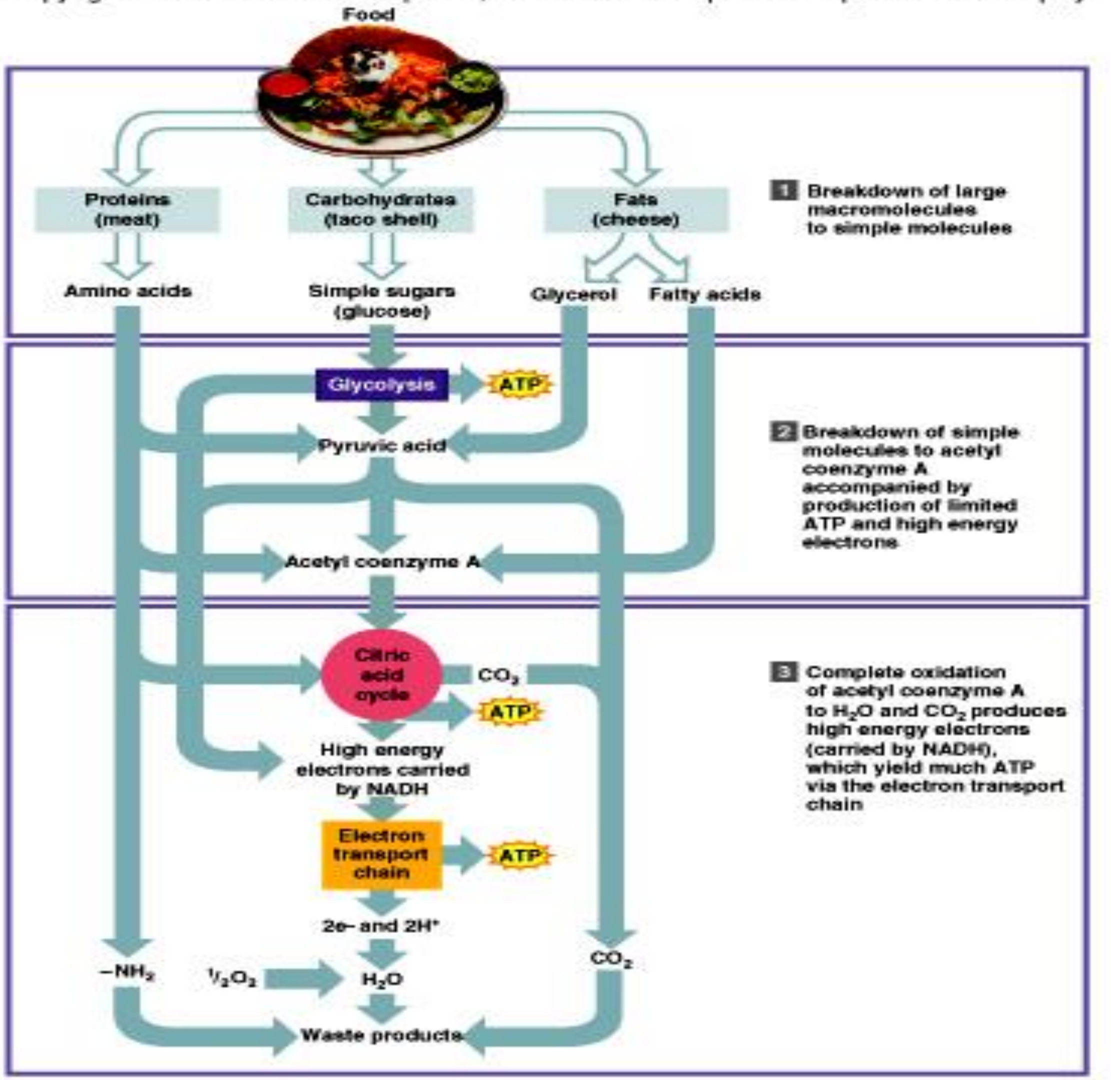
3 Each acetyl CoA combines with a 4-carbon oxaloacetic acid to form the 6-carbon citric acid, for which the cycle is named. For each citric acid a series of reactions removes 2 carbons (generating 2 CO_2's), synthesizes 1 ATP and releases more high energy electrons. The figure shows 2 ATP, resulting directly from 2 turns of the cycle per glucose molecule that enters glycolysis.

Electron Transport Chain

4 The high energy electrons still contain most of the chemical energy of the original glucose molecule. Special carrier molecules bring the high energy electrons to a series of enzymes that convert much of the remaining energy to more ATP molecules. The other products are heat and water. The requirement of oxygen in this last step is why the overall process is called aerobic respiration.



Summary of Catabolism of Proteins, Carbohydrates, and Fats



Carbohydrate Storage

Excess glucose stored as

- glycogen (primarily by liver and muscle cells)
- fat
- converted to amino acids