Chapter 7

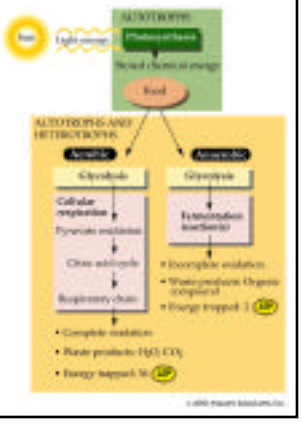
Cellular respiration

How do organisms acquire energy?

- Inorganic materials
  - Autotrophs
- Organic materials
  - Heterotrophs

Autotrophs and heterotrophs

Both autotrophs and heterotrophs use cellular respiration to obtain energy for growth and reproduction.

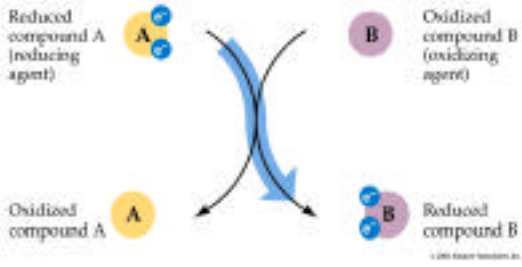


Oxidation - reduction

Transfer of electrons

oxidation = loss of electrons

reduction = gain of electrons



Oxidation-Reduction Reactions

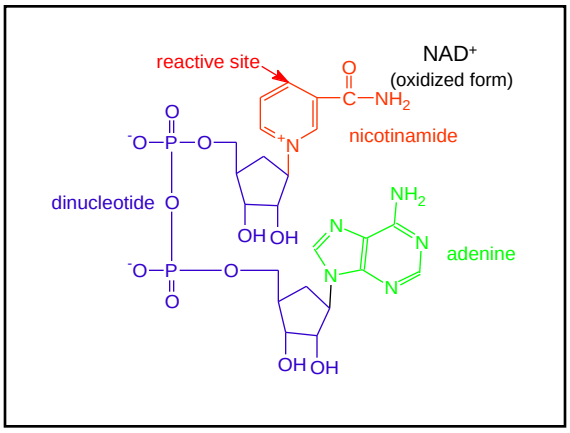
- Loss of electrons is OXIDATION.
  - Loss of energy
  - Loss of hydrogen
- Gain of electrons is REDUCTION.
  - Gain of energy
  - Gain of hydrogen

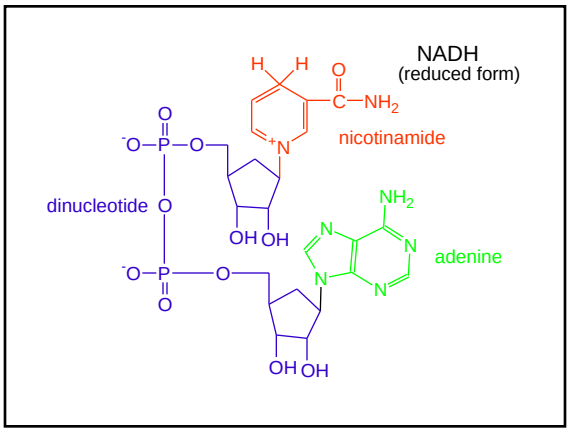
Common electron acceptors

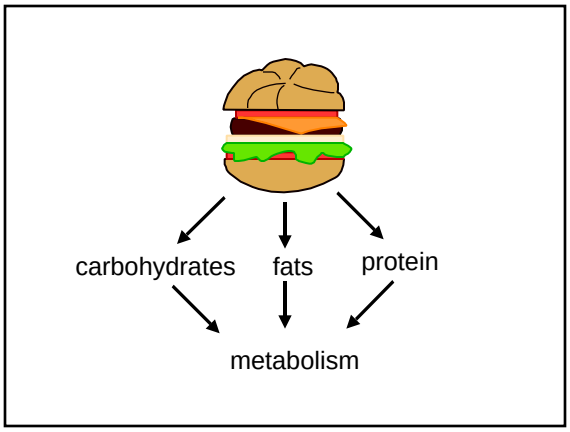
- Nicotinamide adenine dinucleotide (NAD^+).
- Flavin adenine dinucleotide (FAD^+)

$$NAD^+ + 2e^- + 2H^+ \rightarrow NADH + H^+$$

oxidized form — reduced form







Cellular Respiration (4 stages)

Stage 1; Glycolysis

↓

Stage 2; Pre-Krebs (pre-Citric acid cycle)

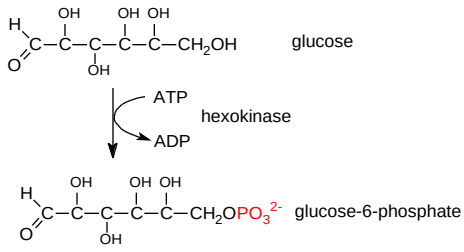
↓

Stage 3; Krebs cycle (Citric acid cycle)

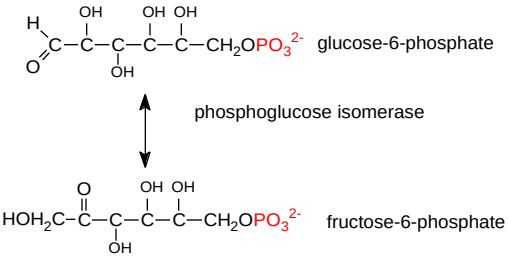
↓

Stage 4; Electron Transport System

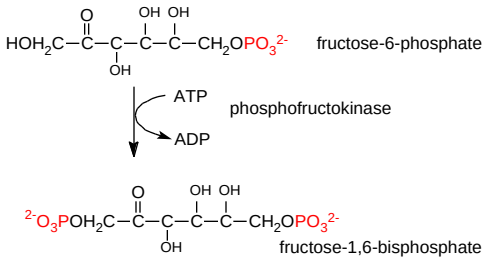
Phosphorylation prevents glucose from leaving the cell



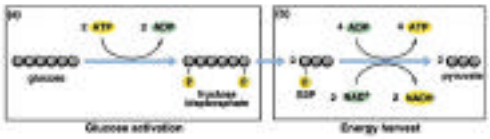
Aldose to ketose



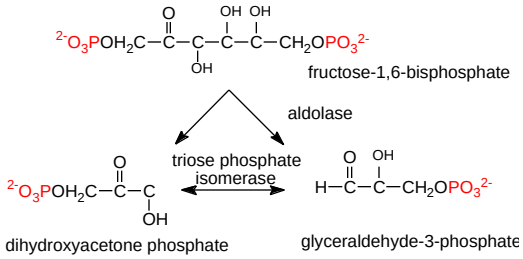
Phosphofructokinase is the key enzyme in glycolysis



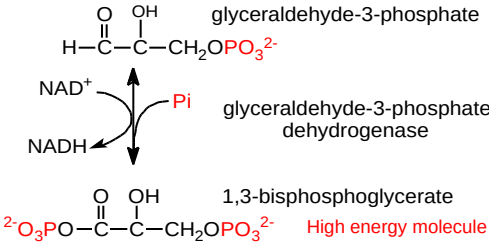
Activating glucose



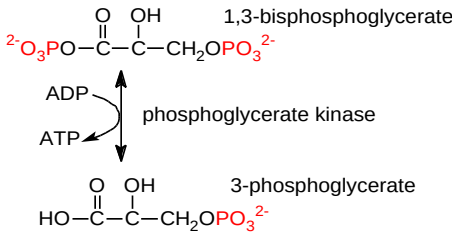
Sugar-splitting



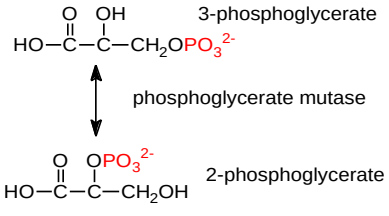
Energy transfer



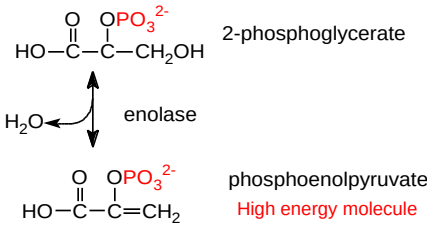
Forming ATP (substrate phosphorylation)



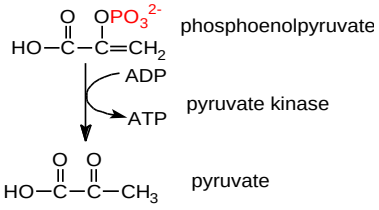
Rearrangement



Dehydration increases the potential for transfer of phosphate to ADP



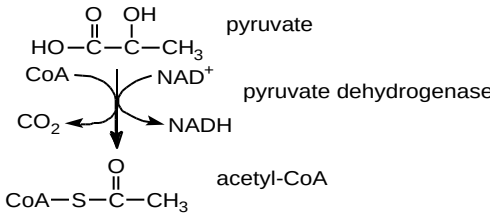
Transfer of P to ADP is irreversible (substrate phosphorlyation)



Glycolysis summary

- IN
  - 1 glucose
  - 2 ATP
  - 2 NAD^+
  - 2 Pi
  - 2 ADP
- OUT
  - 2 pyruvate
  - 4 ATP
  - 2 NADH
  - 2 H_2O

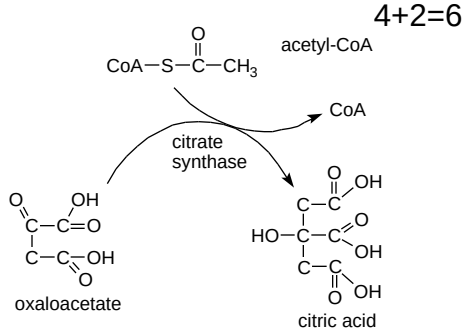
CoA activates the carbons from pyruvate



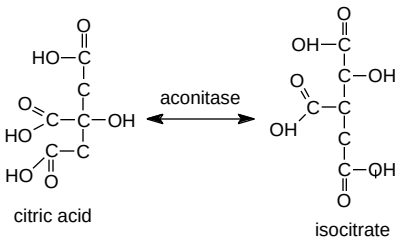
ATP is required to move pyruvate into the mitochondrial matrix

Acetyl-CoA can be used to synthesis fats

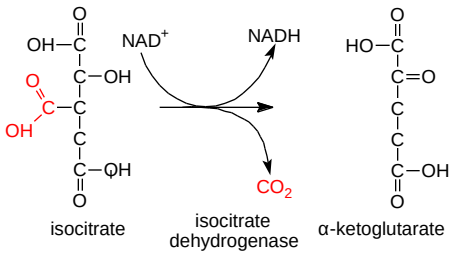
4+2=6



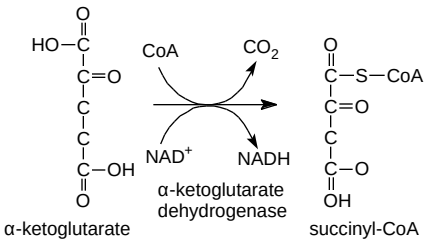
Moving an -OH



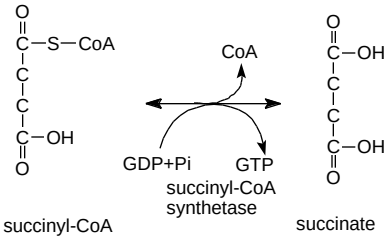
Oxidation and decarboxylation



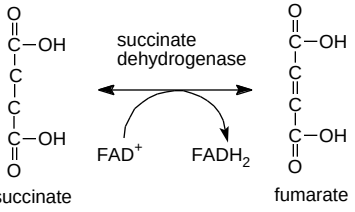
Energizing the bonds



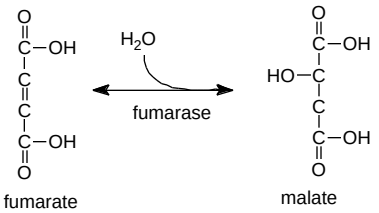
Making ATP



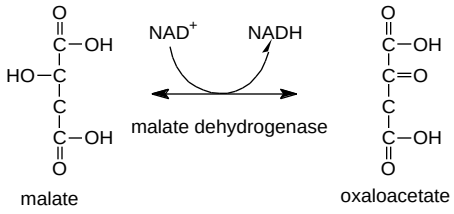
Using FAD+



Hydrating fumarate

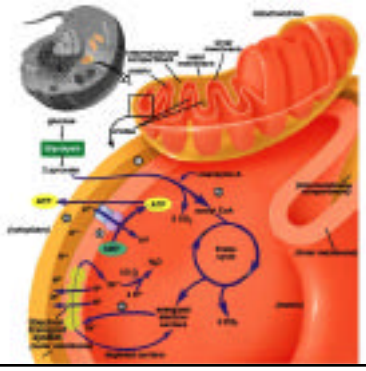


Oxidation of malate

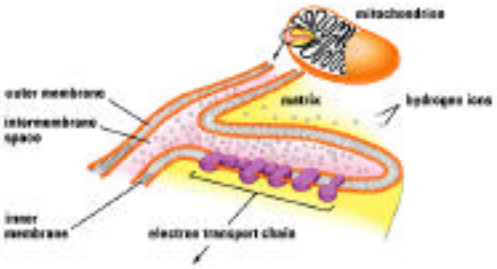


Krebs cycle summary

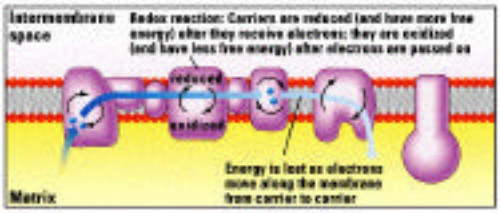
IN	OUT
■2 acetyl-CoA	■$2CO_2$
■6 NAD^+	■6NADH
■2 FAD^+	■$2FADH_2$
■2GDP	■2GTP
■2Pi	■$2H^+$
■$2H_2O$	■2 CoA



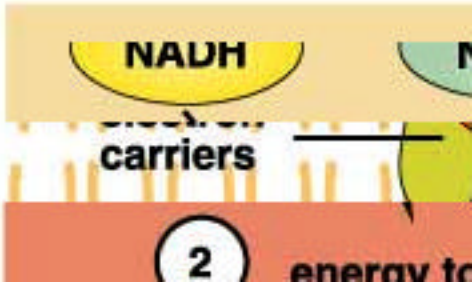
Structure of the mitochondrion

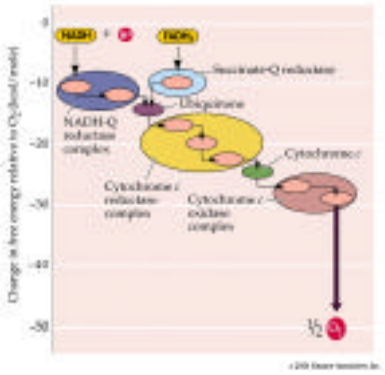


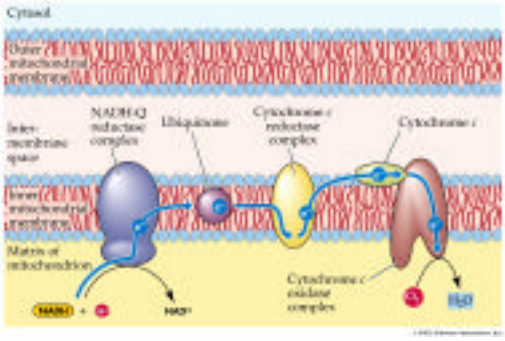
Electron Transport System

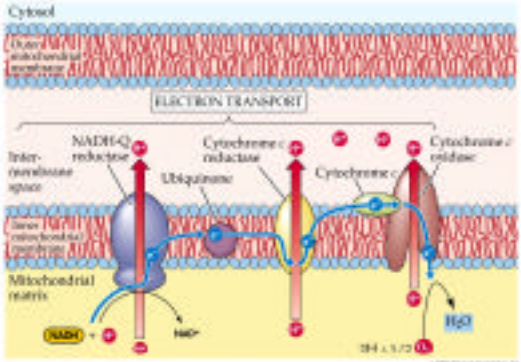


Electron transport chain



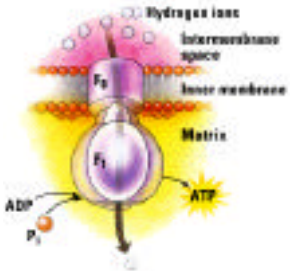


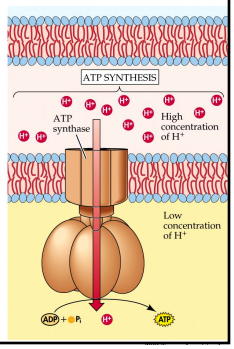


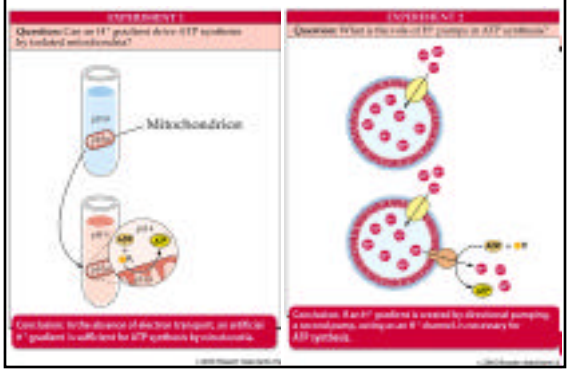


ATP synthase uses energy from a proton motive force (chemiosmosis)

Proton gradient







Krebs cycle leads to 20 ATP

IN	OUT
2 acetyl-CoA	$2CO_2$
6 NAD^+	6NADH=15ATP
2 FAD^+	2$FADH_2$=3ATP
2GDP	2GTP=2ATP
2Pi	$2H^+$
$2H_2O$	2 CoA

Energy summary

- Glycolysis
  - 2ATP
  - 2NADH
- Pre-Kreb's cycle
  - 2NADH
- Kreb's cycle
  - 6NADH
  - 2$FADH_2$
  - 2GTP

- Glycolysis
  - 7 ATP
- Pre-Kreb's cycle
  - 5 ATP
- Kreb's cycle
  - 20 ATP

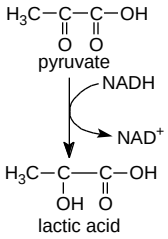
NADH = 2.5 ATP
$FADH_2$ = 1.5 ATP

Total ATP = 32

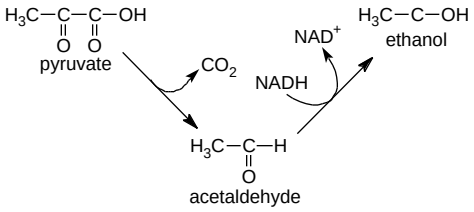
Fermentation

- Anaerobic process
  - Formation of 2 ATP (net) in glycolysis.
  - Regeneration of NAD^+

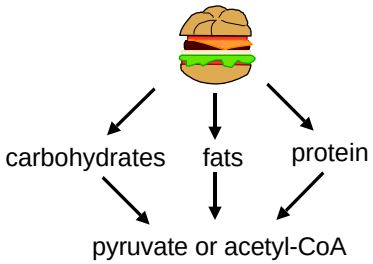
Lactic acid fermentation

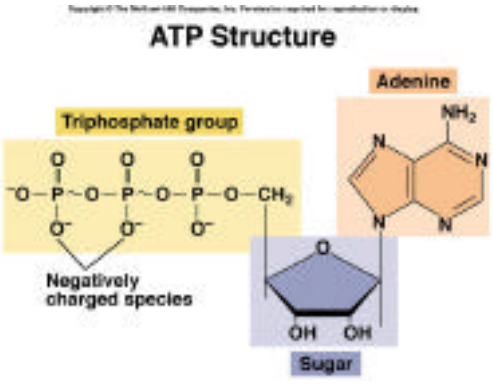


Alcoholic fermentation

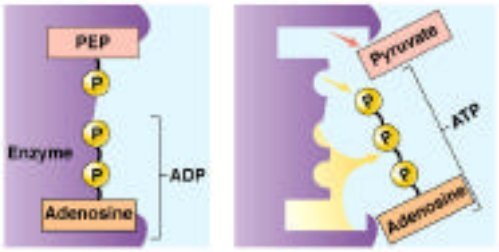


Glycolysis and Krebs cycle are central to all metabolic processes

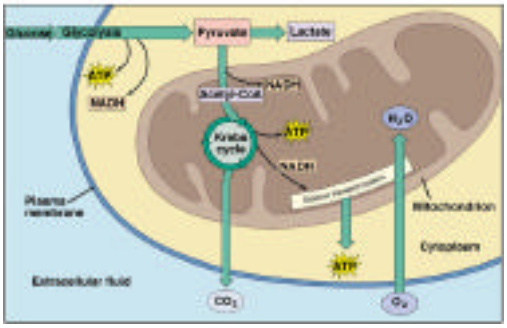




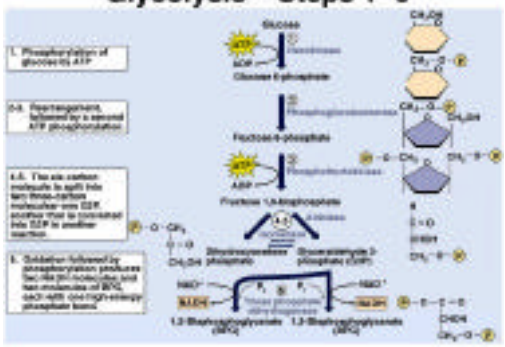
Substrate-Level Phosphorylation



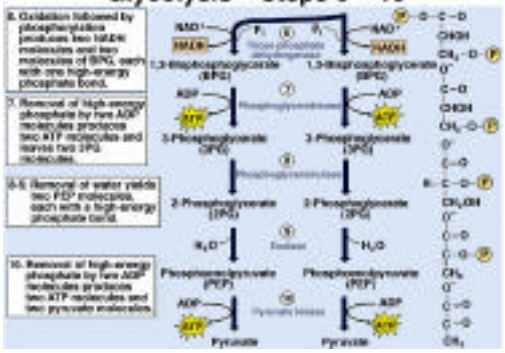
Aerobic Respiration

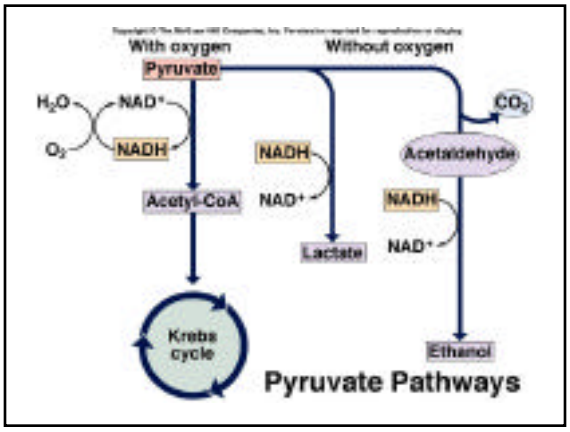


Glycolysis—Steps 1–6

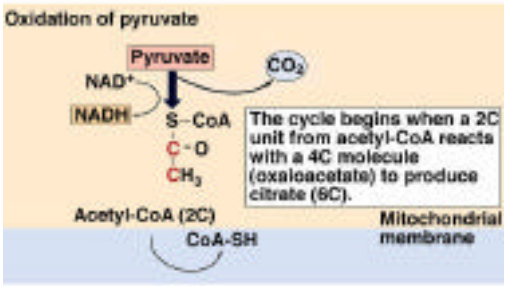


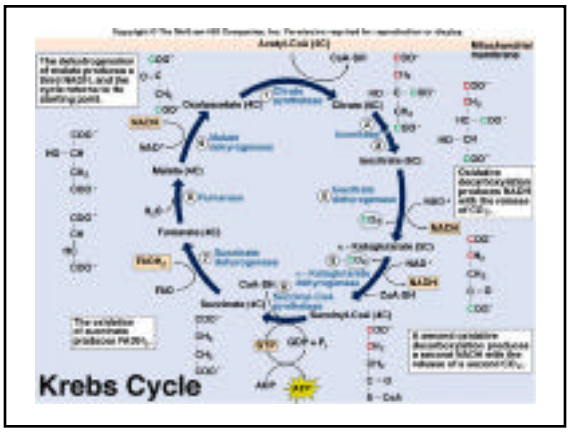
Glycolysis—Steps 6 – 10

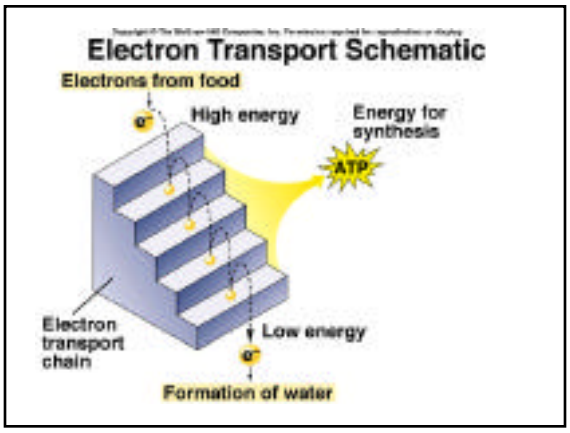


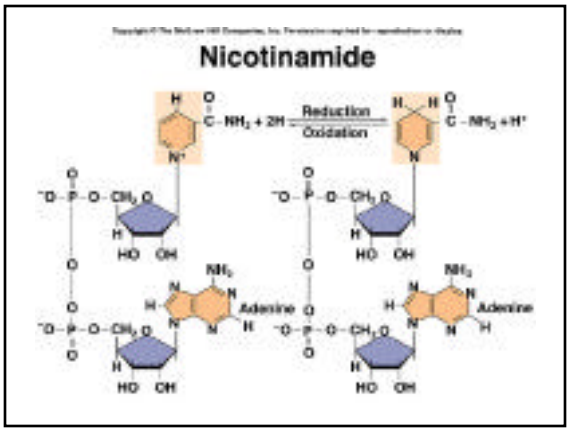


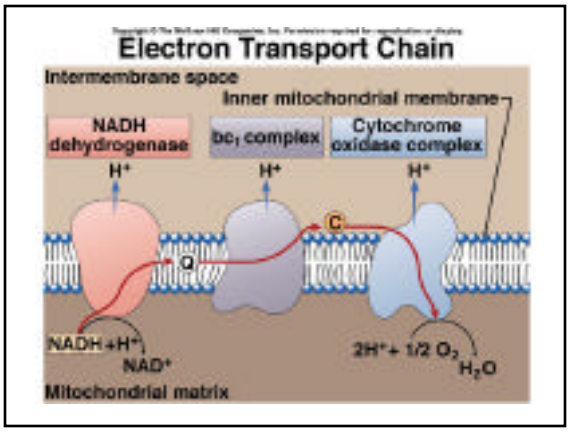
Krebs Cycle Begins

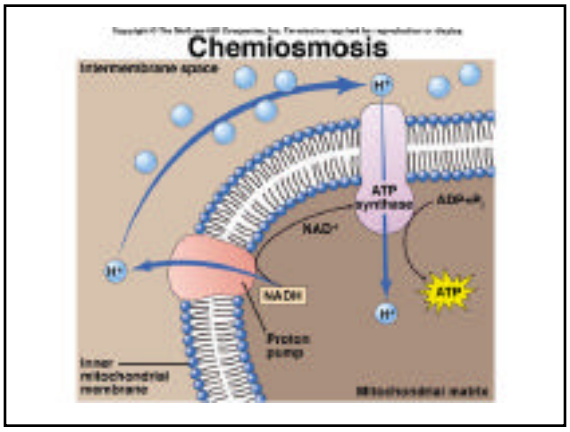


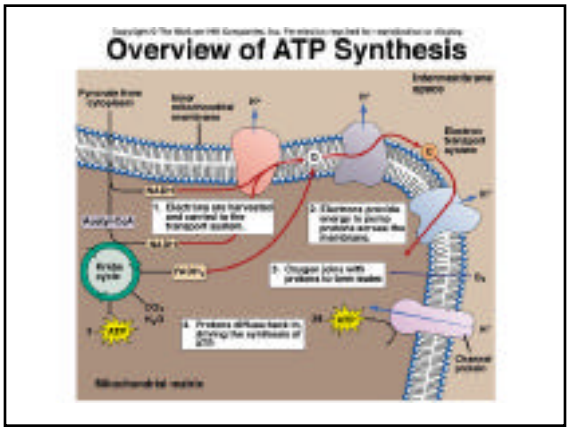

Krebs Cycle

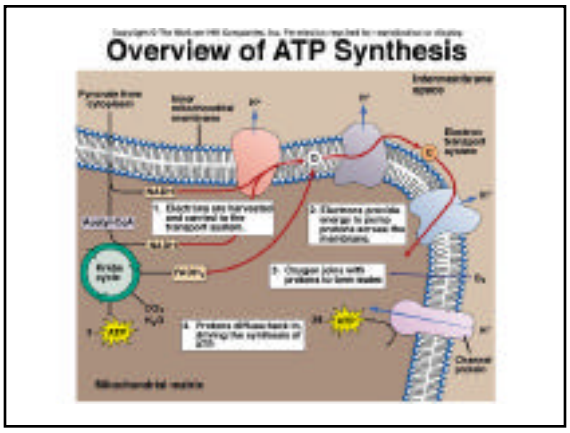

Electron Transport Schematic
Electrons from food
High energy
Energy for synthesis
ATP
Electron transport chain
Low energy
Formation of water

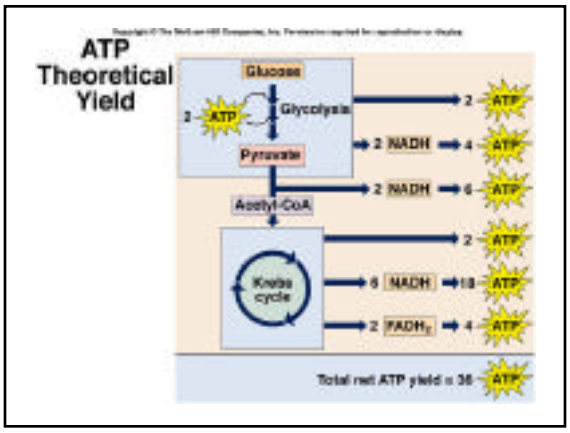

Nicotinamide
Reduction
Oxidation
Adenine
Adenine

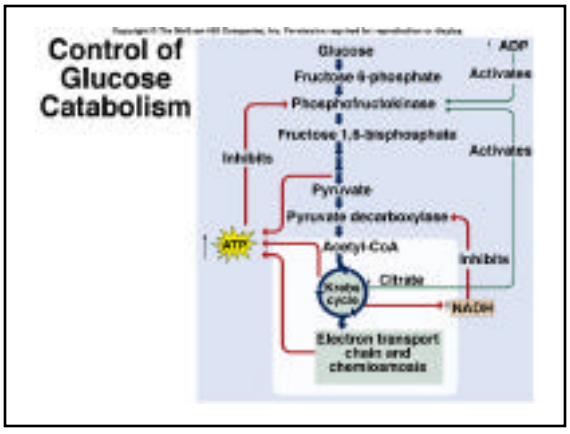

Electron Transport Chain
Intermembrane space
Inner mitochondrial membrane
NADH dehydrogenase
bc1 complex
Cytochrome oxidase complex
Q
C
NADH +H+
NAD+
2H+ + 1/2 O2
H2O
Mitochondrial matrix

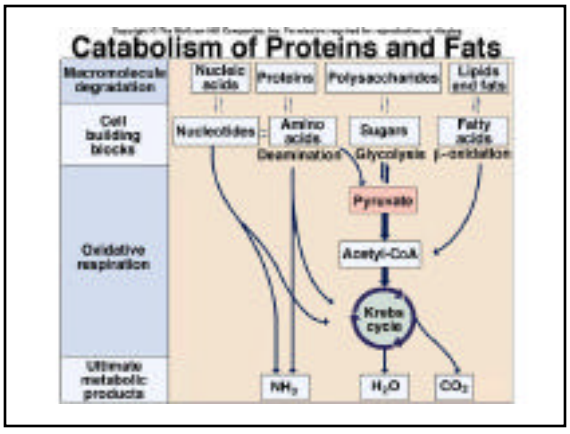

Chemiosmosis
Intermembrane space
ATP synthase
NAD+
NADH
ATP
Proton pump
Inner mitochondrial membrane
Mitochondrial matrix

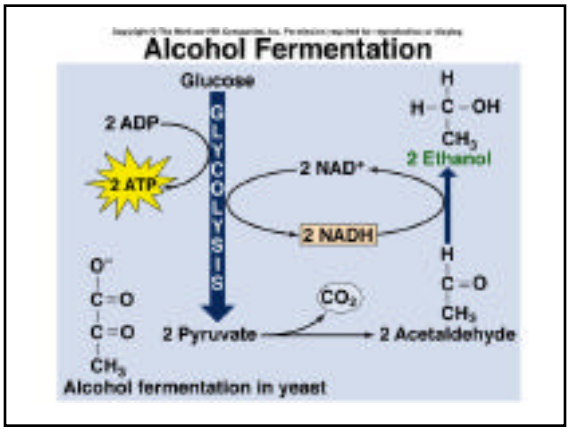

Overview of ATP Synthesis

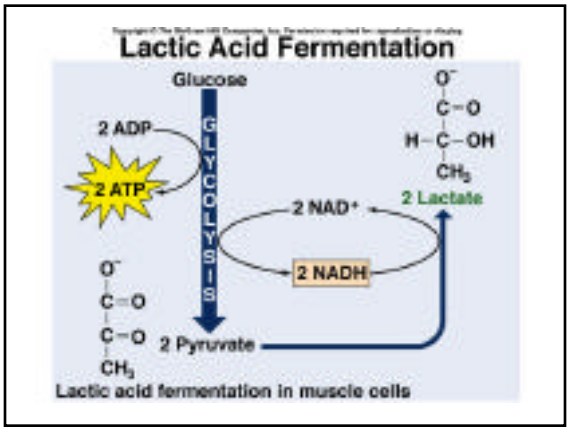

Overview of ATP Synthesis

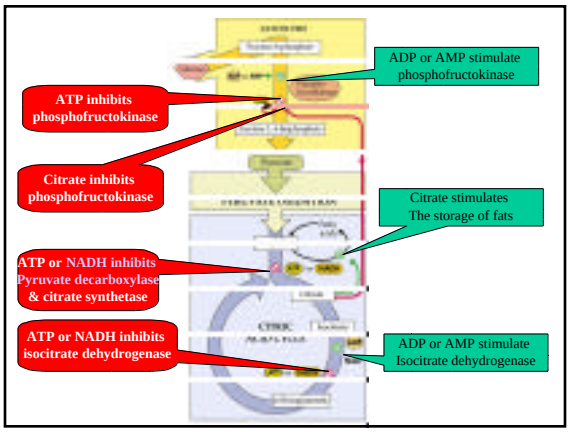

ATP Theoretical Yield
Glucose
Glycolysis
Pyruvate
Acetyl-CoA
Krebs cycle
Total net ATP yield = 38

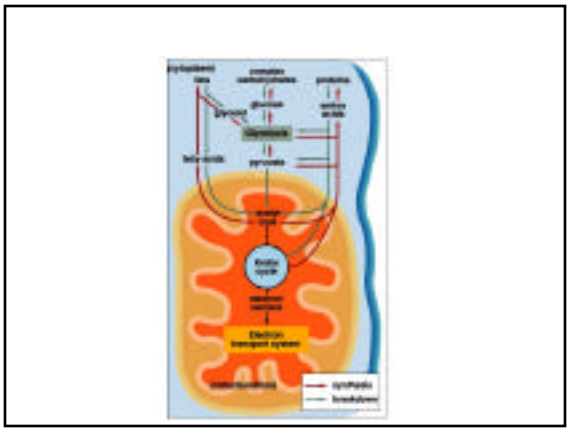

Control of Glucose Catabolism
Glucose
Fructose 6-phosphate
Phosphofructokinase
Fructose 1,6-bisphosphate
Pyruvate
Pyruvate decarboxylase
Acetyl-CoA
Citrate
Krebs cycle
NADH
Electron transport chain and chemiosmosis
ATP
ADP
Activates
Inhibits
Inhibits

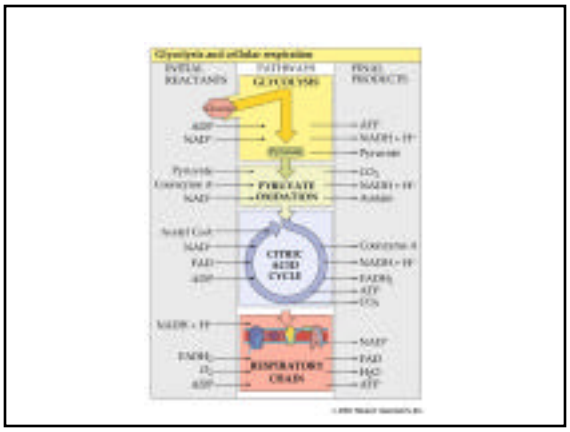

Catabolism of Proteins and Fats
Nucleic acids
Proteins
Polysaccharides
Lipids and fats
Nucleotides
Amino acids
Sugars
Fatty acids
Deamination
Glycolysis
β-oxidation
Pyruvate
Acetyl-CoA
Krebs cycle
Macromolecule degradation
Cell building blocks
Oxidative respiration
Ultimate metabolic products

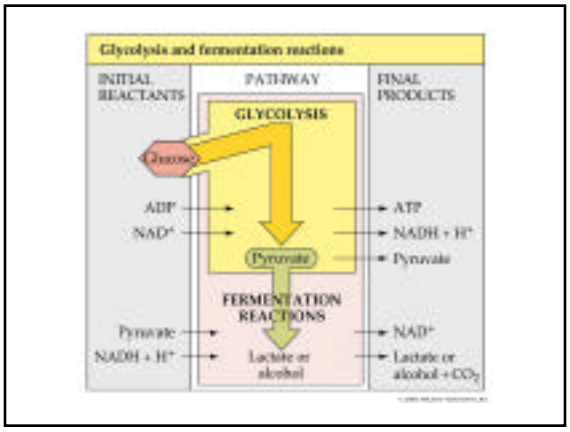

Alcohol Fermentation
Glucose
2 ADP
2 ATP
GLYCOLYSIS
2 NAD+
2 NADH
2 Ethanol
2 Pyruvate
CO2
2 Acetaldehyde
Alcohol fermentation in yeast

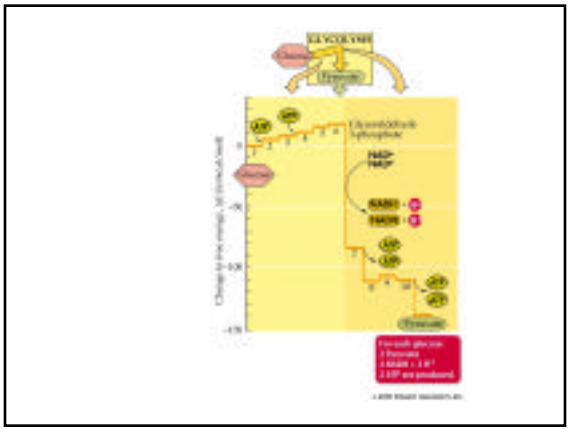

Lactic Acid Fermentation
Glucose
2 ADP
2 ATP
GLYCOLYSIS
2 NAD+
2 NADH
2 Lactate
2 Pyruvate
Lactic acid fermentation in muscle cells

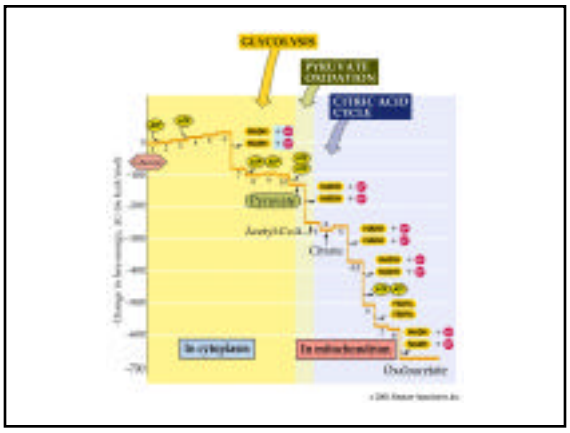

ADP or AMP stimulate phosphofructokinase
ATP inhibits phosphofructokinase
Citrate inhibits phosphofructokinase
Citrate stimulates The storage of fats
ATP or NADH inhibits Pyruvate decarboxylase & citrate synthetase
ATP or NADH inhibits isocitrate dehydrogenase
ADP or AMP stimulate Isocitrate dehydrogenase






Glycolysis and fermentation reactions
INITIAL REACTANTS
PATHWAY
FINAL PRODUCTS
GLYCOLYSIS
Glucose
ADP
NAD+
ATP
NADH + H+
Pyruvate
Pyruvate
FERMENTATION REACTIONS
Pyruvate
NADH + H+
Lactate or alcohol
NAD+
Lactate or alcohol + CO2





7.1 Cellular Locations for Energy Pathways in Eukaryotes and Prokaryotes

EUKARYOTES	PROKARYOTES
External to mitochondrion	**In cytoplasm**
Glycolysis	Glycolysis
Fermentation	Fermentation
	Citric acid cycle
Inside mitochondrion	**On inner face of plasma membrane**
Inner membrane	Pyruvate oxidation
Pyruvate oxidation	Respiratory chain
Respiratory chain	
Matrix	
Citric acid cycle