

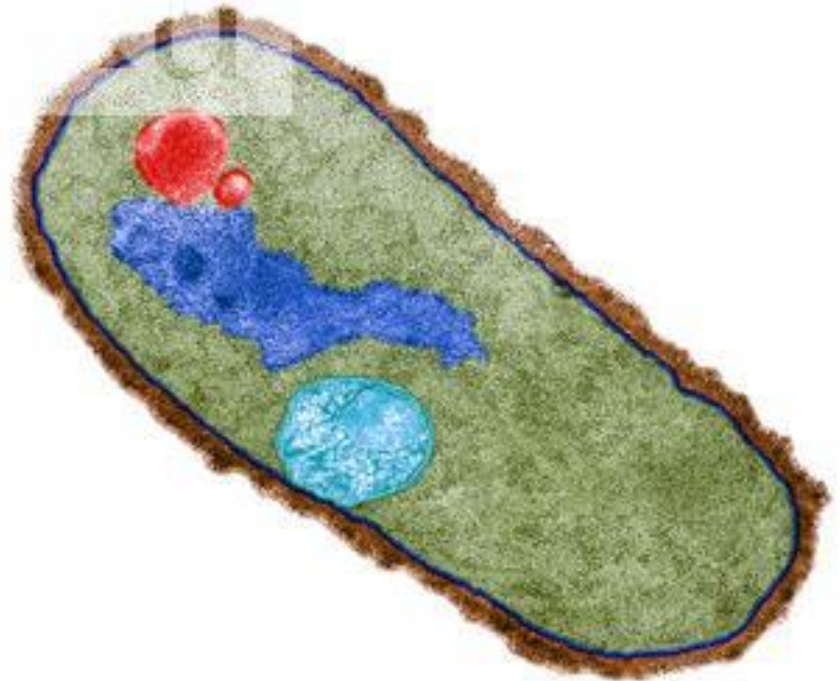


Microbial Metabolism

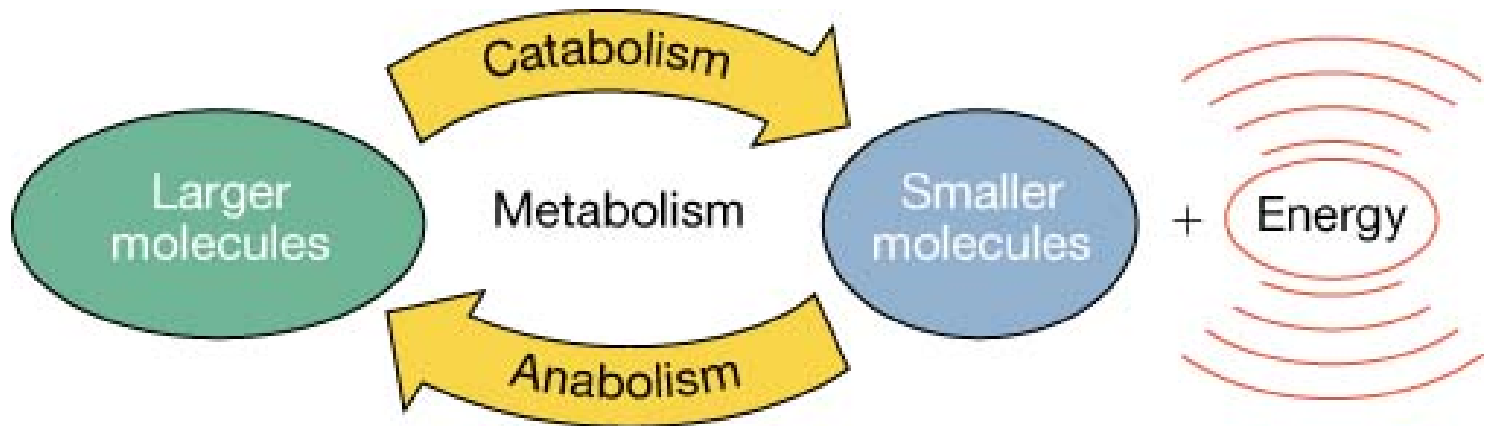
Biochemical diversity

Metabolism

- Define
- Requirements
 - Energy
 - Enzymes
- Rate
 - Limiting step
 - Reaction time
- Types
 - Anabolic
 - Endergonic
 - Dehydration
 - Catabolic
 - Exergonic
 - Hydrolytic



Metabolism Relationships



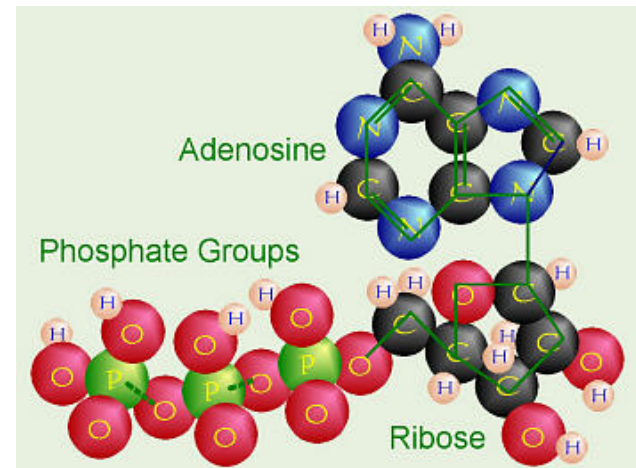
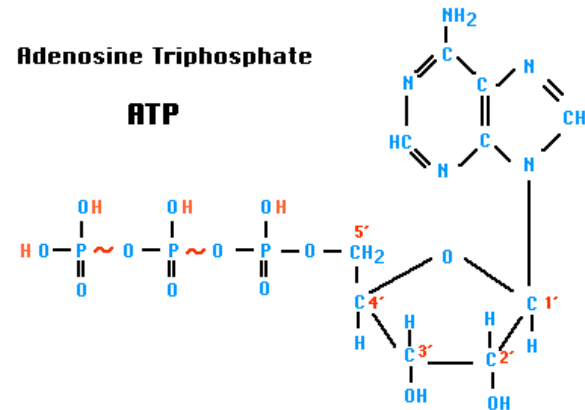


Metabolic Diversity

- Energy generating metabolism
 - Fermentation
 - Alcohol
 - Acid Formation
 - Lactic Acid
 - Mixed Acids
 - Others
 - Respiration
 - Aerobic
 - Anaerobic
- Biosynthesis of secondary metabolites
 - Heterotrophic
 - Autotrophic

Energy

- Forms
 - Kinetic
 - Potential
- Use
 - Chemical
 - Mechanical
 - Electrical
 - Radiation [EM]
- Chemical Types
 - ATP
 - UTP
 - GTP
- Heat
 - Byproduct
 - 45%





Various Types of Prokaryotic Energy Production Processes

- Fermentation
- Anaerobic Respiration
- Aerobic Respiration
- Lithotrophy
- Photoheterotrophy
- Anoxygenic photosynthesis
- Methanogenesis

Enzymes

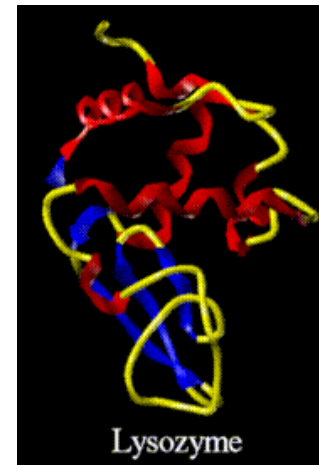
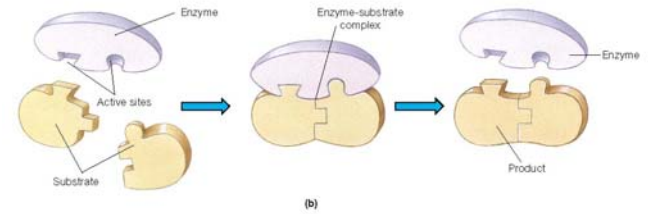
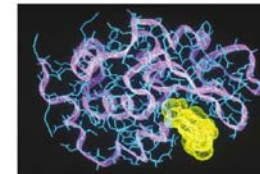
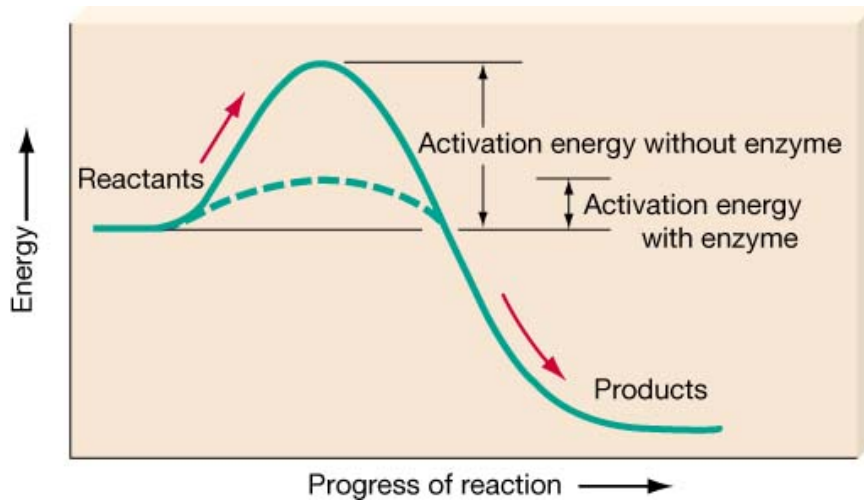
- Structure
 - Protein
 - Ribozyme [ribosome]
- Characteristic functions
 - Active site
 - Specific
 - Modified Forms
 - Inactive
 - Active
 - Coenzyme/Cofactor
 - -ase



Polymerase

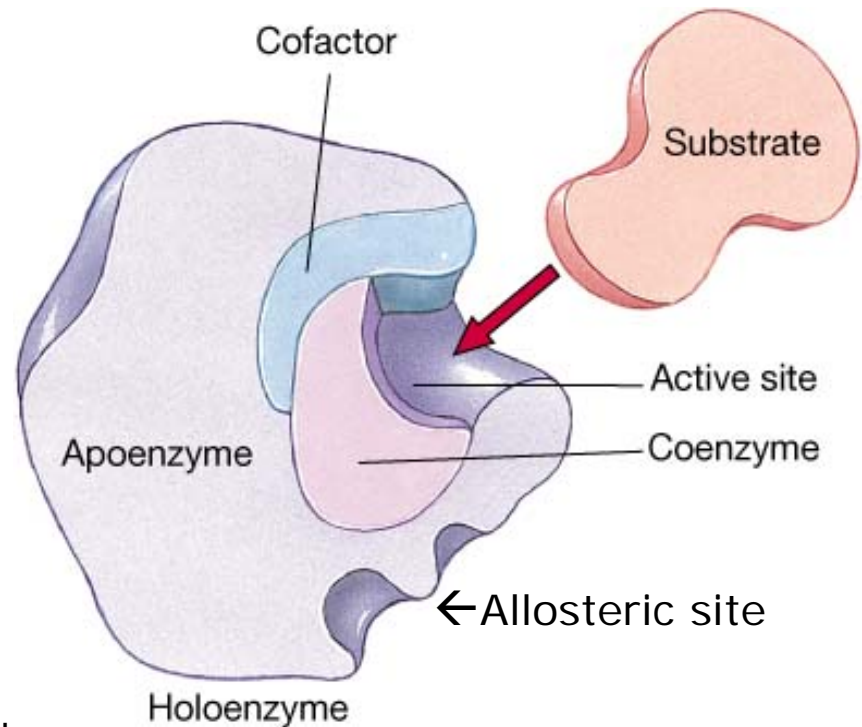
Others: Lyases, Hydrolases,
Isomerases, Transferases

Enzyme Characteristics



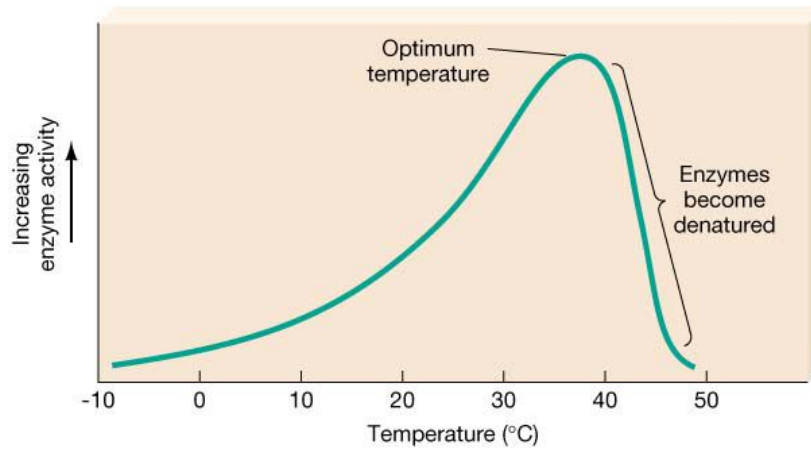
Enzyme Structure

- Apoenzyme
 - Protein
 - Allosteric site
- Cofactor
 - Metal ions
 - Cu
 - Zn
 - Mg
 - Fe
 - Ca
- Coenzyme
 - Vitamins
 - CoA
 - NAD
 - FAD
 - FMN

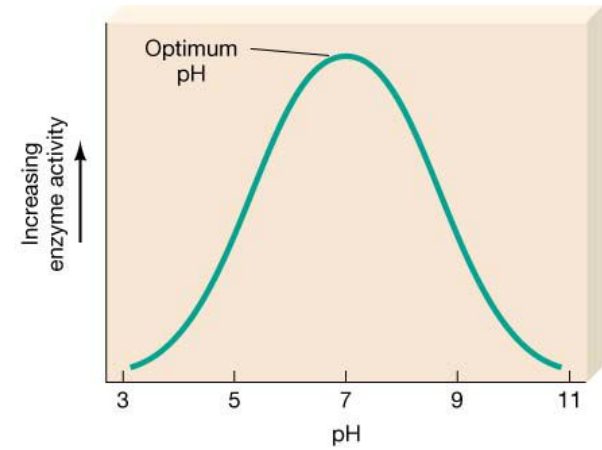


Create Holoenzyme with active site

Factors Affecting Enzymes



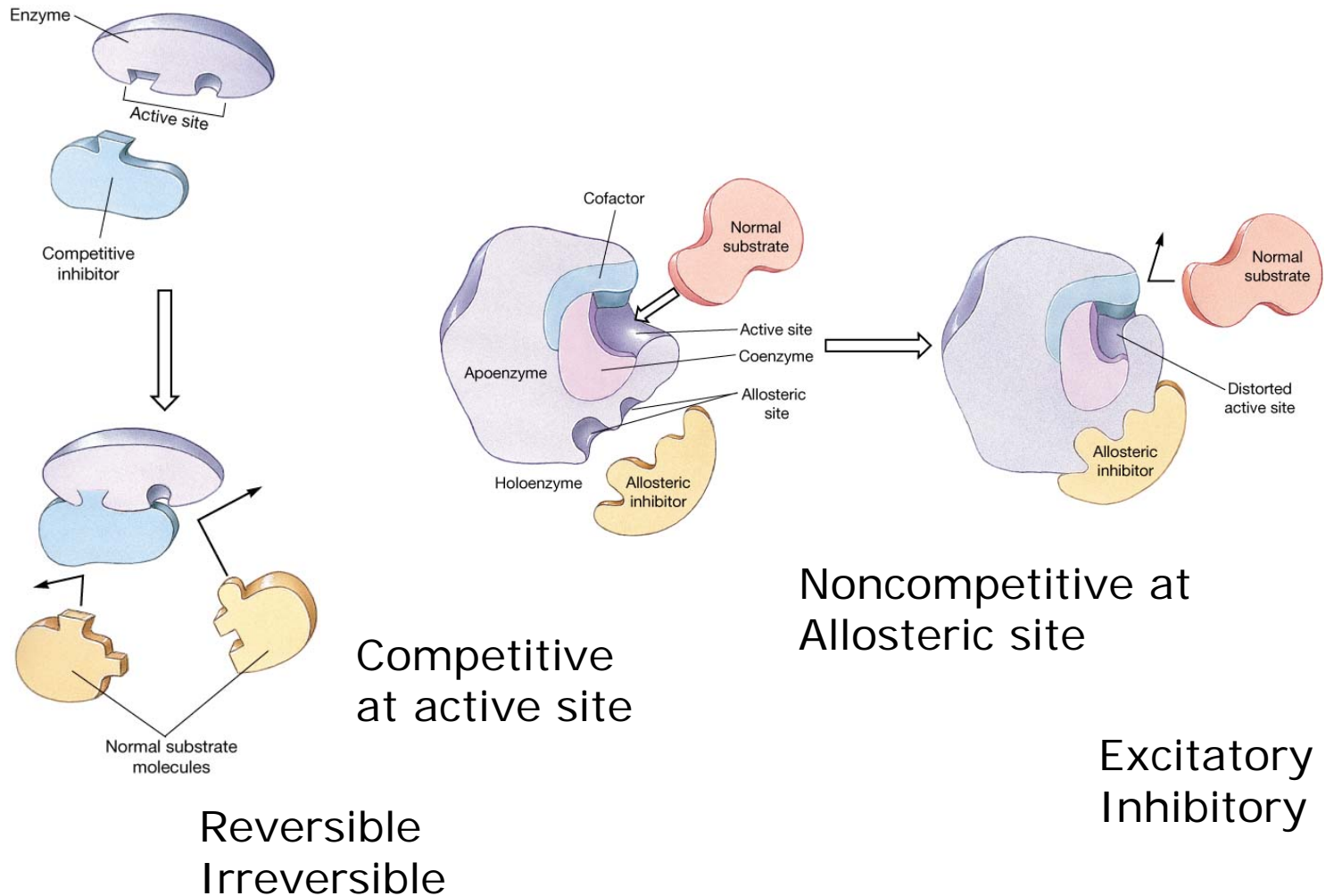
(a)



(b)

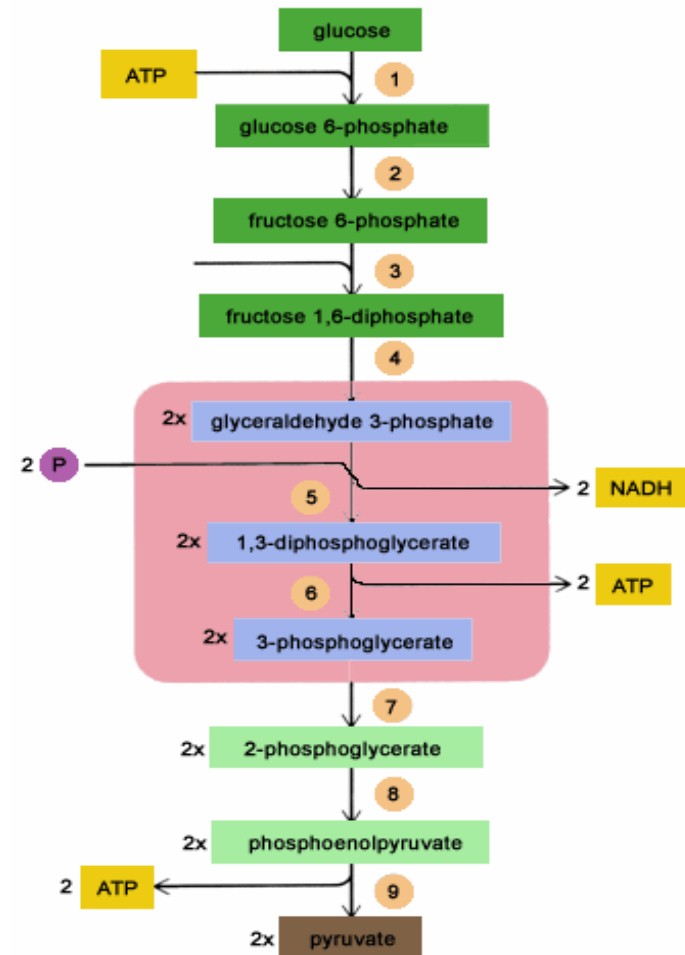
- Temperature
- pH
- Acids/bases
- UV light
- Concentration of substrates

Enzyme Inhibition

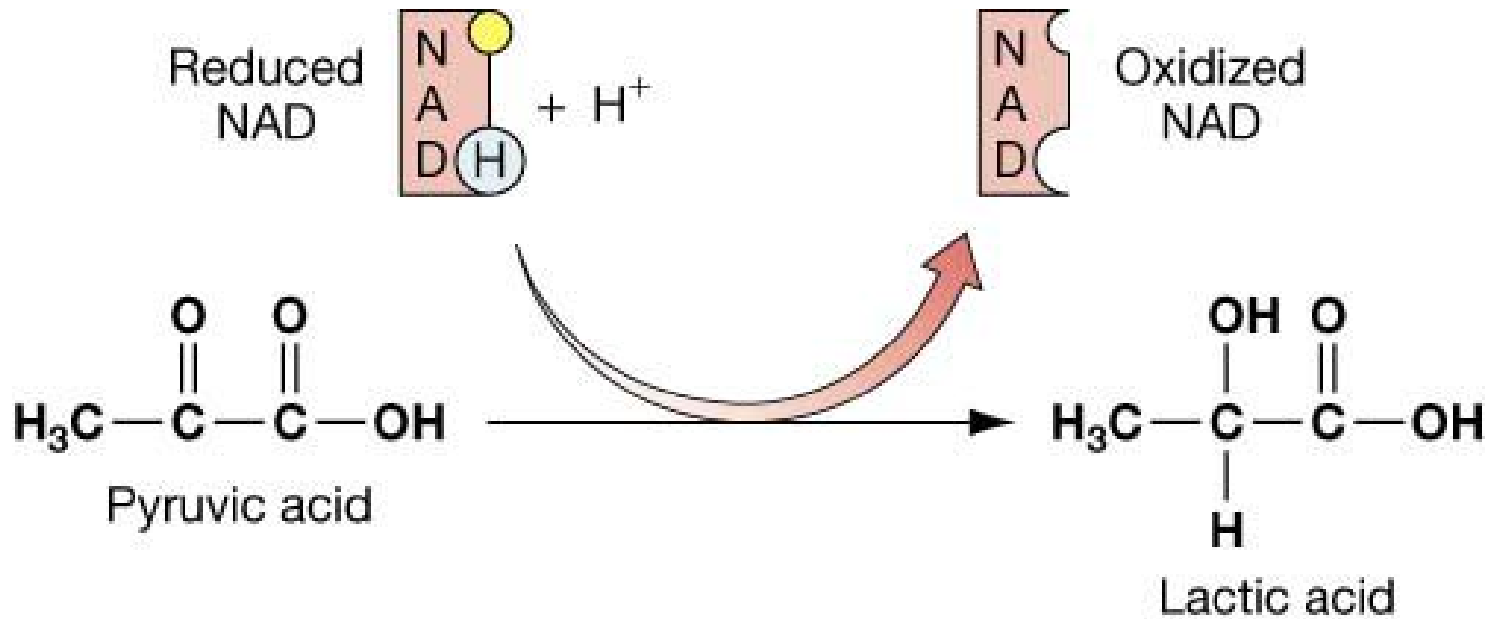


Glycolysis: Embden-Meyerhoff

- Glycolytic
- Cytoplasm
- Anaerobic
- End products
 - 2 Pyruvic acids
 - 4-2 = 2 net ATP
 - 2 NADH
 - 2 H₂O



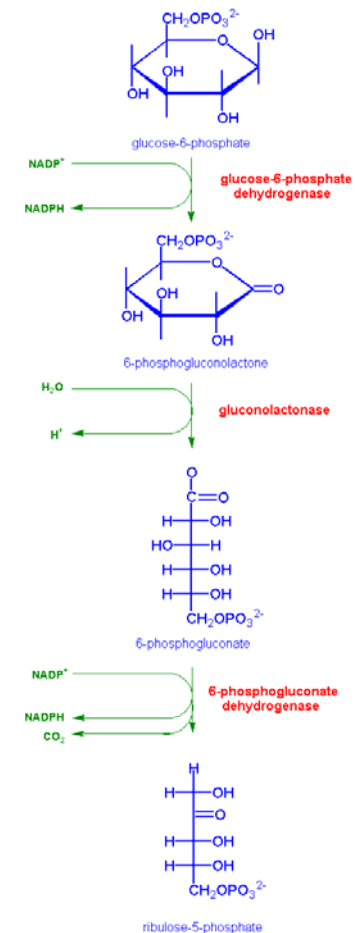
Lactic Acid Formation



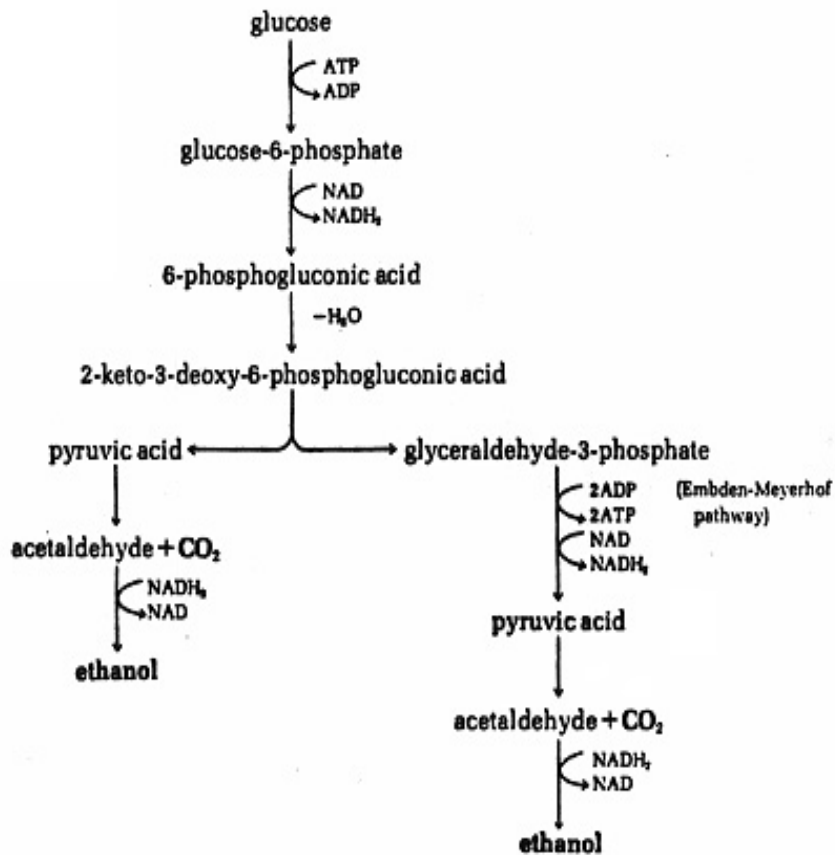
Glycolysis: PPP

- Breakdown 5-6 C
- Cytoplasm
- Anaerobic
- End products
 - ATP
 - NADPH
 - CO₂
 - 4,5,6,7 C
 - AA
 - Nucleotides
 - Glycolytic pathways
 - Photosynthesis

Oxidative Stage of Pentose Phosphate Pathway



Glycolysis: Entner-Duodoroff [E-D]



- Glycolytic
- Cytoplasm
- Anaerobic
- Different enzymes
 - *Pseudomonas*
 - *Enterococcus*
- End products
 - 2-1 = 1 net ATP
 - NADPH
 - NADH
 - 2 Pyruvic acids
 - 2H₂O

Glycolytic Pathways used by various Bacteria

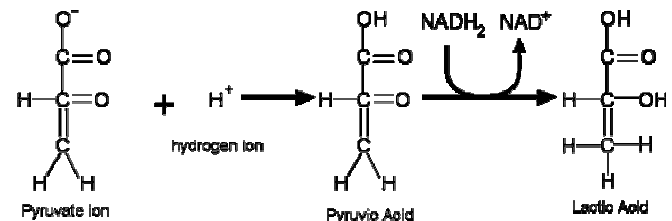
Bacterium	E-M	PPP	E-D
<i>Acetobacter aceti</i>	-	+	-
<i>Bacillus subtilis</i>	major	minor	-
<i>E. coli</i>	+	-	-
<i>Lactobacillus acidophilus</i>	+	-	-
<i>Pseudomonas aeruginosa</i>	-	-	+
<i>Vibrio cholera</i>	minor	-	major

Anaerobic Processes

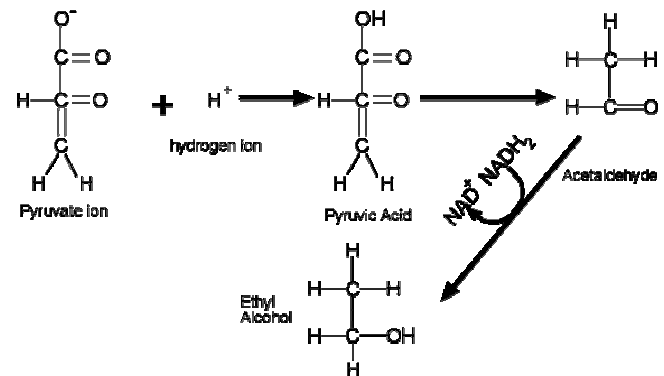
- Lactic Acid
 - *Lactobacillus*
- Mixed Acid
 - *Enterobacteriaceae*
- Butanediol
 - *Klebsiella*
 - *Enterobacter*
- Butyric Acid
 - *Clostridia*
- Butanol-Acetone
 - *Clostridia*
- Propionic Acid
 - *Corynebacteria*

Anaerobic Respiration

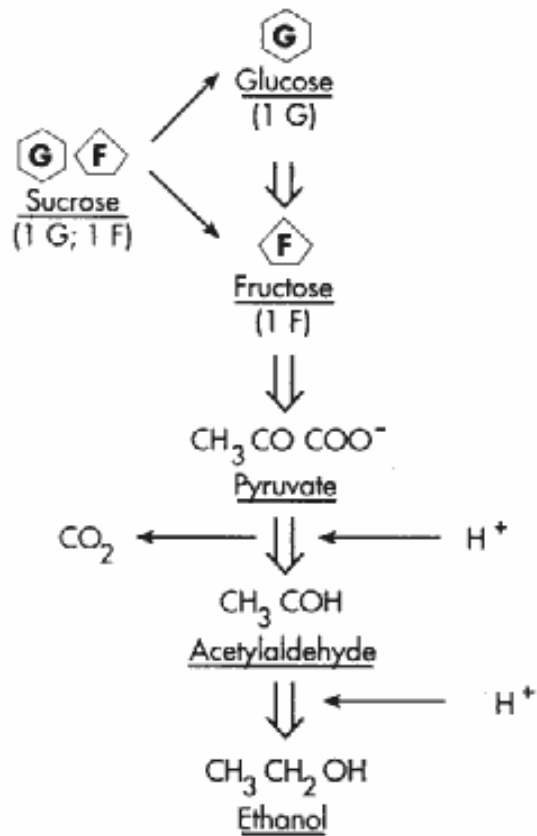
Lactic Acid Fermentation



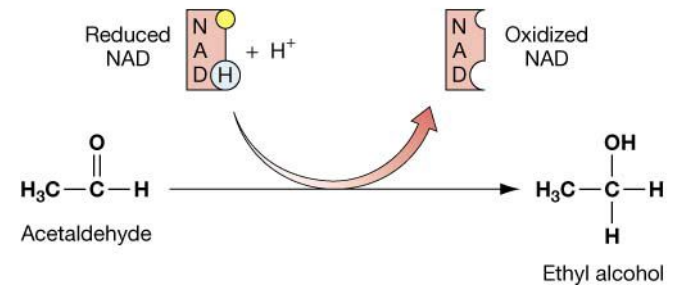
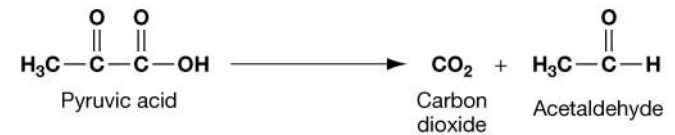
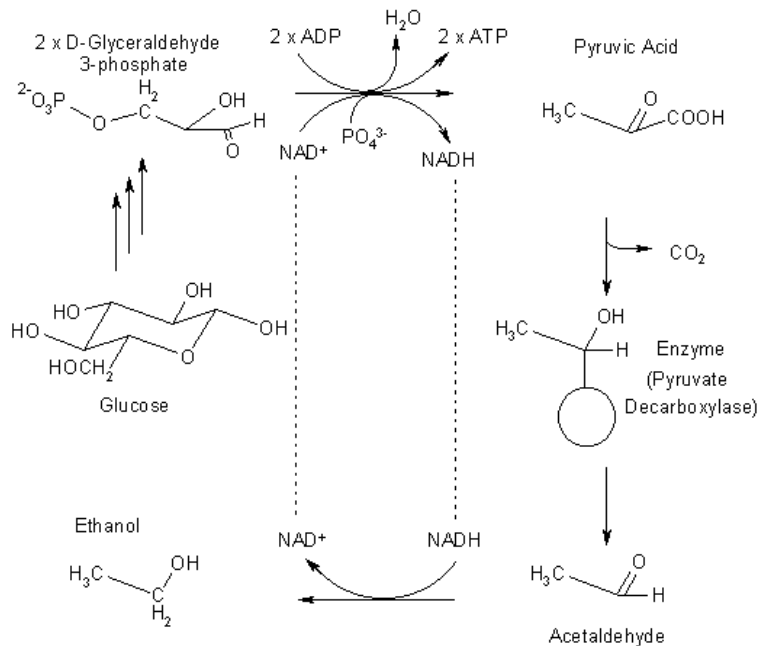
Alcoholic Fermentation



Fermentation



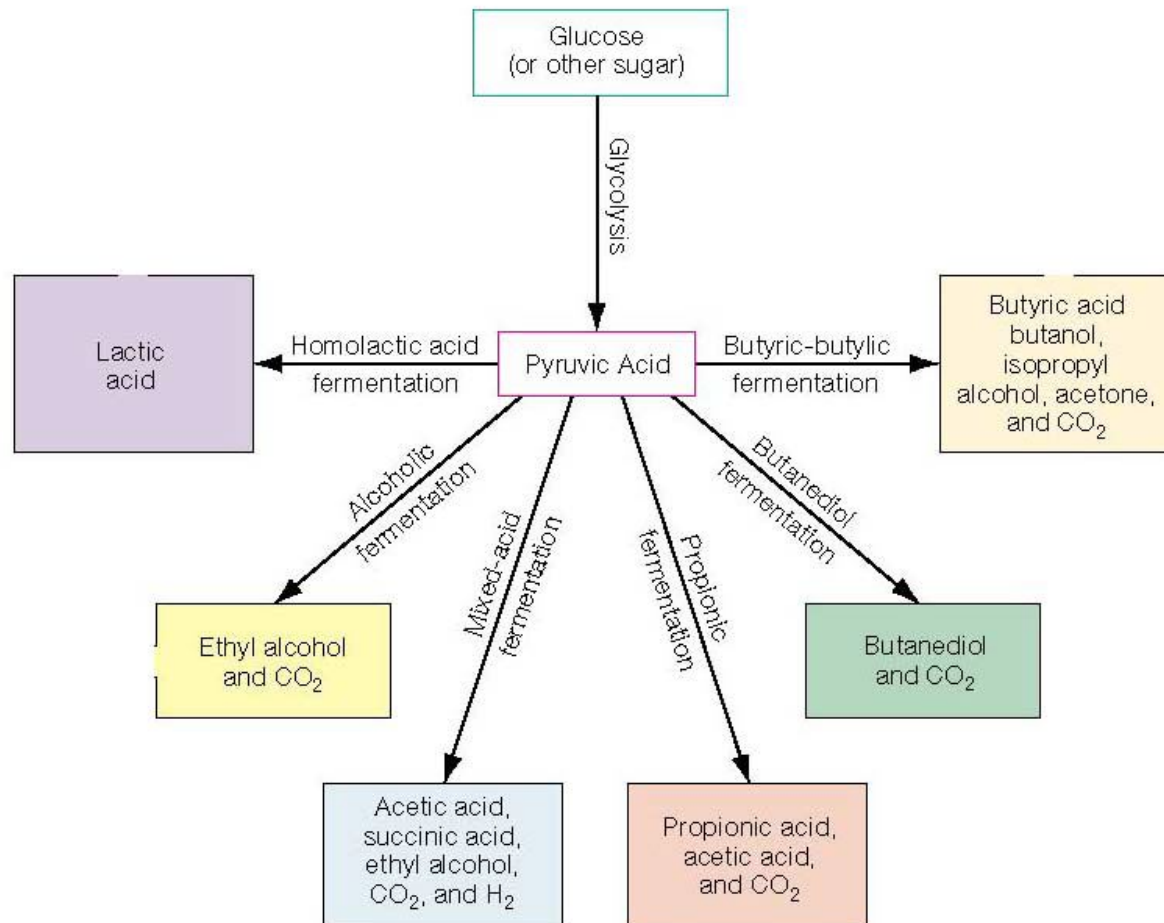
Fermentation Pathways



Fermentation Summary

- Anaerobic
- Cytoplasm
- Partial Oxidation
- Small amounts of ATP generated via substrate level phosphorylation
- Organic intermediaries as final electron acceptors
- End products
 - Acid: Lactic Acid, Acetic Acid, Butyric Acid, Acetone
 - Alcohol: Ethanol, Isopropyl
 - Gas : CO₂, H₂
 - Contaminants

Summary



Carbohydrate Fermentation Tests

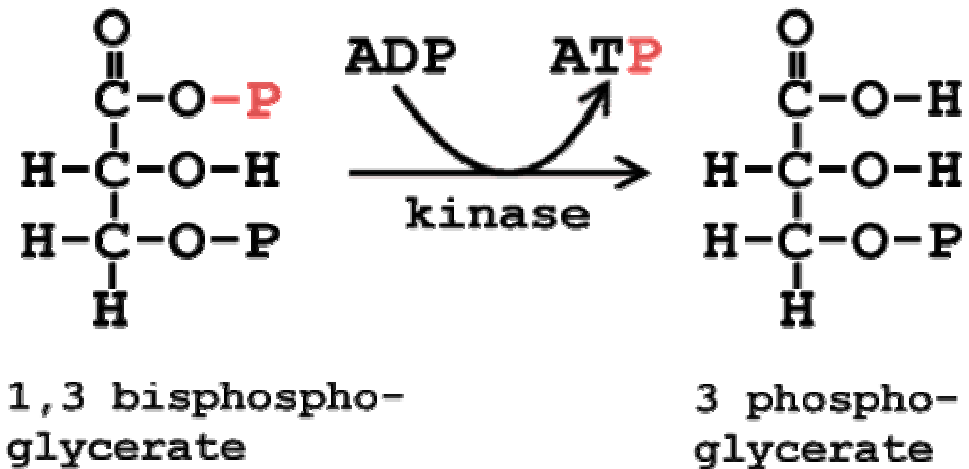
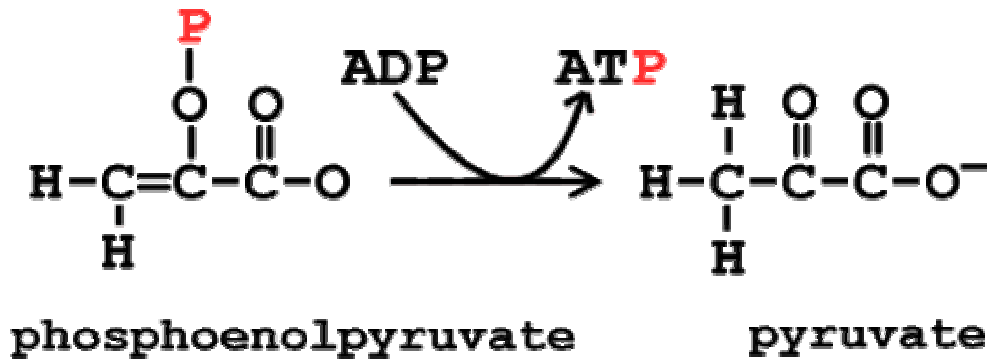




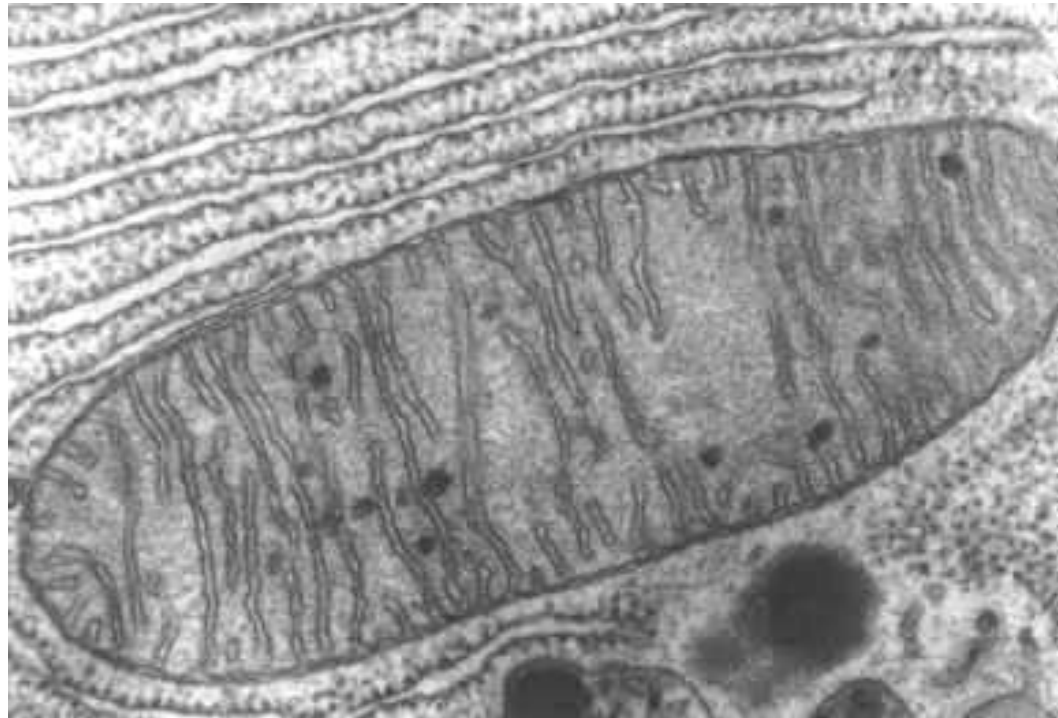
Phosphorylation

- Substrate Level
 - Direct transfer of phosphate
 - Glycolysis
- Oxidative Phosphorylation
 - Electron transfer
 - Chemiosmosis
- Photophosphorylation
 - Light energy to chemical energy

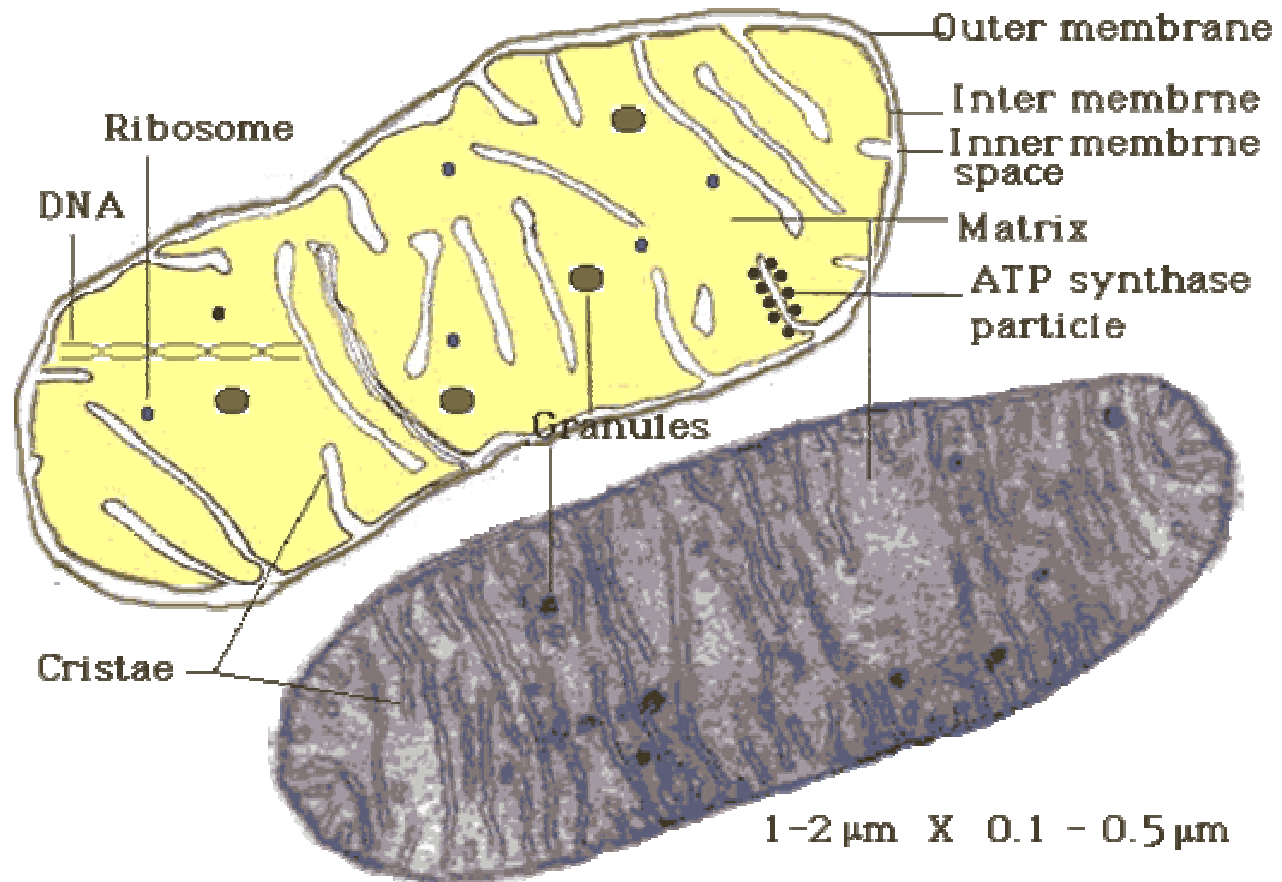
Substrate Level Phosphorylation



Aerobic Respiration



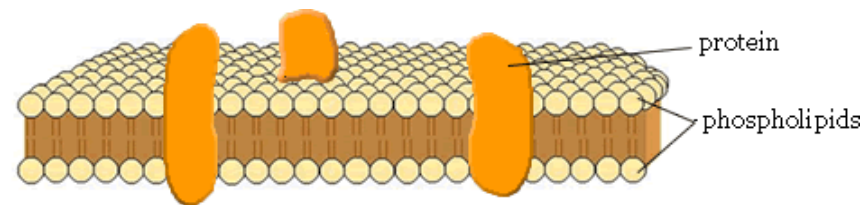
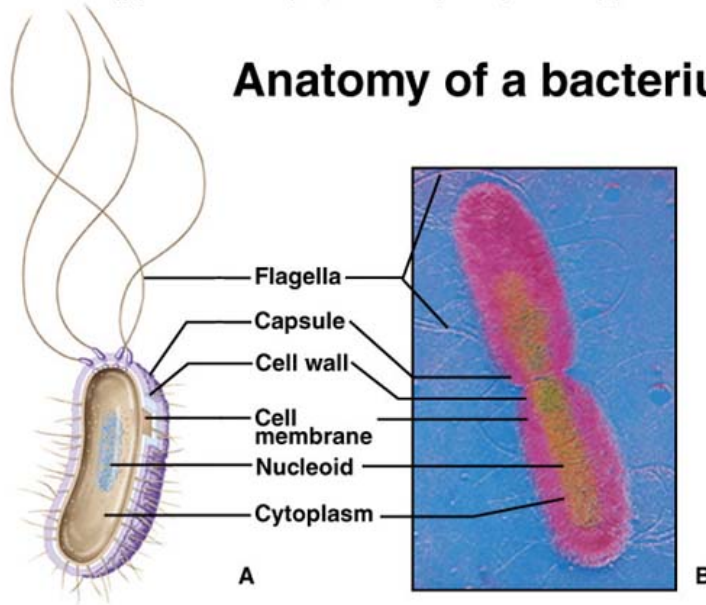
Mitochondria of Eukaryotes



Plasma [cell] membrane

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Anatomy of a bacterium

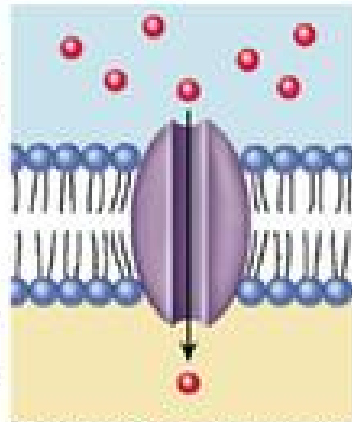


Functions of Plasma Membrane Proteins

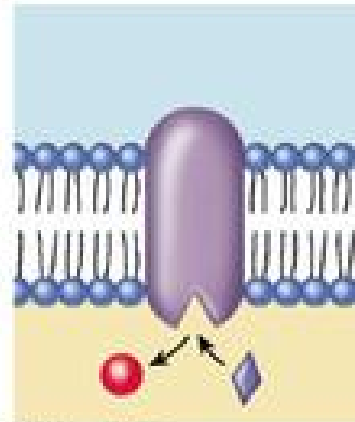
Outside

Plasma membrane

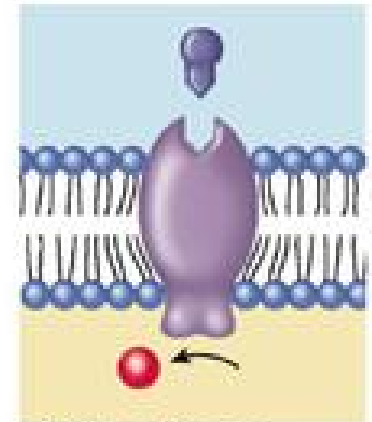
Inside



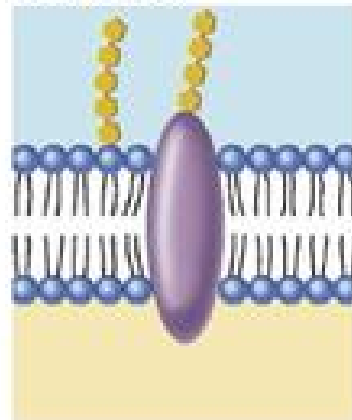
Selective transport channel



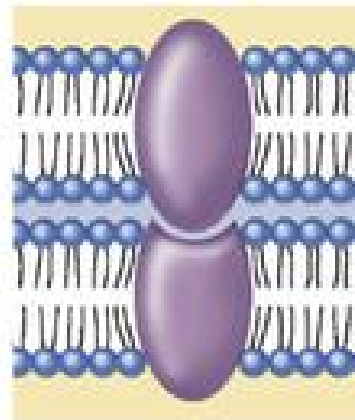
Enzyme



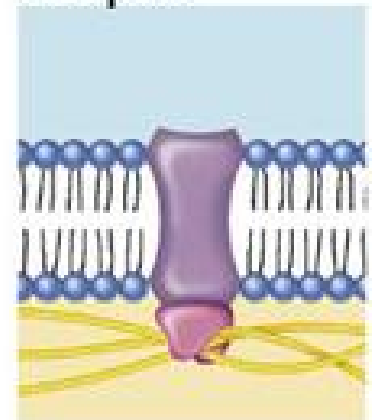
Cell surface receptor



Cell surface identity marker

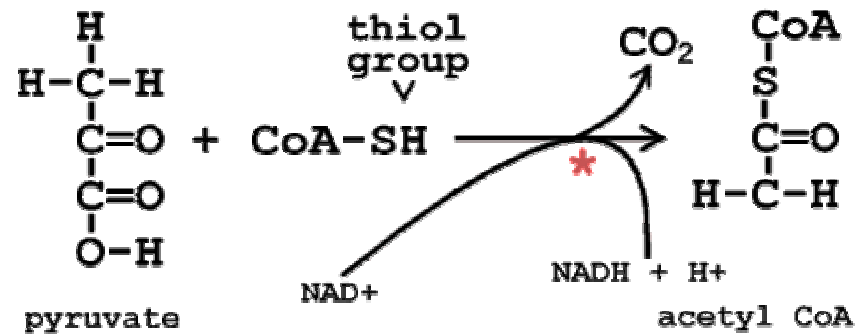
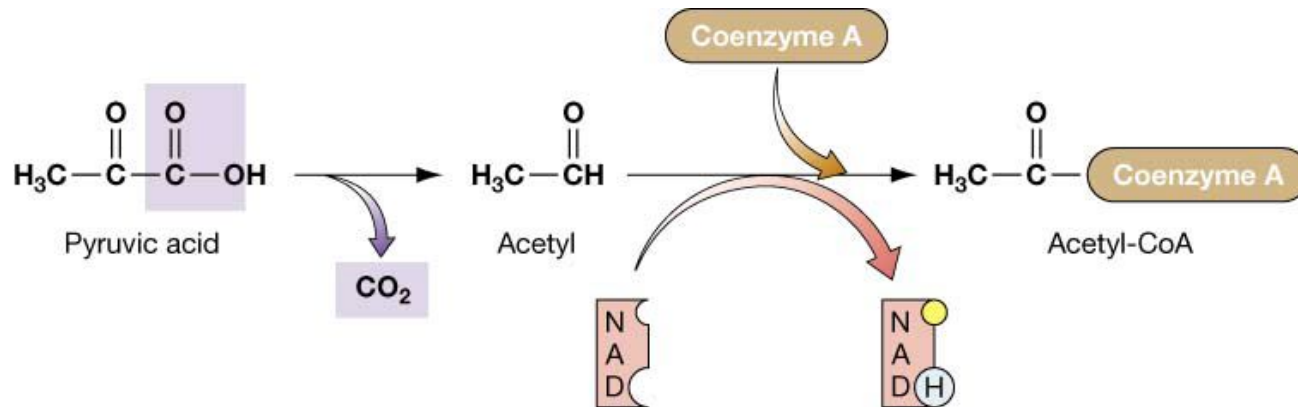


Cell adhesion

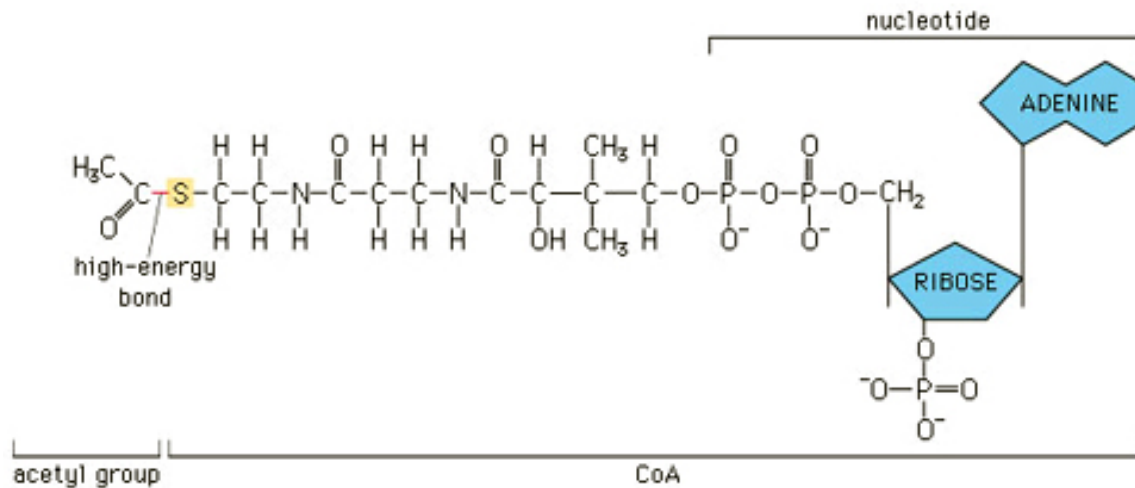
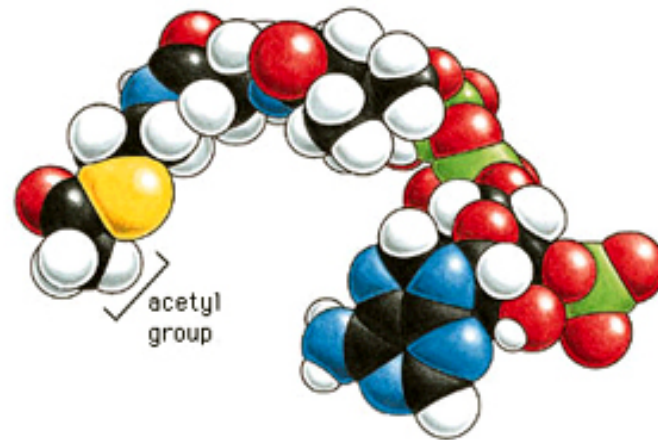


Attachment to the cytoskeleton

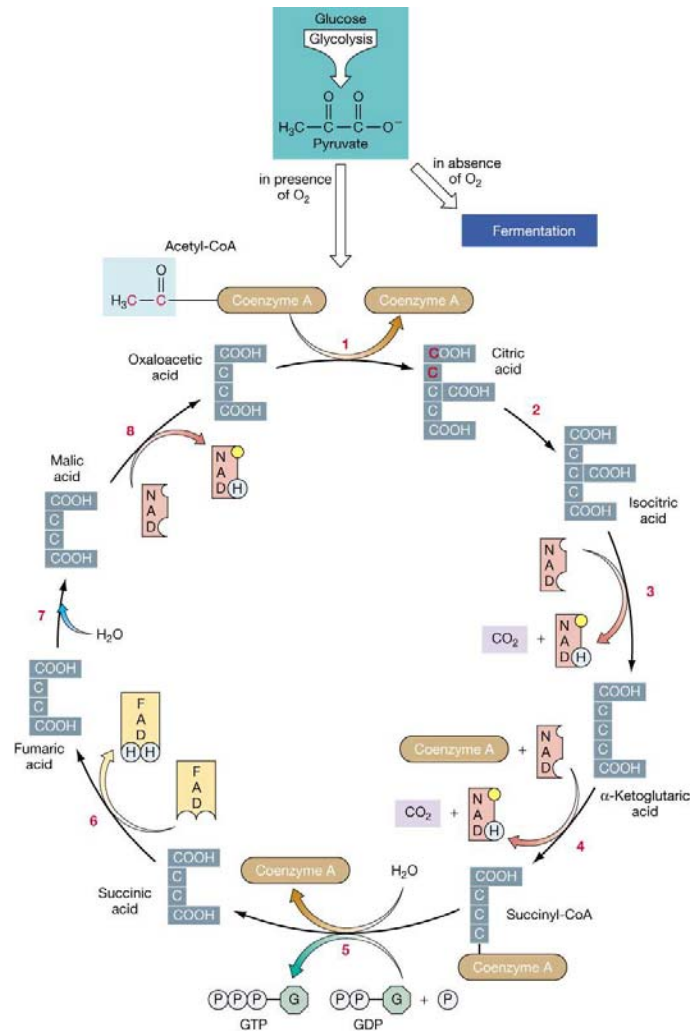
Acetyl CoA Formation



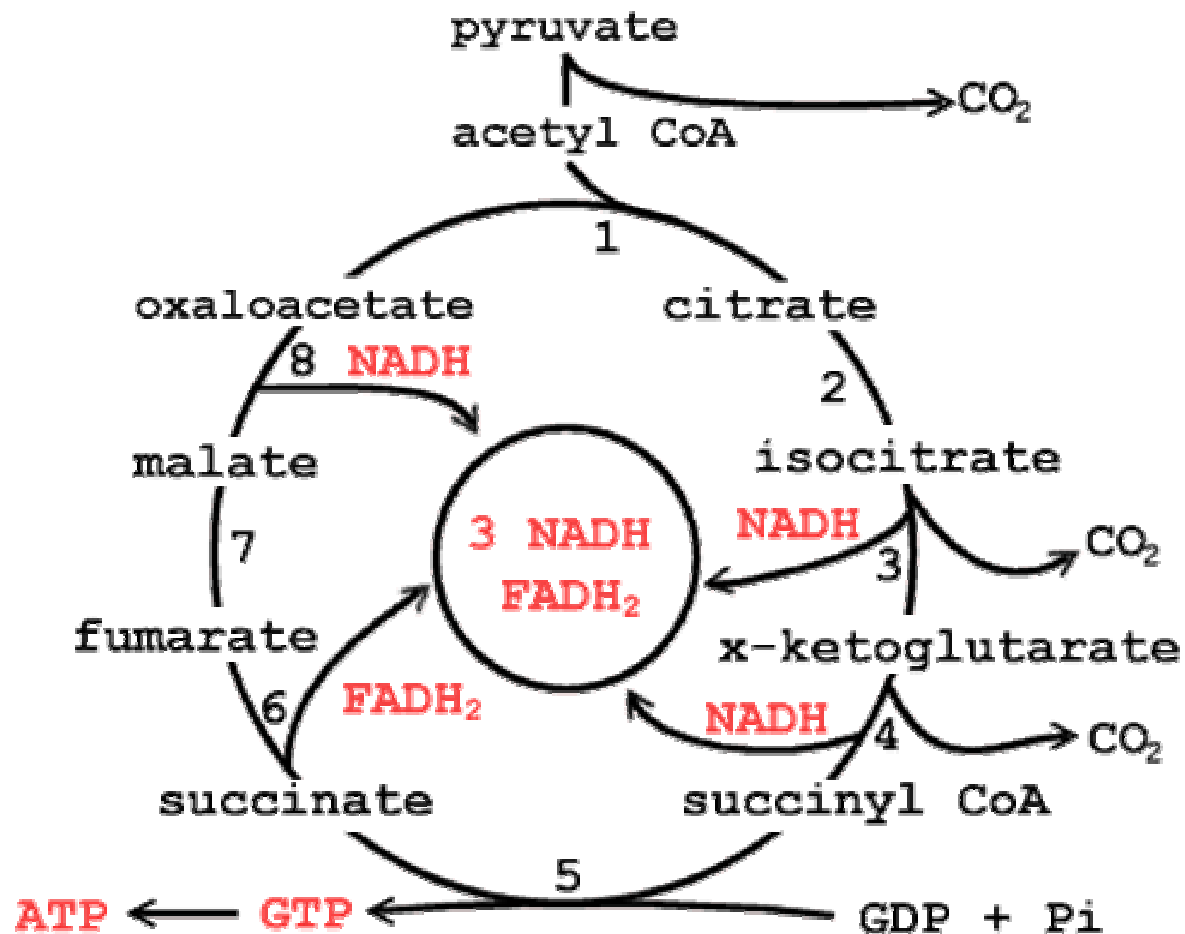
Acetyl CoA Final Structure



Krebs Cycle

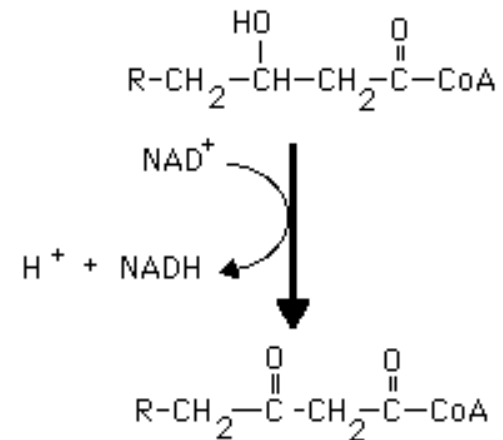
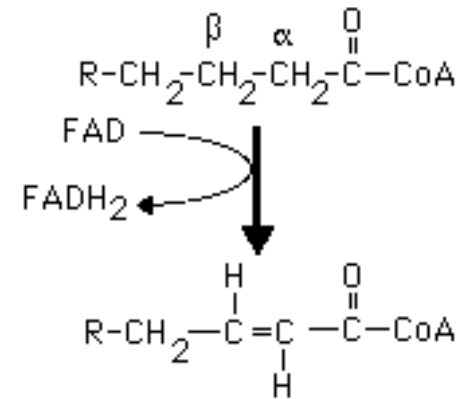


Oxidation in Krebs Cycle

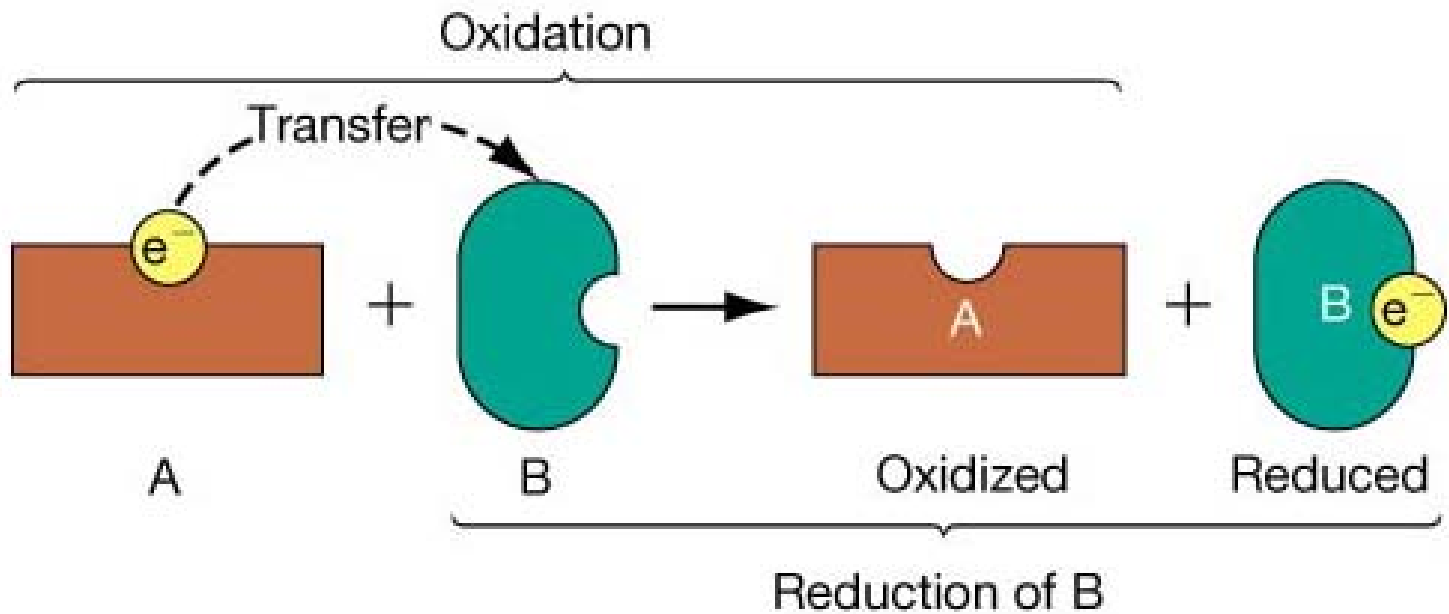


Dehydrogenation

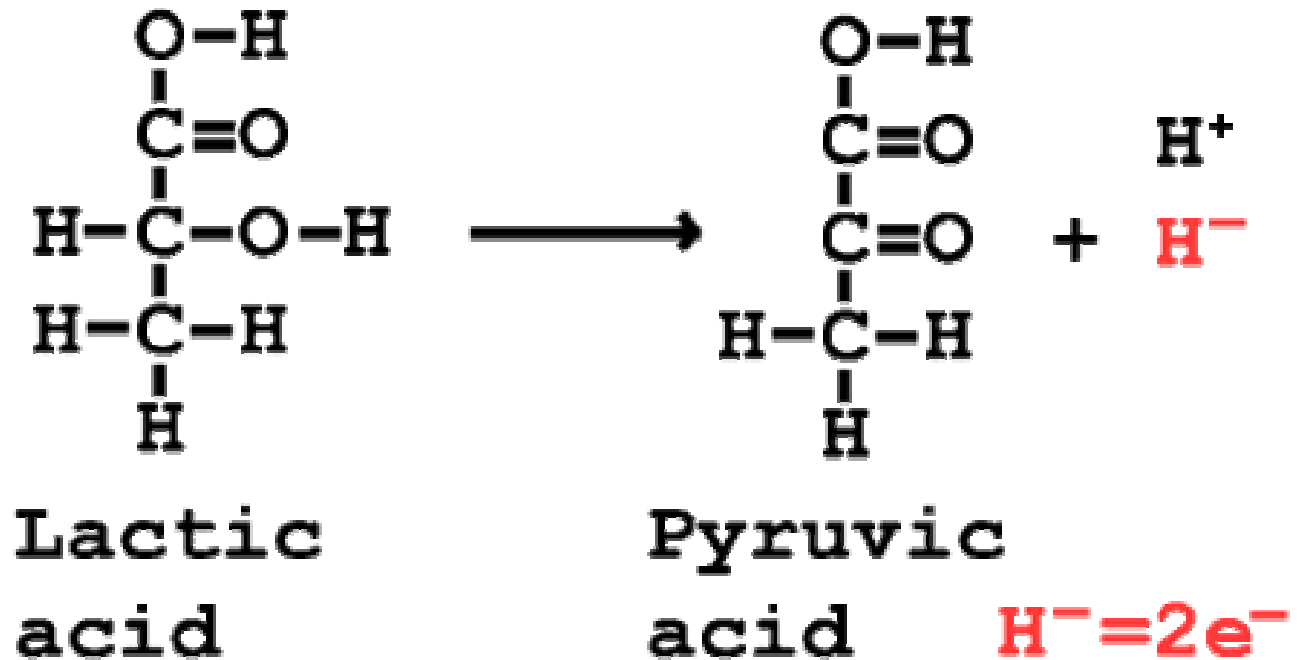
- Use of hydrogen in oxidative reactions
 - Removal of electron from hydrogen
 - Carried on vitamin B derivatives
- Energy released is trapped in chemical bonds



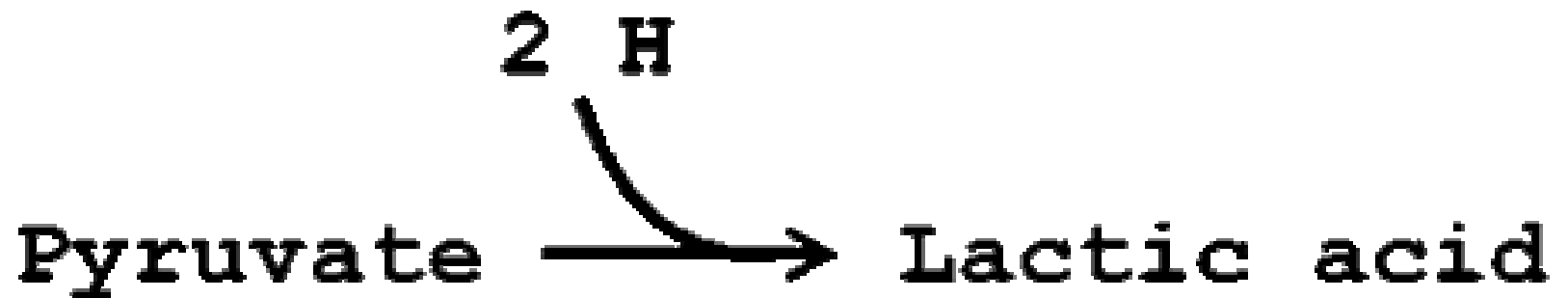
Redox Reactions



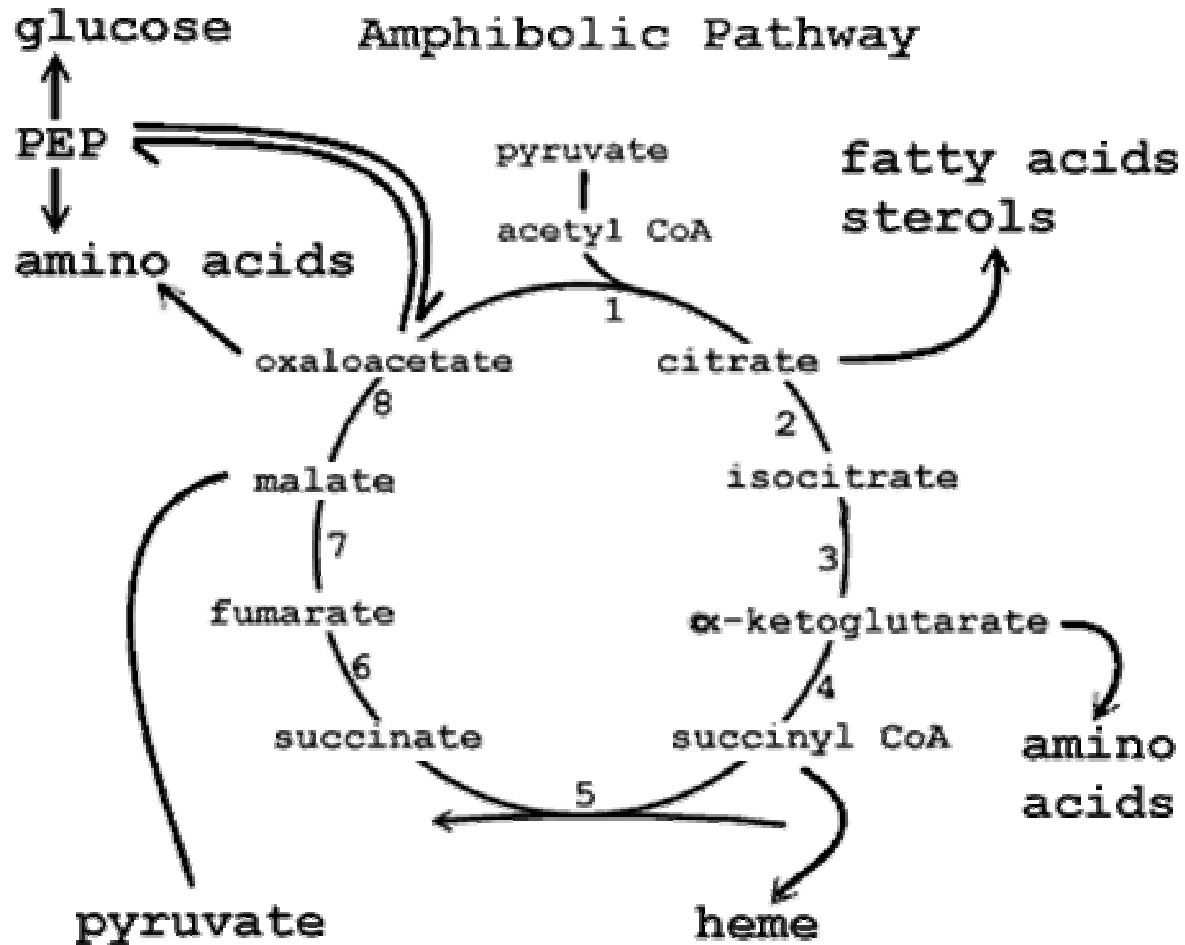
Oxidation



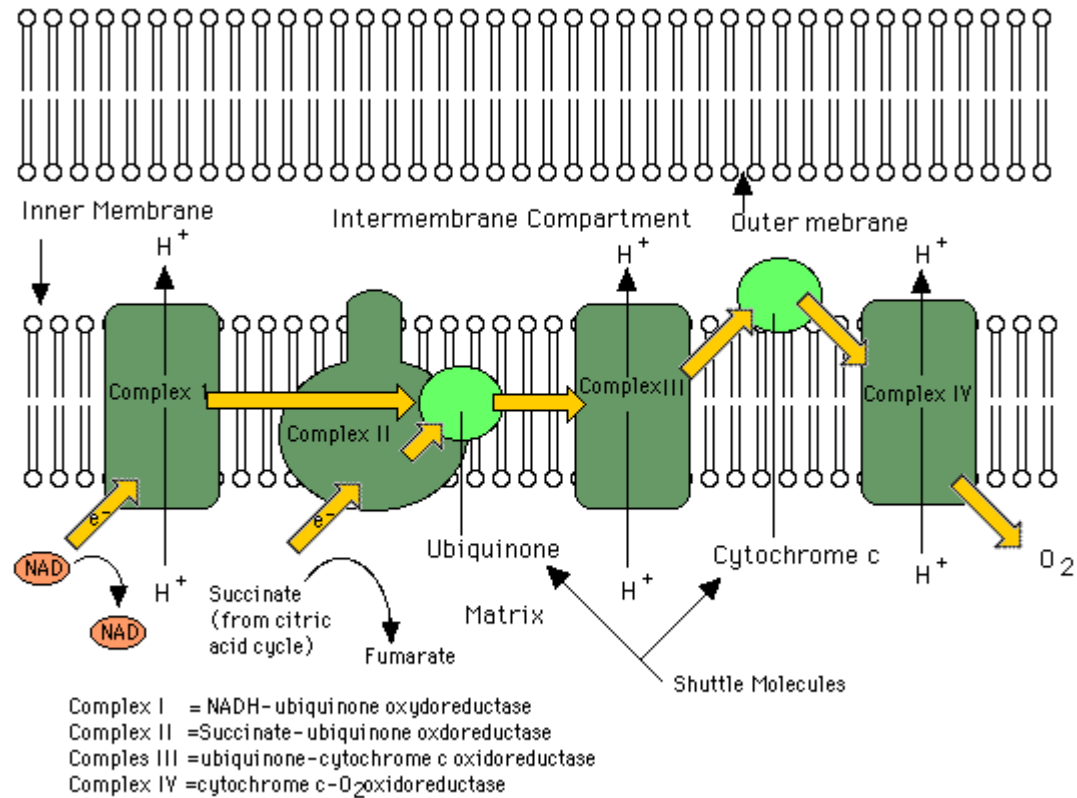
Reduction



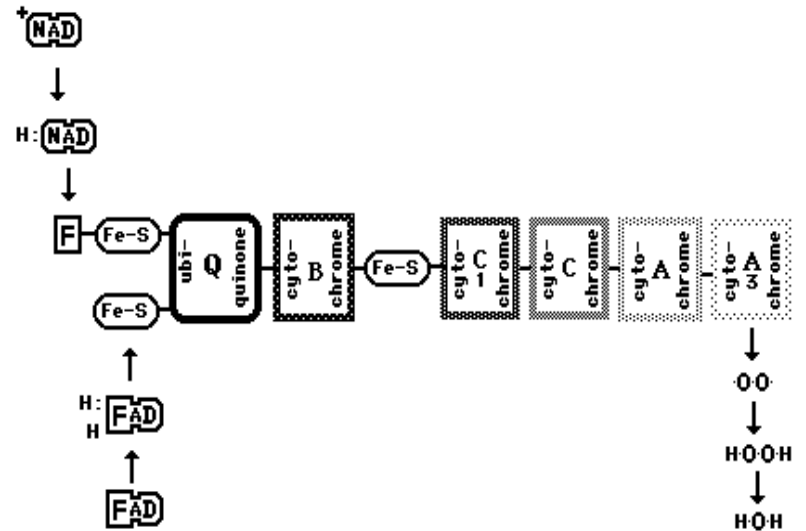
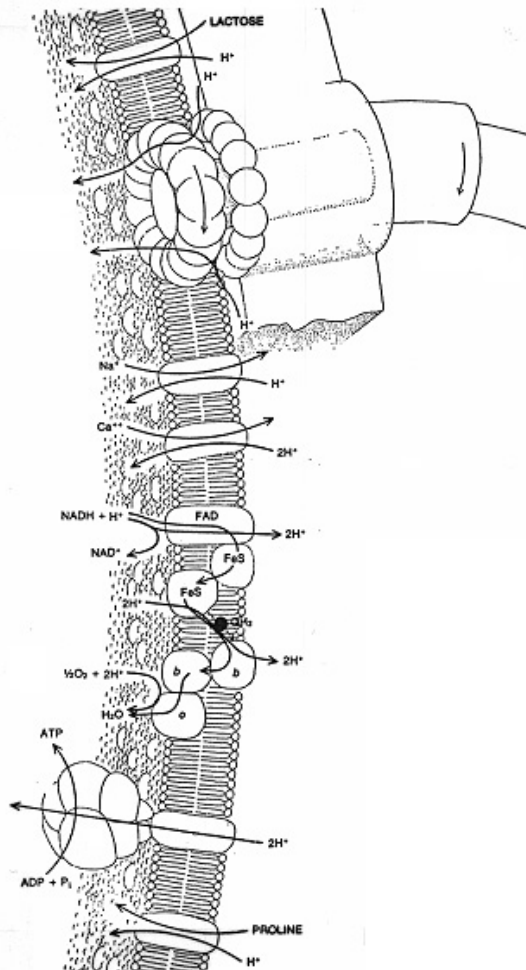
Catabolism + Anabolism



Eukaryotic ETC



Prokaryotic ETC



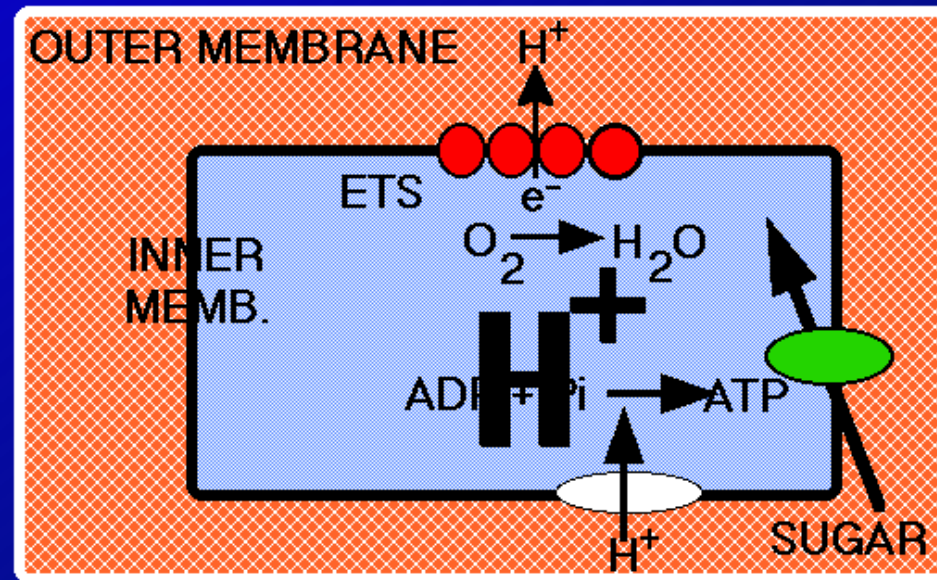
Vit B based Flavoproteins
 Iron based Cytochromes
 CoEnzyme Q

ETC Steps

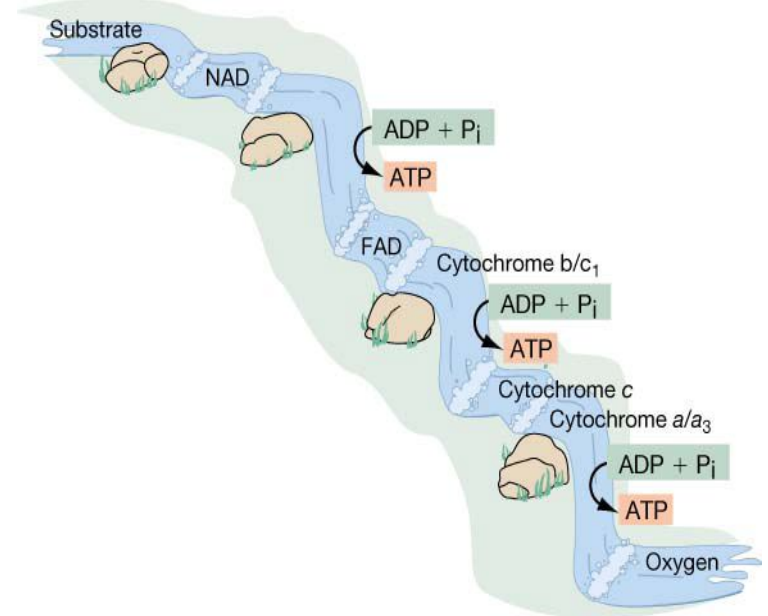
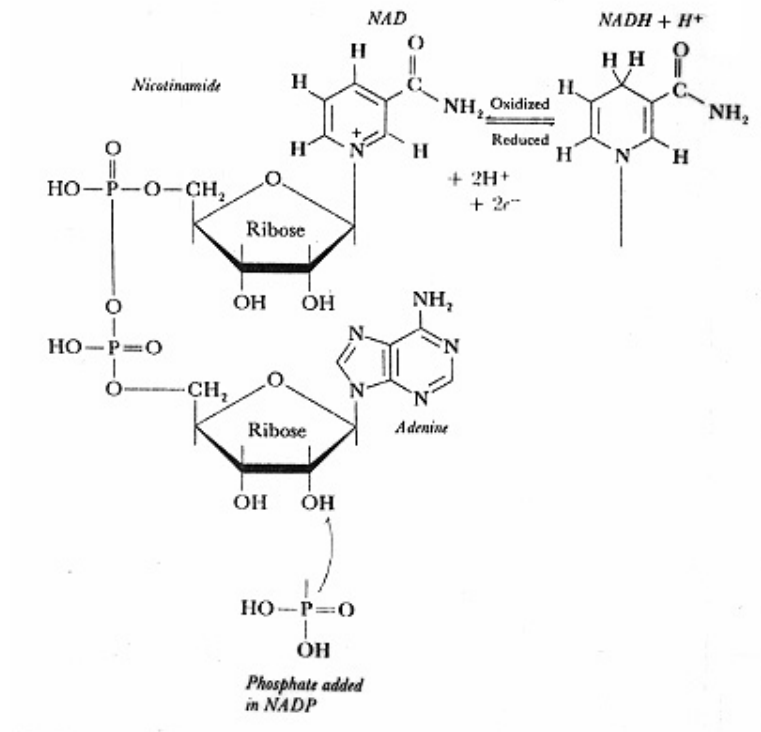
- Electrons from NADH or FADH₂ to flavoproteins
- H⁺ pumped into periplasm
- Electrons transported
 - To Iron-Sulfur proteins from NADH
 - To CoQ from FADH₂
- Cytochromes
- Final Electron Acceptor
 - O₂ if Aerobic
 - Other if Anaerobic

Proton Pump

ACTIVE TRANSPORT

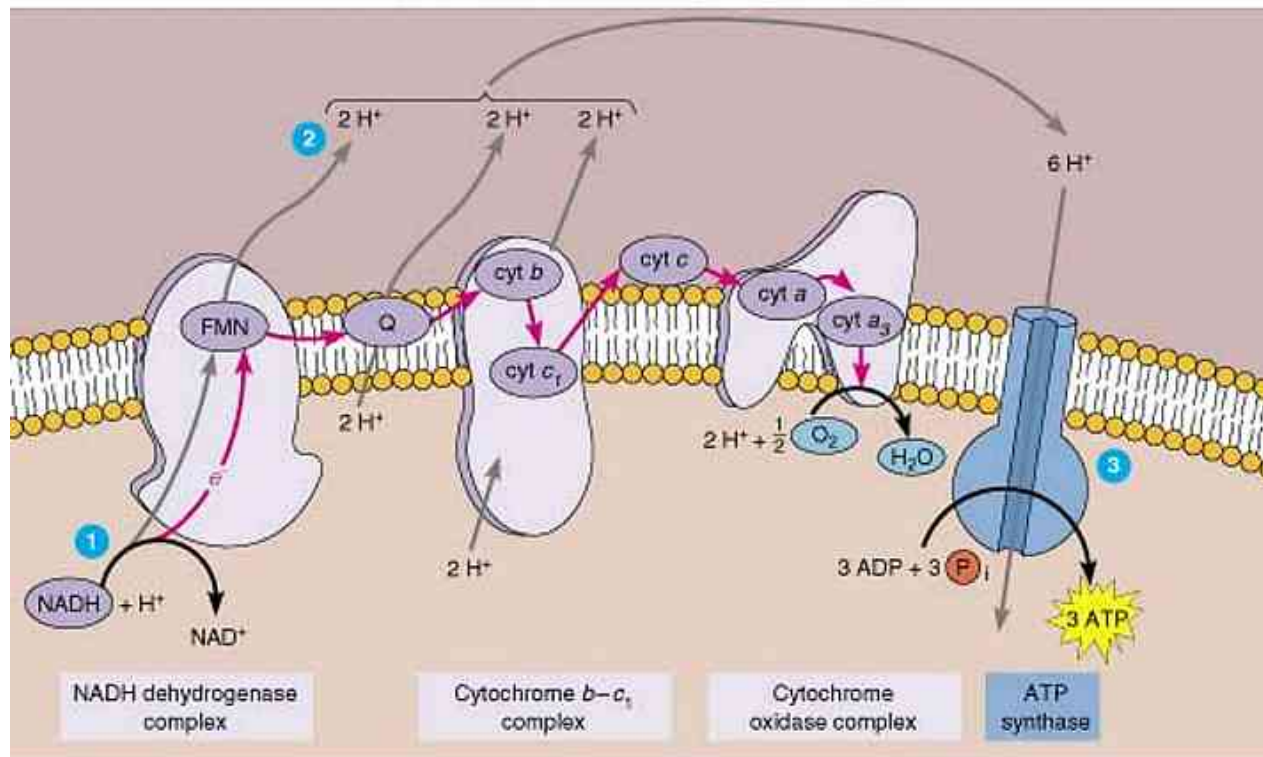


ETC: NAD



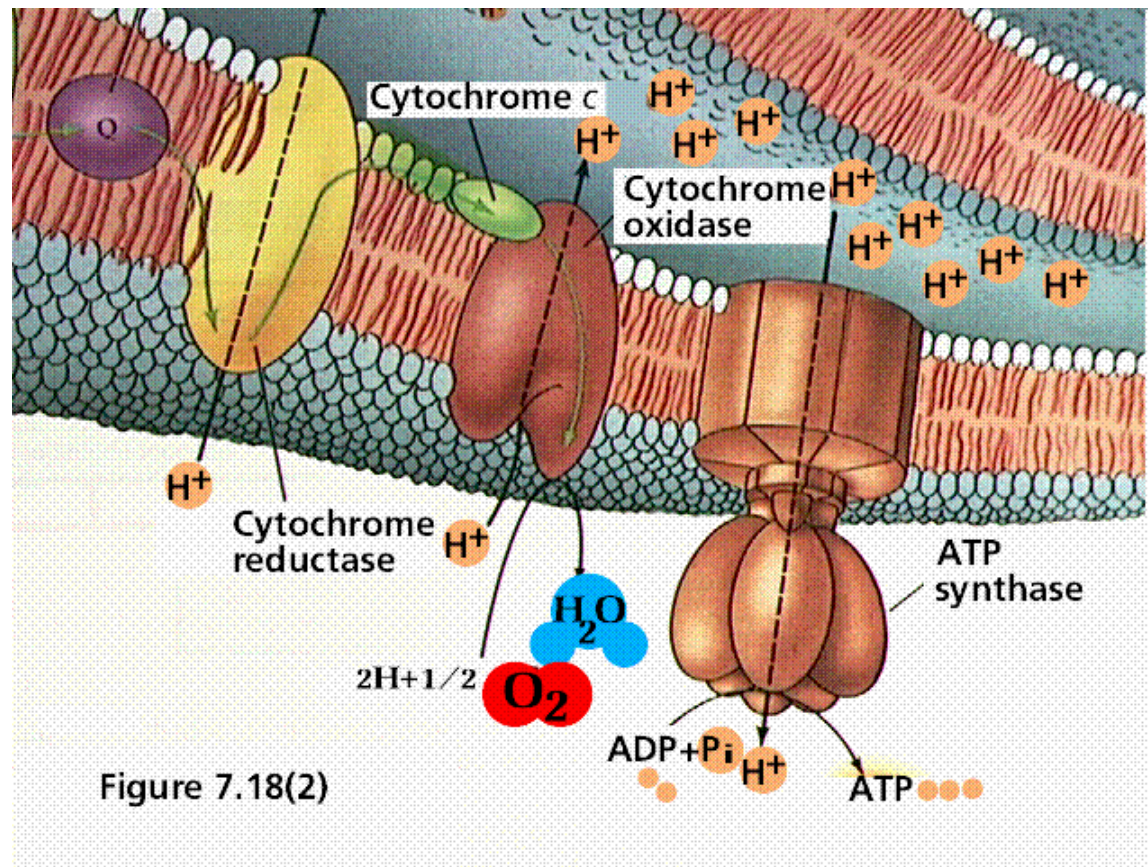
ETC: Cytochromes

ELECTRON TRANSPORT CHAIN

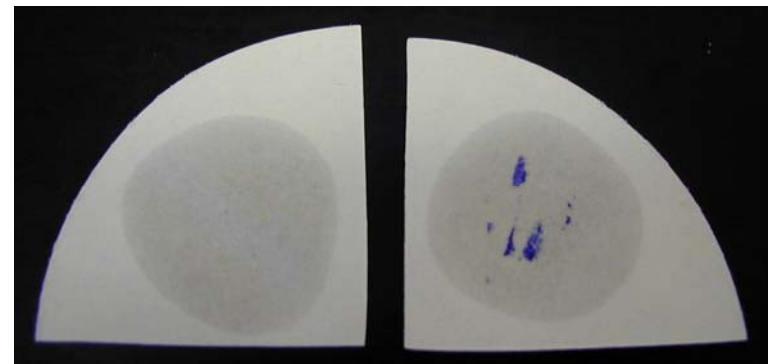
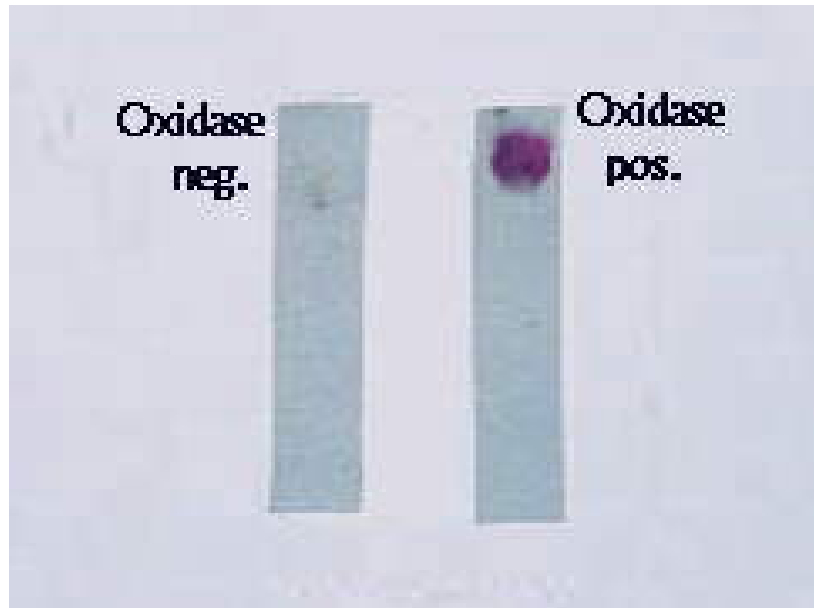


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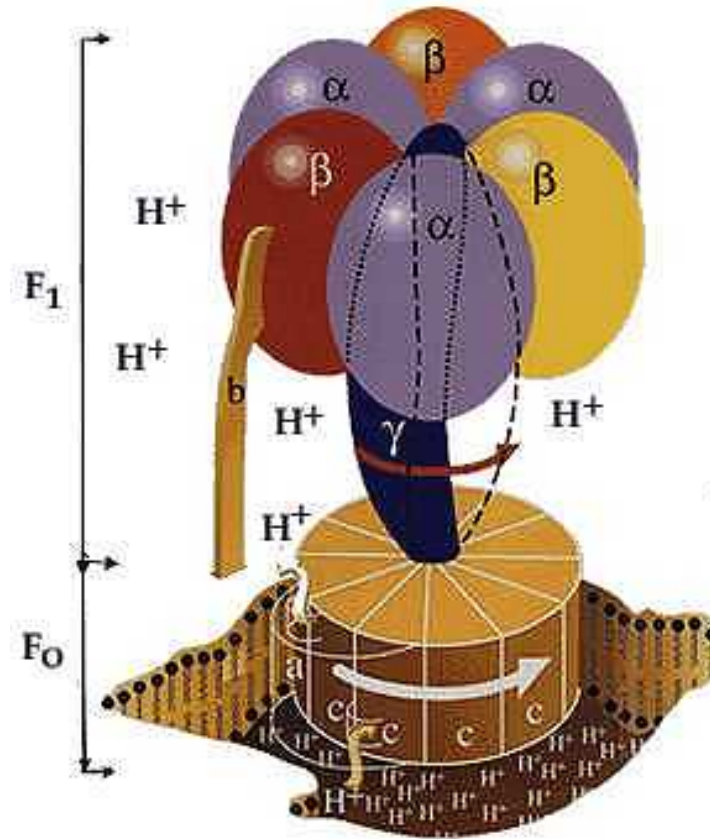
Cytochrome Oxidase



Oxidase Test

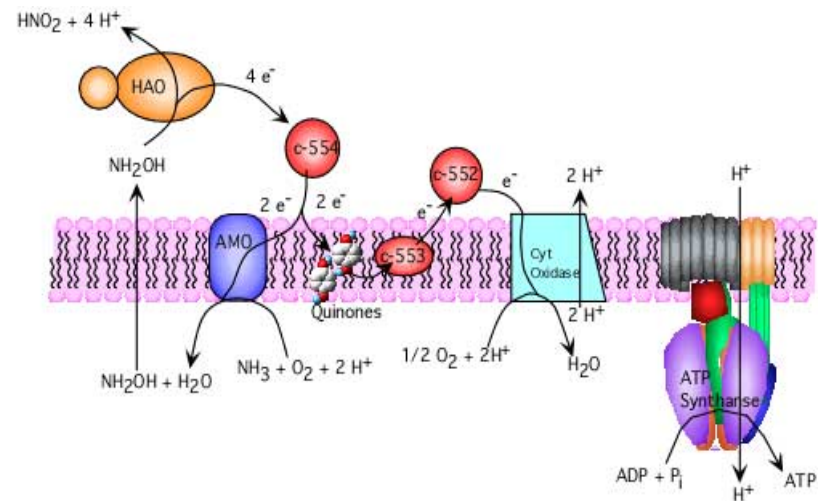


ATP Synthetase



Anaerobic Respiration

- Use of another compound than O_2 as final electron acceptor in the ETC
- Examples
 - Nitrate ion NO_3^- [*Pseudomonas*, *E coli*, *Bacillus*]
 - NO_2^-
 - N_2O
 - N_2
 - Sulfate ion $SO_4^{=}$ to H_2S
 - *Methanogens*
 - Carbonate ion $CO_3^{=}$ to CH_4
 - *Methanogens*



Nitrogen Reduction Test



Nitrate Reduction +



Nitrate Reduction
+ with Zinc



Nitrate Reduction
Neg with zinc

Other Catabolic Processes

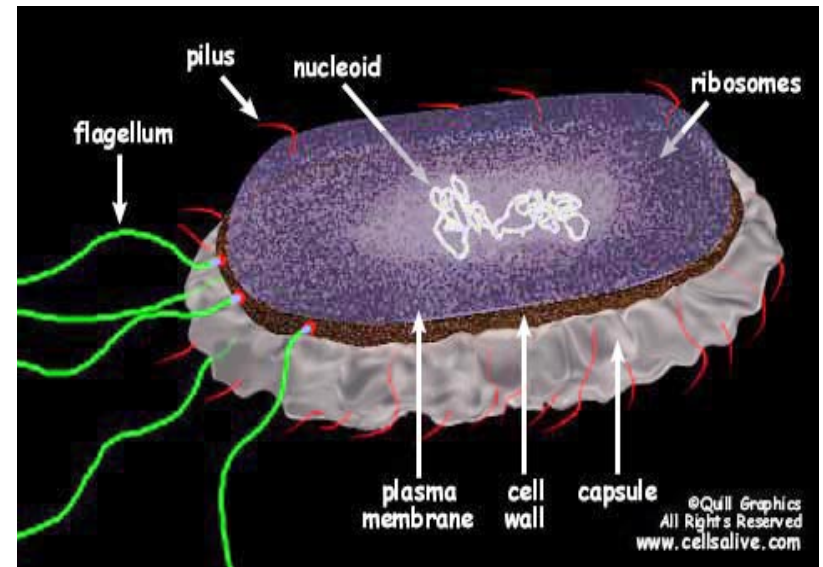
- Protein
 - Deamination
 - Decarboxylation
 - Dehydrogenation
- Lipid
 - Glycerol
 - FA
 - Beta oxidation
 - Acetyl CoA

Biosynthesis

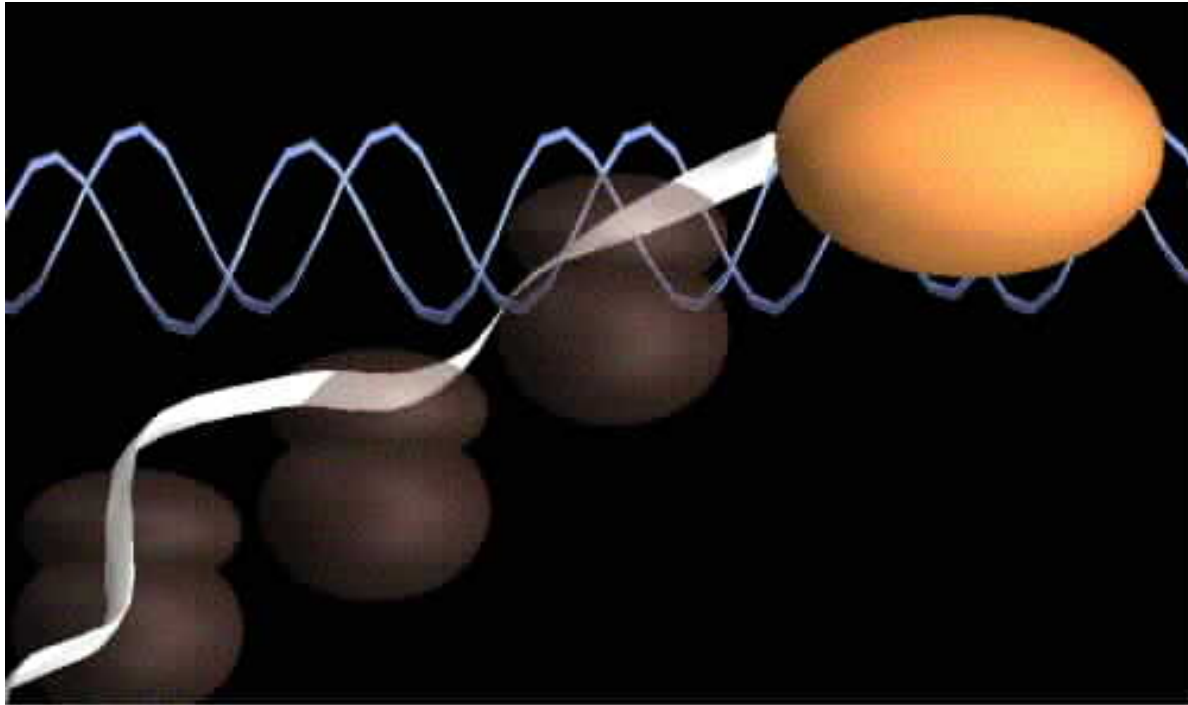
- Polysaccharide
 - Keto acids
 - AA
 - Glycerol from FA
- Lipid
 - Glycerol + FA
- AA
 - Keto acids + NH₂
- Nucleotides
 - Nitrogen bases from Keto acids + NH₂
 - 5 C sugars from alternate CH₂O Metabolism

Functions

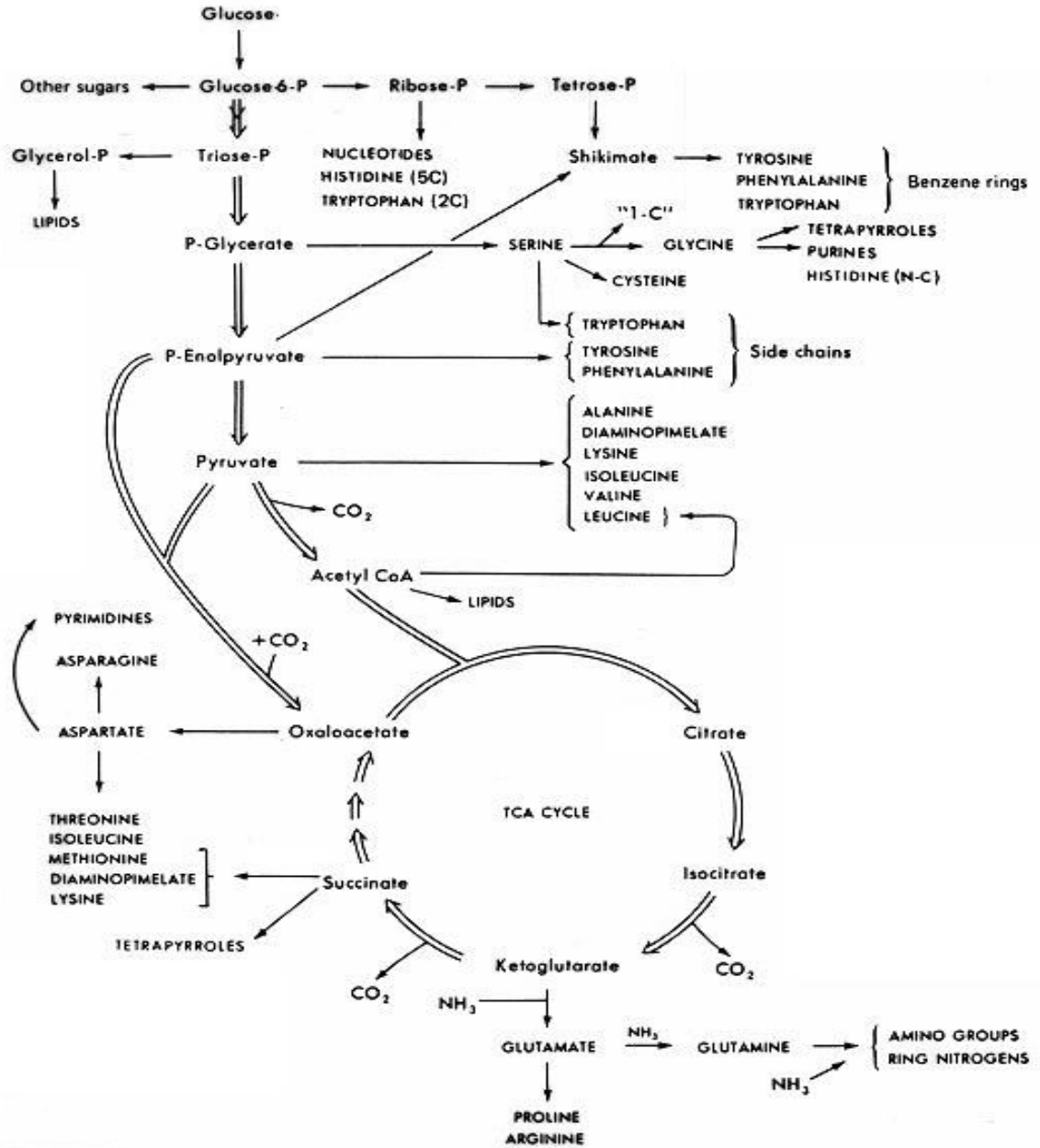
- Polysaccharide
 - Cell wall components
- Lipid
 - Cell wall
 - Plasma membranes
- AA/Protein
 - Cell wall / membrane components
 - Enzymes
 - Toxins
- Nucleotide
 - DNA
 - RNA
 - ATP
 - NAD
 - NADP



Protein Synthesis and Enzyme Regulation



Metabolism Summary



Questions?

