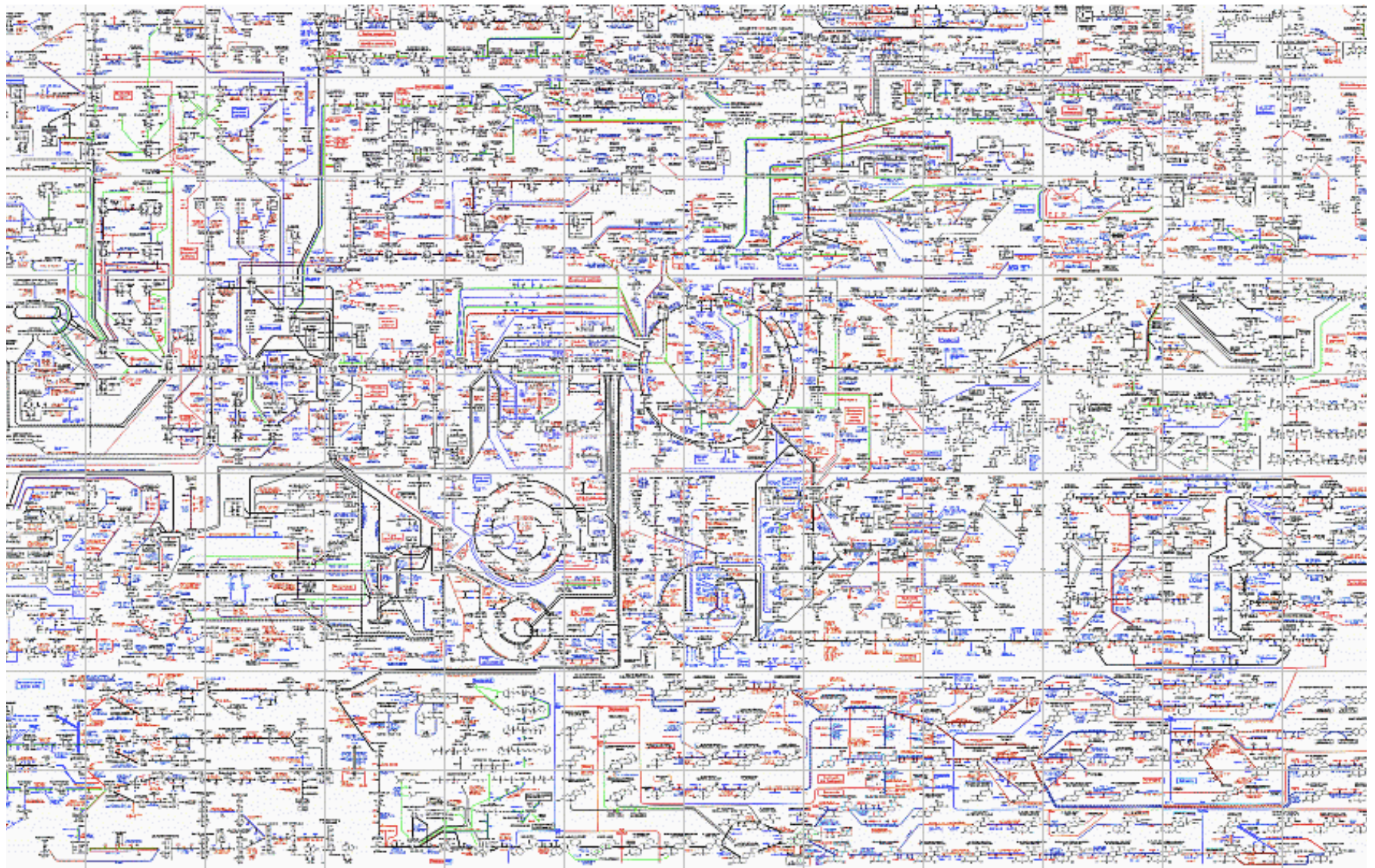
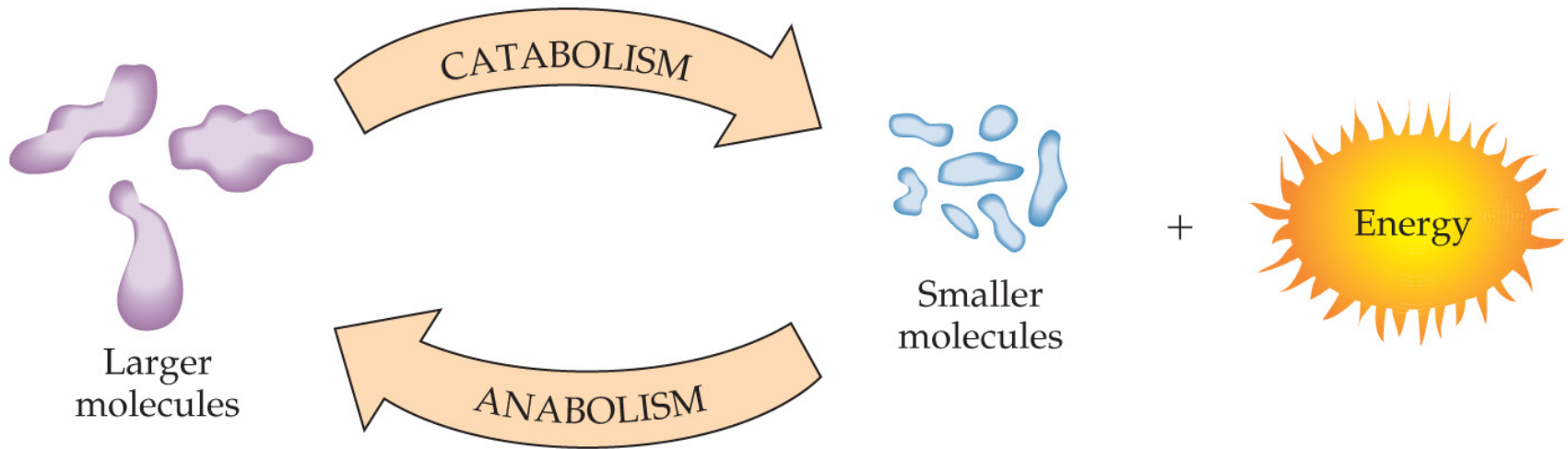


Ch20/21: The Generation of
Biochemical Energy

Metabolic Pathways



Catabolism and Anabolism



Overview of Catabolism

Stage 1. Digestion
Bulk food is digested in the mouth, stomach, and small intestine to yield small molecules.

LIPIDS
↓
Fatty acids and glycerol

CARBOHYDRATES
↓
Glucose and other sugars

PROTEINS
↓
Amino acids

Stage 2. Acetyl-CoA Production
Sugar and amino acid molecules are degraded in the cytoplasm of cells to yield acetyl-CoA. Fatty acid molecules are degraded in the mitochondria of cells to yield acetyl-CoA.

Fatty acid oxidation

Glycolysis

Amino acid catabolism

ATP

Pyruvate

Acetyl-CoA

Stage 3. Citric Acid Cycle
Acetyl-CoA is oxidized inside mitochondria by the citric acid cycle to yield CO₂ and reduced coenzymes.

ATP

Citric acid cycle

CO₂

Stage 4. ATP Production
The energy transferred to the reduced coenzymes in stage 3 is used to make ATP by the coupled pathways of electron transport and oxidative phosphorylation.

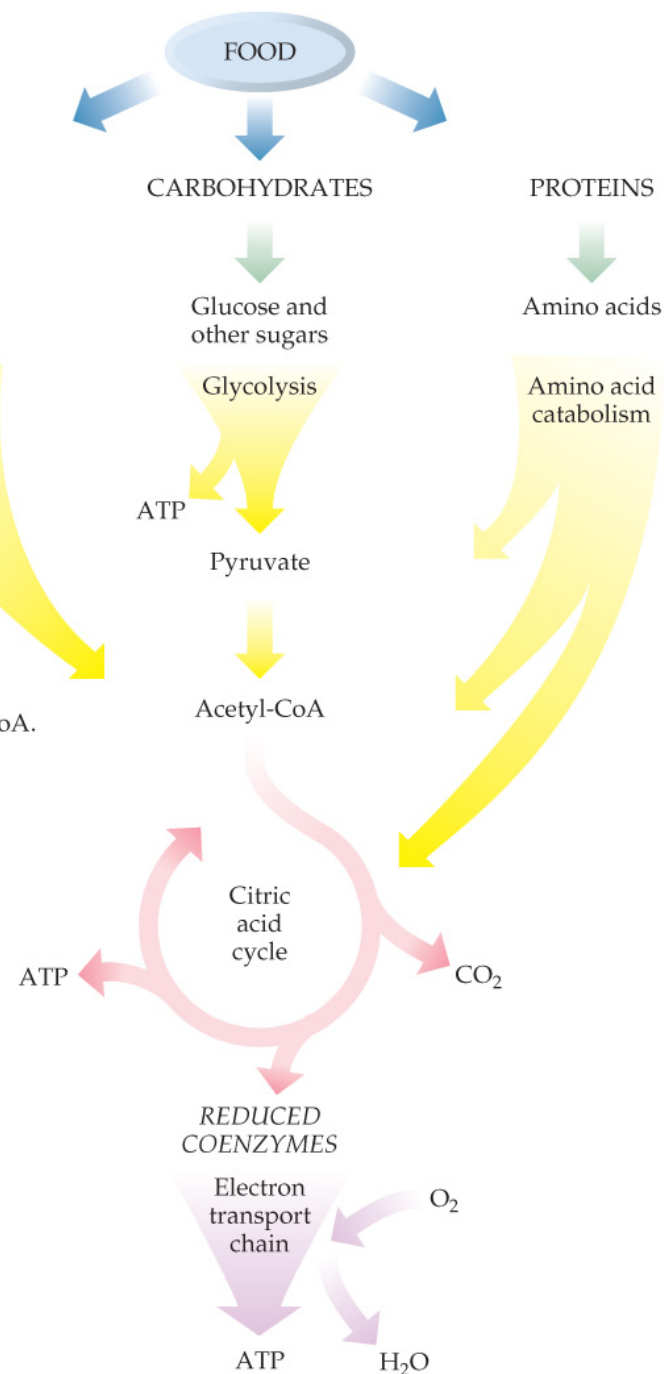
REDUCED COENZYMES

Electron transport chain

O₂

ATP

H₂O



[Handout] Catabolism Flow Chart

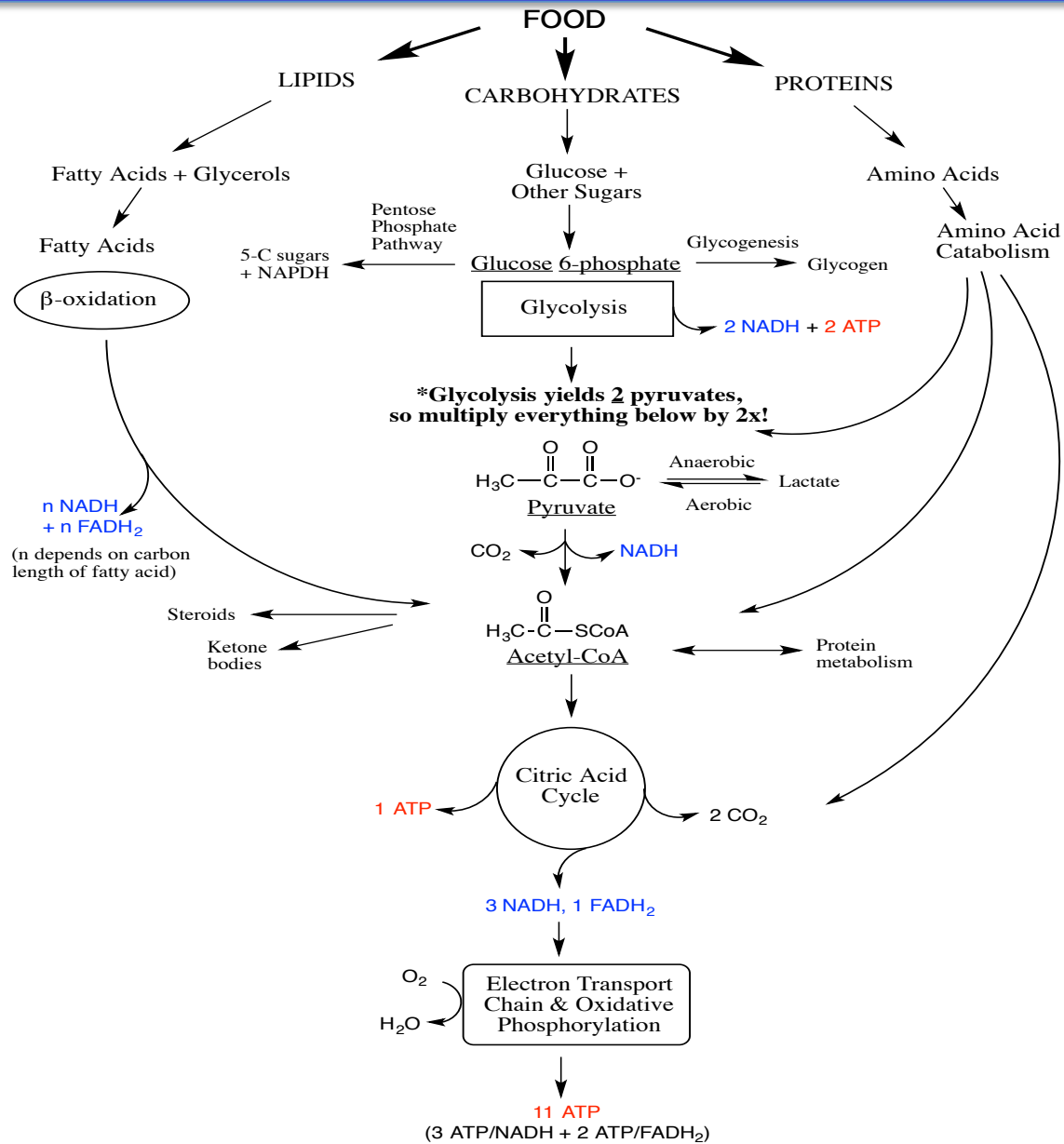
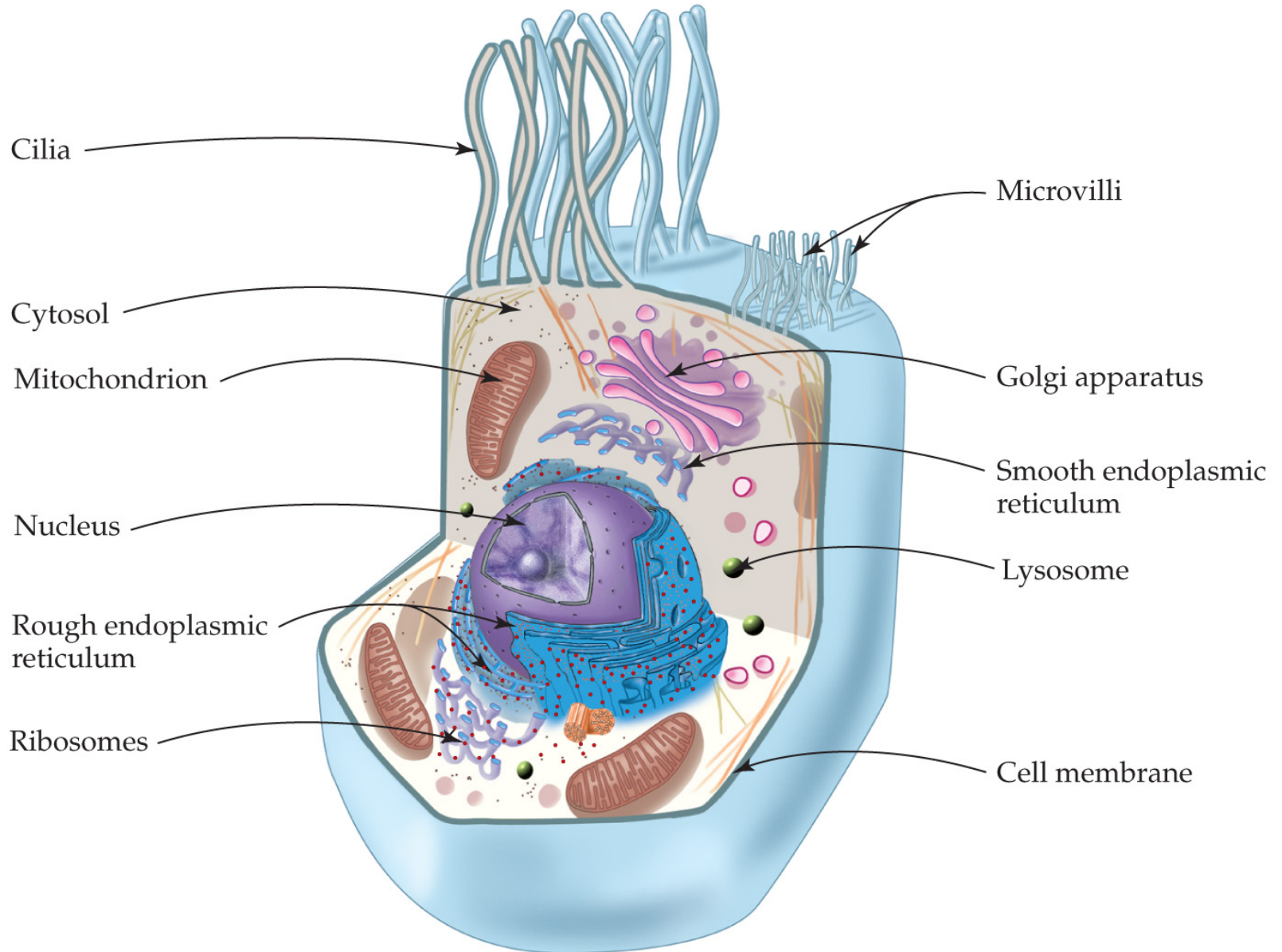
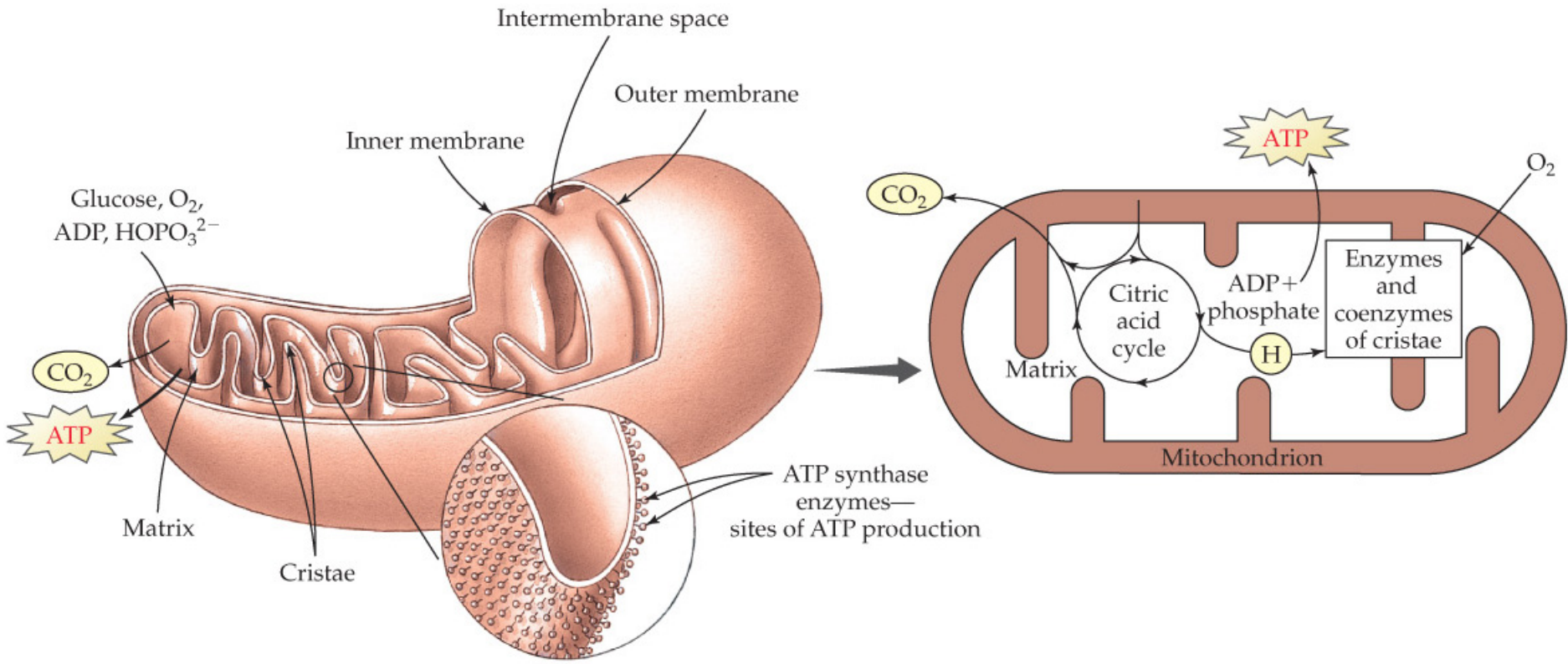


Diagram of a Eukaryotic Cell

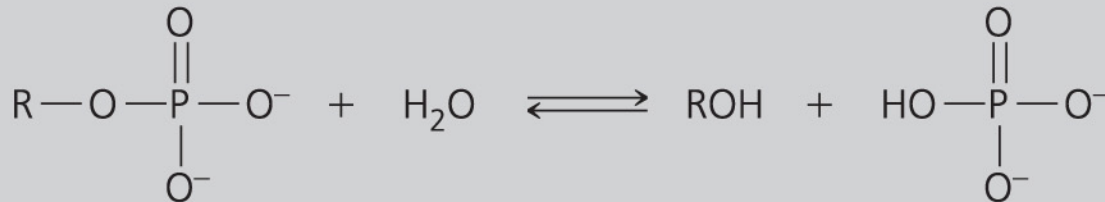


Mitochondrion



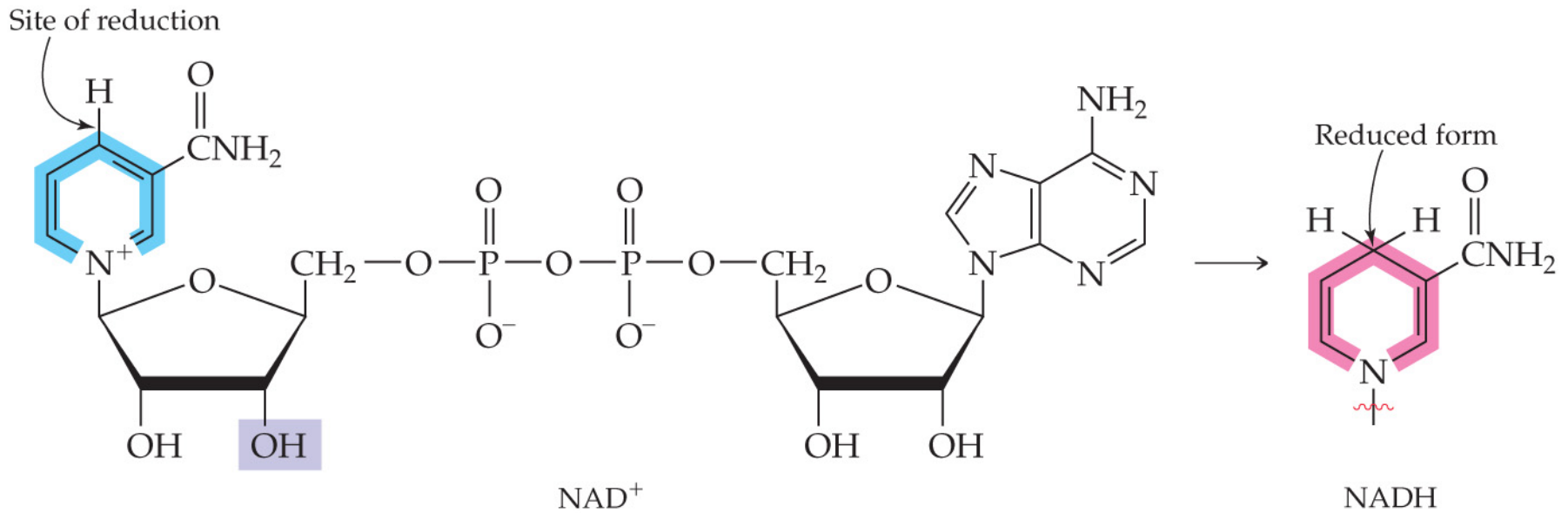
Free Energies of Hydrolysis

TABLE 20.1 Free Energies of Hydrolysis of Some Phosphates



Compound Name	Function	ΔG (kcal/mol)	ΔG (kJ/mol)
Phosphoenol pyruvate	Final intermediate in conversion of glucose to pyruvate (glycolysis)— Stage 2, Figure 20.5	-14.8	-61.9
1, 3-Bisphosphoglycerate	Another intermediate in glycolysis	-11.8	-49.4
Creatine phosphate	Energy storage in muscle cells	-10.3	-43.1
ATP (→ADP)	Principal energy carrier	-7.3	-30.5
Glucose 1-phosphate	First intermediate in breakdown of carbohydrates stored as starch or glycogen	-5.0	-20.9
Glucose 6-phosphate	First intermediate in glycolysis	-3.3	-13.8
Fructose 6-phosphate	Second intermediate in glycolysis	-3.3	-13.8

Nicotinamide Adenine Dinucleotide (NADH)

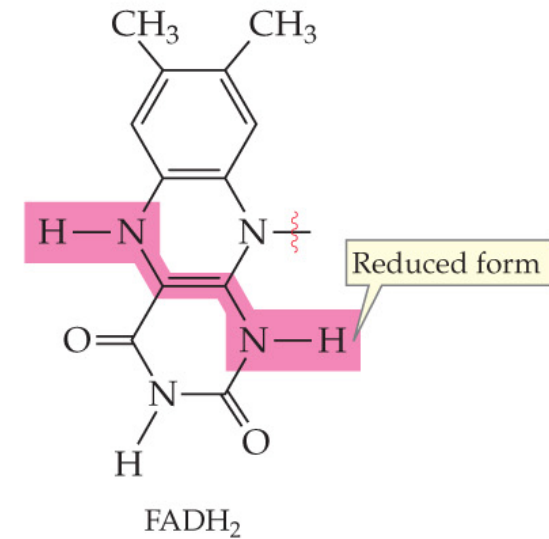
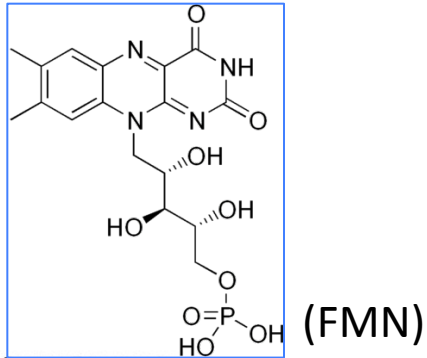
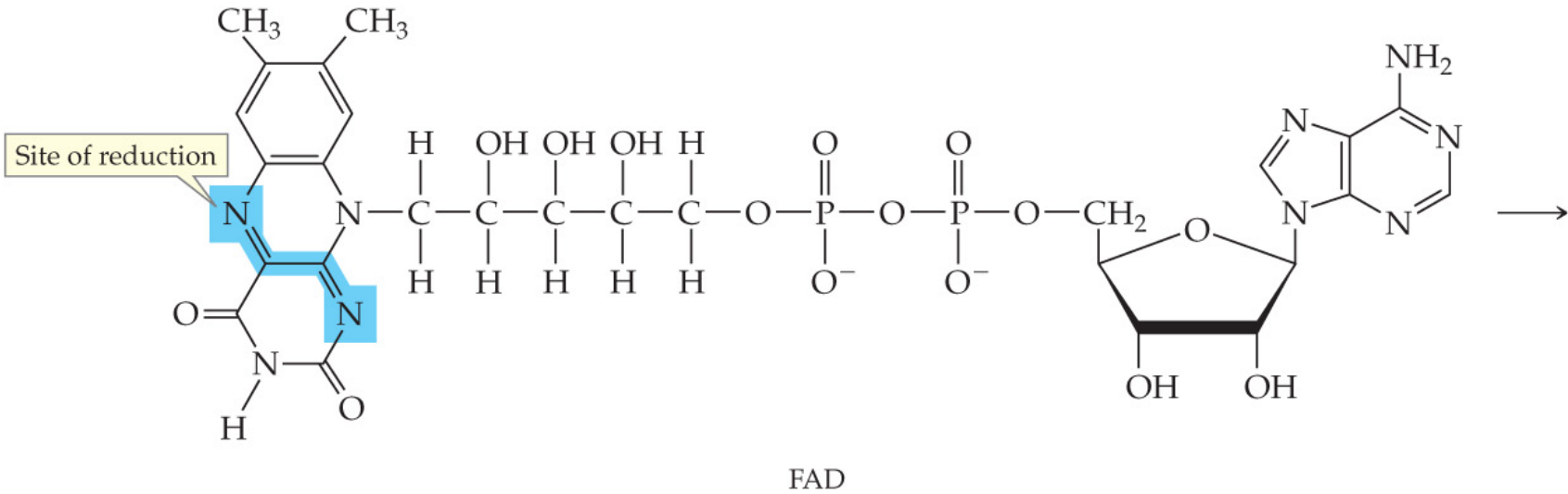


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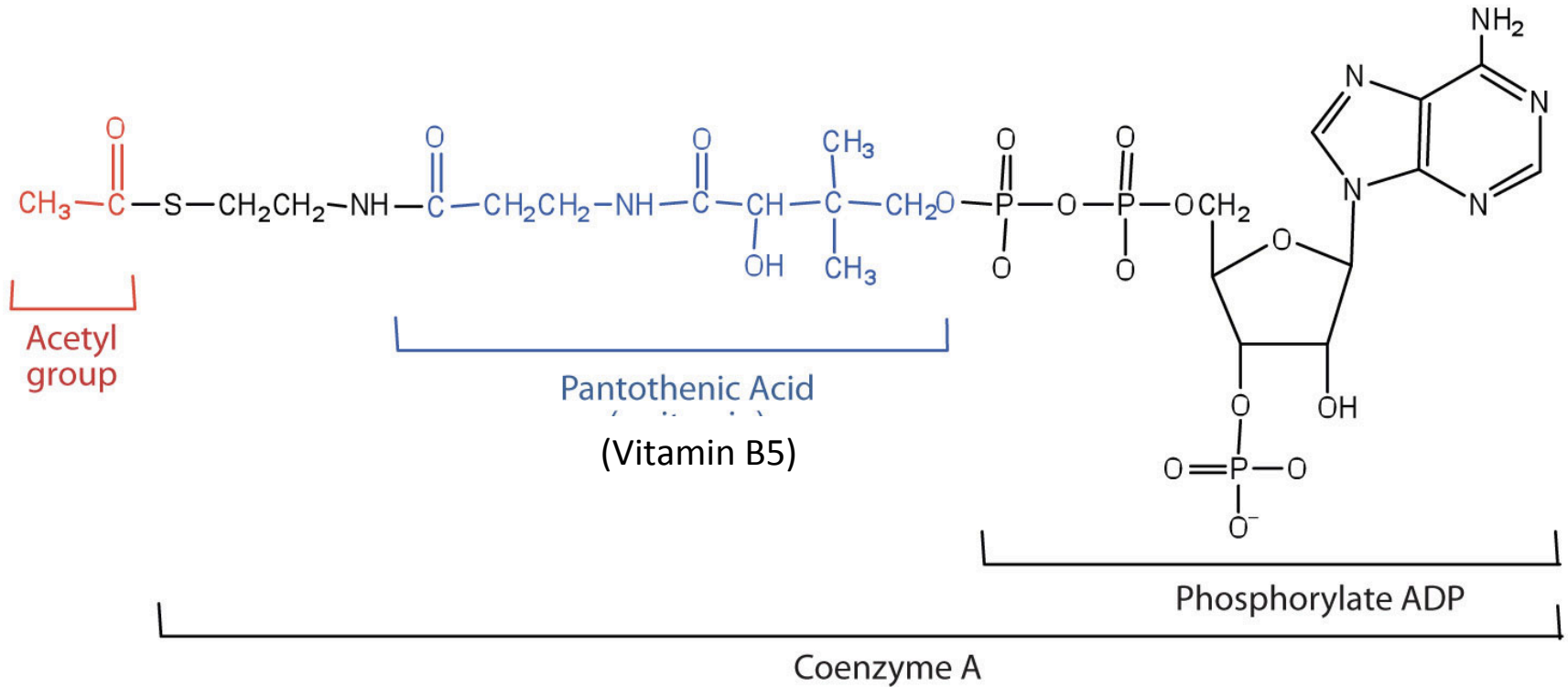
(NADPH if $-OH$ is replaced by $-OPO_3^{2-}$)

(Often written as NADH/H⁺)

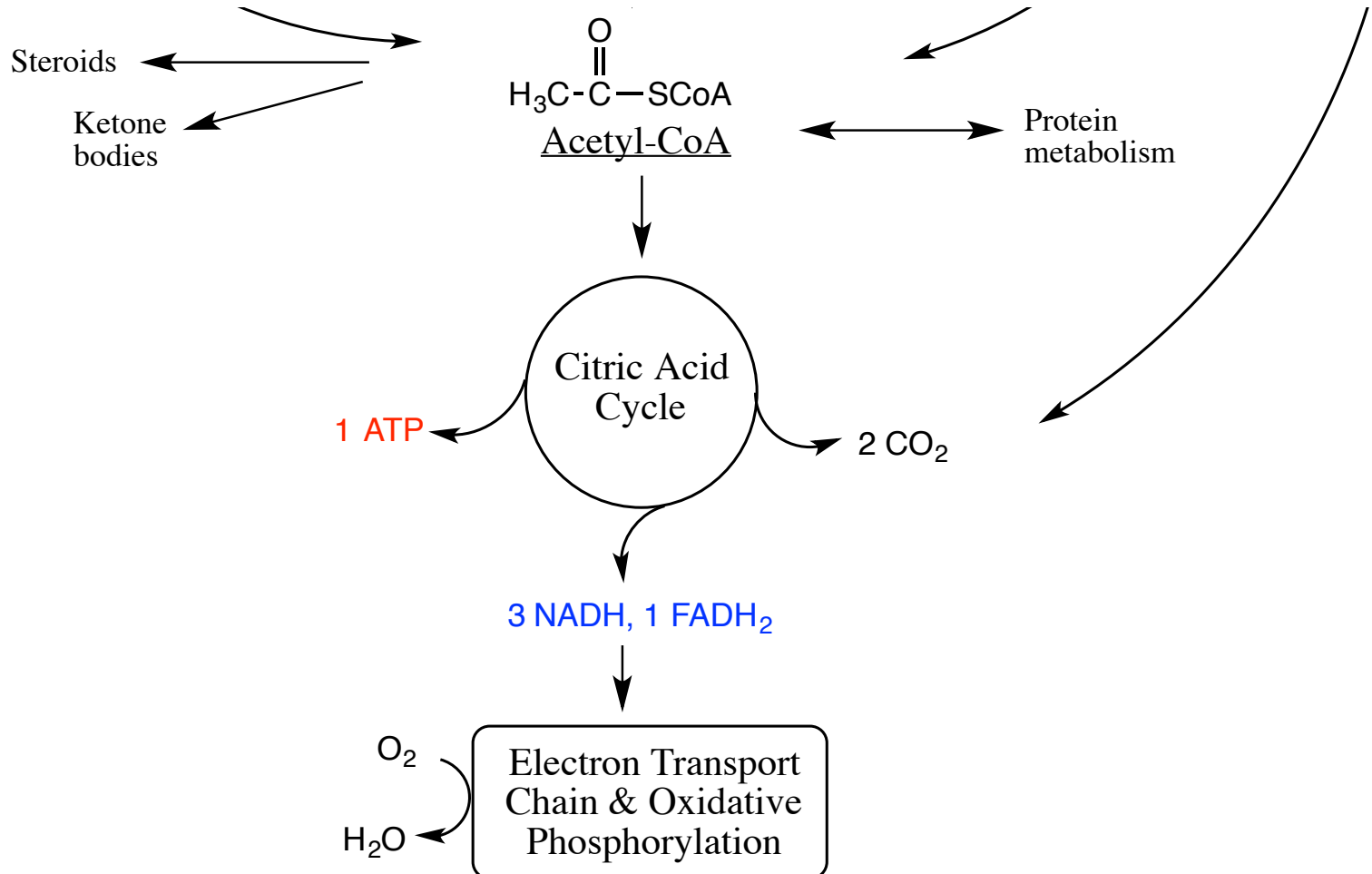
Flavin Adenine Dinucleotide (FADH₂)



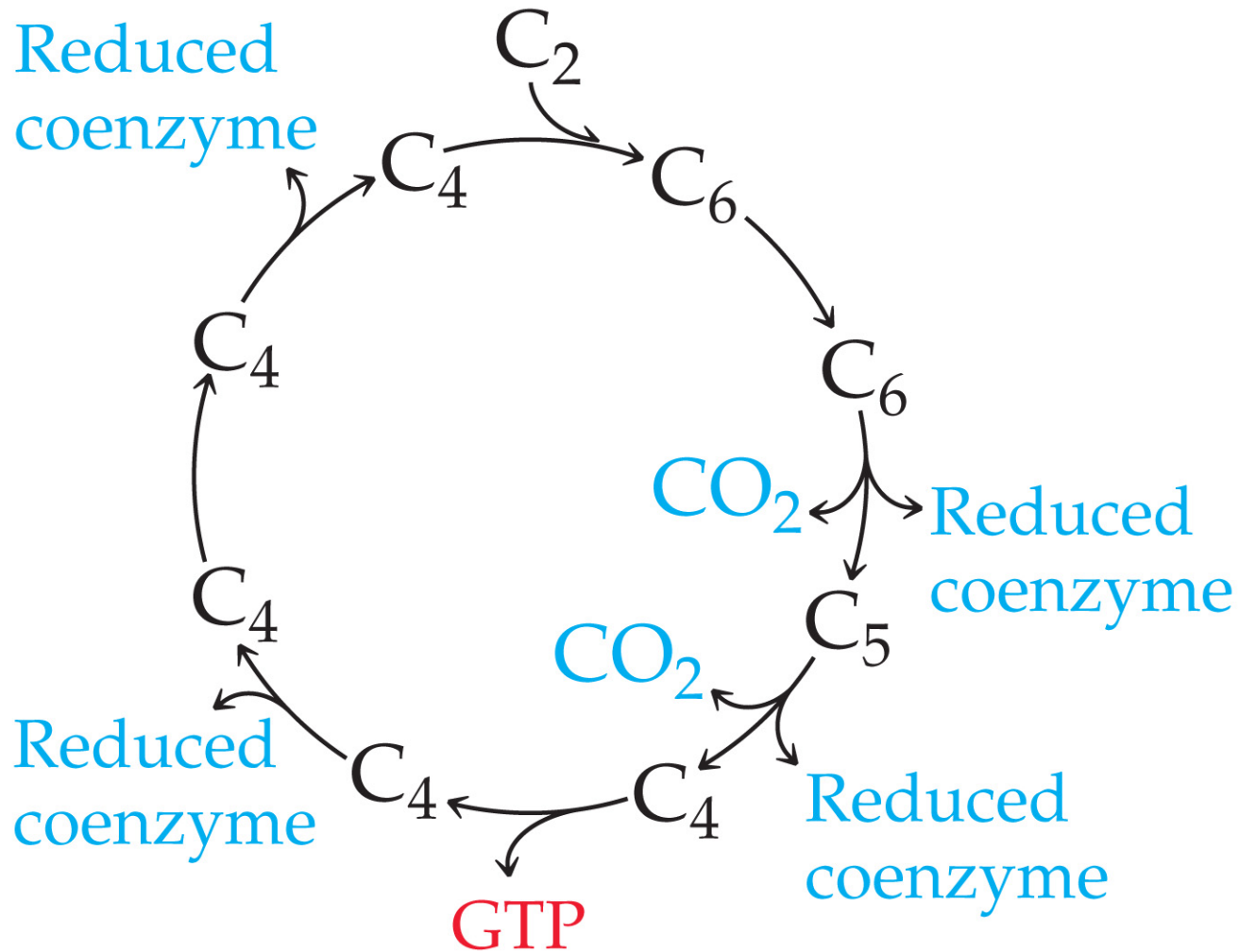
Acetyl-CoA



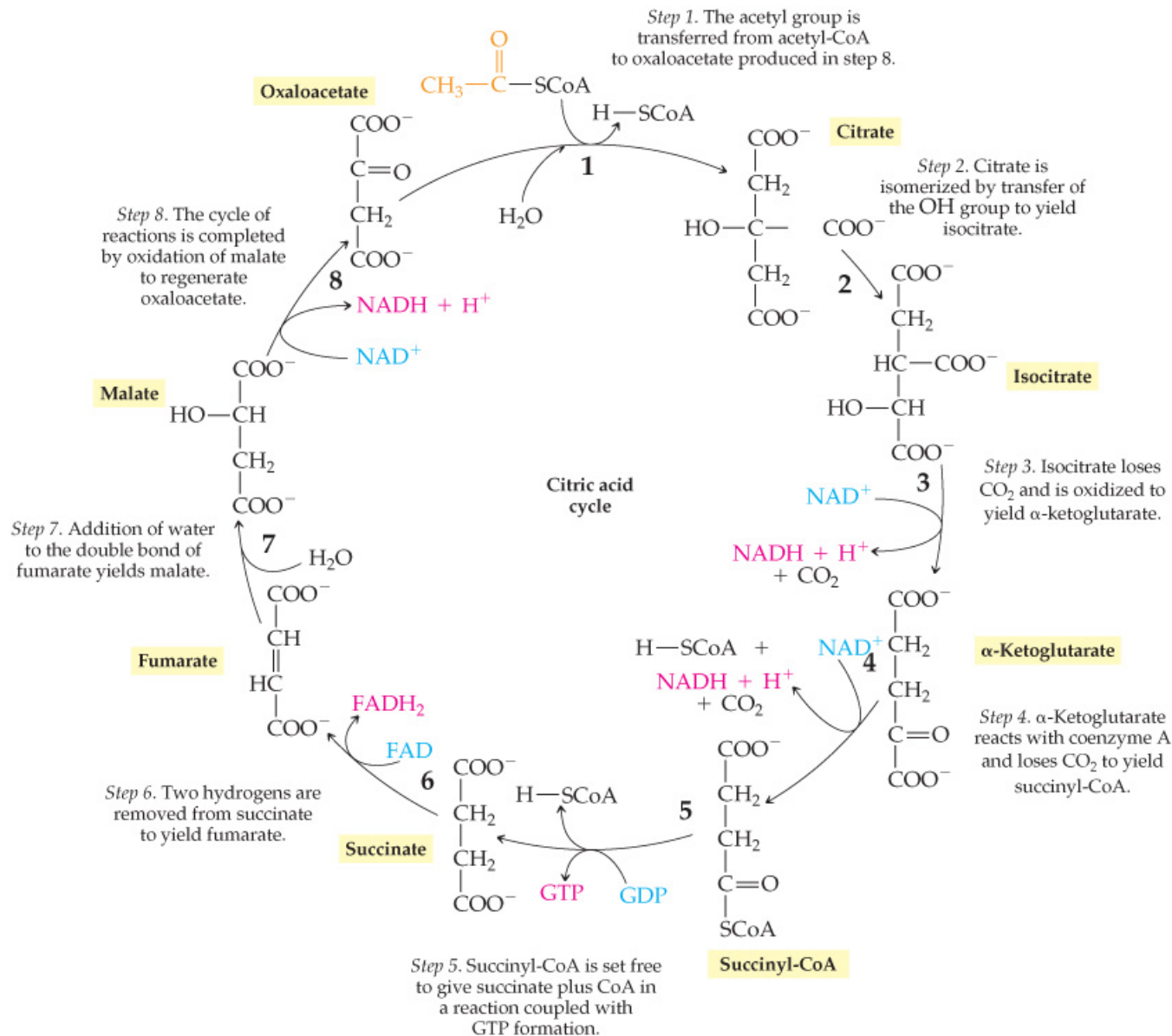
Citric Acid Cycle



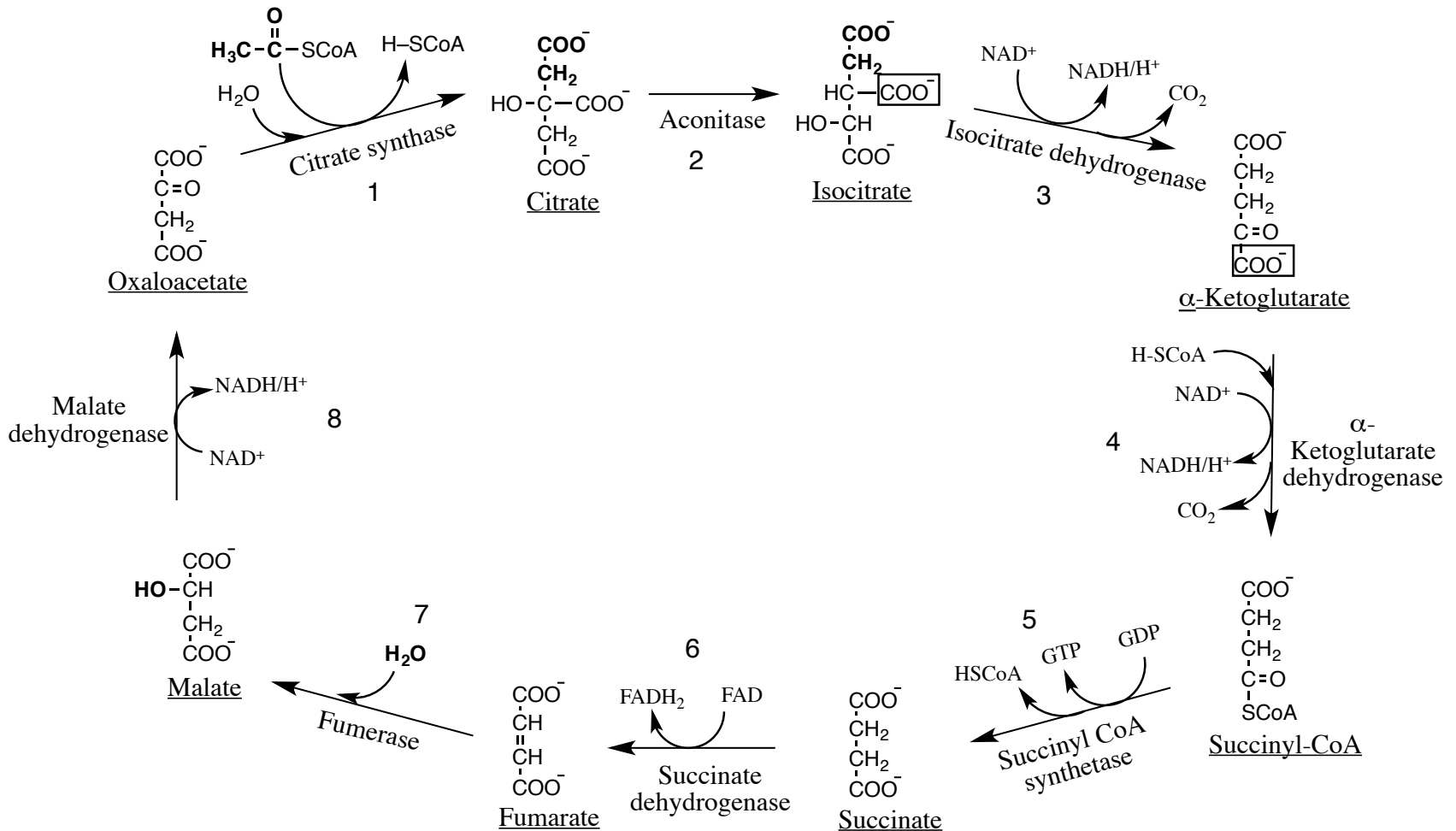
Citric Acid Cycle, in more detail



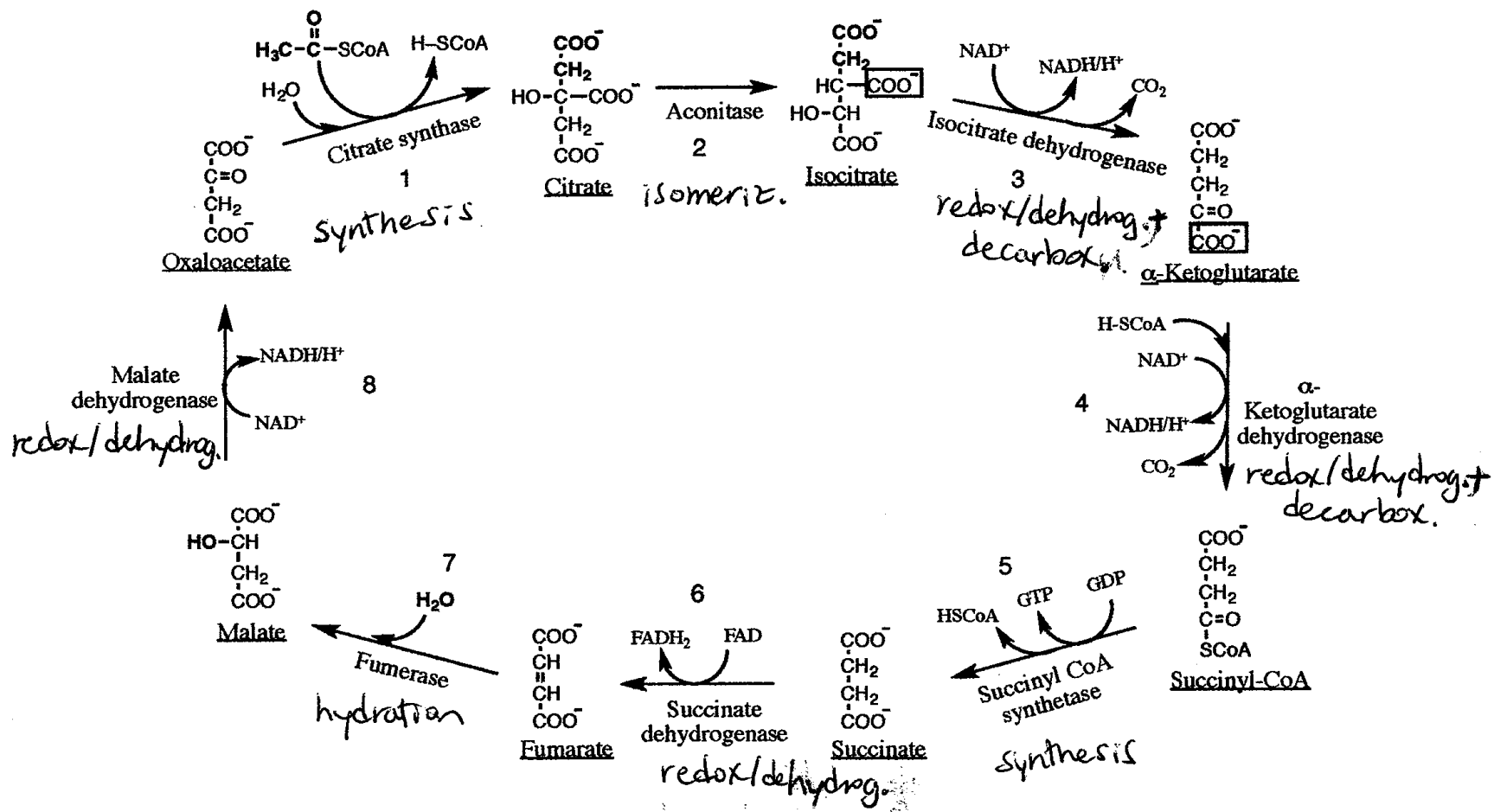
Citric Acid Cycle, even more detail



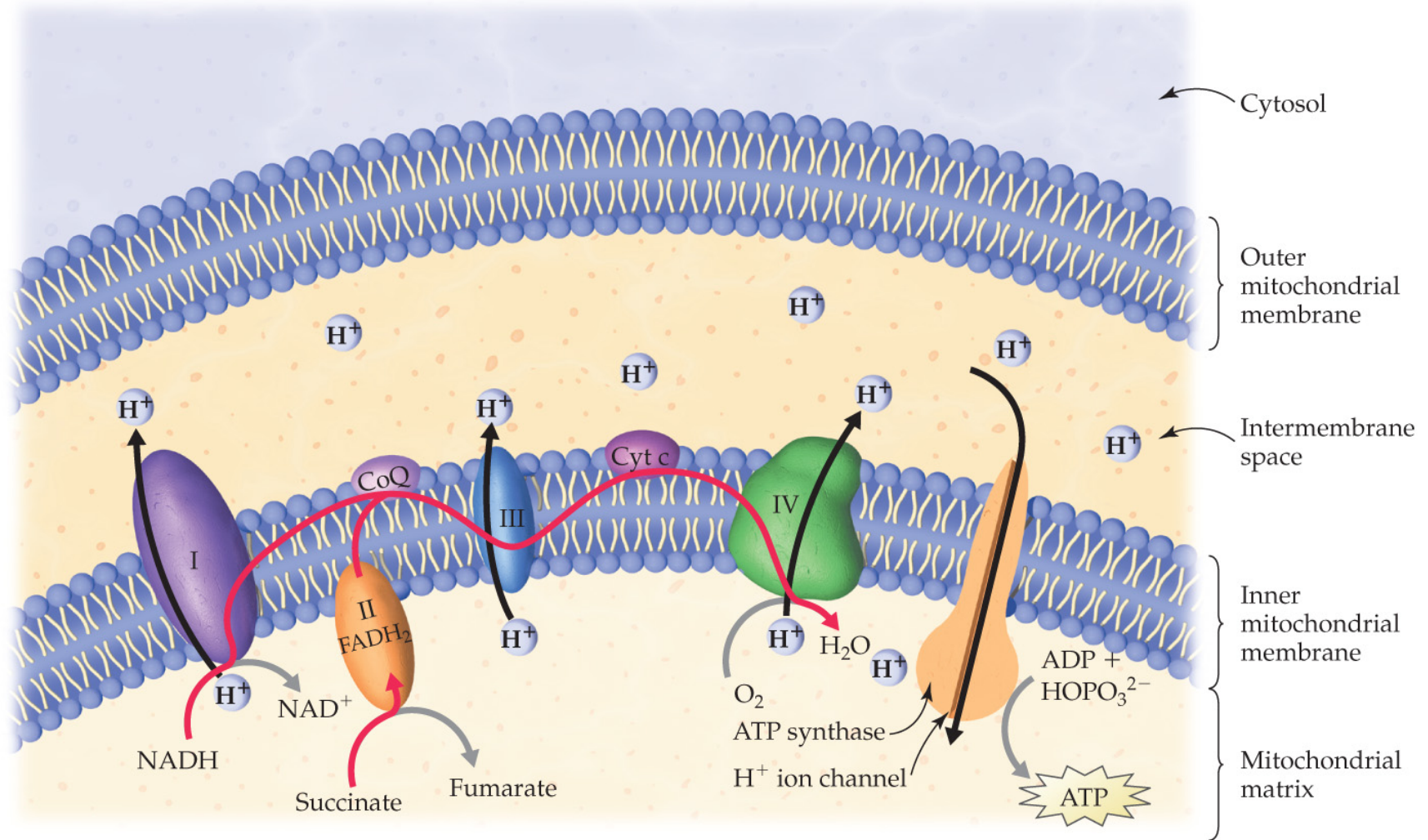
[Handout] Citric Acid Cycle



Chemistry of Citric Acid Cycle

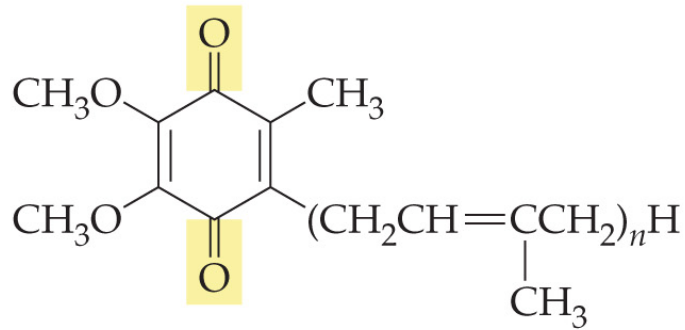


Electron Transport Chain and ATP Synthase



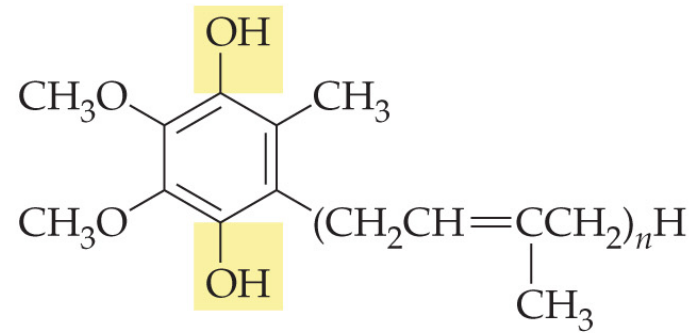
The Mobile Components of Electron Transport Chain

Coenzyme Q



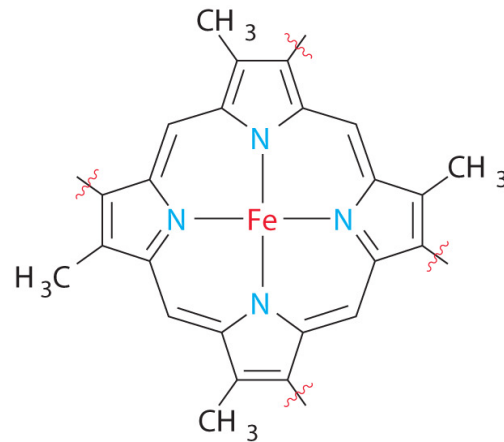
Oxidized coenzyme Q

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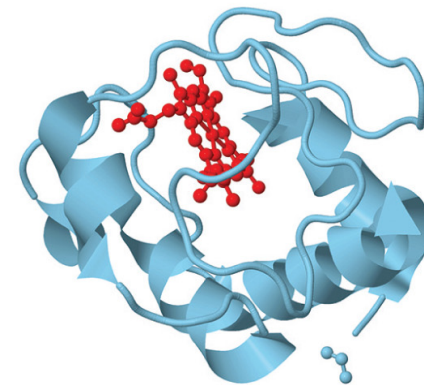
Reduced coenzyme Q

Cytochrome C (with heme cofactor)



(a) A heme group

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(b) A representative cytochrome protein

Energy Diagram for Electron Transport Chain

