

Chemistry 1506: Allied Health Chemistry 2

Section 11: Bioenergetics

Energy Generation in the Cell

Outline

SECTION	11.1 INTRODUCTION & MITOCHONDRIA	2
SECTION	11.2 COMMON CATABOLIC MOLECULES	6
SECTION	11.3 CITRIC ACID CYCLE.....	12
SECTION	11.4 ATP SYNTHESIS.....	14
SECTION	11.5 USES OF ENERGY IN CELLS	15

Section 11.1 Introduction & Mitochondria

➤ Metabolism

➤ All of the **chemical reactions in a cell**

➤ Catabolism

➤ The chemical reactions in the cell that **break complex molecules down**

➤ Anabolism

➤ The chemical reaction in the cell that **build complex molecules**

➤ Complexity

➤ Thousands of interrelated compounds, reactions, and enzymes

➤ All under detailed **feedback and control**

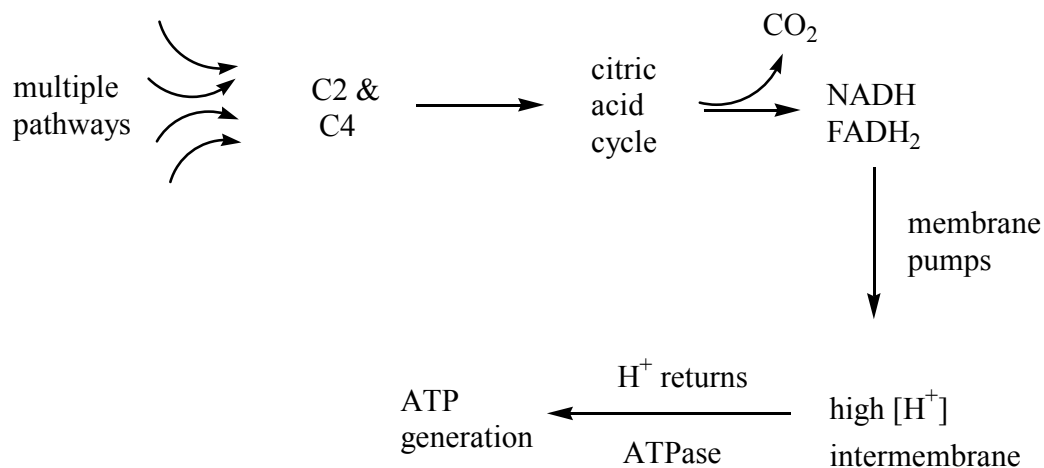
➤ Ultimately governed by the **DNA** and the cell's responses to the environment

➤ Energy Generation in the Cell

➤ General Process

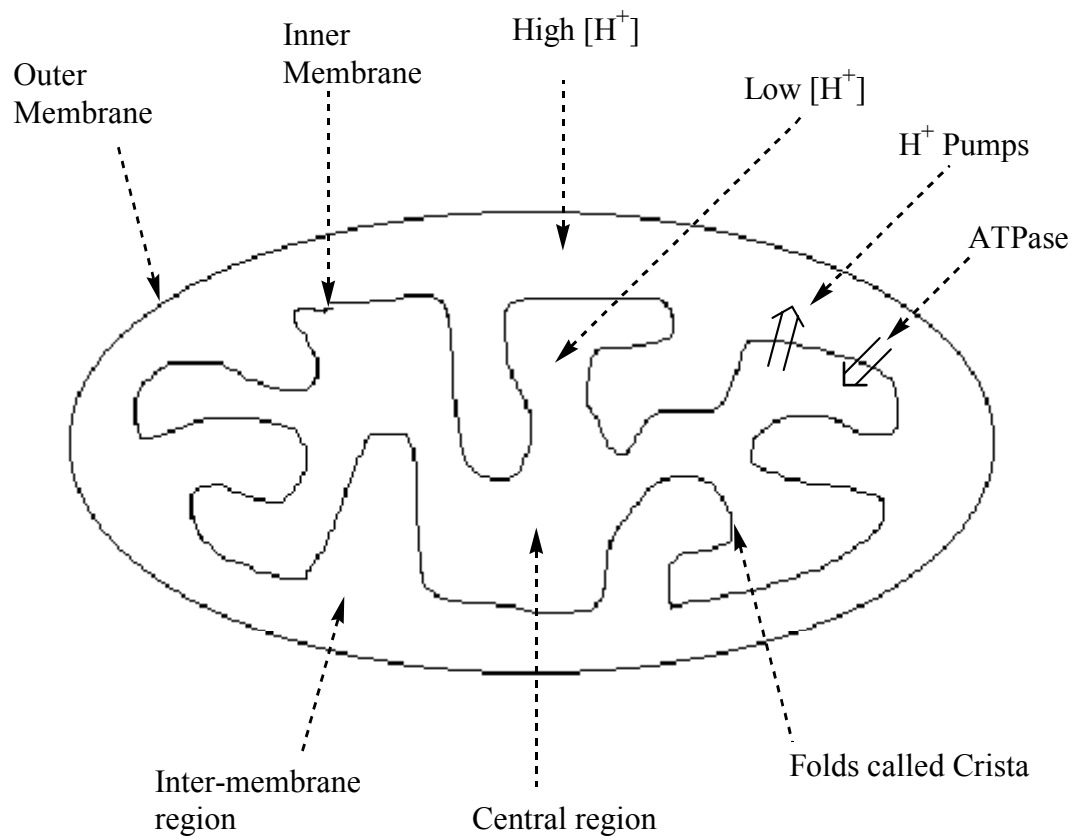
➤ Overall Catabolic Pathway

➤ See Figures in Text



➤ Structure of **Mitochondrion**

➤ See Figures in Text



- Summary of Process
 - Multiple “food” molecules get converted into a small number of common C2 and C4 molecules
 - These C2/C4 molecules enter the center of the mitochondria where they are “processed” by the citric acid pathway
 - The citric acid pathway gives H^+ and e^- which are used to generate NADH and $FADH_2$
 - These are e^- , H^+ , and energy carrier molecules
 - These are used by proteins on the inner mitochondrial membrane to pump H^+ ions from the center to the inter-membrane region
 - This gives a proton gradient
 - This proton gradient drives protein reactions on the inner membrane which allow them back into the center of the mitochondrion which simultaneously using their energy to generate ATP from ADP

Section 11.2 Common Catabolic Molecules

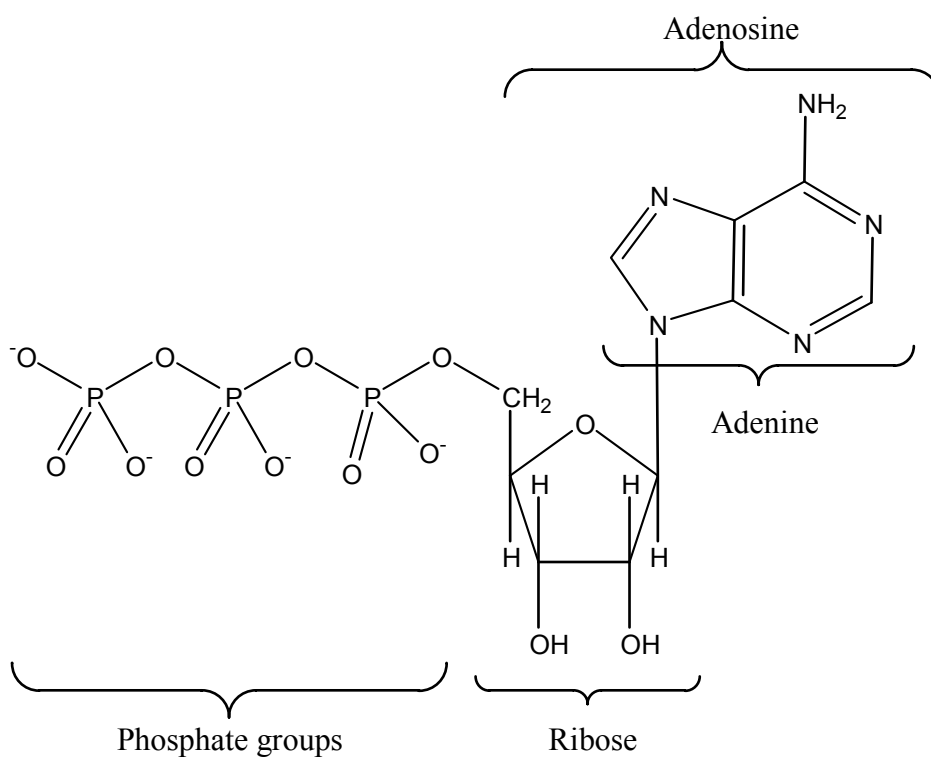
- P_i -AMP-ADP-ATP Path
 - Inorganic Phosphate, P_i , $H_2PO_4^-$ (charge depends on pH)
 - Adenosine Monophosphate, AMP
 - Adenosine Diphosphate, ADP
 - Adenosine Triphosphate, ATP
 - ATP is the highest energy

➤ Structure of ATP Molecule

➤ See Text

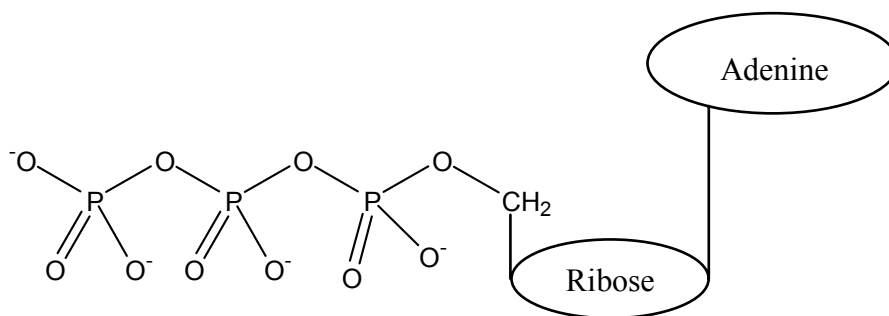
➤ Adenine, Ribose, Adenosine, and Phosphate moieties

➤ ADP and AMP structures



➤ Phosphate Bonds

- ATP is “energy currency” of the cell
- “high energy bonds” vs. convertible energy



➤ Hydrolysis

➤ Hydrolysis of ATP

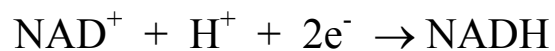
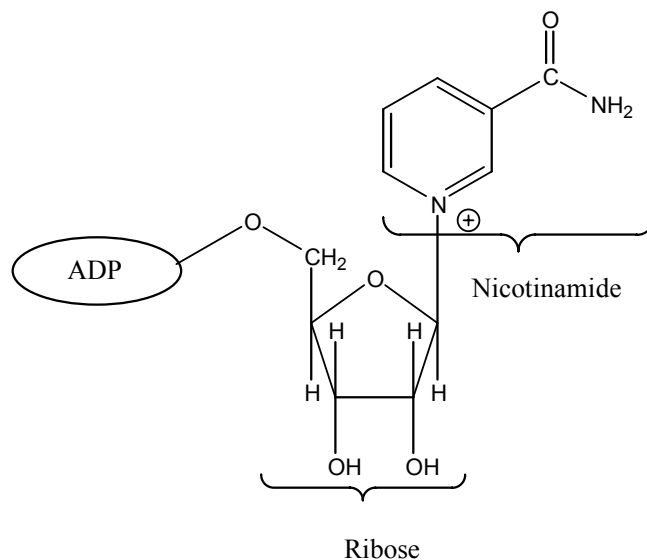


➤ Hydrolysis of ADP



- Normally ADP not hydrolyzed by cells

- Nicotinamide Adenine Dinucleotide, NAD
- See Text
- Often Referred to as NAD^+ to reflect the charge on the Nicotinamide base
- Is a Coenzyme
- Contains ADP, Ribose, and a Nicotinamide Base



- Thus NADH carries 2e^- , a proton, and energy to where it is needed

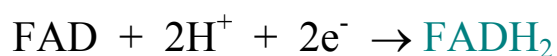
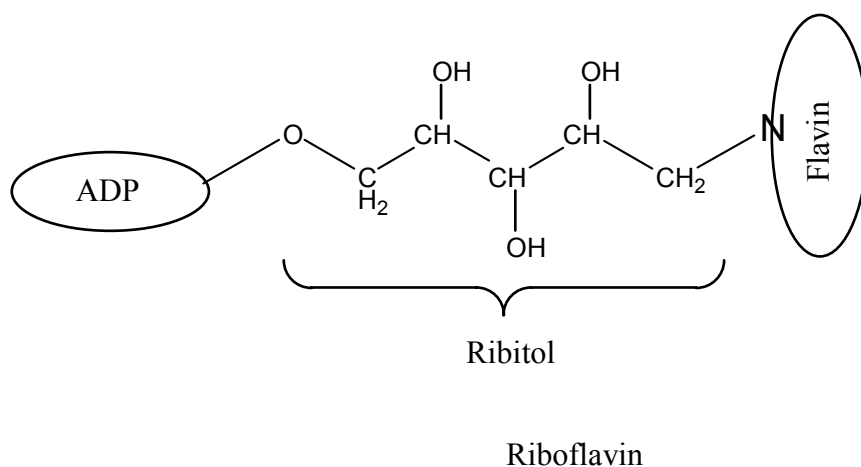
➤ **Flavin Adenine Dinucleotide, FAD**

➤ See Text

➤ Is a **Coenzyme**

➤ Contains **ADP**, **Ribitol** (a straight chain **sugar**), and **Flavin**

➤ The latter two groups making up **Riboflavin** (the **vitamin**)



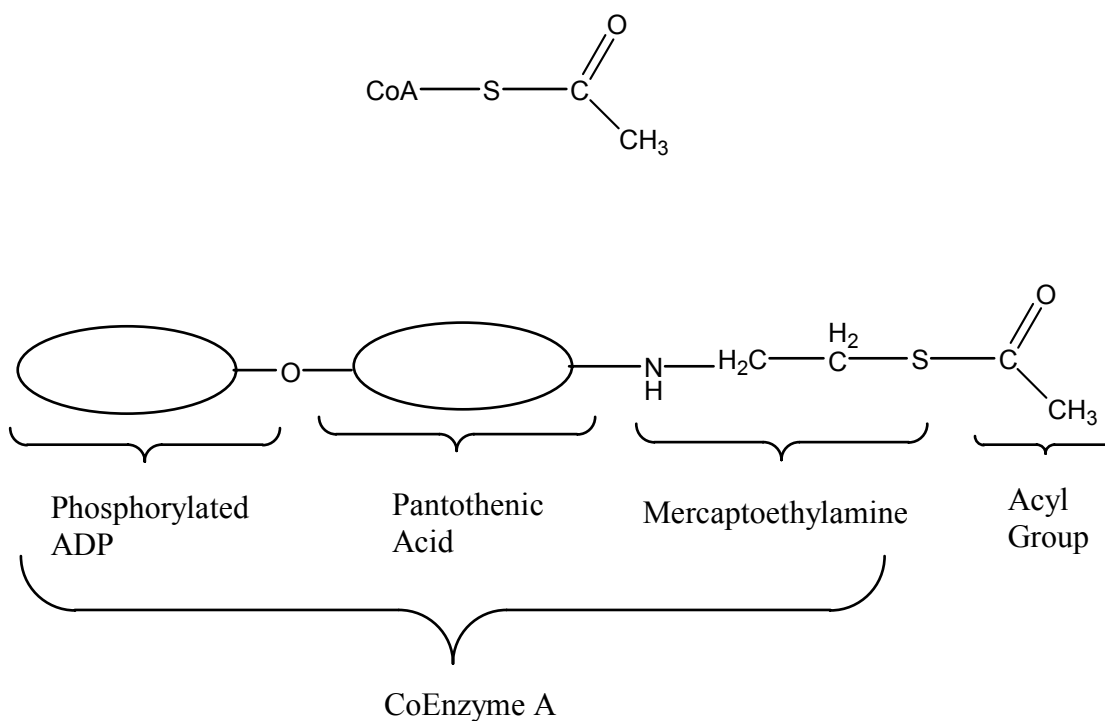
➤ Thus FADH₂ carries 2e⁻, two **protons**, and **energy** to where it is needed

➤ Acetyl CoA

➤ See Text

➤ Transports C2 units (acyl groups)

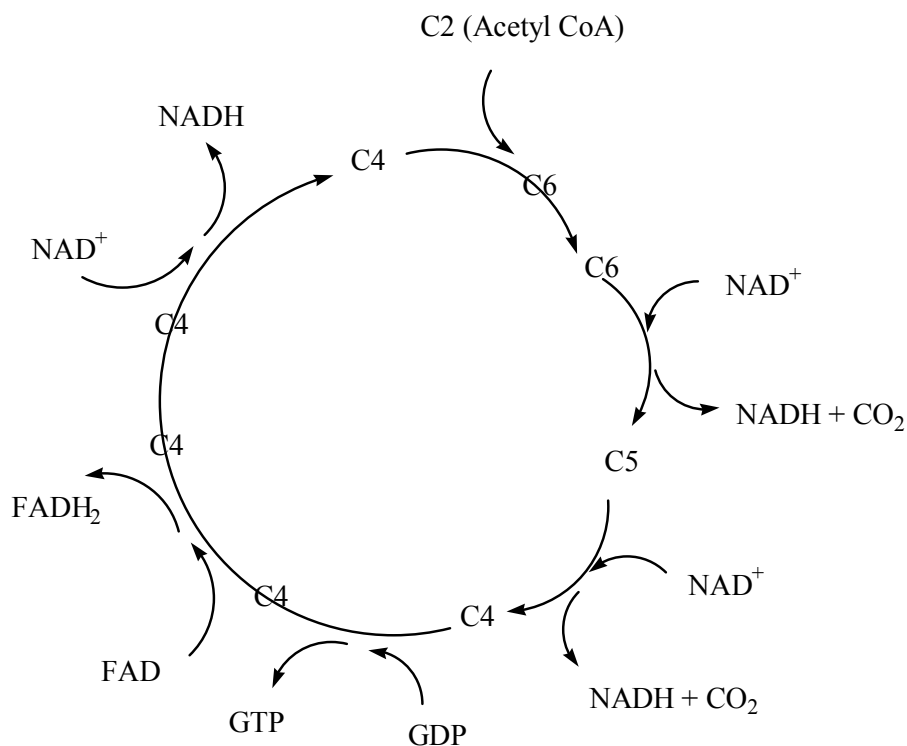
➤ Often written as $\text{CH}_3\text{-CO-S-CoA}$ or Acyl-CoA



➤ Notice the overall similarity in the structures of ATP, NADH, FADH_2 , and Acetyl CoA

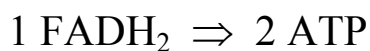
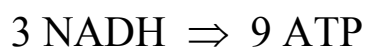
Section 11.3 Citric Acid Cycle

- Also known as **Krebs Cycle** and **Tricarboxylic Acid Cycle**
- See Text
- Overall **Molecular Flow**
 - 8 different chemicals
 - 8 different sets of **enzymes**
 - Takes place in the center of the **mitochondrion**
 - **C2 fragments** enter the cycle as **Acetyl CoA**



➤ Overall Energy Flow

- Produces two CO_2 , three NADH , one FADH_2 , and one GTP per cycle
- GTP is Guanidine Triphosphate (ATP like)



Section 11.4 ATP Synthesis

➤ Proton Pumps

- Flavo Protein, FeS Protein, Quinone Enzyme Complex
- Sited on the inner mitochondrial membrane
- Use NADH and FADH₂ to pump H⁺ into the inter-membrane space
- This generates the proton gradient

➤ ATPase

- An enzyme on the inner mitochondrial membrane
- Allows H⁺ to flow back into the central membrane cavity
- H⁺ flow mechanically coupled to ATP generation



➤ Net Results

Each NADH \Rightarrow 3 ATP

Each FADH₂ \Rightarrow 2 ATP

Section 11.5 Uses of Energy in Cells

- Molecular Synthesis
 - Anabolic Pathways

- To Generate Gradients via Active Pumps
 - H^+ , K^+ , etc.

- Mechanical Energy
 - Muscles
 - Molecular motors

- Heat

Index of Topics and Vocabulary

Acetyl Co.....	13	GTP	13
Acetyl CoA.....	11, 12	Guanidine Triphosphate	13
acyl groups.....	11	H ⁺ 5, 14, 15	
Acyl-CoA	11	H ₂ PO ₄ ⁻	6
Adenine	7	Heat	15
Adenosine	7	high energy bonds.....	8
Adenosine Diphosphate.....	6	Hydrolysis.....	8
Adenosine Monophosphate	6	Hydrolysis of ADP	8
Adenosine Triphosphate	6	Hydrolysis of ATP.....	8
ADP	5, 6, 7, 9, 10, 14	inner membrane	5
AMP	6, 7	inner mitochondrial membrane.....	5, 14
Anabolic Pathways	15	Inorganic Phosphate	6
Anabolism.....	2	inter-membrane region	5
ATP	5, 6, 8, 11, 14	inter-membrane space.....	14
ATP like.....	13	Introduction & Mitochondria.....	2
ATP Synthesis	14	K ⁺ 15	
ATPase	14	Krebs Cycle	12
break complex molecules down.....	2	Mechanical Energy	15
build complex molecules	2	mechanically coupled to ATP generation	14
C2 fragments	12	Metabolism	2
C2 units.....	11	mitochondrion.....	12
Catabolic Pathway	3	Mitochondrion	4
Catabolism.....	2	Molecular Flow	12
central membrane cavity.....	14	Molecular motors.....	15
CH ₃ -CO-S-CoA.....	11	Molecular Synthesis	15
chemical reactions in a cell.....	2	Muscles.....	15
Citric Acid Cycle.....	12	NAD	9
CO ₂	13	NAD ⁺	9
Coenzyme	9, 10	NADH	5, 11, 13, 14
Common Catabolic Molecules	6	Nicotinamide Adenine Dinucleotide	9
Complexity	2	Nicotinamide base	9
convertible energy	8	Nicotinamide Base.....	9
DNA	2	Phosphate.....	7
e ⁻ 5, 9, 10		Phosphate Bonds	8
energy.....	9, 10	P _i 6, 14	
Energy	8	proton	9, 10
energy carrier molecules.....	5	proton gradient.....	5, 14
energy currency	8	Proton Pumps.....	14
Energy Flow	13	pump H ⁺	14
Energy Generation in the Cell	3	pump H ⁺ ions.....	5
enzyme.....	14	Quinone Enzyme Complex	14
enzymes	12	Ribitol.....	10
FAD	10	Riboflavin	10
FADH ₂	5, 10, 11, 13, 14	Ribose.....	7, 9
feedback and control.....	2	similarity in the structures	11
FeS Protein	14	Structure of ATP Molecule.....	7
Flavin.....	10	sugar	10
Flavin Adenine Dinucleotide.....	10	Tricarboxylic Acid Cycle	12
Flavo Protein	14	Uses of Energy in Cells	15
food molecules.....	5	vitamin.....	10
Gradients via Active Pumps	15		

