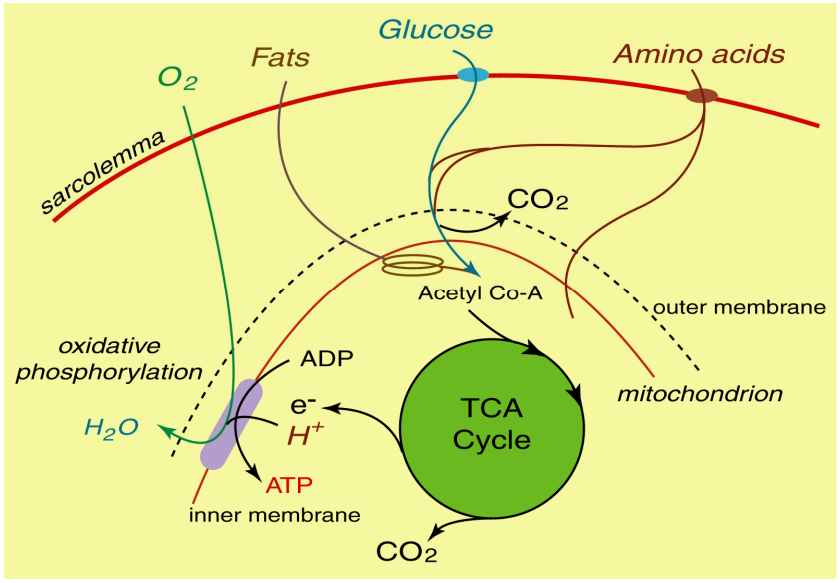
Mitochondrial Respiration - overview



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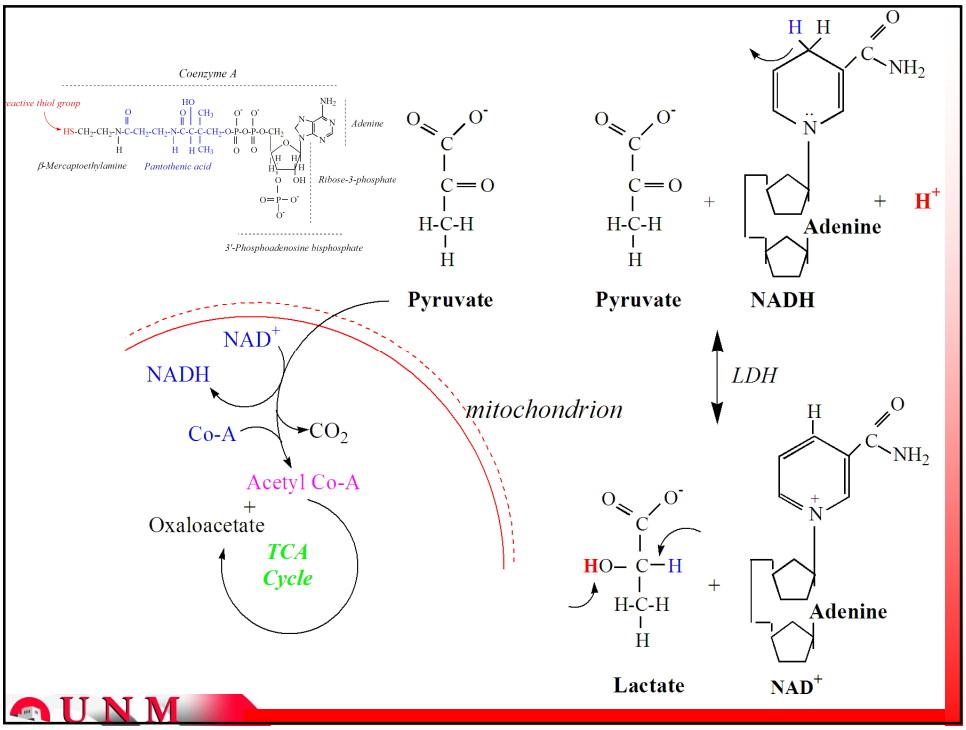

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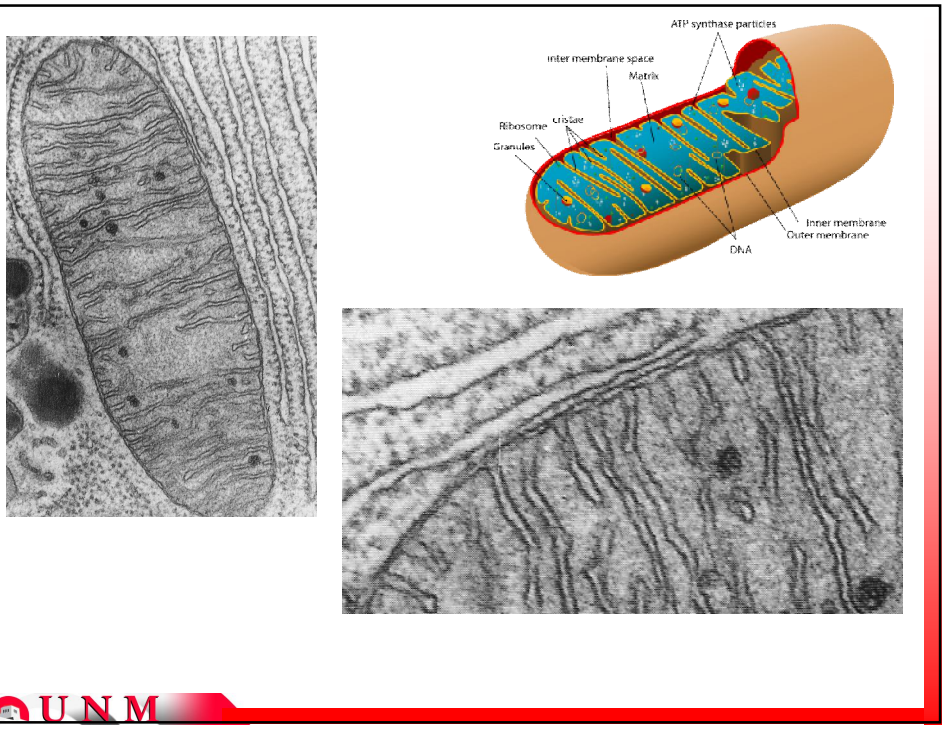

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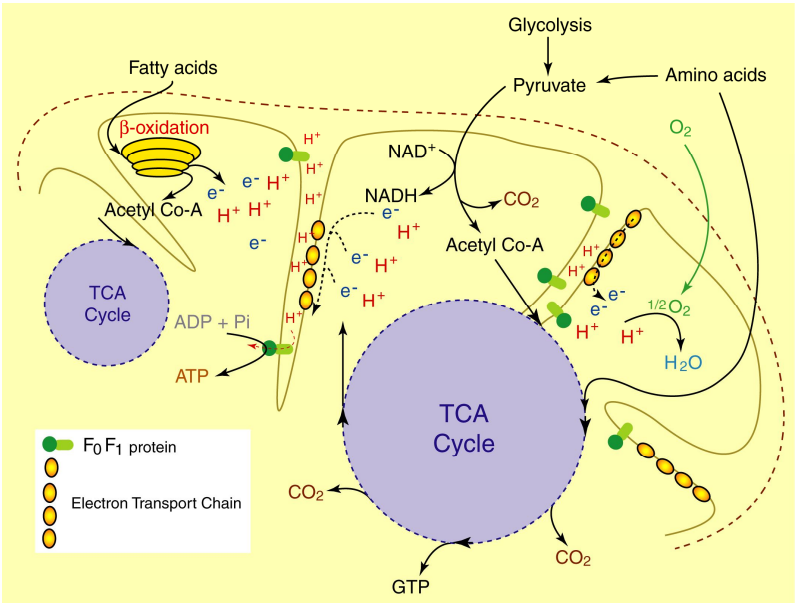
Pyruvate Oxidation and the TCA Cycle



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Glycolytic glucose oxidation:

$$Glucose + 2\ NAD^{+} + 2\ ADP + 2\ Pi \rightarrow 2\ Pyruvate + 2\ NADH + 2\ ATP + 2\ H_2O + 2\ H^{+}$$

Complete glucose oxidation:

$$Glucose + 6\ O_2 \rightarrow 6\ H_2O + 6\ CO_2 + energy$$

What are the differences in these two chemical equations?

Why?

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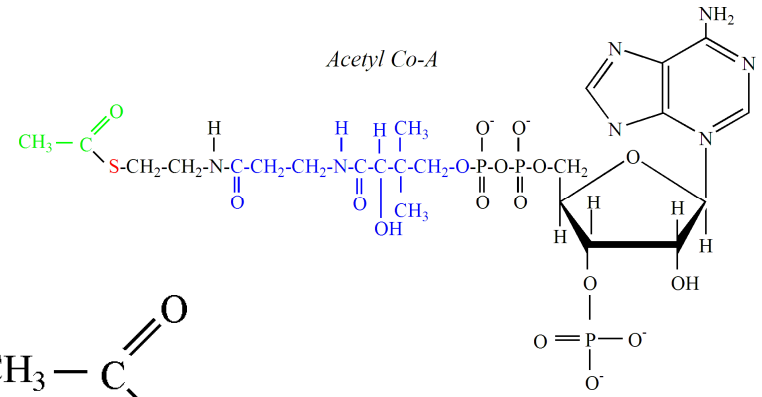
Acetyl Co-A



acetate

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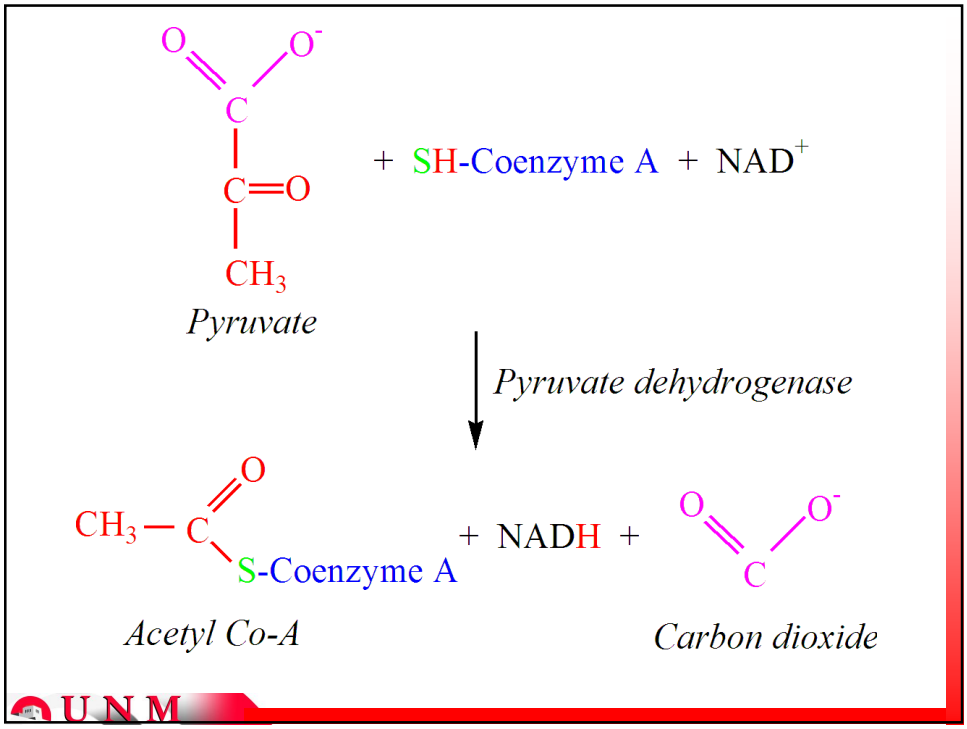
+ SH-Coenzyme A + NAD+
Pyruvate
Pyruvate dehydrogenase
+ NADH +
S-Coenzyme A
Acetyl Co-A
Carbon dioxide
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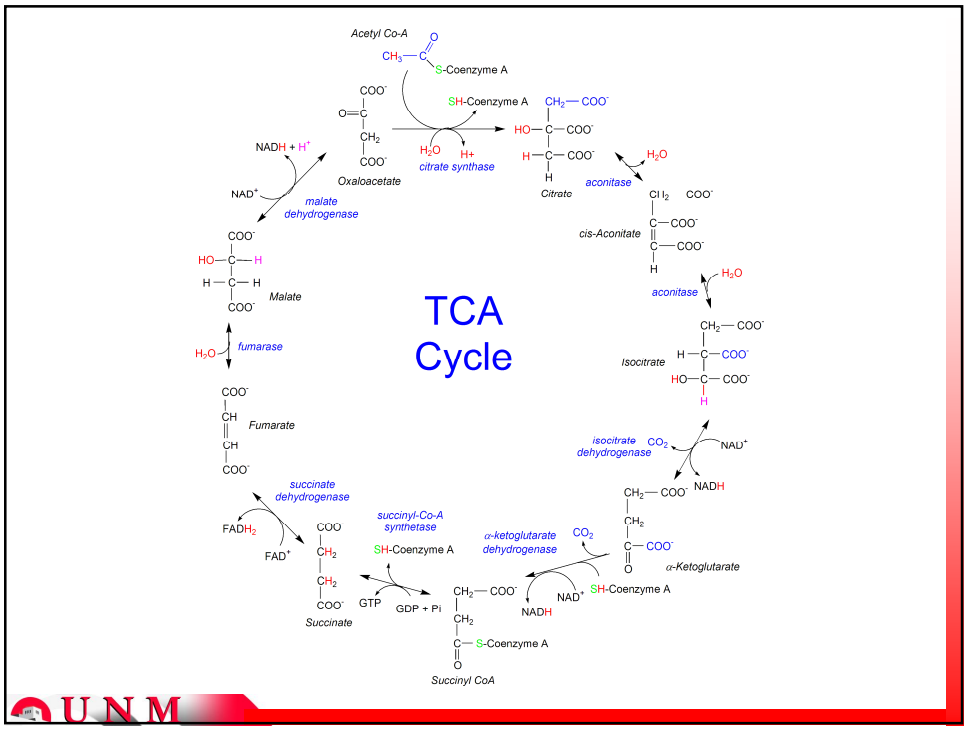
Acetyl Co-A
S-Coenzyme A
SH-Coenzyme A
Oxaloacetate
citrate synthase
Citrate
aconitase
cis-Aconitate
aconitase
Isocitrate
isocitrate dehydrogenase
NADH
α-Ketoglutarate
α-ketoglutarate dehydrogenase
SH-Coenzyme A
Succinyl CoA
succinyl-Co-A synthetase
GTP
GDP + Pi
Succinate
succinate dehydrogenase
Fumarate
fumarase
Malate
malate dehydrogenase
TCA Cycle
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Reaction	Enzyme	CO_2	NADH	FADH	ATP	H^+
Pyruvate + Co-A + $NAD^+ \rightarrow$ Acetyl CoA + NADH + CO_2	Pyruvate dehydrogenase	1	1			
TCA Cycle						
Acetyl CoA + Oxaloacetate + $H_2O \rightarrow$ Citrate + SH-CoA + H^+	Citrate synthase					1
CItrate $\rightarrow$ Isocitrate	Aconitase					
Isocitrate + $NAD^+ \rightarrow$ α-Ketoglutarate + $NADH^+$ + CO_2	Isocitrate dehydrogenase	1	1			
α-Ketoglutarate + NAD+ + SH-CoA $\rightarrow$ Succinyl-CoA + NADH + CO_2	α-Ketoglutarate dehydrogenase	1	1			
Succinyl-CoA + GDP + Pi $\rightarrow$ Succinate + GTP + SH-CoA	Succinyl-CoA synthetase				1	
Succinate + $FAD^+ \rightarrow$ Fumarate + $FADH_2$	Succinate dehydrogenase			1		
Fumarate + $H_2O \rightarrow$ Malate	Fumarase					
Malate + $NAD^+ \rightarrow$ Oxaloacetate + NADH + H^+	Malate dehydrogenase		1			1
Single cycle	**Tally**	1 + 2	1 + 3	1	1	2
	Totals	3	4	1	1	2
	ATP Equivalents		**12**	**2**	**1**	
Double cycle	**Tally**	2 + 4	2 + 6	2	2	4
	Totals	**6**	8	2	2	**4**
	ATP Equivalents		**24**	**4**	**2**	
	Total ATP		**30**			

How many ATP do we get from glycolysis?

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ATP Production From the Complete Oxidation of Glucose vs. Palmitate					
Glucose	**Product**	**ATP**	**Palmitate**	**Product**	ATP
Glycolysis	2 NADH	4*	Fatty acid activation	-2 ATP	-2
	2 ATP	2 or 3^	β-oxidation	7 NADH	21
PDH complex	2 NADH	6		7 FADH2	14
	2 acetyl CoA			8 acetyl CoA	
	2 CO2				
	Sub-Total	**12 or 13**		***Sub-Total***	**33**
From Oxidative Phosphorylation			*From Oxidative Phosphorylation*		
2 TCA cycles	6 NADH	18	8 TCA cycles	24 NADH	72
	2 FADH	4		8 FADH	16
	2 ATP	2		8 ATP	8
	4 CO2			16 CO2	
	Sub-Total	**24**		***Sub-Total***	**96**
	Totals	**36 or 37**		**Totals**	**129**

*assumes glycerol-3-phosphate shuttle; ^2 from glucose, 3 from glycogen

TCA Cycle:

$$acetyl\ CoA + 2\ NAD^+ + FAD^+ + Pi + ADP + 2\ H_2O \rightarrow 2\ CO_2 + 3\ NADH + FADH_2 + ATP + 2\ H^+ + CoA$$

(Pyruvate dehydrogenase complex + TCA Cycle) x 2:

$$2\ pyruvate + 4\ NAD^+ + 2\ FAD^+ + 2\ Pi + 2\ ADP + 4\ H_2O \rightarrow 6\ CO_2 + 8\ NADH + 2\ FADH_2 + 2\ ATP + 4\ H^+$$

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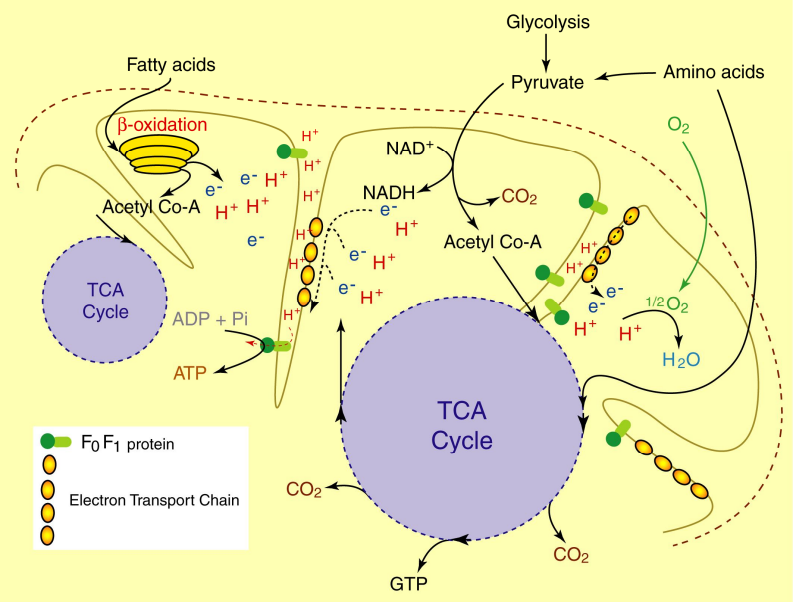
ETC and Oxidative Phosphorylation



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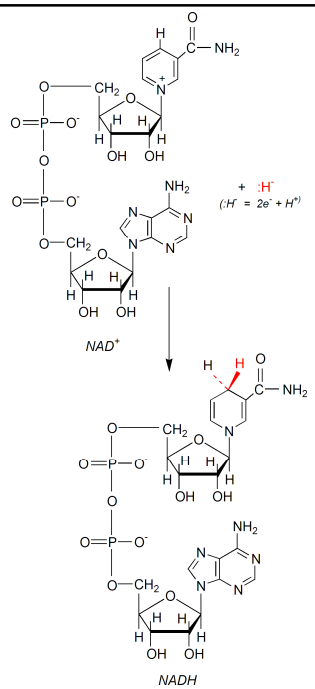

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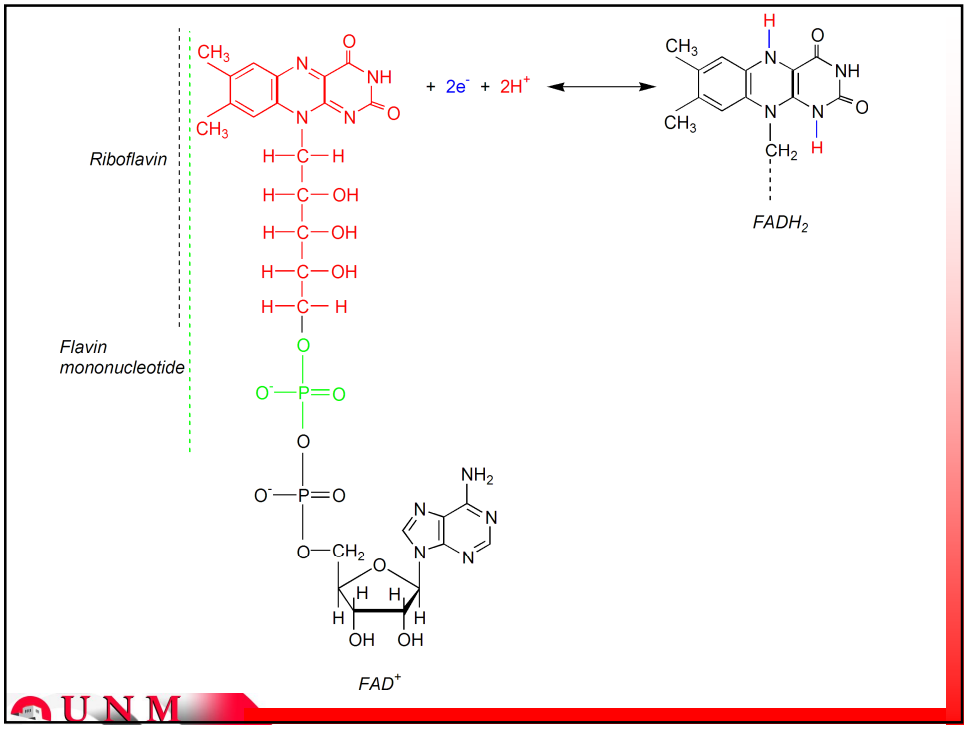
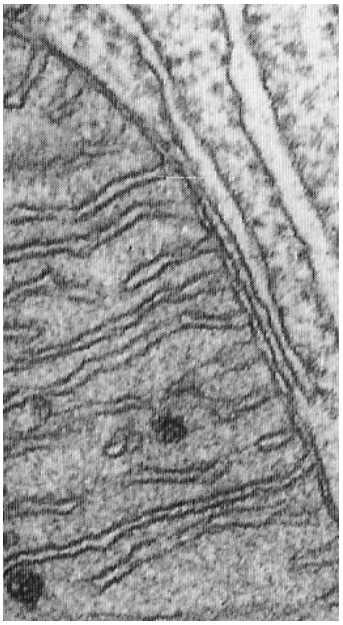
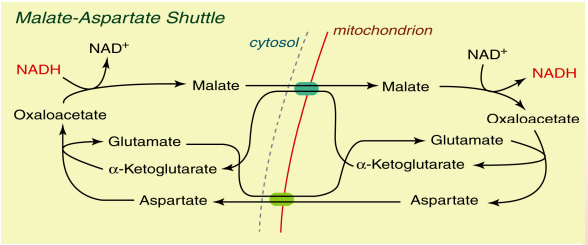
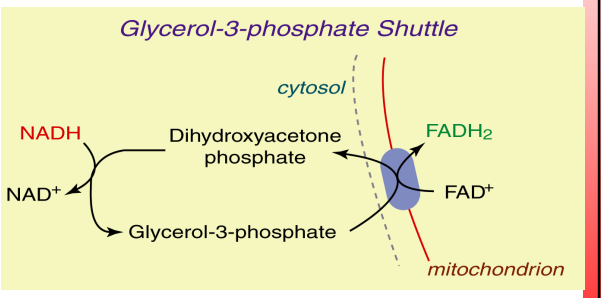
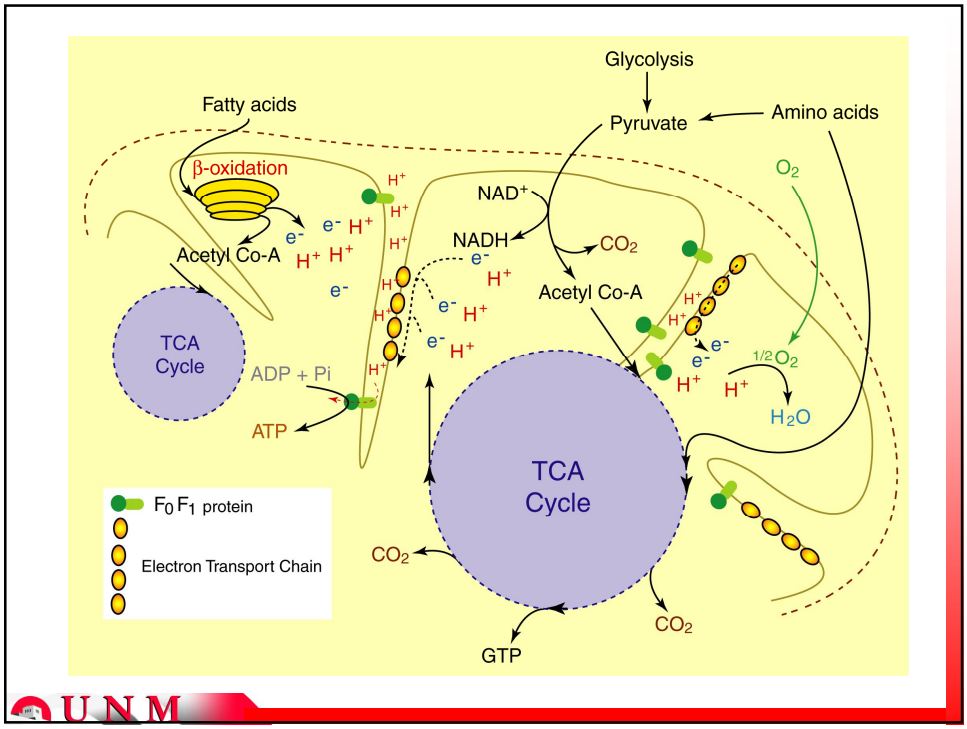
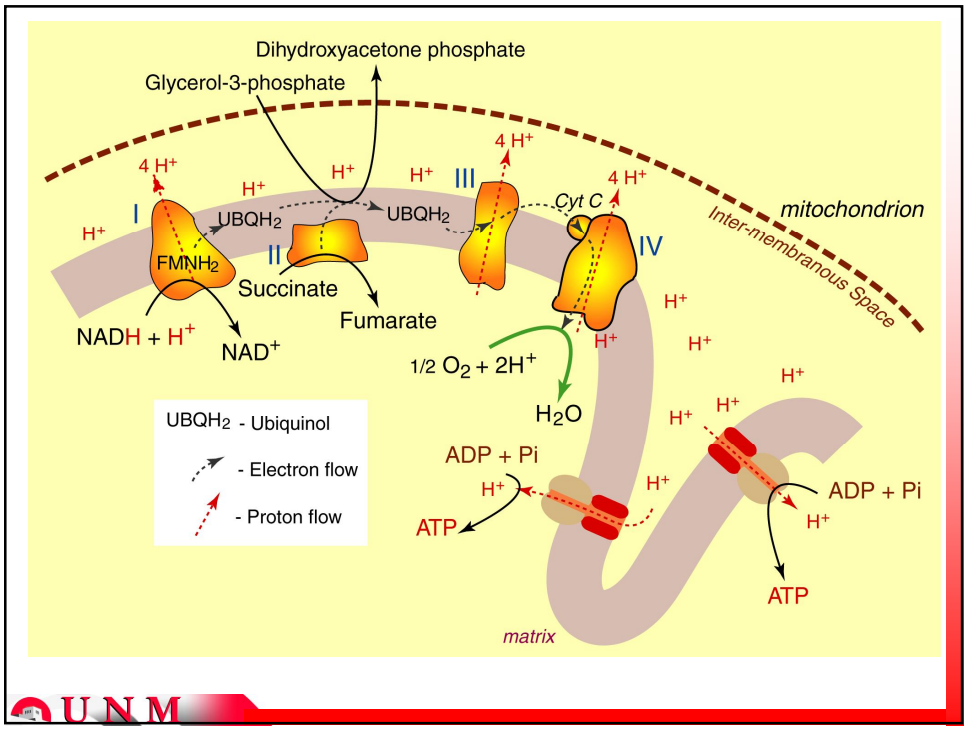

Riboflavin
Flavin mononucleotide
+ 2e⁻ + 2H⁺
FADH2
FAD+




Malate-Aspartate Shuttle
cytosol
mitochondrion
NAD+
NADH
Malate
Oxaloacetate
Glutamate
α-Ketoglutarate
Aspartate


Glycerol-3-phosphate Shuttle
cytosol
NADH
NAD+
Dihydroxyacetone phosphate
Glycerol-3-phosphate
FADH2
FAD+
mitochondrion


Glycolysis
Fatty acids
Pyruvate
Amino acids
β-oxidation
NAD+
NADH
CO2
O2
Acetyl Co-A
Acetyl Co-A
TCA Cycle
ADP + Pi
ATP
1/2 O2
H2O
TCA Cycle
F0 F1 protein
Electron Transport Chain
CO2
CO2
GTP


Dihydroxyacetone phosphate
Glycerol-3-phosphate
4 H+
4 H+
4 H+
I
II
III
IV
UBQH2
UBQH2
Cyt C
FMNH2
Succinate
Fumarate
mitochondrion
Inter-membranous Space
NADH + H+
NAD+
1/2 O2 + 2H+
H2O
UBQH2 - Ubiquinol
- Electron flow
- Proton flow
ADP + Pi
ATP
ADP + Pi
ATP
matrix

Unidirectional Redox Reactions	E'_0 (V)
$2H^+ + 2e^- \rightarrow H_2$	-0.414
$NAD^+ + H^+ + 2e^- \rightarrow NADH$	-0.320
$NADP^+ + H^+ + 2e^- \rightarrow NADPH$	-0.324
$FMN + 2H^+ + 2e^- \rightarrow FMNH_2$	-0.300
Ubiquitone + $2H^+ + 2e^- \rightarrow$ Ubiquinol	0.045
Cytochrome b (Fe^{+3}) + $e^- \rightarrow$ Cytochrome b (Fe^{+2})	0.077
Cytochrome c (Fe^{+3}) + $e^- \rightarrow$ Cytochrome b (Fe^{+2})	0.254
Cytochrome a_3 (Fe^{+3}) + $e^- \rightarrow$ Cytochrome a_3 (Fe^{+2})	0.550
½ $O_2 + 2H^+ + 2e^- \rightarrow H_2O$	0.816

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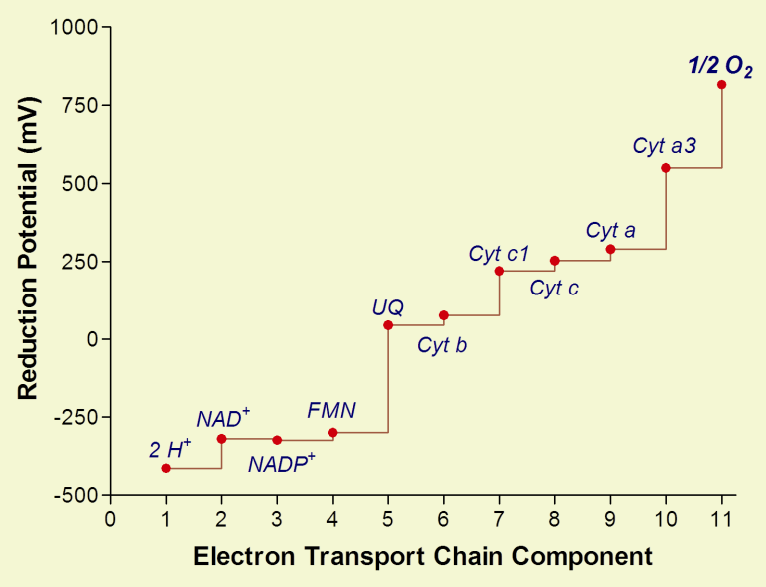

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