Notes

AP BIOLOGY NAME_____

ACTIVITY 1.17 DATE_____HOUR_____

CELLULAR RESPIRATION

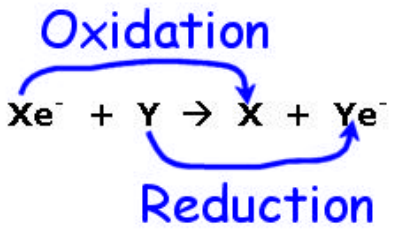
SUMMARY EQUATION

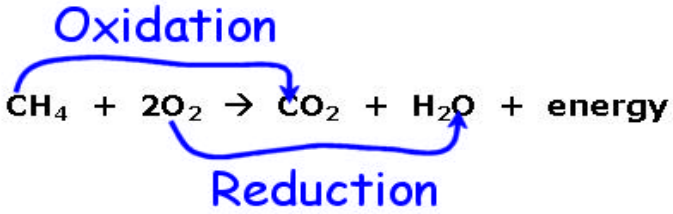
$C_6H_{12}O_6 + O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy (ATP)}$

STEPWISE REDOX REACTION

Oxidation: partial or complete loss of electrons

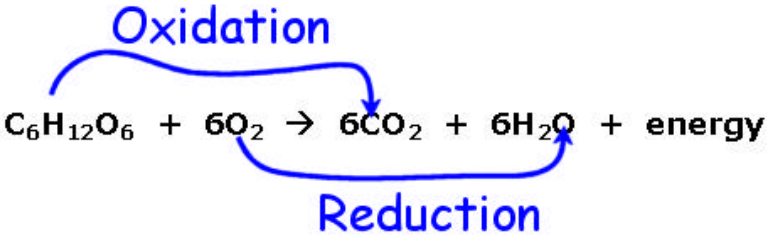
Reduction: partial or complete gain of electrons





C partial loss of e-

O partial gain of e-



ROLE OF NAD+ Nicotinamide adenine dinuleotide

- Coenzyme
- e- acceptor
- Traps high energy e- from glucose

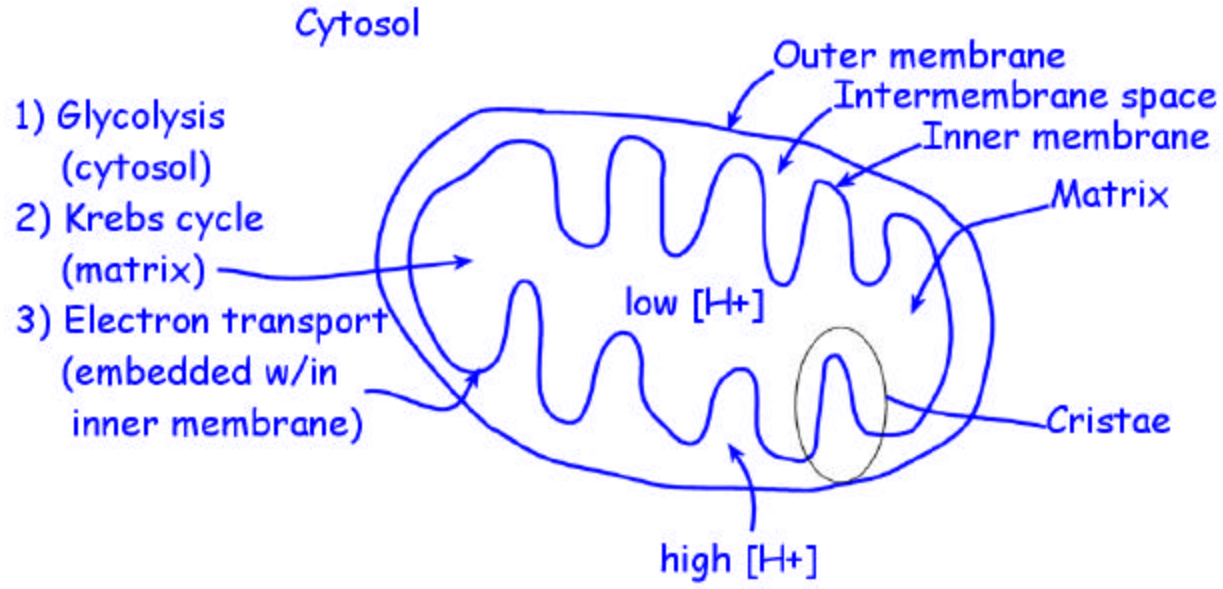
Dehydrogenases

- Remove 2 H (2e- & 2H+) from substrate
- Delivers 2e- & 1H+ to NAD+
- NAD+ + 2e- + 1H+ → NADH

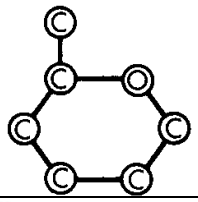
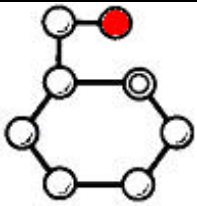
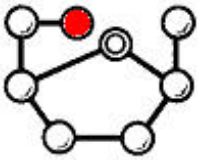
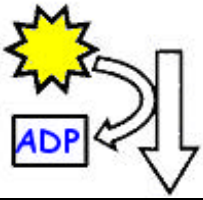
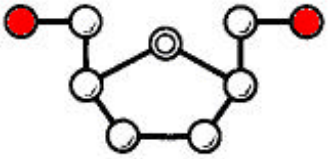
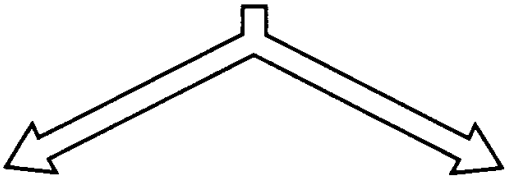
PHOSPHORYLATION

SUBSTRATE LEVEL	OXIDATIVE
▪ ATP produced ▪ ADP + P_i → ATP ▪ Direct transfer of P_i from intermediate compound to ADP	▪ ATP produced ▪ ADP + P_i → ATP ▪ Exergonic slide of e- used to create H+ gradient; KE of H+ moving down conc. gradient used to add P_i to ADP

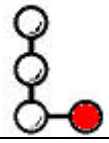
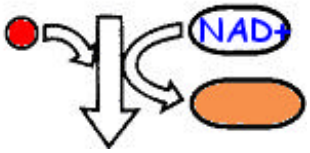
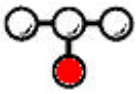
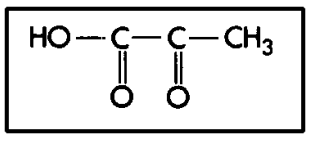
STRUCTURE OF MITOCHONDRION



GYCOLYSIS Energy Investment

	Glucose
	ATP → ADP + P P added to glucose
	Glucose 6-phosphate
	isomerase converts glucose 6-phosphate to fructose 6-phosphage
	Fructose 6-phosphate
	ATP → ADP + P P added to fructose
	Fructose 1,6-diphosphate
	Enzyme splits fructose into two 3-carbon compounds
	Glyceraldehyde phosphate

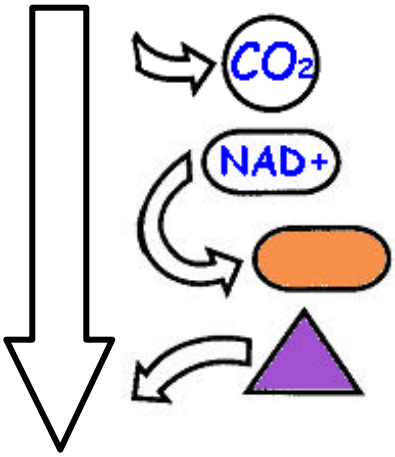
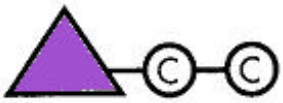
GLYCOLYSIS – Energy Yielding (times 2 once for each glyceraldehyde phosphate

	Glyceraldehyde phosphate
	Dehydrogenases • remove 2 H from glyceraldehyde phosphate • deliver 2 e^- & 1 H+ to NAD+ • $2e^- + 2H^+ + NAD^+ \rightarrow NADH$ P added to glyceraldehyde phosphate
	1,3 - diphosphoglycerate
	P from carbon 1 added to ADP ADP + P → ATP
	3 - phosphoglycerate
	enzyme moves P to carbon 2
	2 - phosphoglycerate
	enzyme removes water
	phosphoenolpyruvate (PEP)
	enzyme transfers P to ADP ADP + P → ATP
	Pyruvate (3-carbon compound)

GLYCOLYSIS SUMMARY

ENERGY INVESTMENT	
Uses 2 ATP molecules Glucose split	
ENERGY YIELDING	
Produces 4 ATP molecules by substrate level phosphorylation	
IN	**OUT**
Glucose 2 ATP	2 pyruvate 4 ATP 2 NADH

KREBS CYCLE – ACETYL COA PREP (Times two – once for each pyruvate)

	Pyruvate (3-carbon compound)
	• Pyruvate converted into 2-carbon compound; CO_2 released • 2 H removed from 2-carbon compound • $2e^-$ and H+ added to NAD+ • NAD+ + $2e^-$ + H+ → NADH • Coenzyme A added to acetyl group
	Acetyl CoA

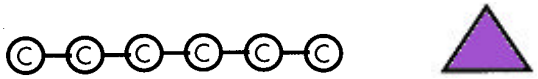
ACETYL CO A PREP PER PYRUVATE

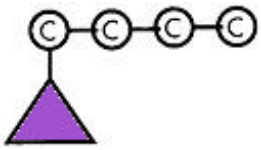
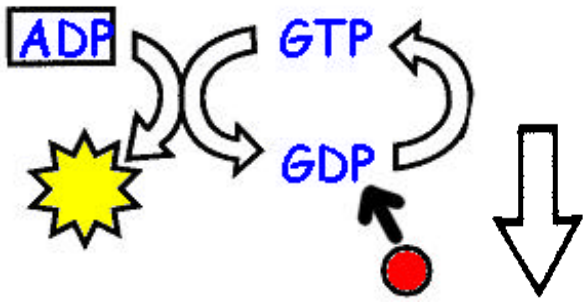
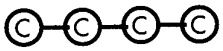
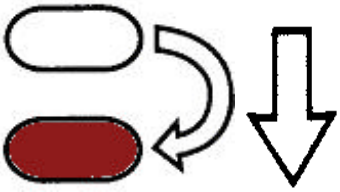
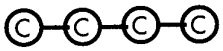
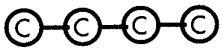
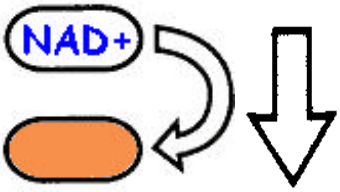
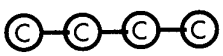
In	OUT
Pyruvate	CO_2 NADH Acetyl CoA

ACETYL CO A PREP PER GLUCOSE

In	OUT
2 Pyruvate	2 CO_2 2 NADH 2 Acetyl CoA

KREBS CYCLE

	• Coenzyme A removed from acetyl group (2-C) • Acetyl group added to oxaloacetate (4-C)
	
	• Citrate (6-C) produced • Coenzyme A released
	Water removed Water added
	Isocitrate (6-C) produced
	• CO_2 removed • 2H removed from isocitrate • $2e^- + H^+ + NAD^+ \rightarrow NADH$
	α - Ketoglutarate (5-C) produced
	• CO_2 removed • 2H removed from isocitrate • $2e^- + H^+ + NAD^+ \rightarrow NADH$
	Coenzyme A added to 4-C compound

	Succinyl CoA produced
	
	• P transferred from matrix to GDP • GDP + P → GTP • P transferred from GTP to ADP • ADP + P → ATP
	Succinate (4-C) produced
	• 2 H removed from succinate • 2e- + 2H+ + FAD → $FADH_2$ • FAD = flavin adenine dinucleotide
	Fumarate (4-C) produced
	water added
	Malate (4-C) produced
	• 2 H removed from malate • 2e- + H+ + NAD+ → NADH
	Oxaloacetate (4-C) produced

Back to the beginning of the Krebs cycle

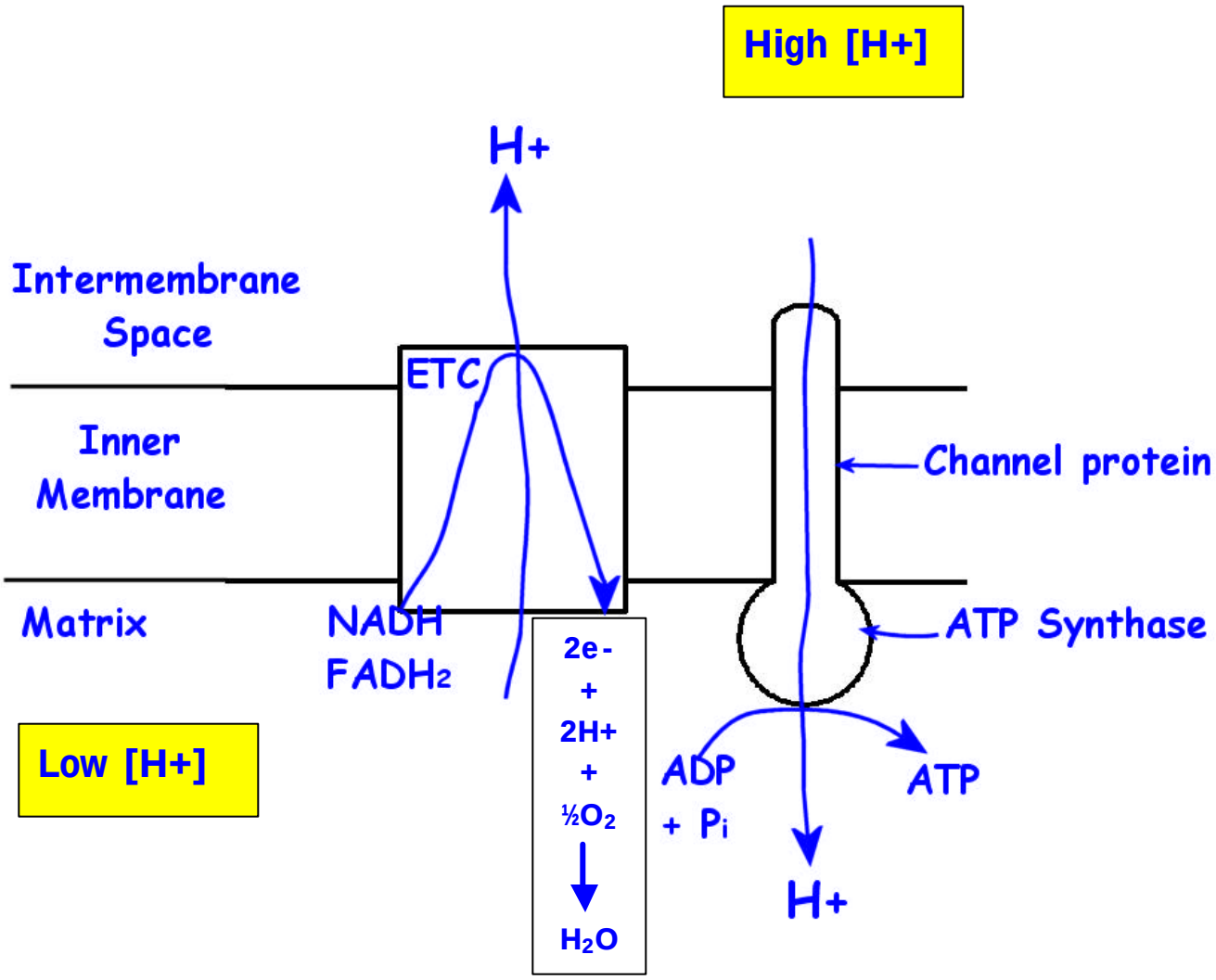
KREBS CYCLE SUMMARY PER PYRUVATE

KREBS CYCLE IN	KREBS CYCLE OUT
1 acetyl CoA	• 2 CO_2 • 3 NADH • 1 $FADH_2$ • 1 ATP

KREBS CYCLE SUMMARY PER GLUCOSE

KREBS CYCLE IN	KREBS CYCLE OUT
2 acetyl CoA	• 4 CO_2 • 6 NADH • 2 $FADH_2$ • 2 ATP

ELECTRON TRANSPORT & OXIDATIVE PHOSPHORYLATION



1. ETC accepts e- from NADH & $FADH_2$
2. ETC passes e- to various molecules in chain
3. When some ETC molecules accept e- must also accept H+
4. H+ released to opposite side of membrane when e- passed to next molecule

5. High [H+] established in intermembrane space
6. e- accepted by O_2 forming H_2O
7. Channel protein allows H+ to move down conc. gradient
8. ATP synthase uses KE of H+ to add P_i to ADP forming ATP

KEY

NADH

NAD+

H+

$FADH_2$

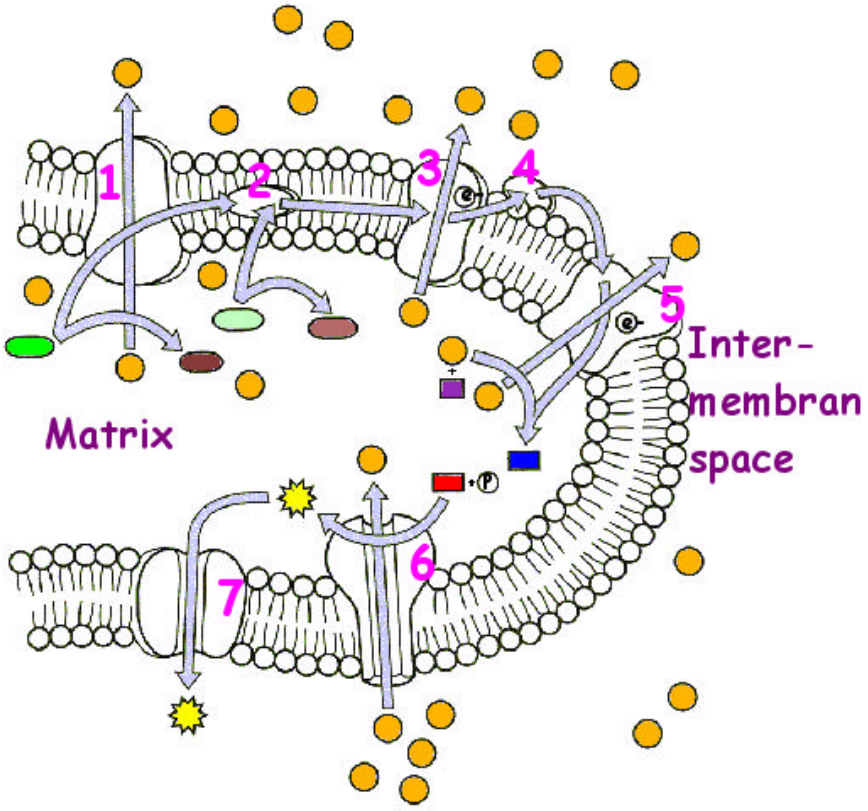
FAD

$1/2\ O_2$

H_2O

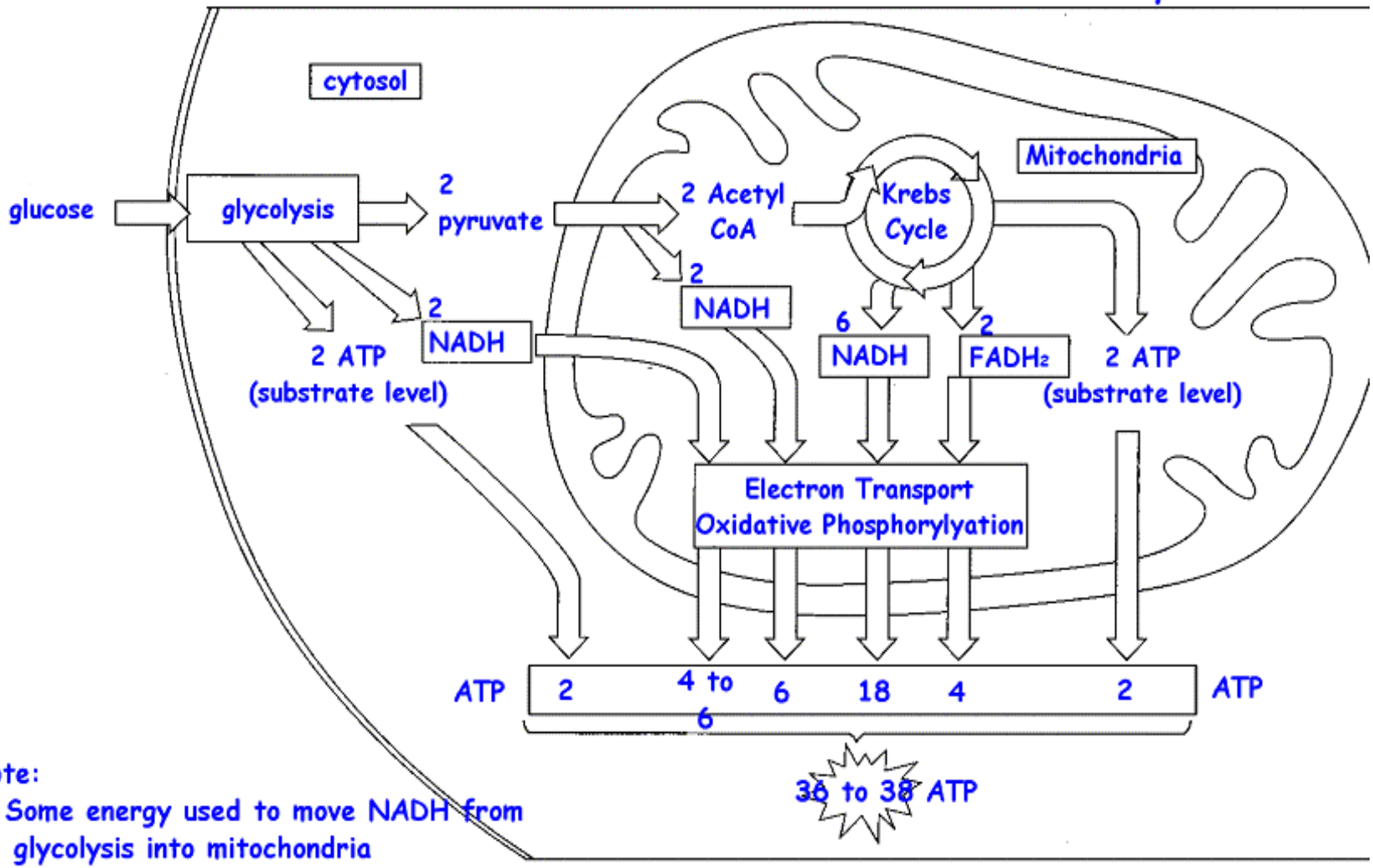
ADP

ATP



1. NADH donates e- to ETC ETC accepts H+ when accepts e- H+ released to opposite side of membrane	5. Complex accepts e- Accepts H+; H+ released to opposite side of membrane Passes e- to O_2; O_2 accepts two H+; forms H_2O
2. Ubiquinone carries e- to next complex Accepts e- from $FADH_2$	6. ATP synthase uses KE of H+ moving down conc. gradient to add P to ADP
3. Complex accepts e- Must also accept H+ H+ released to opposite side of membrane	7. Transport protein moves ATP out of matrix
4. Cytochrome c carries e- to next complex	

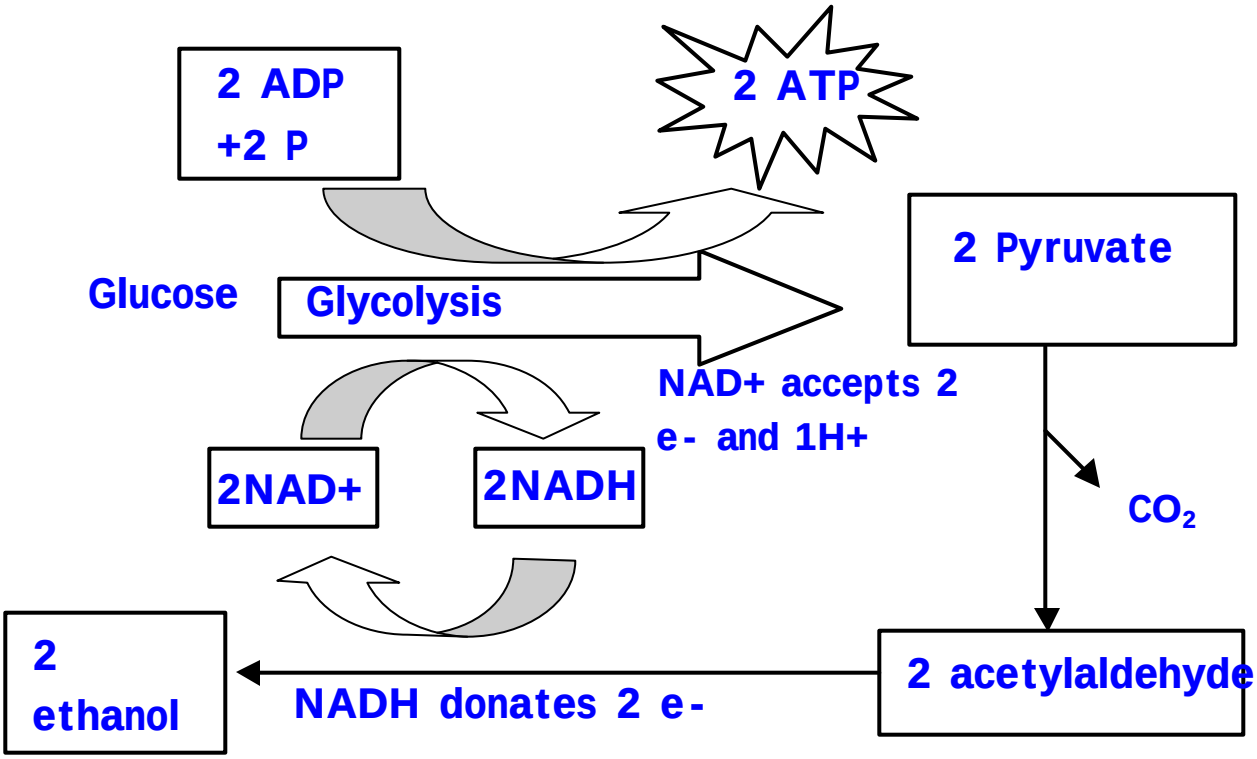
ATP Production Summary



Note:

1) Some energy used to move NADH from glycolysis into mitochondria
2) $FADH_2$ adds electrons at lower level in ETC

ALCOHOL FERMENTATION



LACTIC ACID FERMENTATION