L3: Bioenergetics (Metabolism)

Metabolism: All biochemical reactions involving use, production and storage of energy

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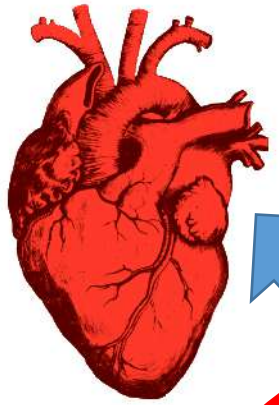
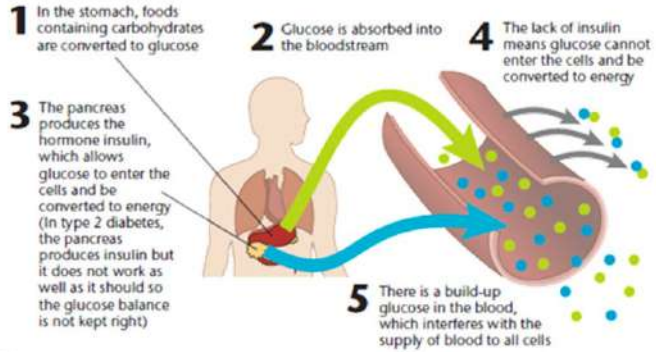
Photosynthesis:
Energy from sun is converted into chemical bonds (Glucose)
$6H_2O+6CO_2+ h\nu(Energy) \rightarrow C_6H_{12}O_6+6O_2$

ATP → ADP+ Pi + Energy



Cellular respiration:
Glucose broken down into usable form of Energy **ATP.**
$C_6H_{12}O_6+6O_2$
$\rightarrow 6H_2O+6CO_2+$ ATP(energy)

Carbohydrates>Glucose>Energy



- It is insulin that allows glucose to enter the body's cells
- The absence of insulin results in abnormally high blood sugar and eventually DIABETES.

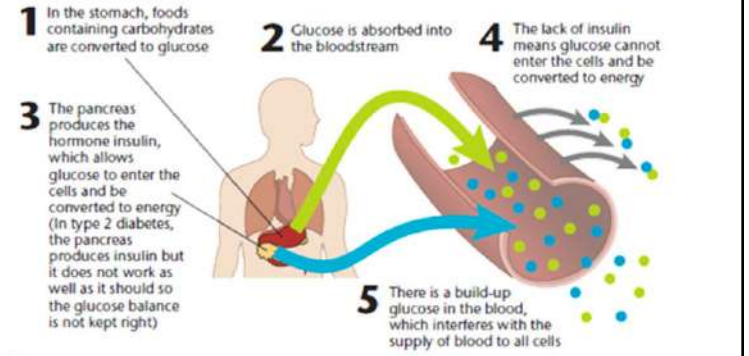
Carbohydrates

↓ H_2O

Monosacharides/Glucose

Stage1: Hydrolysis

Carbohydrates>Glucose>Energy



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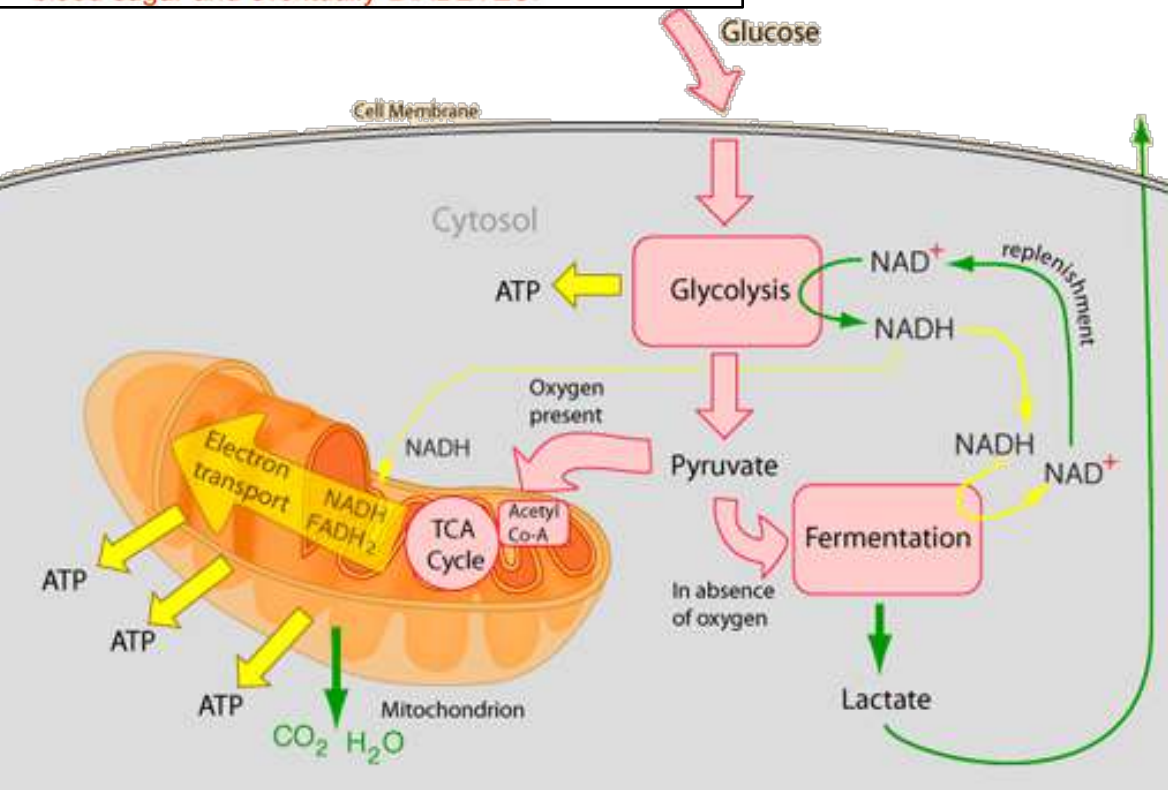


What happens to the food we eat ?

Carbohydrates

H_2O

Monosacharides/Glucose

Glycolysis

Pyruvate

Acetyl CoA

Citric Acid Cycle → $2CO_2$

Electrons/Reduced coenzyme

Electron Transport Chain + O_2 → $2\ H_2O$

ATP ADP+Pi

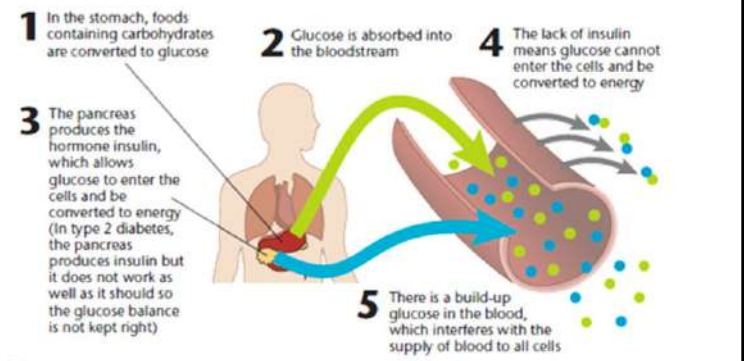
Stage1: Hydrolysis

Stage2: Acetyl CoA production

Stage2: Energy production

₹

Carbohydrates>Glucose>Energy



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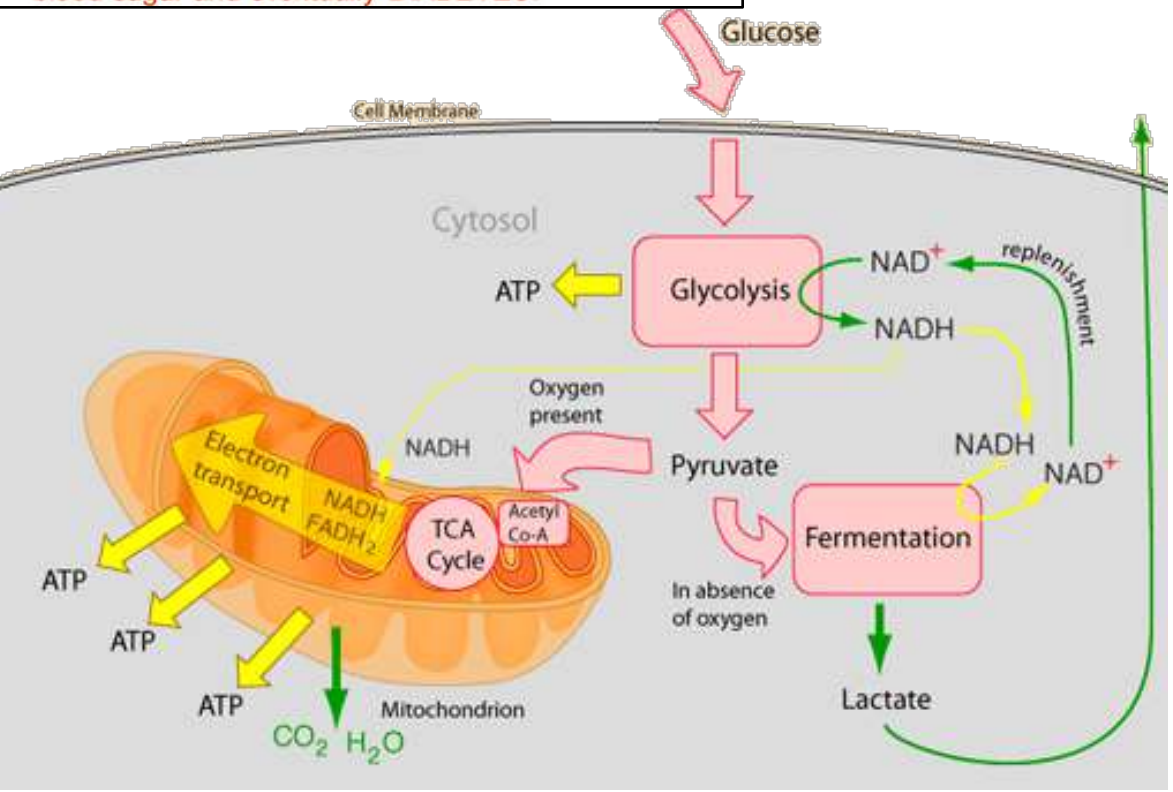

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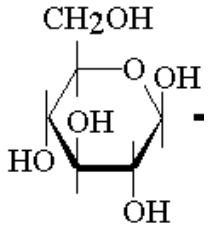
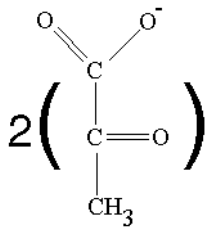


D-glucose

Glycolysis



Pyruvate

Pyruvate

Acetyl CoA

Citric Acid Cycle → $2CO_2$

Electrons/Reduced coenzyme

Electron Transport Chain + O_2 → Oxidative phosphorylation → $2\ H_2O$

ATP ← ADP+Pi

Stage1: Hydrolysis

Stage2: Acetyl CoA production

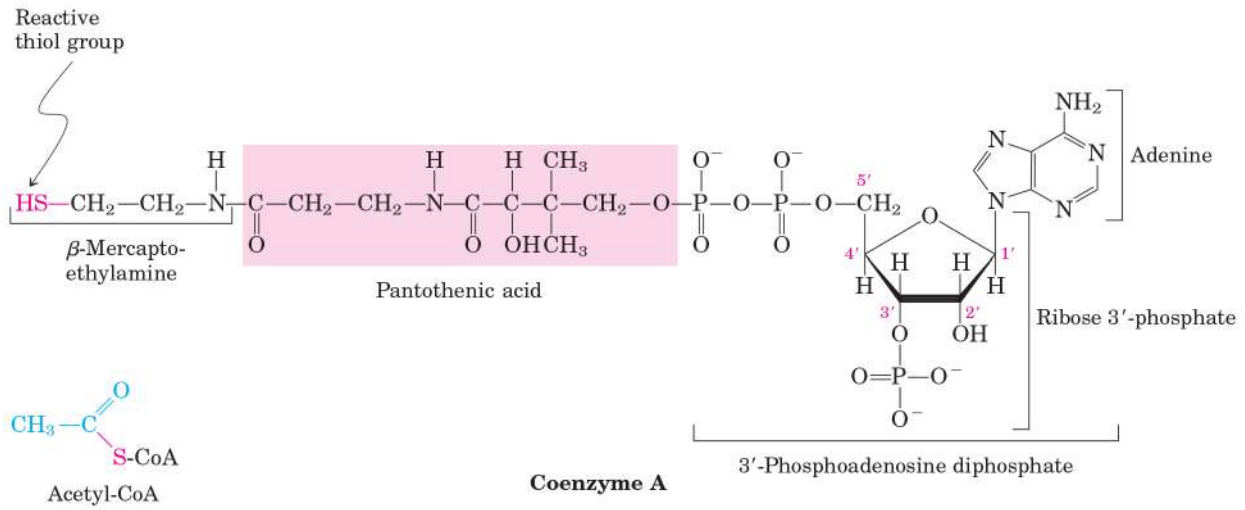
Stage2: Energy production

₹

Before the citric acid cycle

(Coenzyme A)

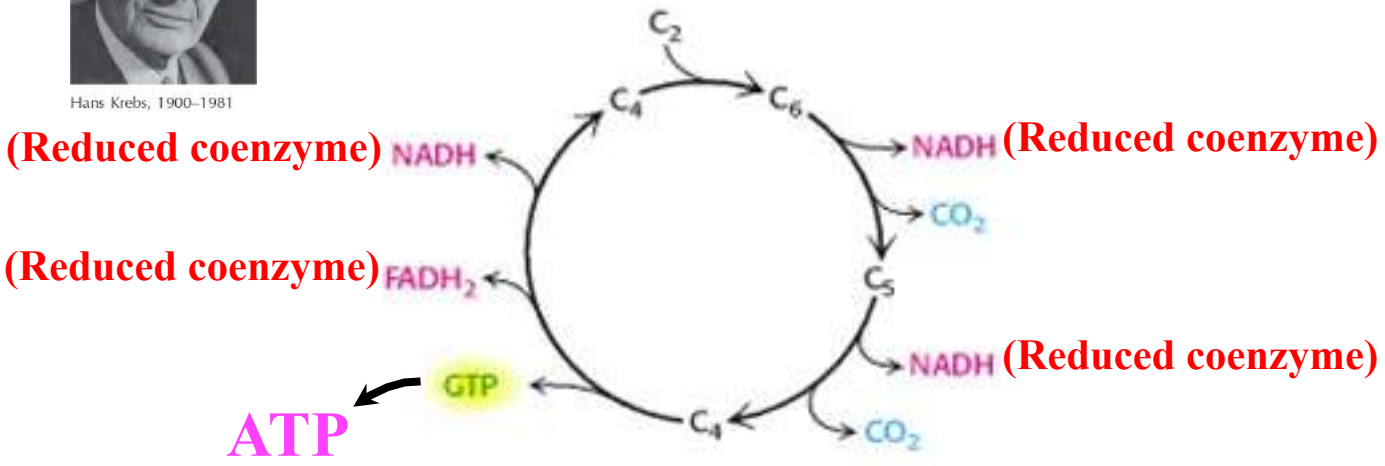
Glucose —Glycolysis→ pyruvate —(CoA–SH; NAD^+ → NADH + CO_2)→ acetyl CoA (Thio ester)



Taken from: Principles of Biochemistry- Albert Leningher

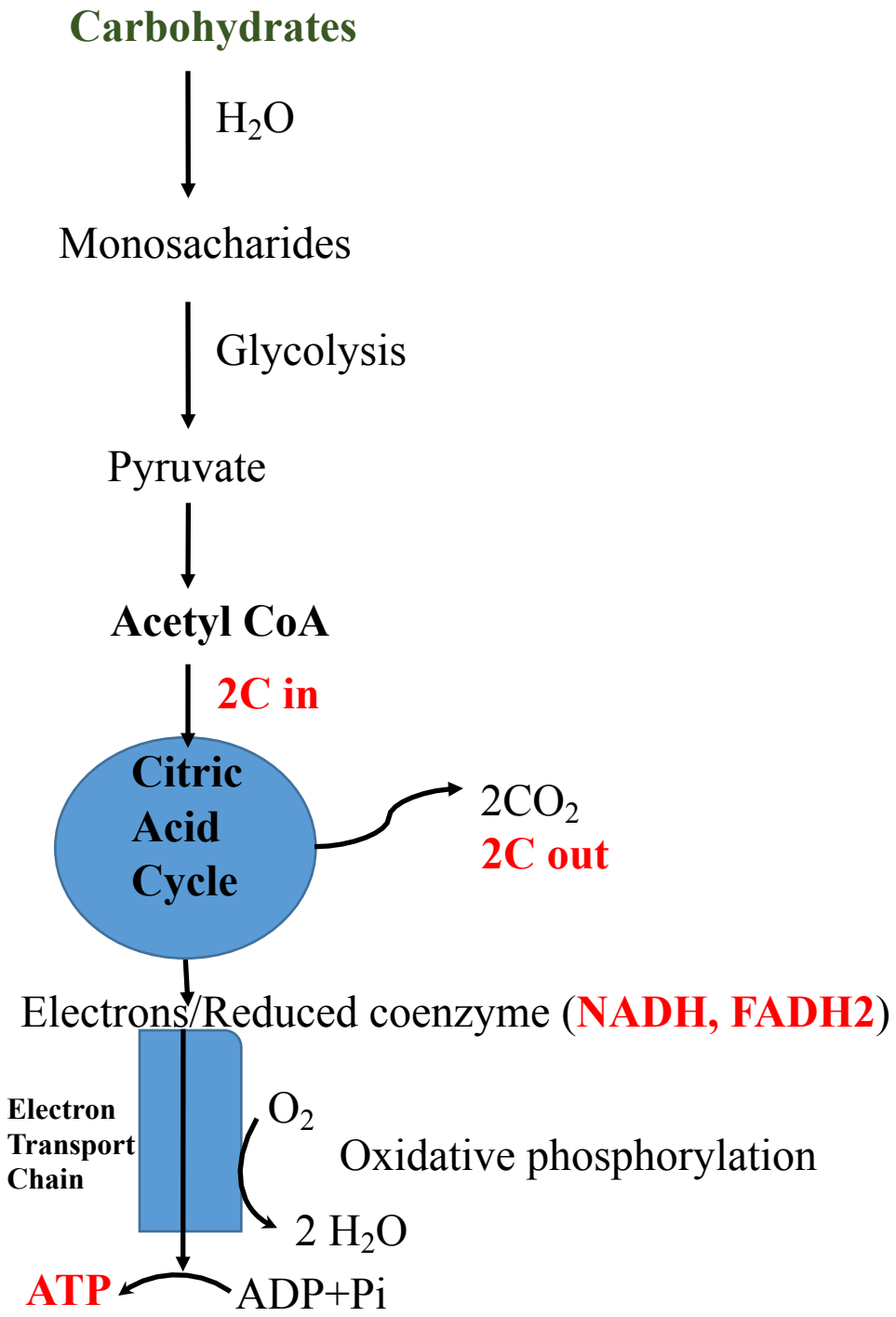
Hans Krebs, 1900–1981

Citric acid cycle (CAC)/ Kreb's cycle



Summary :

1. 2C in and 2C out
2. Reduced coenzyme formation
3. ₹
   - ATP
   - NADH
   - FADH2

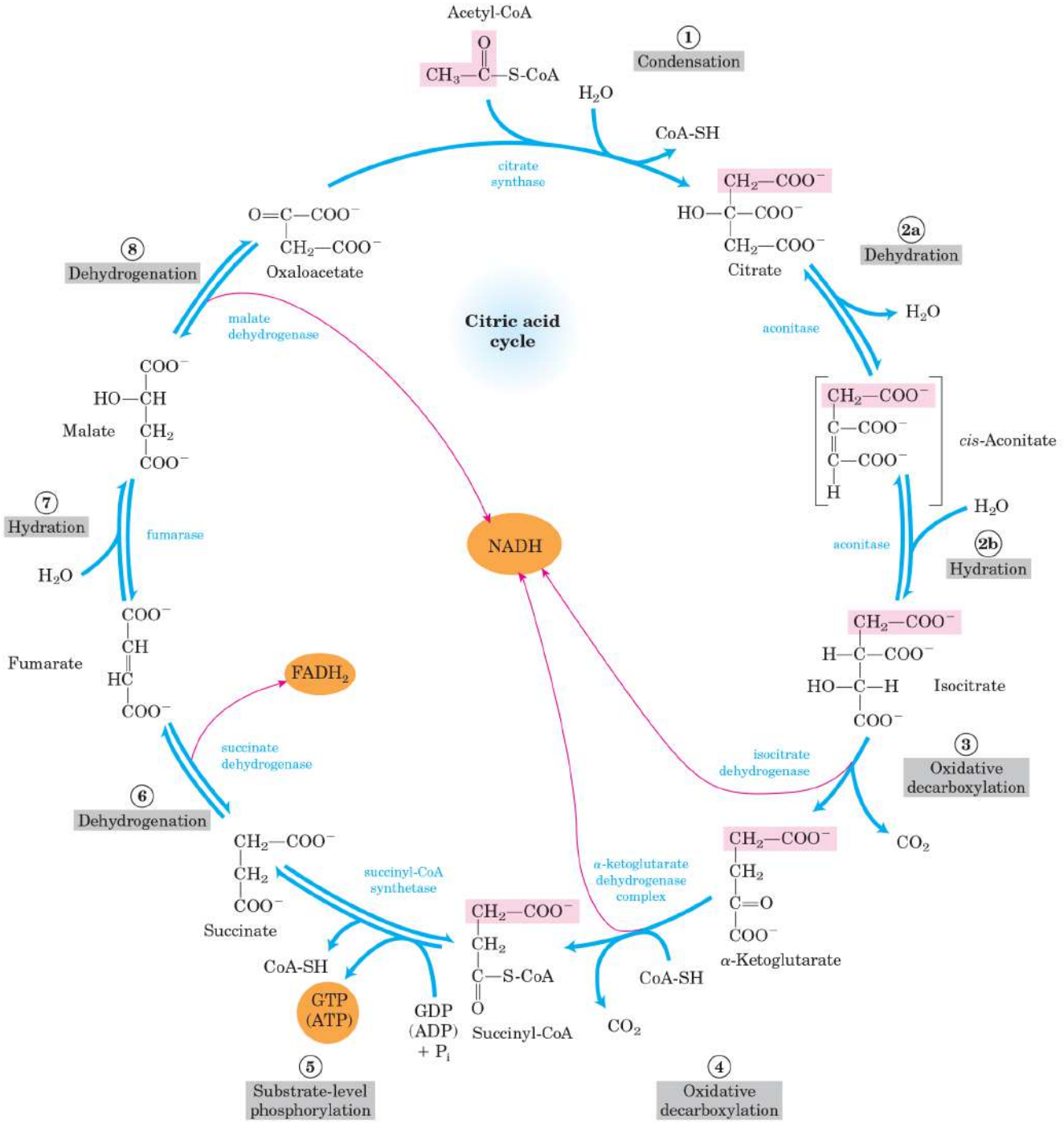


Citric acid cycle/ Kreb's cycle – Details

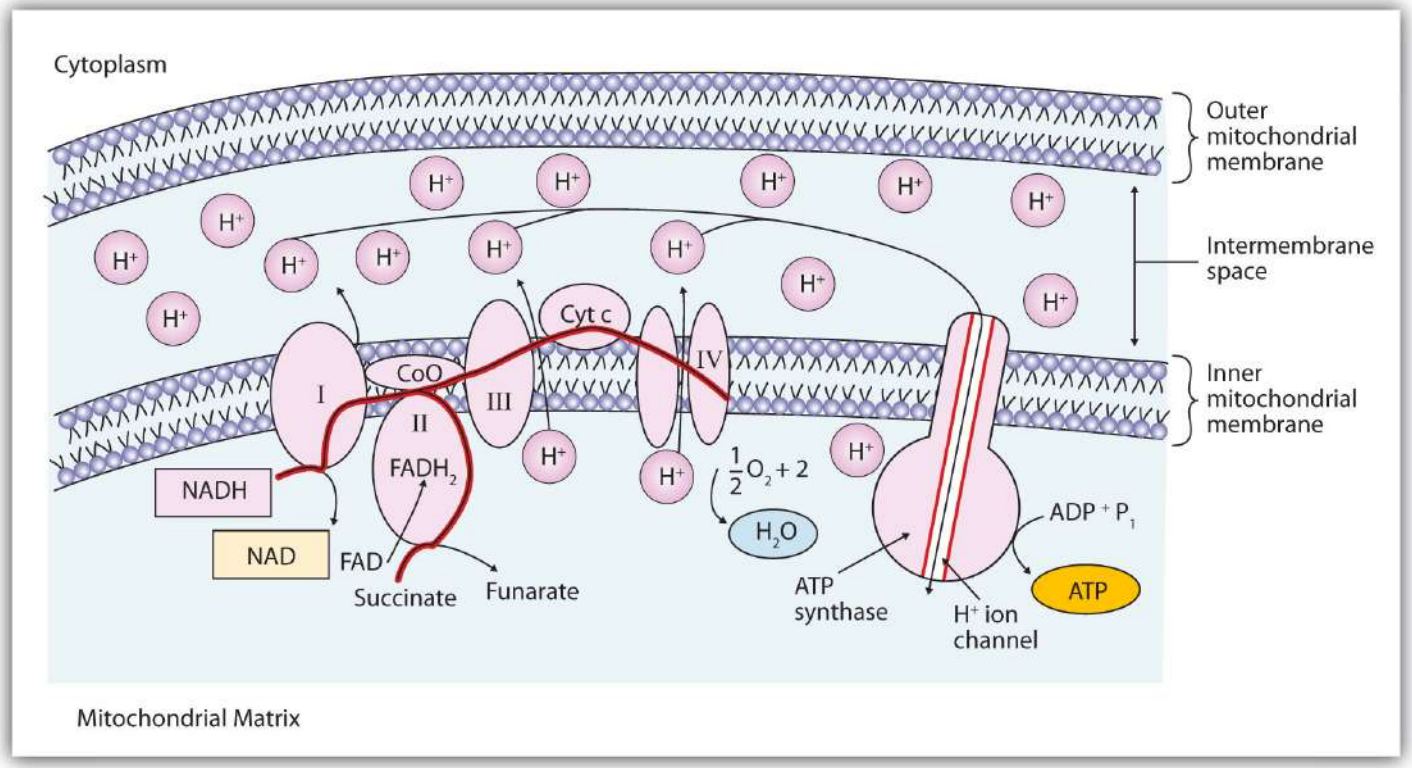
Points to be noted:

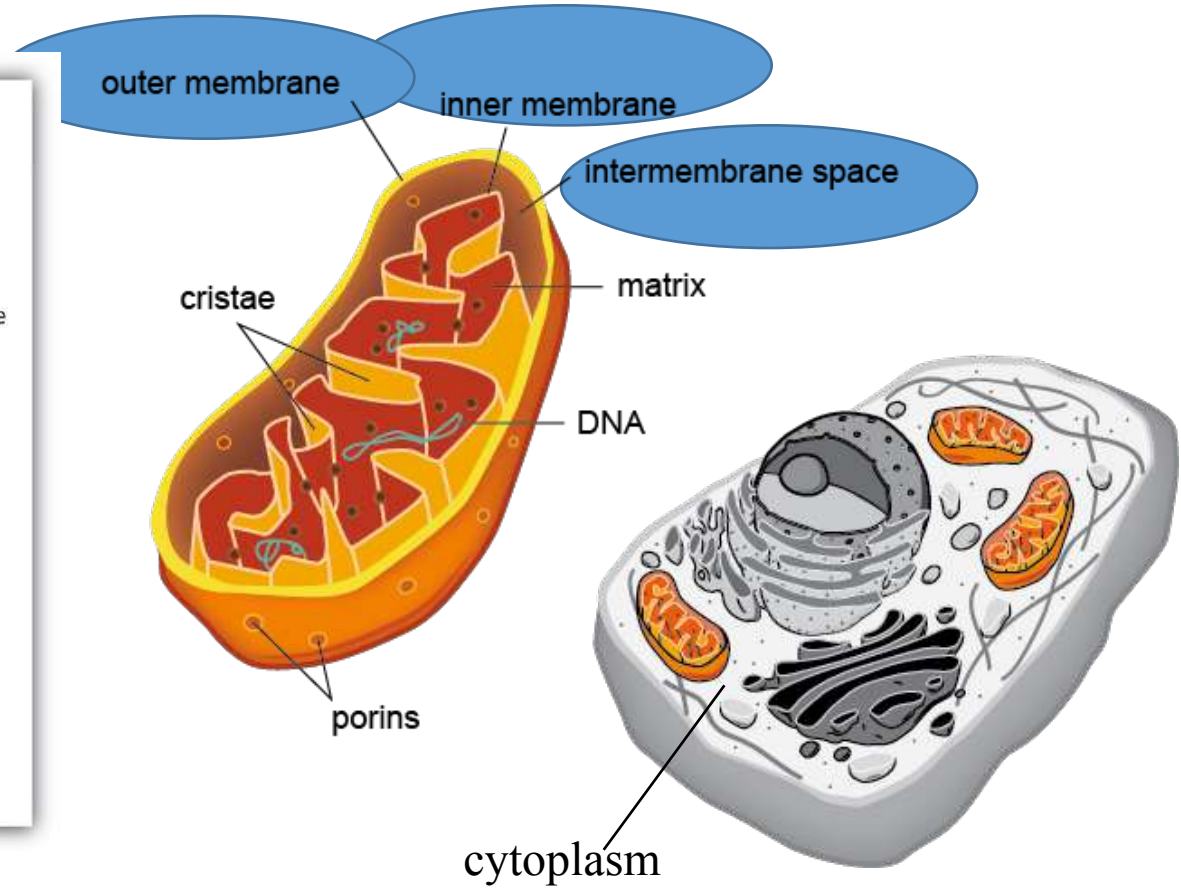
(1) 2C out from CAC are different from Acetyl carbon.

(2) Cyclic (produces oxaloacetate at the end)



Where does the Electron transport chain (ETC) and ATP production takes place ?

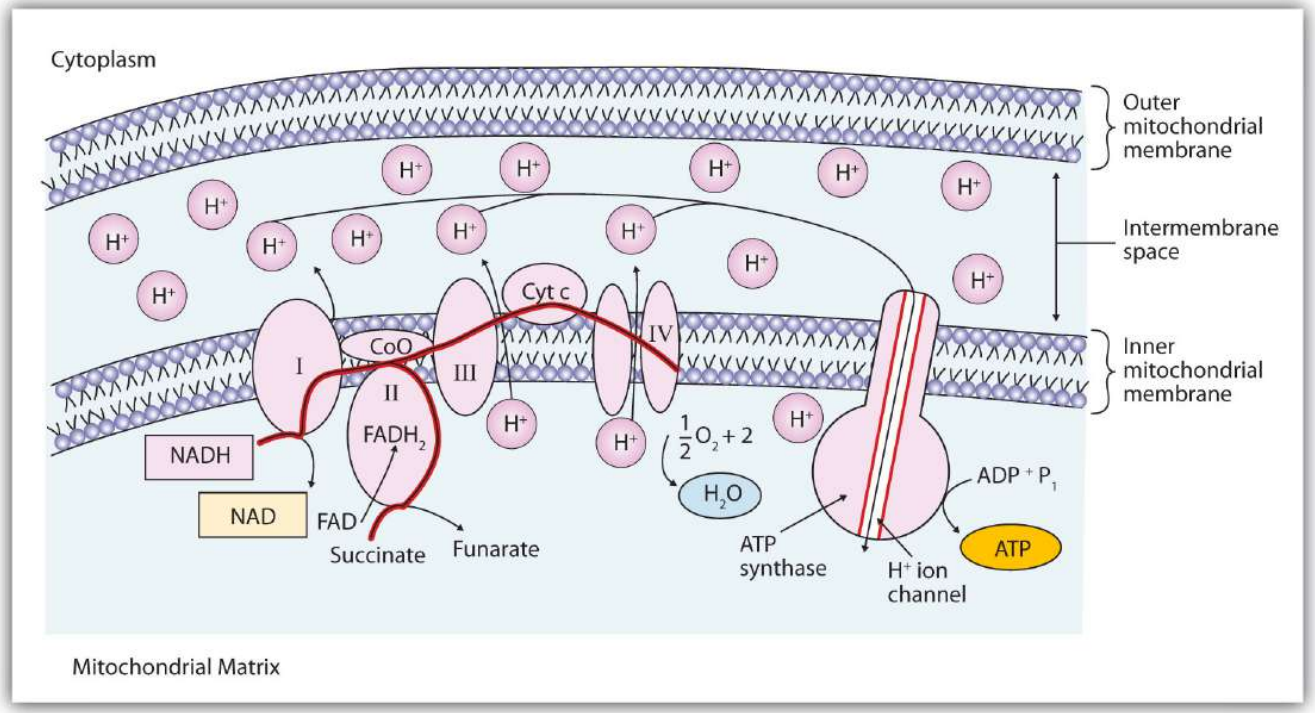




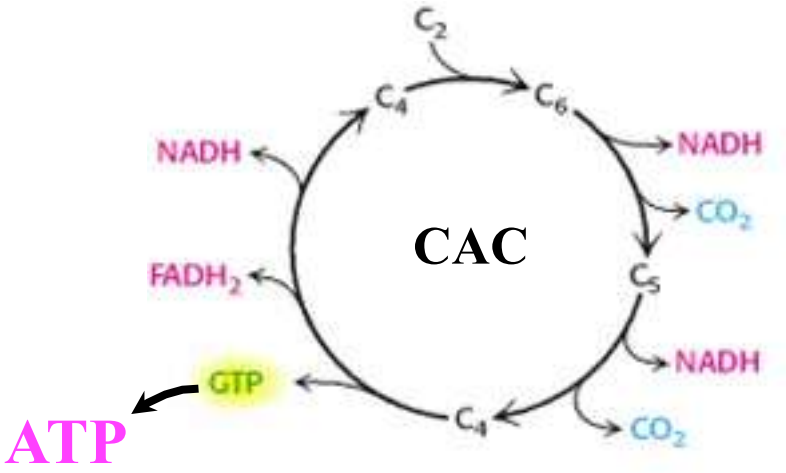
(ETC) = Complex I - IV → ATP synthase → ATP

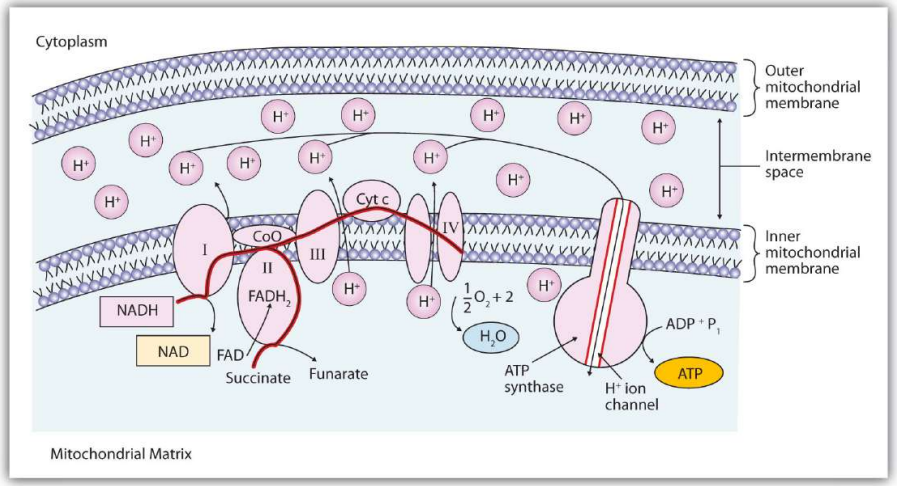
Summary

1. CAC produces reduced enzymes (NADH, $FADH_2$).
2. NADH, $FADH_2$ enters ETC. Pumps H^+ from matrix to inter membrane space of mitochondria.
3. Accumulation of H+ in the inter membrane of mitochondria. Chemical and electrical potential energy.
4. Diffusion of H^+ through ATPase from inter to inner membrane → synthesis of ATP



How much energy (ATP) is produced per Acetyl coA ?





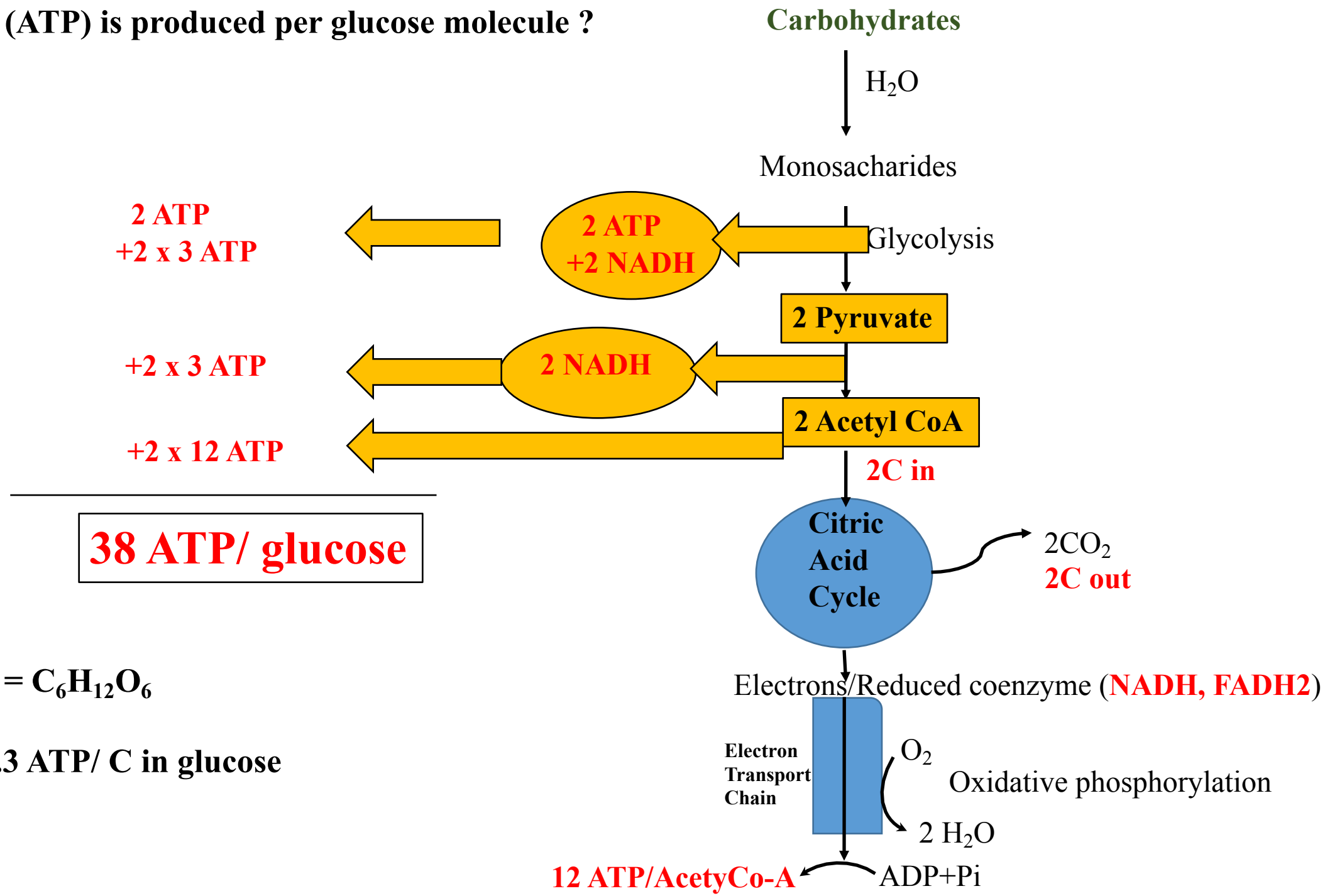
ETC

- **ATP = 1**
- **NADH = 3**
- **$FADH_2$ = 1**

- **1 NADH ➔ 3 ATP**
- **1 $FADH_2$ ➔ 2 ATP**

Total ATP production = 1+ 3x3 + 1x2 = 12 ATP (per Acetyl coA)

How much energy (ATP) is produced per glucose molecule ?

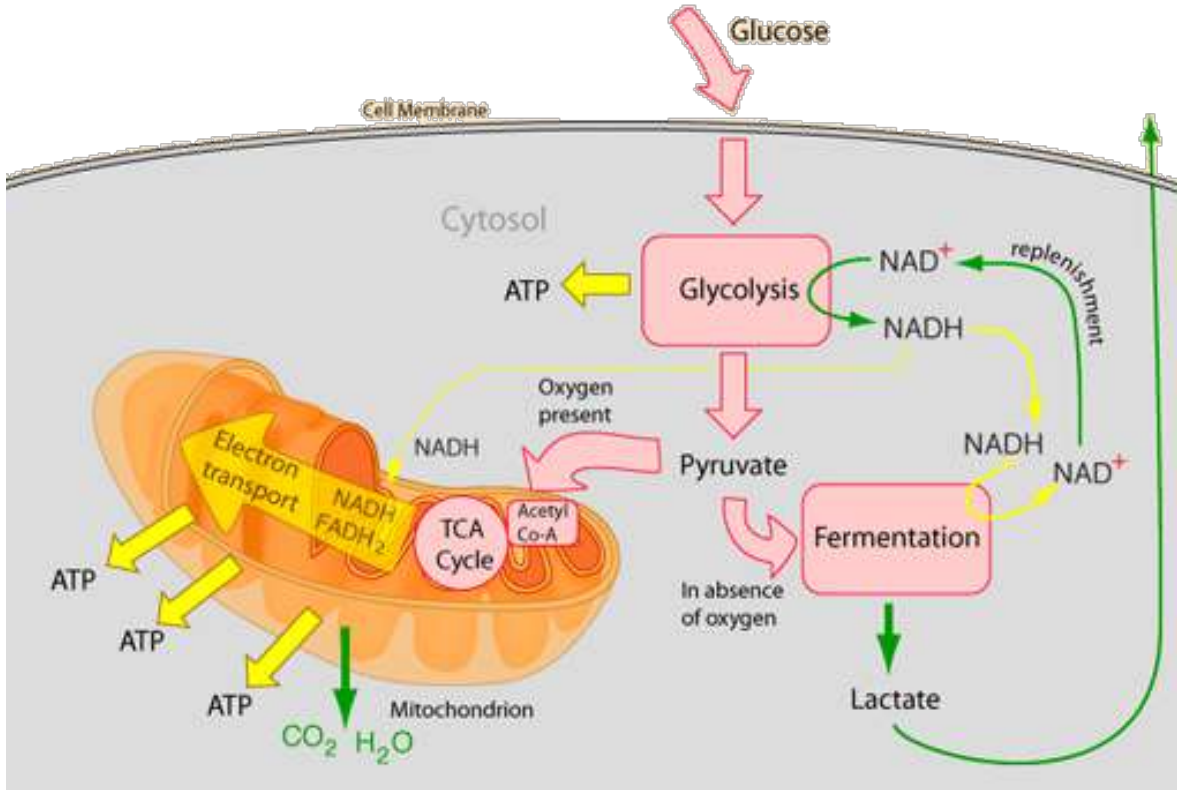


38 ATP/ glucose

Glucose = $C_6H_{12}O_6$

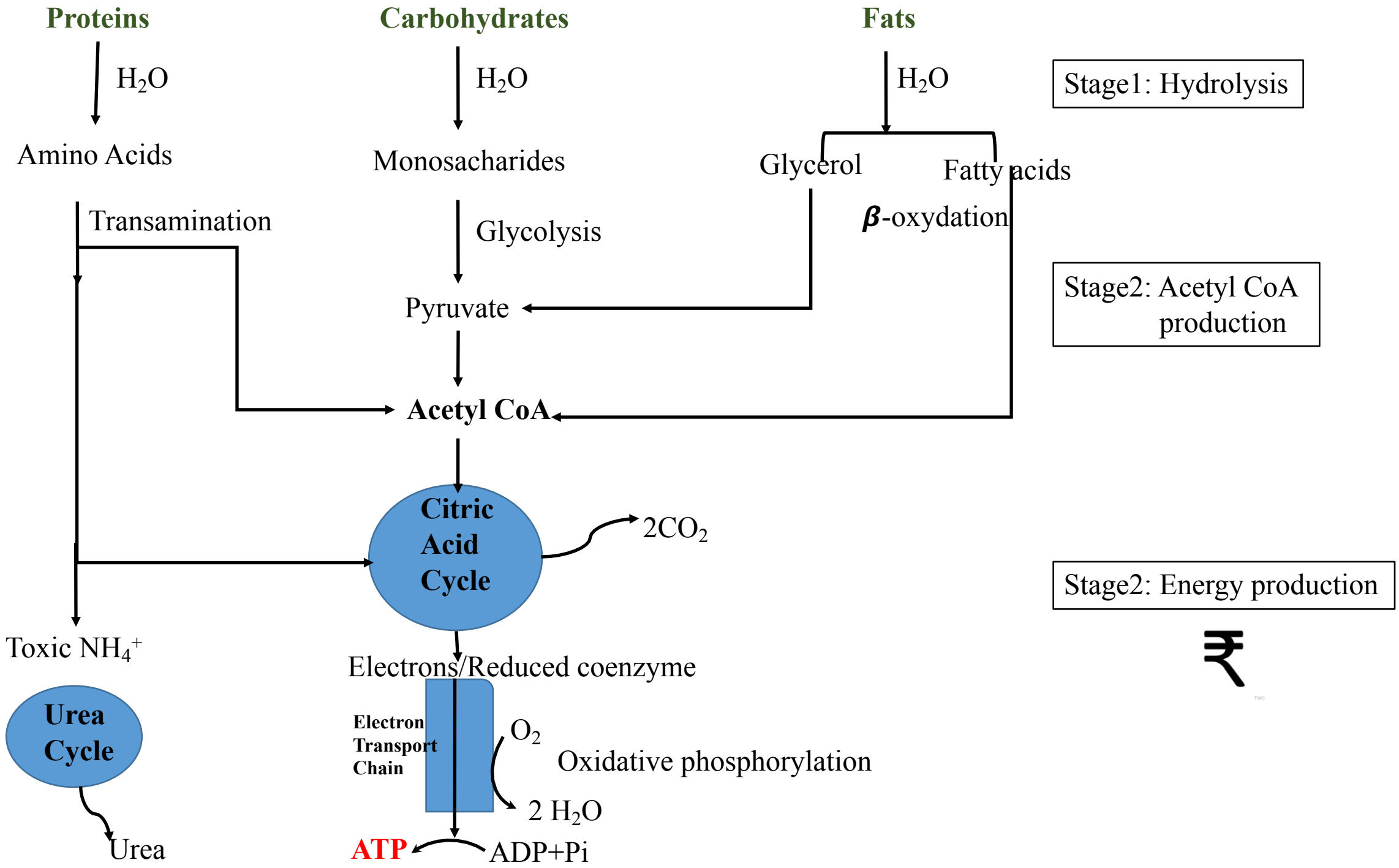
38/6 = 6.3 ATP/ C in glucose

How much energy (ATP) is produced per glucose molecule (For anaerobic condition) ?



ANSWER: 2 ATP

(Note NADH is used up for Fermentation)


Proteins
Carbohydrates
Fats
H_2O
H_2O
H_2O
Stage1: Hydrolysis
Amino Acids
Monosacharides
Glycerol
Fatty acids
Transamination
Glycolysis
β-oxydation
Stage2: Acetyl CoA production
Pyruvate
Acetyl CoA
Citric Acid Cycle
$2CO_2$
Stage2: Energy production
Toxic NH_4^+
Electrons/Reduced coenzyme
Urea Cycle
Electron Transport Chain
O_2
Oxidative phosphorylation
$2 H_2O$
Urea
ATP
ADP+Pi

How much energy (ATP) is produced from FAT ?

Fats & oils

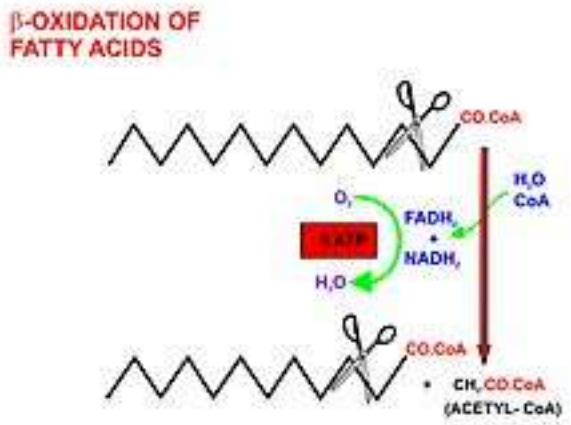
↓ H_2O Stage1: Hydrodysis

Fatty acids (EVEN NUMBER OF carbon atoms)

↓ ***β*-oxydation**

#Each turn
1 FADH2
1 NADH
1 Acetyl coA

 # Last Turn
2 Acetyl coA



Cycles of β-Oxidation

The length of a fatty acid:

- **Determines the number of oxidations and**
- **The total number of acetyl CoA groups.**

Carbons in Fatty Acid	Acetyl CoA (C/2)	β-Oxidation Cycles (C/2 –1)
12	6	5
14	7	6
16	8	7
18	9	8

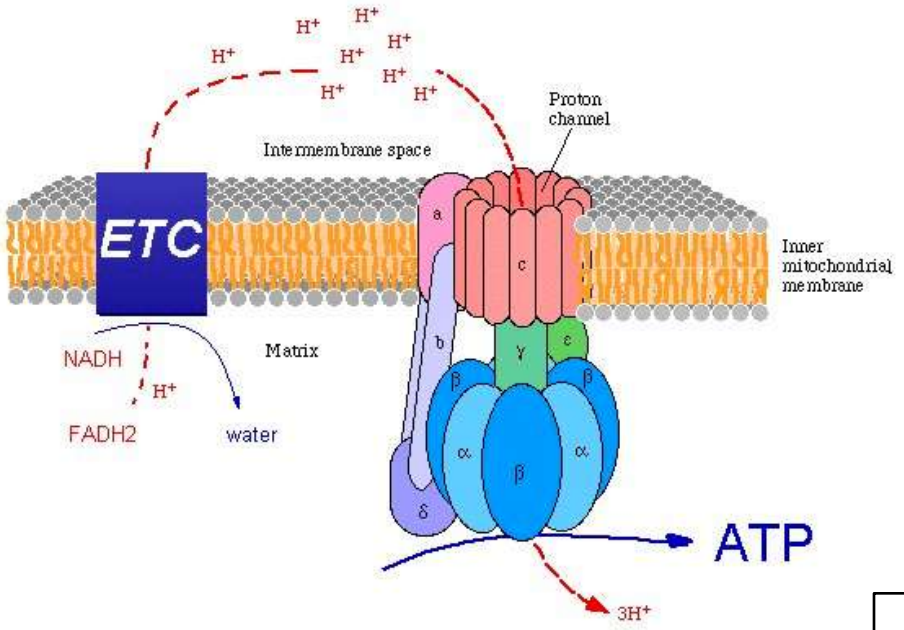
ATP for Lauric Acid C_{12}

ATP production for lauric acid (12 carbons):

Activation of lauric acid	-2 ATP
6 Acetyl CoA	
6 acetyl CoA x 12 ATP/acetyl CoA	72 ATP
5 Oxidation cycles	
5 NADH x 3ATP/NADH	15 ATP
5 $FADH_2$ x 2ATP/$FADH_2$	10 ATP
Total	95 ATP

95/12 = 7.92 ATP/ C in fat

Fats gives more energy than glucose



Free energy coupling

$$n\,[H^+]_{out} \rightleftarrows n\,[H^+]_{in} \quad \ldots(\Delta G_1)$$

$$ADP + Pi \rightleftarrows ATP \quad \ldots(\Delta G_2)$$

$$ADP + Pi + n\,[H^+]_{out} \rightleftarrows ATP + n\,[H^+]_{in} \quad \ldots(\Delta G_1 + \Delta G_2)$$

$$\Delta G_2\ (ADP + Pi \rightarrow ATP) = \Delta G^0 + RT \ln \left([ATP] / [ADP][Pi] \right) = +ve$$

$$\Delta G_1\ (\text{Proton diffusion}) = \Delta G^0 + n\,RT \ln \left([H+]_{in} / [H+]_{out} \right) + n\,F\,\psi = -ve$$

$\Delta G^0 = 0$

Non-Mech Work

Membrane potential exist

In case if you are interested in the fascinating motor (ATPase): https://www.youtube.com/watch?v=b_cp8MsnZFA