Why Do We Need To Be Able to Respire?

To produce <u>energy</u> – ATP.

We need energy to eat, breathe, move, stay warm etc.

The Three Main Processes in Respiration

1. Glycolysis

The first step in respiration

2. Krebs' Cycle
3. Electron Transport Chain

Learning Intentions

By the end of this lesson, you should be able to:

- State that glycolysis is the **first step** in respiration.
- Describe the **aim** of glycolysis is in respiration and where it takes place.
- Explain the **key stages** in the process of glycolysis, krebs cycle and electron transport chain.
- Identify the **net gain** of ATP from aerobic respiration.

Glycolysis

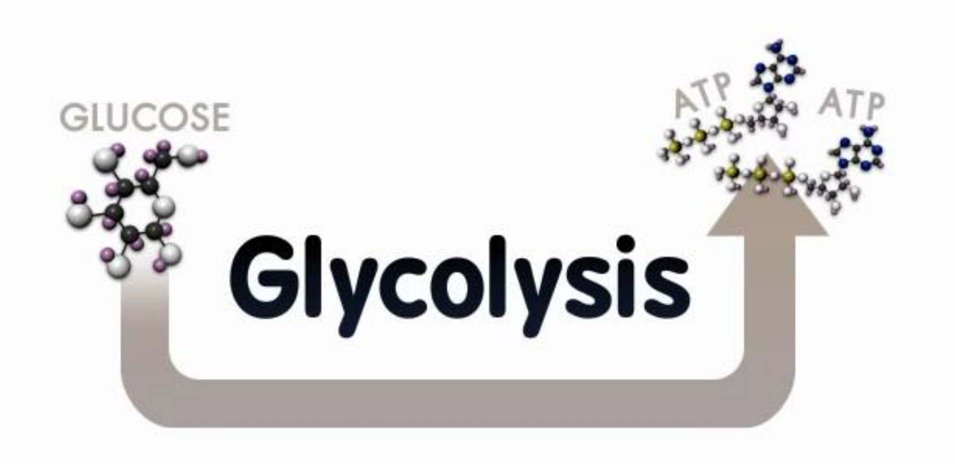
The first step in respiration…

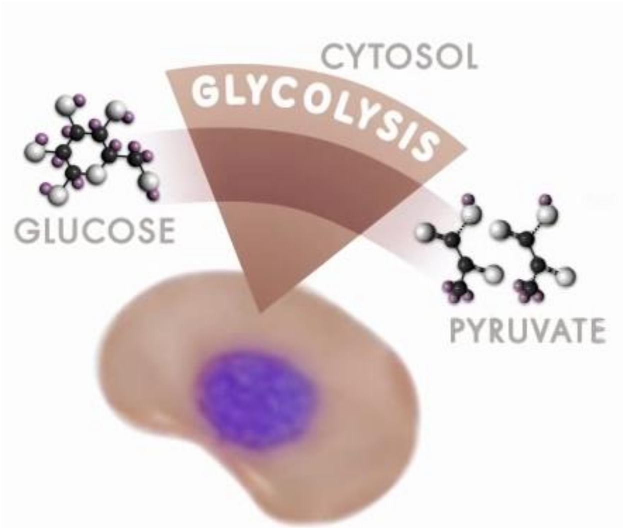
What Is Glycolysis?

- “Sugar Splitting”   “Sugar breakdown”

- Glycolysis is the break down of glucose.

- What is the aim of glycolysis?
- To produce energy (ATP) and two molecules of pyruvate.





Key Facts

Where does glycolysis happen?

- In the cytoplasm of cells.
- It does not require oxygen.

There are three parts to the process:

1. Phosphorylation of Glucose
2. Lysis
3. Oxidation by Dehydrogenation.

Do you think this first stage of respiration will produce a lot of ATP or only a little ATP?

Key Players

- Glucose
- NAD – Hydrogen carrier molecule
- ATP

Key Vocabulary

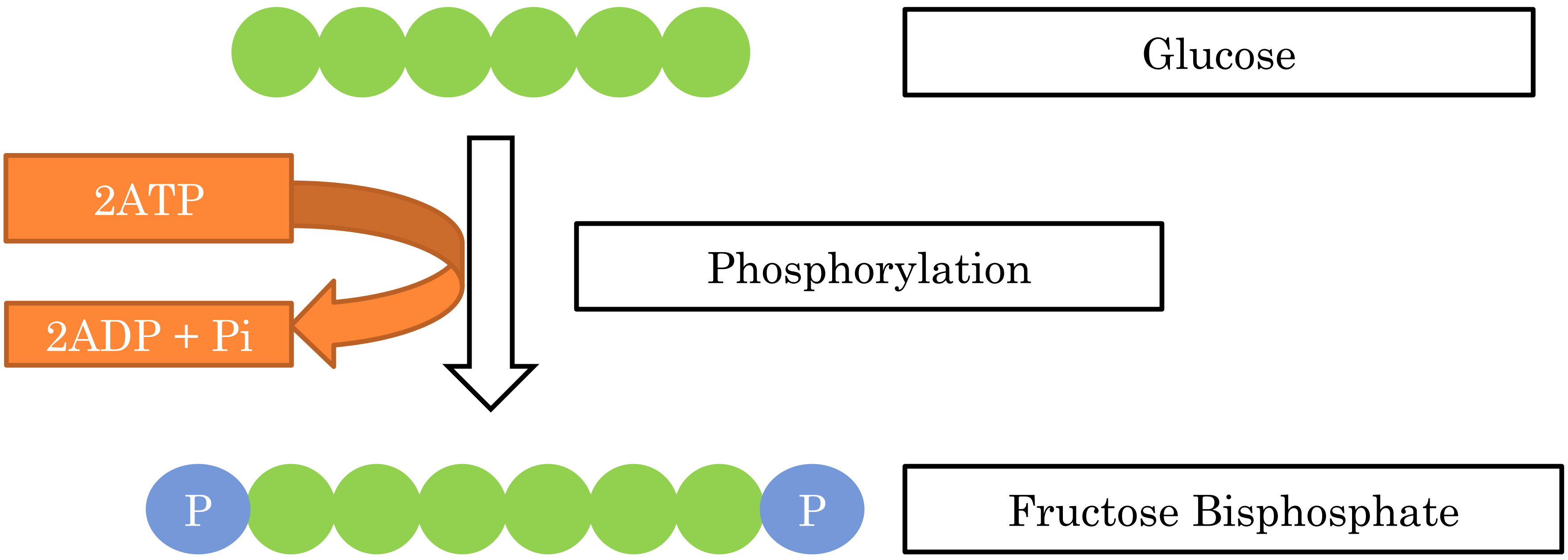
- **Phosphorylation:** the addition of a phosphate group to a molecule.
- **Reduction:** the gain of hydrogen molecules/electrons (or loss of oxygen).
- **Oxidation:** the loss of hydrogen molecules/electrons (or gain of oxygen molecule)

OIL RIG

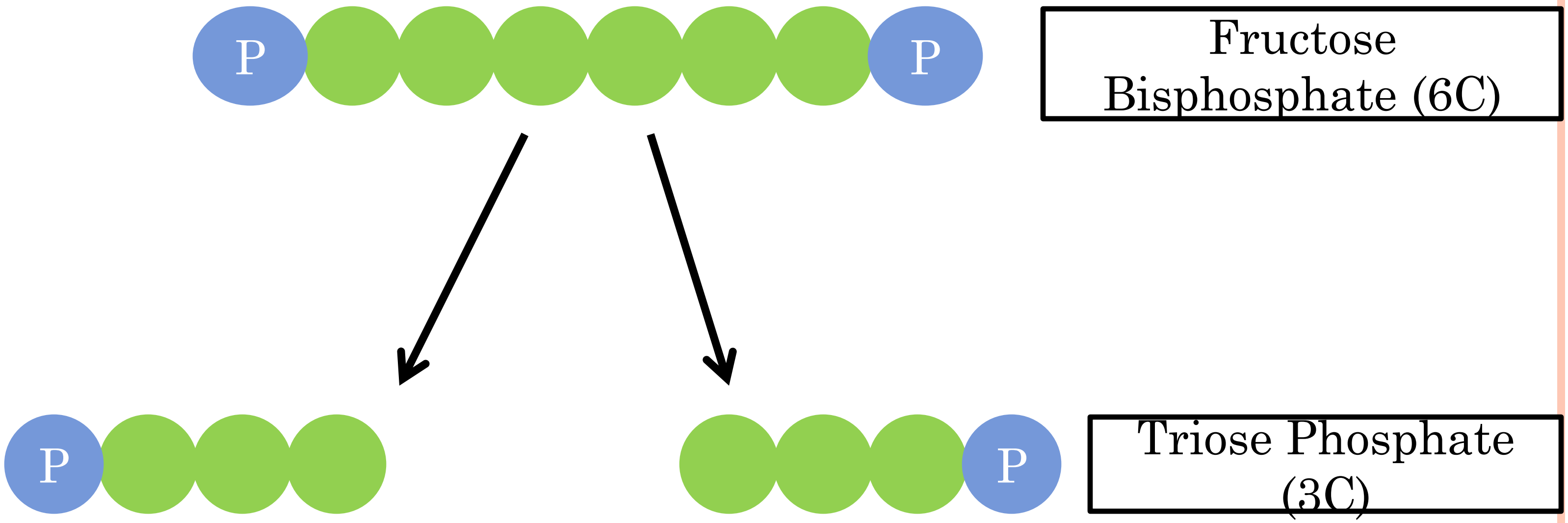
of electrons/hydrogen

- **Dehydrogenation** – Removal of hydrogen.
- **Decarboxylation** – Removal of carboxyl group and releases CO_2.
- **Substrate Level Phosphorylation** – Formation of ATP by direct donation of a phosphate group.

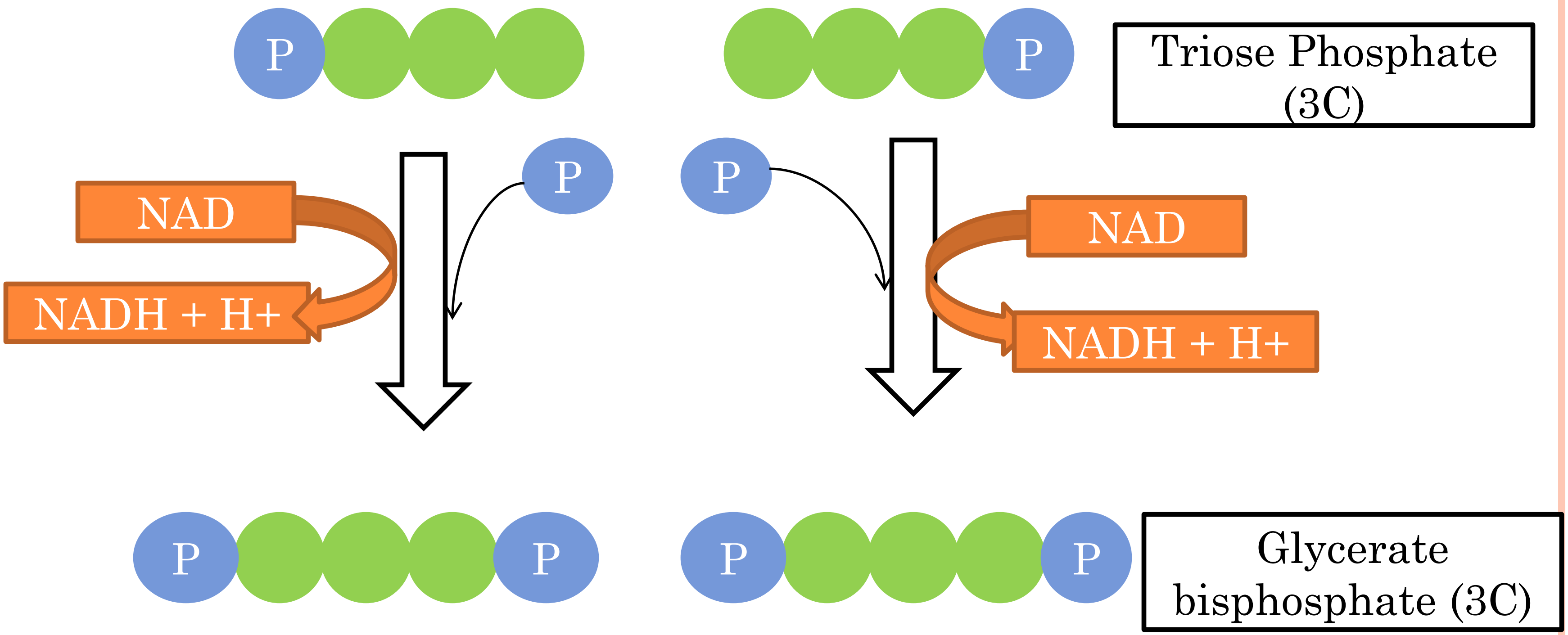
Phosphorylation of Glucose – Requires Energy!



Lysis.



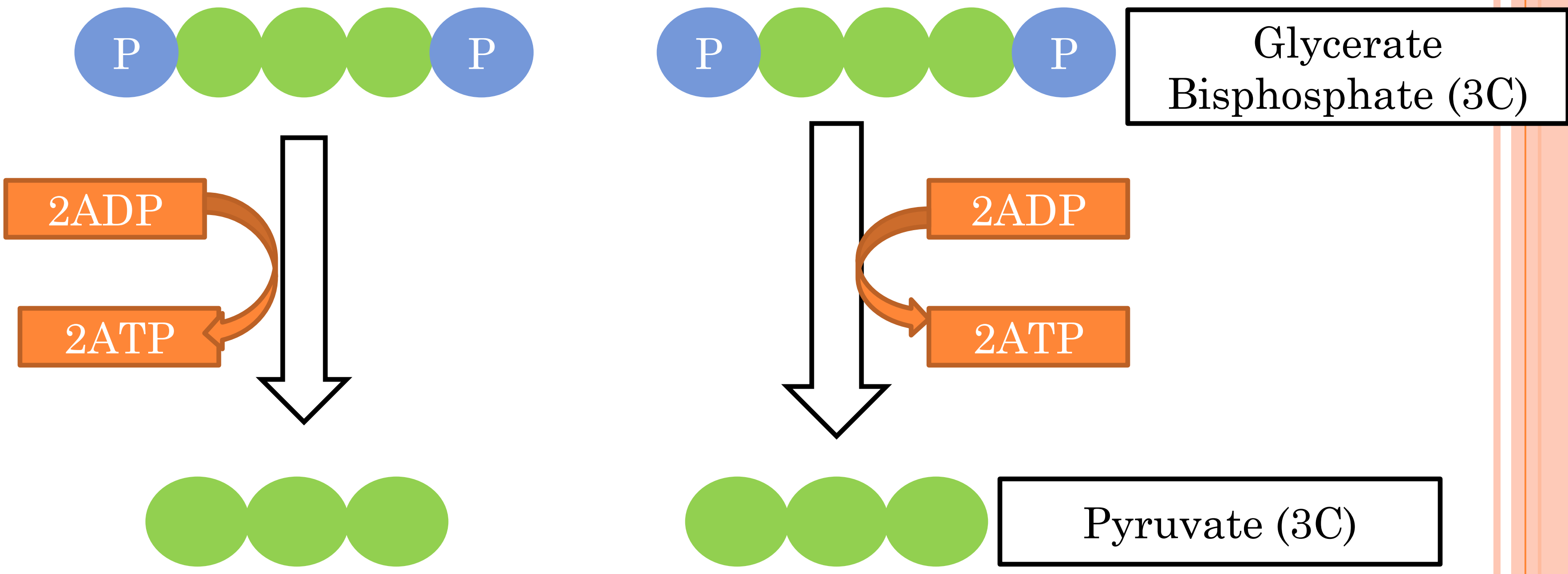
Oxidation by dehydrogenation

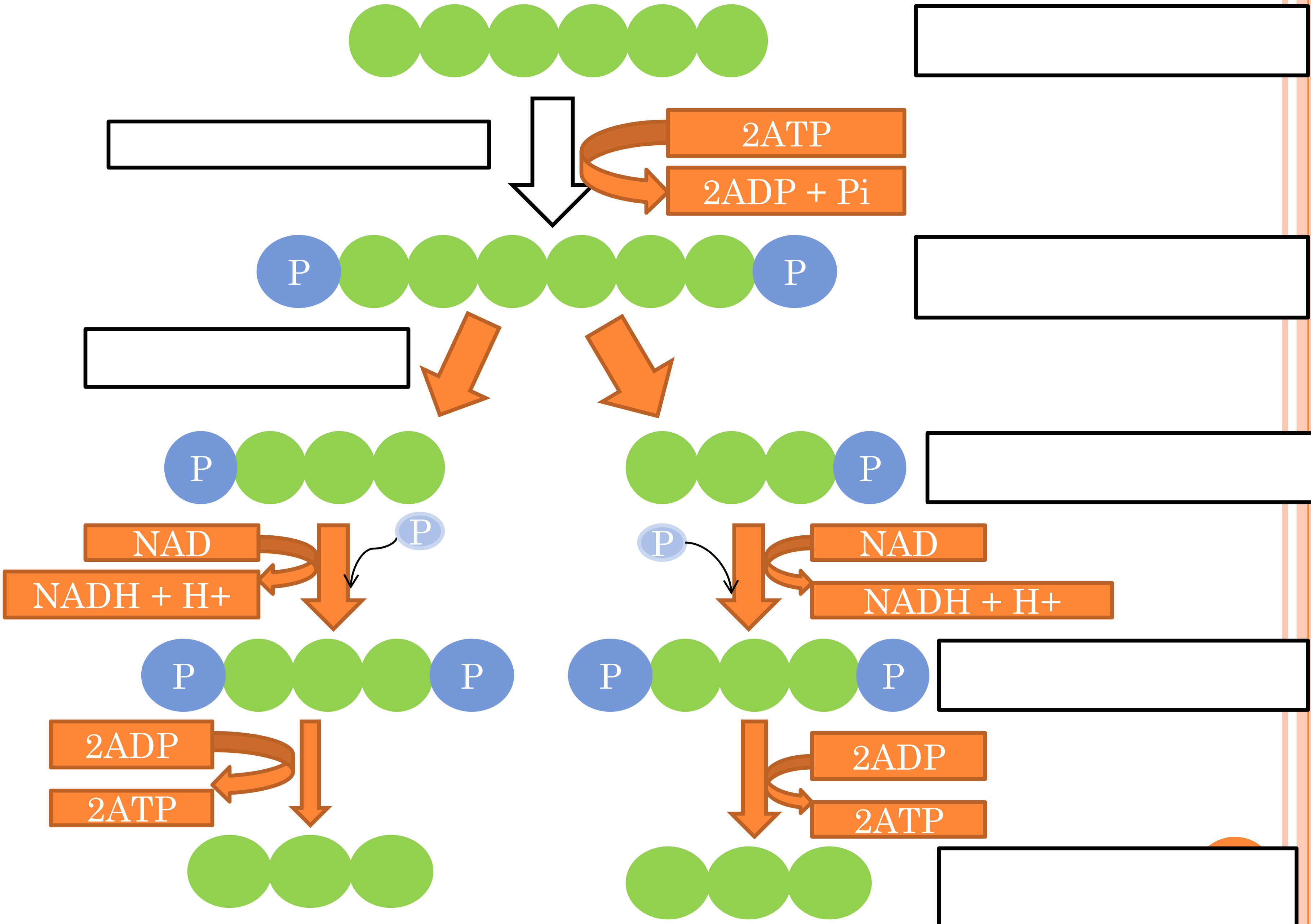


Which molecule is oxidised?? Triose Phosphate

Which molecule is reduced?? NAD+ is reduced. It accepts hydrogen atoms – never say it accepts hydrogen ions or molecules

ATP Production via substrate level phosphorylation.




2ATP
2ADP + Pi
P
P
P
P
NAD
NADH + H+
P
NAD
NADH + H+
P
P
P
P
P
2ADP
2ATP
2ADP
2ATP

The Outcome of Glycolysis

- 4 x ATP molecules per glucose molecule
- 2 x pyruvate
- 2 x NADH molecules

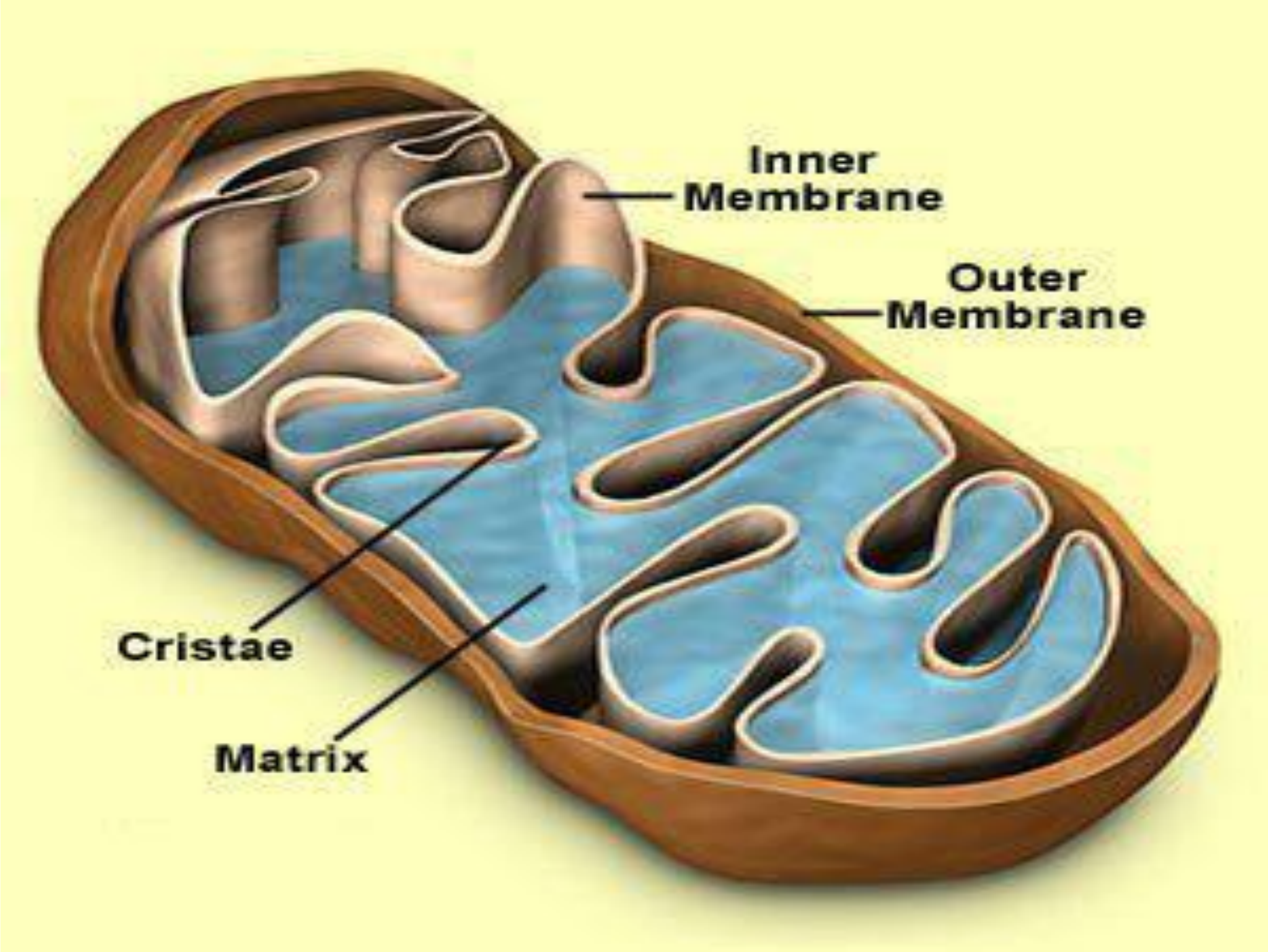
Note: Net Gain of ATP = 2

http://highered.mheducation.com/sites/0072507470/student_view0/chapter25/animation__how_glycolysis_works.html

Anaerobic Conditions

- Glycolysis is also the first stage of anaerobic respiration (does not require oxygen).
- Further reactions in anaroebic conditions produce no more ATP but which regenerate co-enzyme NAD^+. Ethanol and CO_2 is produced in plants and in microorganisms. Lactate is produced in animals.
- If no oxygen is present then there is no terminal (end) hydrogen acceptor in the ETC and the carriers remain reduced – therefore the link reaction and Krebs cycle can't take place as there is no new supply of NAD^+ and FAD.

The Link Reaction



The Link reaction – aerobic Conditions

- Pyruvate is initially broken down in a **link reaction** (so called because it connects glycolysis to the krebs cycle).
- Takes place in the mitochondrial matrix.
- Involves removal of hydrogen (dehydrogenation) and removal of carbon dioxide (decarboxylation) from pyruvate,

Link Reaction

Start Pyruvate (3 carbon compound)

Step1

Pyruvate decarboxylase removes a carboxyl group from pyruvate. CO_2 formed.

Step 2

- Pyruvate dehydrogenase removes hydrogen atoms from the pyruvate.

- Hydrogen atoms are accepted by co-enzyme NAD^+ which is reduced to NADH

Formed = NADH + Acetate (2 carbon compound)

Step 3

- Coenzyme A (CoA) accepts the Acetate to form Acetyl Coenzyme A

- This is carried into the Krebs cycle

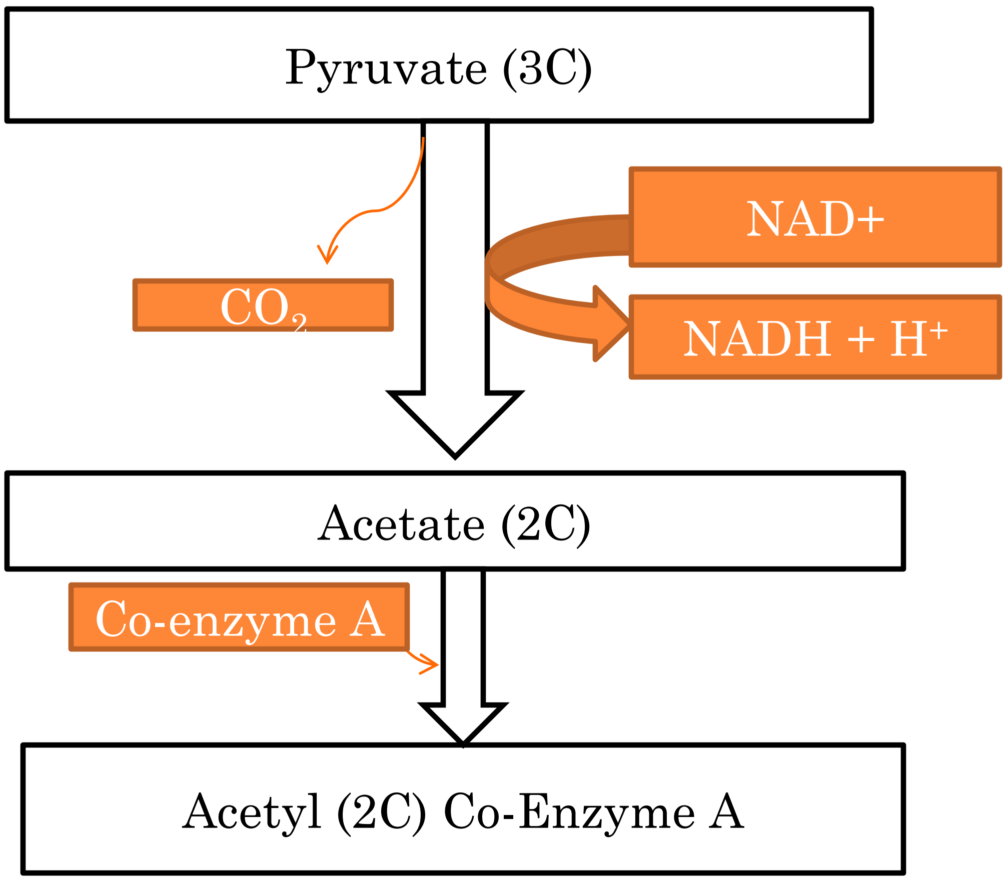
$$2\ \text{Pyruvate} + 2NAD^{+} + 2CoA \rightarrow 2CO_2 + 2NADH + 2\text{acetyl CoA}$$

Why is there two of everything?

What is being oxidised, what is being reduced?

The Link Reaction

X2



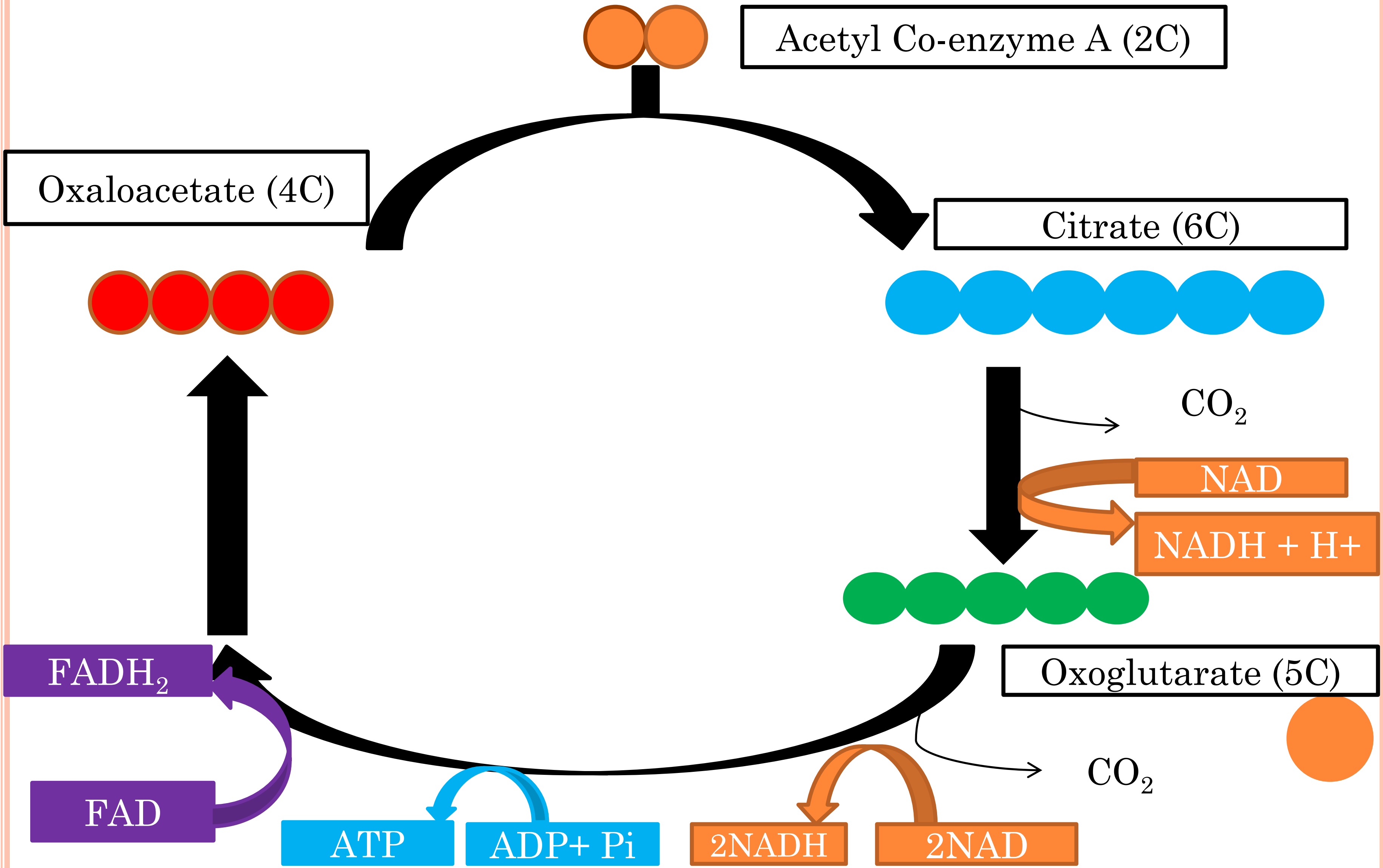
Main Purpose of Krebs Cycle

- To produce NADH and FADH for Electron Transport Chain.

Krebs Cycle

x2

Occurs in matrix of mitochondria.



Key stages

1. Acetyl Co-Enzyme A (2C) combines with Oxaloacetate (4C) to produce Citrate (6C)

2. Decarboxylation and dehygrodenation of citrate (6C) results in the formation of Oxoglutarate (5C). CO_2 released. Hydrogen is picked up by NAD and reduced NAD (NADH) is formed.

3. Decarboxylation of oxaloglutarate (5C) results in the formation of oxaloacetate (4C). The reactions at this stage also involves dehydrogenation. The hydrogen released is picked up by 2 NAD and 1FAD (another hydrogen carrier).

4. One molecule of ATP is produced via substrate level phosphorylation.

Products of Links Reaction & Krebs Cycle.

1. $8NADH^+$ (Reduced NAD)
2. $2FADH_2$ (Reduced FAD)
3. 2ATP
4. $3CO_2$

Other respiratory Substrates

- While glucose is the primary respiratory substrate in many living organisms, it is not the only one. If glucose supplies are low, **fat** and eventually **protein** can be used.

- Fats can be broken down into glycerol and fatty acids. Fatty acids are broken down into 2C lengths. Each length forms a molecule of acetyl co-enzyme A. Each acetyl co-enzyme A molecule can enter at the krebs cycle. The glycerol is converted into triose phosphate and enters at glycolysis.

- Proteins are hydrolysed into amino acids and these enter cycle at acetyl co-A.

Electron Transport Chain

- Occurs in the cristae of the mitochondrial membrane.

- The hydrogen atoms being carried by NAD and FAD are carried into the electron transport chain.

- The energy in the hydrogen is converted to ATP.

Step By Step

1. Hydrogen passes along the carriers at NAD, Flavoprotein and co-enzyme Q at progressively lower energy levels.

2. Hydrogen then dissociates into electrons and these electrons are passed through cytochromes in a series of redox reactions.

3. The final electron acceptor is oxygen – it is at this stage that oxygen is used in respiration.

4. As the carriers lie at progressively lower energy levels along the chain, energy becomes available as the redox reactions take place.

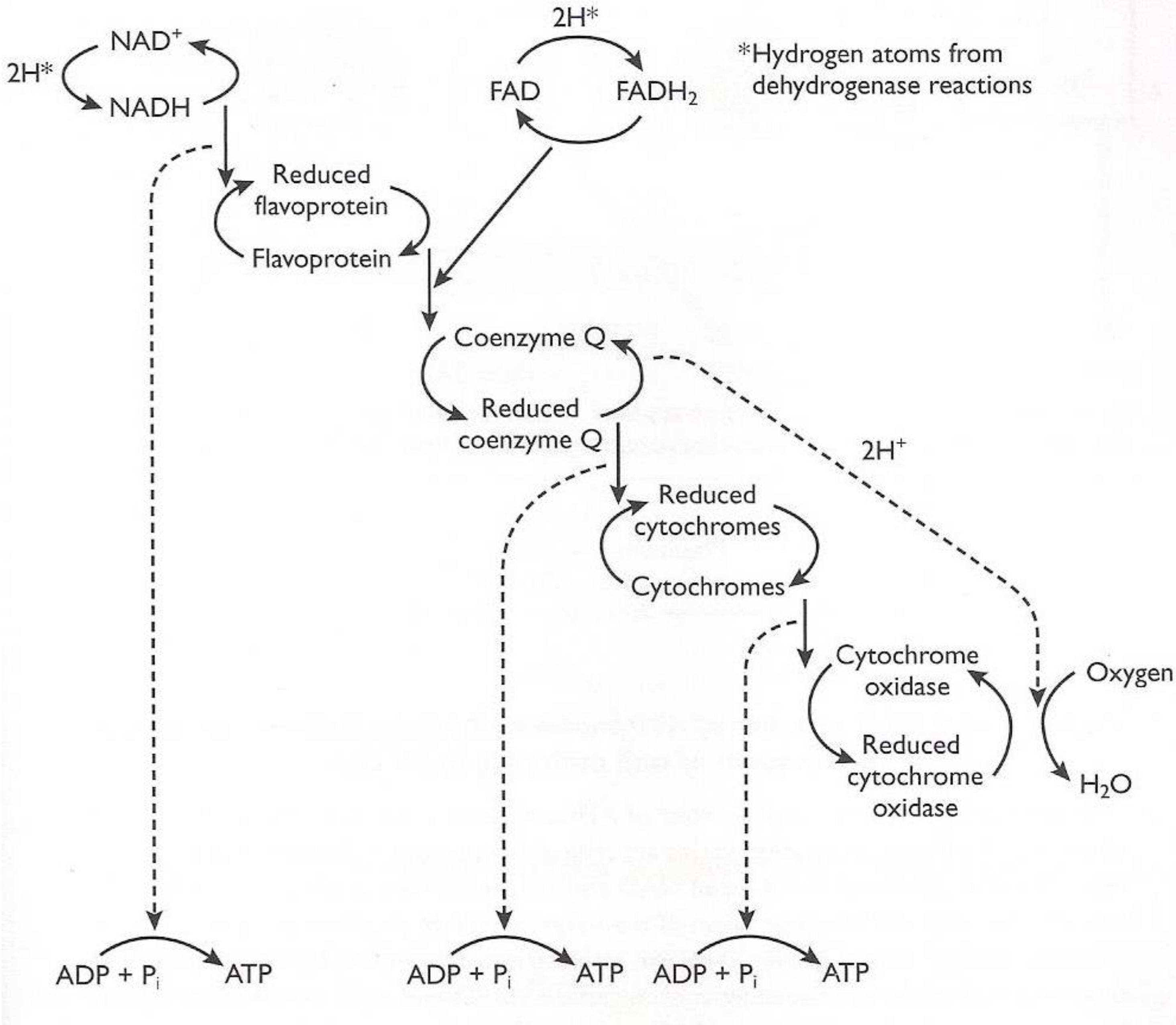


Figure 6 The electron transport chain and oxidative phosphorylation

ATP PRODUCED FROM ETC

- 1 NADH + H+ produces **3ATP**
- $1FADH_2$ produces **2ATP**

8NADH + H^+ from Krebs cycle & 2NADH + H^+ from glycolysis = 10 x 3 = 30ATP

2FADH2 from Krebs Cycle = 2 x 2 = 4ATP

Total = 34 ATP.

ATP Produced from aerobic respiration

34 ATP from ETC
2 ATP from Krebs
2 ATP from Glycolysis

Total = 38 ATP per molecule of Glucose

- 2 ATP used for electron shuttling.

- Net Gain = 36 ATP