

# RESPIRATION IN PLANTS

**Cellular respiration** : The mechanism of breakdown of food material within the cell to release energy and trapping of this energy for synthesis of ATP.

**Respiration** : Breaking of C-C bond of complex compounds through oxidation within the cell leading to release of energy is called respiration.

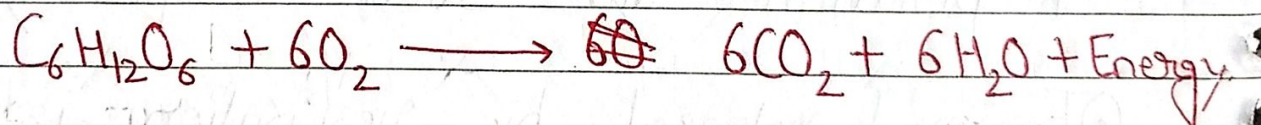
**Respiratory Substrates** : The compound that are oxidised during respiration is called respiratory substrate.

- ① Energy released by respiration is not used directly but is used in synthesis of ATP.
- ② ATP is broken down whenever energy needs to be utilised.
- ③ Hence ATP is Energy currency of cell.

## ① REASONS WHY PLANTS GET ALONG WITHOUT RESPIRATORY ORGANS.

1. Each part take care of its own gas exchange needs
2. Plants do not present great demands for gas exchange. Only during photosynthesis large volume of gaseous exchange.
3. The distance that gaseous must diffuse even in large, bulky plant is not great.

② Complete Combustion of glucose to produce  $\text{CO}_2$  and water is given as



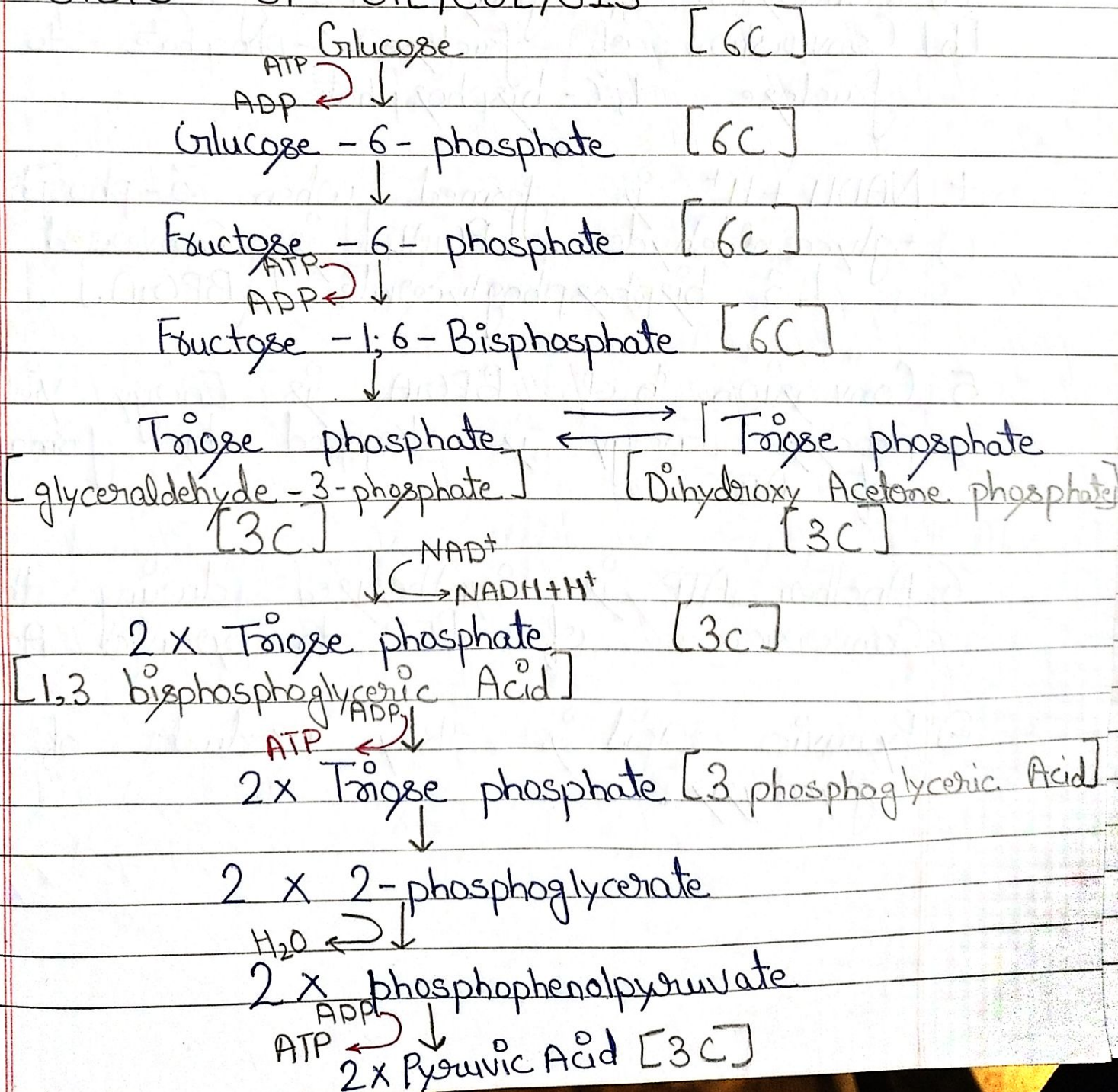
**GLYCOLYSIS**  $\rightarrow$  Glycos = Sugar  
 $\rightarrow$  Lysis = Splitting

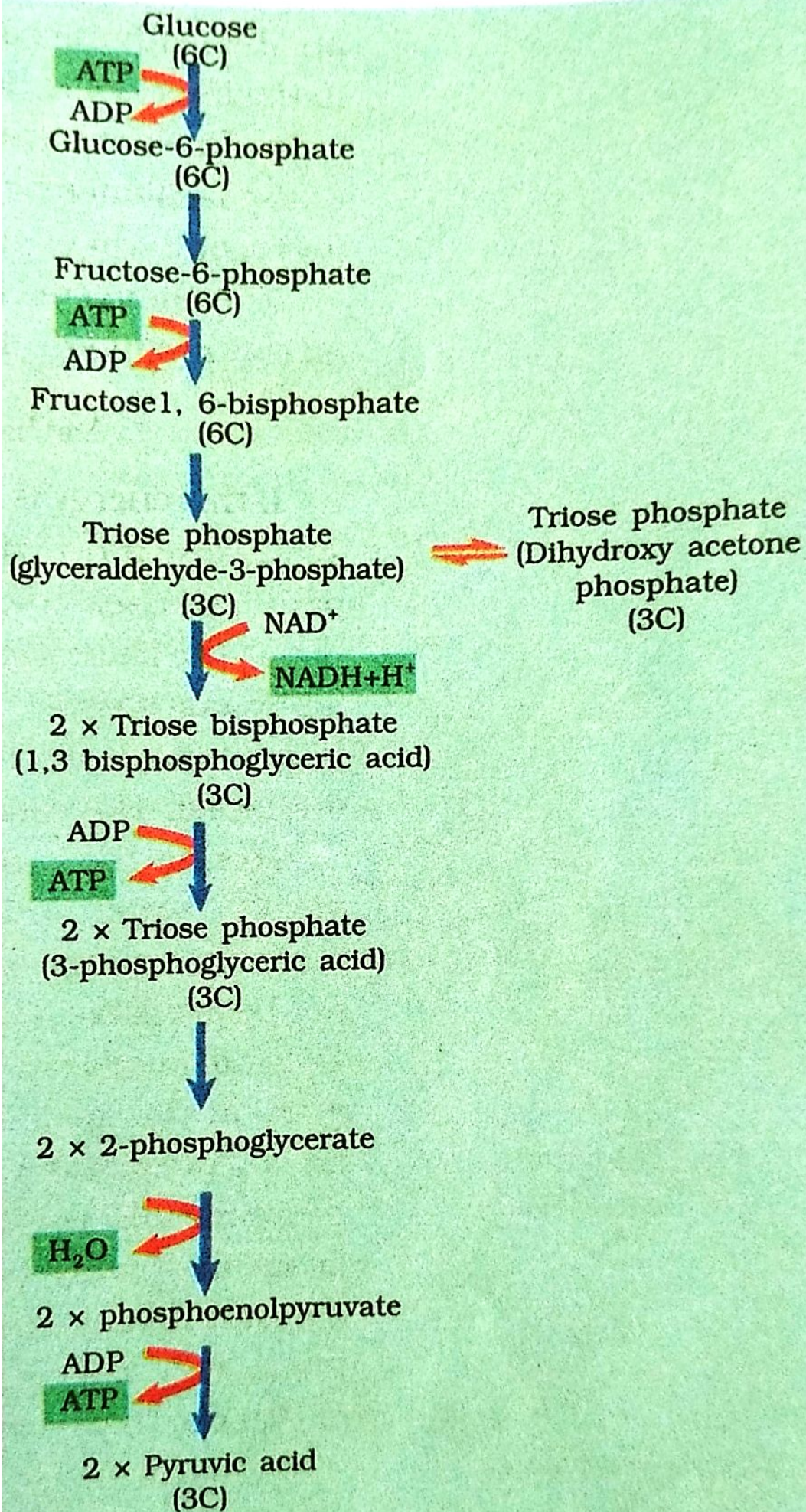
③ breakdown of glucose to 2 molecule of pyruvic Acid is called glycolysis.

④

- ① Scheme of glycolysis given by Gustav Embden, Otto meyerhof and J parnas.
- ② also referred to as EMP Pathway.
- ③ Occur in Cytoplasm of Cell.
- ④ In plant glucose is derived from Sucrose which is end product of photosynthesis

## \* STEPS OF GLYCOLYSIS





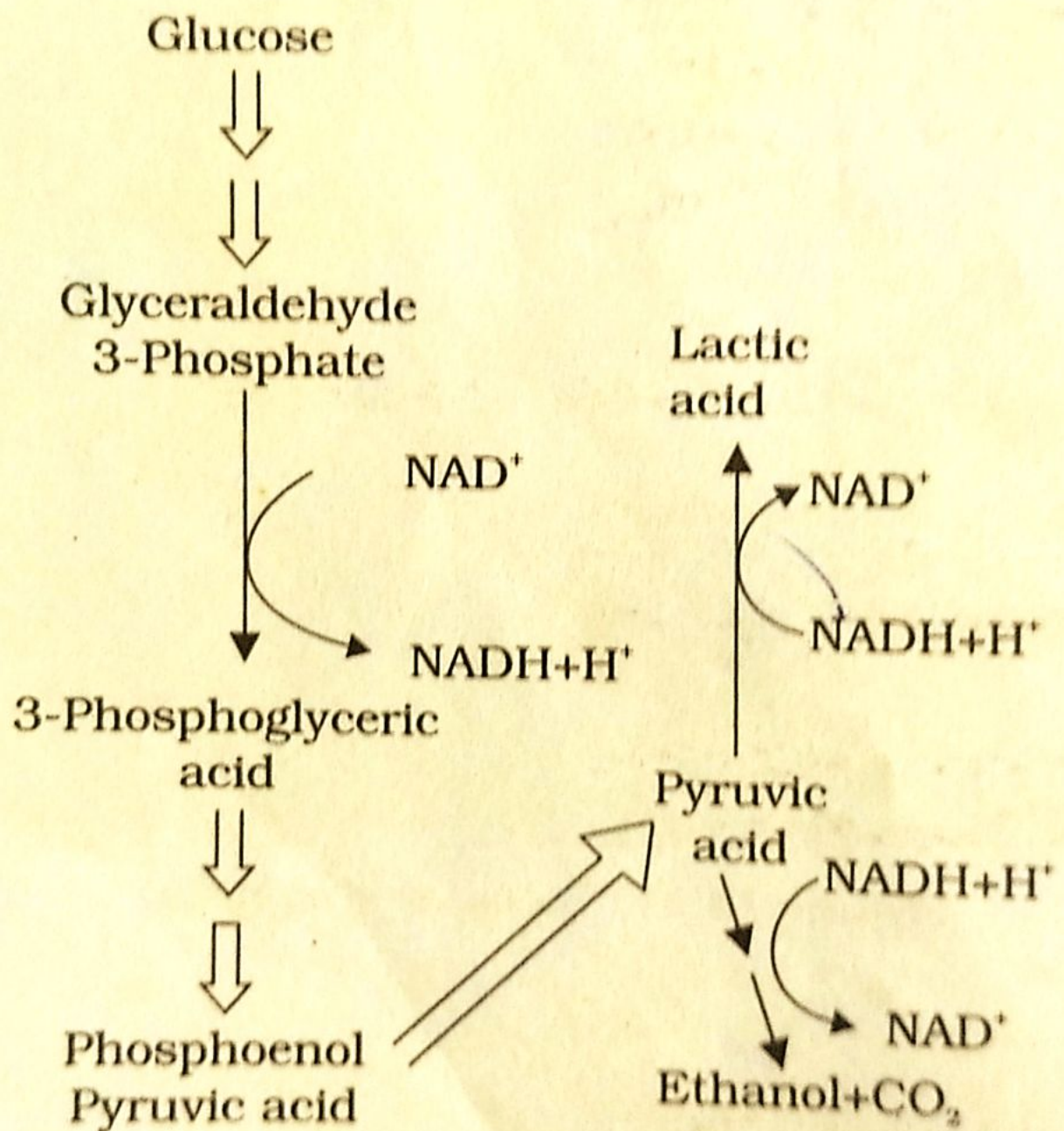
**Figure 14.1** Steps of glycolysis

1. Sucrose is converted into glucose and fructose by Enzyme Invertase.
2. Glucose and fructose are phosphorylated to give rise to glucose-6-phosphate by activity of Enzyme Hexokinase.
3. ATP is utilised at two steps:
  - (a) Conversion of glucose into glucose-6-phosphate.
  - (b) Conversion of fructose-6-phosphate to fructose 1,6-bisphosphate.
4.  $\text{NADH} + \text{H}^+$  is formed when 3-phospho-glyceraldehyde [PGAL] is converted to 1,3-bisphosphoglycerate [BPGA].
5. Conversion of BPGA is Energy yielding process: Energy is trapped by formation of ATP.
6. Another ATP is synthesised during the conversion of PEP to pyruvic Acid.
- Pyruvic acid is key product of glycolysis.

- ① For Complete Oxidation of glucose to  $\text{CO}_2$  and  $\text{H}_2\text{O}$  Organism adopt  $\text{Kreb's Cycle}$  also Called as Aerobic respiration.

## FERMENTATION

- ① In fermentation, Yeast, ~~an~~ Incomplete Oxidation of glucose is achieved Under anaerobic Condition.
- ① Pyruvic Acid is Converted into  $\text{CO}_2$  and Ethanol.
- ① Enzymes Pyruvic Acid decarboxylase and alcohol dehydrogenase Catalyse these reactions.
- ① Organism like Bacteria produce Lactic acid from pyruvic acid.
- ① In animal Cell, muscles during Exercise when Oxygen is inadequate for ~~cellular~~ Pyruvic acid is reduced to Lactic Acid by Lactate dehydrogenase.
- ① The reducing agent is  $\text{NADH} + \text{H}^+$  which is reoxidised to  $\text{NAD}^+$  in both process.



**Figure 14.2** Major pathways of anaerobic respiration

- ① Lactic acid and alcohol fermentation less than seven percent of Energy in glucose is released.
- ② The processes are hazardous - Either or alcohol is produced.
- ③ Yeast poison themselves to death when the concentration of alcohol reaches about 13 per cent.

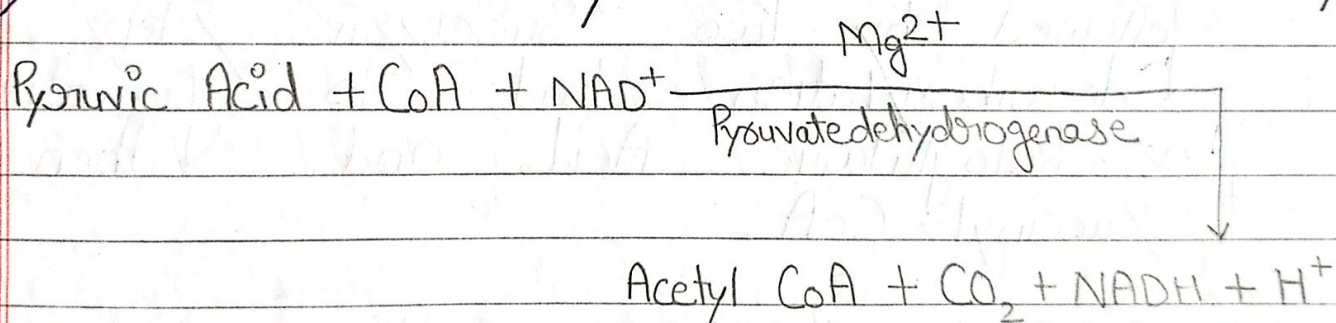
## AEROBIC RESPIRATION

- ① Take place within Mitochondria.
- ② Pyruvate is transported from Cytoplasm into Mitochondria.

\* Crucial event in Aerobic Respiration are:

- [a] Complete Oxidation of Pyruvate by stepwise removal of all Hydrogen atom leaving 3 molecule of  $\text{CO}_2$
- [b] Passing on of Electron removed as part of Hydrogen atom to molecular  $\text{O}_2$  with simultaneous synthesis of  $\text{CO}_2$

- ① First process take place in Matrix of Mitochondria.
- ② Second process is located on inner membrane of Mitochondria.
- ③ Pyruvate after enters mitochondrial matrix Undergoes Oxidative decarboxylation.
- ④ This reaction is Catalysed by **Pyruvic dehydrogenase**. It require participation of several Coenzymes,  $\text{NAD}^+$  and Coenzyme A



- ⑤ Two molecules of NADH are produced from two molecules of pyruvic Acid.
- ⑥ Acetyl CoA enters Tricarboxylic acid Cycle Commonly known as **Krebs's Cycle** after the Scientist Hans Krebs

## TRICARBOXYLIC ACID CYCLE

- ① Start with Condensation of acetyl group with Oxaloacetic Acid [OAA] and water to yield Citric Acid.

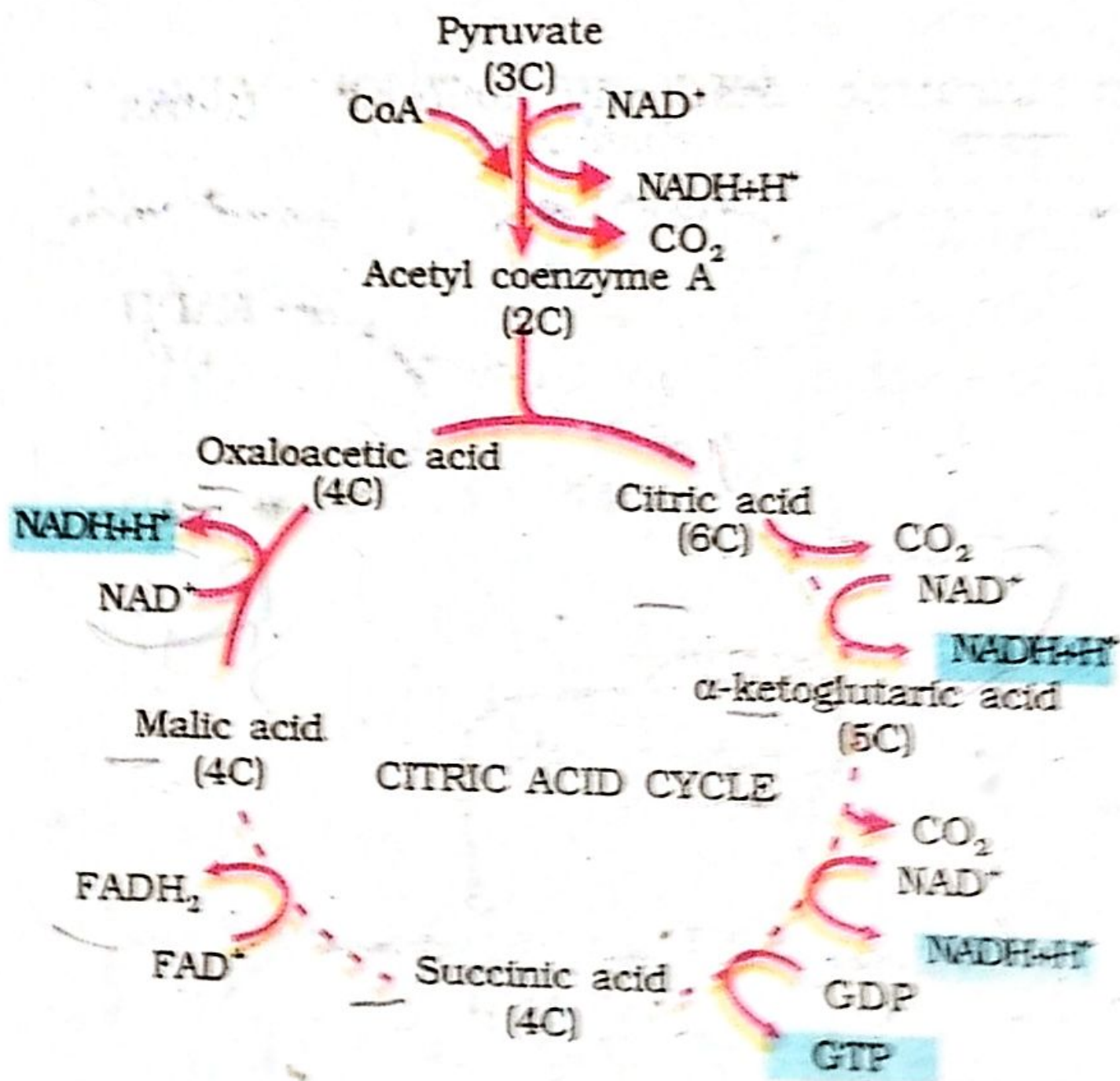
Reaction is Catalysed by Enzyme Citrate Synthase and a molecule of CoA is released.

- ② Citrate then isomerise to Isocitrate and followed by two successive steps of decarboxylation lead to formation of  $\alpha$ -ketoglutaric Acid. and then Succinyl-CoA.

- ③ Succinyl-CoA is Oxidised to OAA.

- ④ During the Conversion of Succinyl-CoA to Succinic Acid a molecule of GDP is Synthesise.

- ⑤ In a Coupled reaction GTP is Converted to GDP with simultaneous Synthesis of ATP from ADP.



**Figure 14.3** The Citric acid cycle

① There are three points in Cycle where  $\text{NAD}^+$  is reduced to  $\text{NADH} + \text{H}^+$  and one point where  $\text{FAD}^+$  is reduced to  $\text{FADH}$ .

② Pyruvic Acid +  $4\text{NAD}^+$  +  $\text{FAD}^+$  +  $2\text{H}_2\text{O}$  +  $\text{ADP}$  +  $\text{P}_i$   
↓ Mitochondrial matrix

$3\text{CO}_2 + 4\text{NADH} + 4\text{H}^+ + \text{FADH}_2 + \text{ATP}$ .

③ Glucose has been broken down to release  $\text{CO}_2$  and Eight molecules of  $\text{NADH} + \text{H}^+$ ; Two of  $\text{FADH}_2$  have been synthesised beside just two molecule of  $\text{ATP}$ .

## ELECTRON TRANSPORT SYSTEM [ETS] AND OXIDATIVE PHOSPHORYLATION

① Metabolic pathway through which the electron passes from one carrier to another is called Electron Transport System.

② Present in inner Mitochondrial membrane.

③ Electron from  $\text{NADH}$  produced in Mitochondrial Matrix during Citric Acid Cycle are oxidised by an  $\text{NADH}$  dehydrogenase [Complex I]

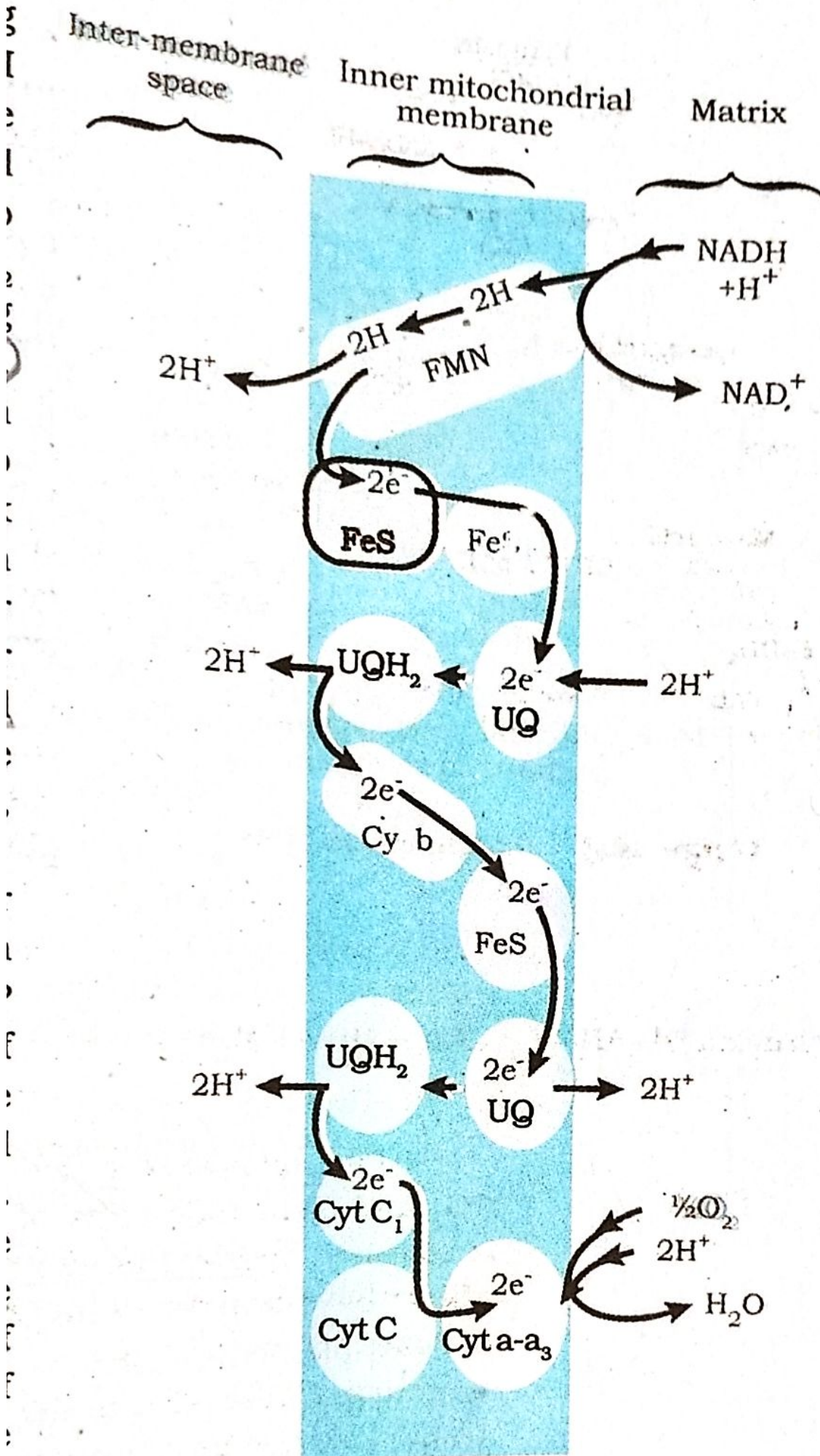
① Ubiquinone [Ubiquinol] is also receives reducing equivalent via  $\text{FADH}_2$  [Complex II] that is generate during Oxidation of Succinate in Citric Acid Cycle.

② Ubiquinone is then Oxidise with the transfer of electrons to Cytochrome c via Cytochrome  $\text{bc}_1$  Complex [Complex III].

③ Cytochrome c is small protein attached to Outer surface of inner membrane and act as mobile Carrier for transfer of electron b/w Complex III and IV.

④ Complex IV refers to Cytochrome c Oxidase Complex Containing Cytochromes a and  $\text{a}_3$  and two Copper centres.

⑤ When electrons pass from one Carrier to another via Complex I to IV in Electron transport chain, they are Coupled to ATP Synthase [Complex V] for production of ATP from ADP and inorganic phosphate.



**Figure 14.4** Electron Transport System (ETS)

① Oxidation of One molecule of NADH give rise to 3 molecules of ATP.

One molecule of  $\text{FADH}_2$  produce 2 molecules of ATP.

② Necessary of Oxygen.

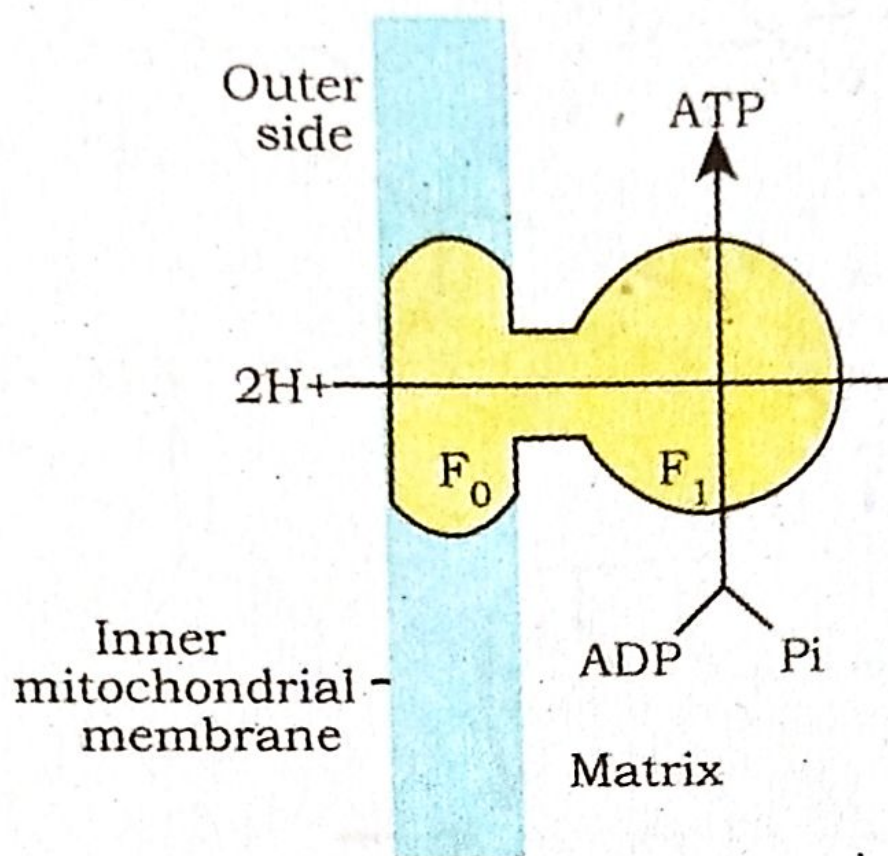
[a] Oxygen drives whole process by removing hydrogen from system.

[b] Also act as final hydrogen acceptor.

③ In respiration energy of Oxidation - reduction utilized for phosphorylation process. It is for reason that the process is called Oxidative phosphorylation.

④ Energy released during electron transport system is utilised in Synthesising ATP with the help of ATP Synthase.

⑤ The  $F_1$  headpiece is a peripheral membrane protein complex and contain the site for Synthesis of ATP from ADP and inorganic phosphate.



**Figure 14.5** Diagrammatic presentation of ATP synthesis in mitochondria

①  $F_0$  is an integral membrane protein complex that forms the channel through which protons cross the inner membrane.

② For each ATP produced,  $2H^+$  passes through  $F_0$  from intermembrane space to matrix.

## THE RESPIRATORY BALANCE SHEET

① Calculation of Net gain of ATP is made only on certain assumption.

- There is sequential, orderly pathway functioning with one substrate forming the next and with glycolysis, TCA Cycle and ETS pathway following one after other.
- The NADH synthesized in glycolysis is transferred into Mitochondria and undergoes oxidative phosphorylation.
- None of intermediates in pathway are utilized to synthesize any other compound.
- Only glucose is being respired - no other alternative substrate are entering in pathway.

○ Hence, There can be net gain of 36 ATP molecules during aerobic respiration of one molecule of glucose.

\* Comparison b/w Fermentation and AEROBIC Respiration.

| FERMENTATION                                                                                                                                                                                  | AEROBIC RESPIRATION                                                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• Partial breakdown of glucose.</li><li>• Net gain of 2 molecule of ATP</li><li>• NADH is Oxidised to <math>\text{NAD}^+</math> rather slowly</li></ul> | <ul style="list-style-type: none"><li>• Complete breakdown of glucose in <math>\text{CO}_2</math> and <math>\text{H}_2\text{O}</math></li><li>• Net gain of 36 molecule of ATP.</li><li>• NADH is Oxidised to <math>\text{NAD}^+</math> Very Vigorous.</li></ul> |

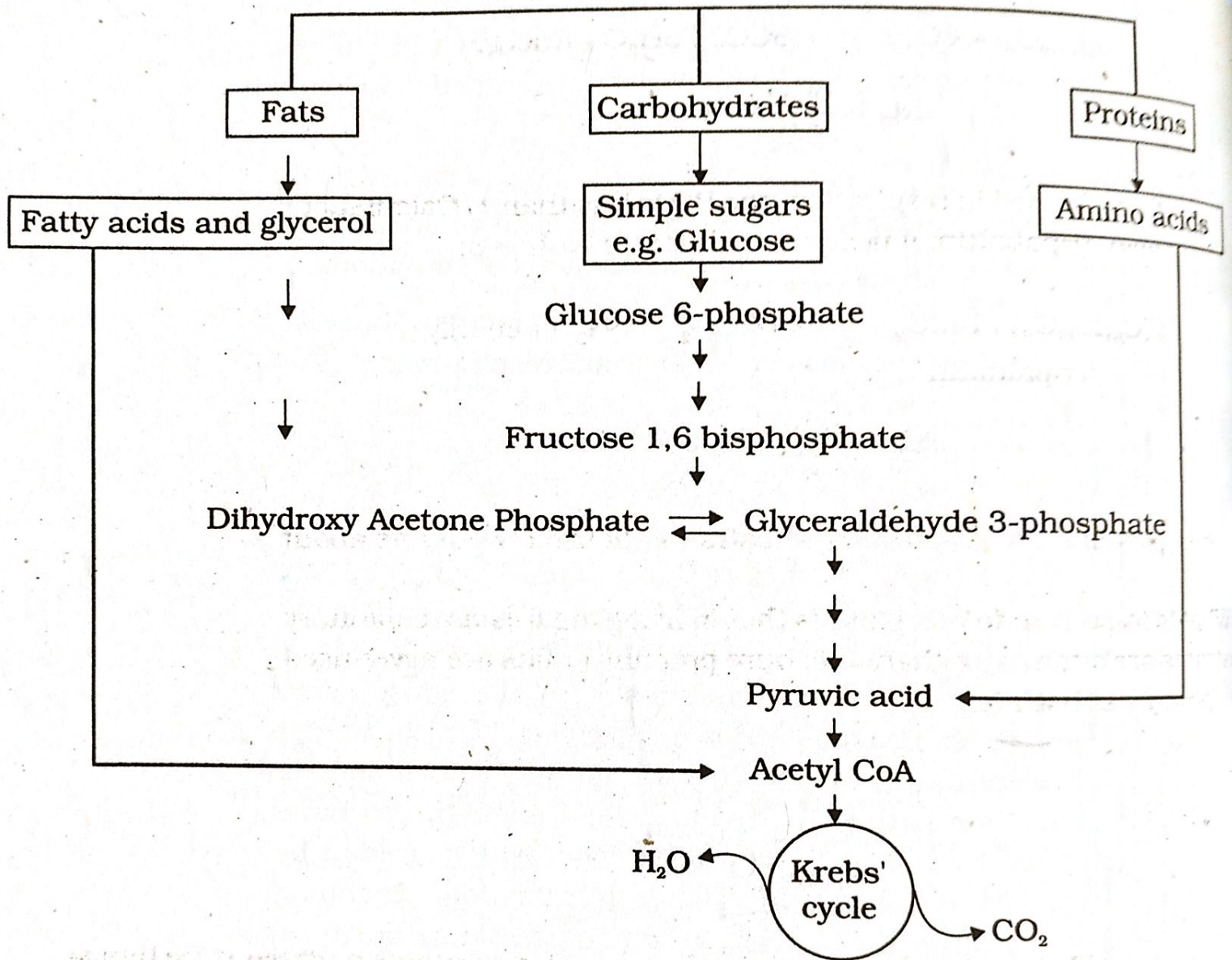
## AMPHIBOLIC PATHWAY

○ All ~~Go~~ Carbohydrates first converted into glucose before they are used for respiration.

- ① Fats broken down into glycerol and fatty acid first.
- ② Fatty acid degraded to Acetyl CoA and Enters pathway.
- ③ Glycerol Enters the pathway after being Converted into PGAL.
- ④ Protein degraded by Proteases and individual amino acid enter the pathway at some stage within Krebs Cycle or even as pyruvate or Acetyl CoA.
- ⑤ Fatty acid broken down to acetyl CoA before entering Respiratory pathway when used as substrate.

But when Organism needs to Synthesis Fatty acid, acetyl CoA withdrawn from Respiratory pathway for it.

- ⑥ Respiratory Pathway involved in both Anabolism and Catabolism. Hence Respiratory pathway Considered to be Amphibolic pathway.



**Figure 14.6** Interrelationship among metabolic pathways showing respiration mediated breakdown of different organic molecules to  $CO_2$  and  $H_2O$

## RESPIRATORY QUOTIENT

○ The ratio of Volume of  $\text{CO}_2$  Evolved to the Volume of  $\text{O}_2$  Consumed in Respiration is called Respiratory Quotient.

$$RQ = \frac{\text{Volume of } \text{CO}_2 \text{ Evolved}}{\text{Volume of } \text{O}_2 \text{ Consumed}}$$

[i] for Carbohydrates :  $RQ = 1$

[ii] For fats :  $RQ < 1$  [less than 1]

[iii] For proteins :  $RQ = 0.9$

○ Pure protein or fats are never used as respiratory substrates.