RESPIRATION IN PLANTS

Cellular respiration : The mechanism of breakdown of food materi 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.

- Energy released by respiration is not used directly but is used in Synthesise ATP.
- ATP is broken down whenever energy needs to be utilised.
- Hence ATP is Energy Currency of Cell.

⊙ REASONS WHY PLANTS GET ALONG WITHOUT RESPIRATORY ORGANS.

1. Each part take care of it's own gas exchange needs
2. Plants do not present great demands for gas exchange. Only during photosyn-thesis large Volume of gaseous exchange.
3. The Distance that gaseous must diffuse even in large, bulky plant is not great.

⊙ Complete Combustion of glucose to produce CO_2 and water is given as

$$C_6H_{12}O_6 + 6O_2 \longrightarrow \text{~~6O~~}\ 6CO_2 + 6H_2O + \text{Energy}$$

GLYCOLYSIS → Glycos = Sugar
→ Lysis = Splitting

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

⊙

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

* STEPS OF GLYCOLYSIS

Glucose [6C]

↓ (ATP → ADP)

Glucose-6-phosphate [6C]

↓

Fructose-6-phosphate [6C]

↓ (ATP → ADP)

Fructose-1,6-Bisphosphate [6C]

↓

Triose phosphate [glyceraldehyde-3-phosphate] [3C] ⇌ Triose phosphate [Dihydroxy Acetone phosphate] [3C]

↓ (NAD^+ → $NADH+H^+$)

2 x Triose phosphate [1,3 bisphosphoglyceric Acid] [3C]

↓ (ADP → ATP)

2x Triose phosphate [3 phosphoglyceric Acid]

↓

2 x 2-phosphoglycerate

↓ (H_2O)

2 x phosphophenolpyruvate

↓ (ADP → ATP)

2x Pyruvic Acid [3C]

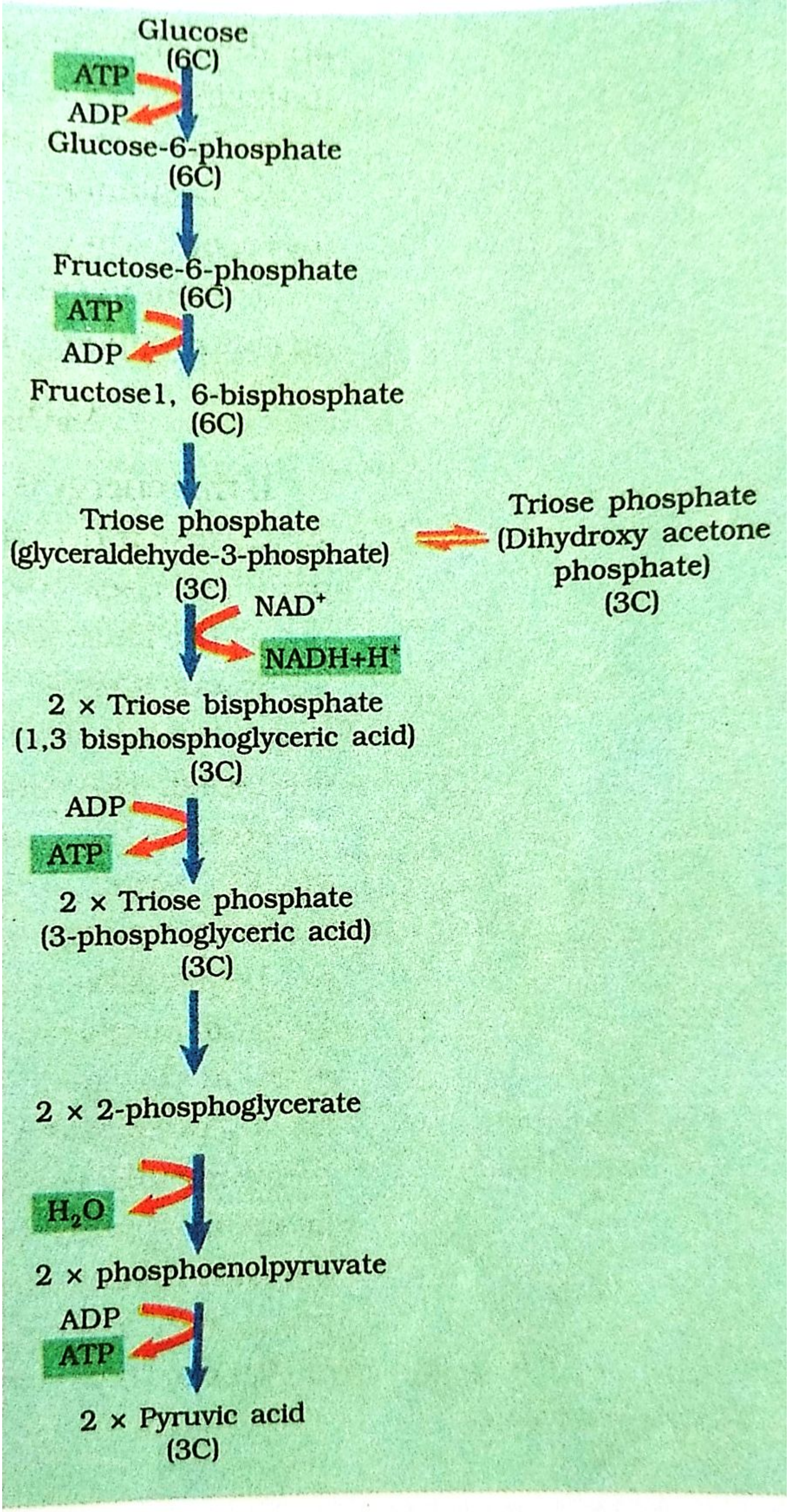

Figure 14.1 Steps of glycolysis

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] Converstion of fructose - 6 - phosphate to fructose 1, 6 - bisphosphate

4. $NADH + H^+$ 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.

- For Complete Oxidation of glucose to CO_2 and H_2O Organism adopt Kreb's Cycle also Called as Aerobic respiration.

FERMENTATION

- In fermentation, Yeast, ~~or~~ incomplete Oxidation of glucose is acheived Under anaerobic Codition.

- Pyruvic Acid is Converted into CO_2 and ethanol.

- Enzymes Pyruvic Acid decarboxylase and alcohol dehydrogenase Catalyse these reactions.

- Organism like Bacteria produce Lactic acid from pyruvic acid.

- In animal Cell, muscles during exercise when Oxygen is inadequate for ~~Cellular~~ Pyruvic acid is reduced to Lactic Acid by Lactate dehydrogenase.

- The reducing agent is $NADH + H^+$ whic is reoxidised to NAD^+ in both process.

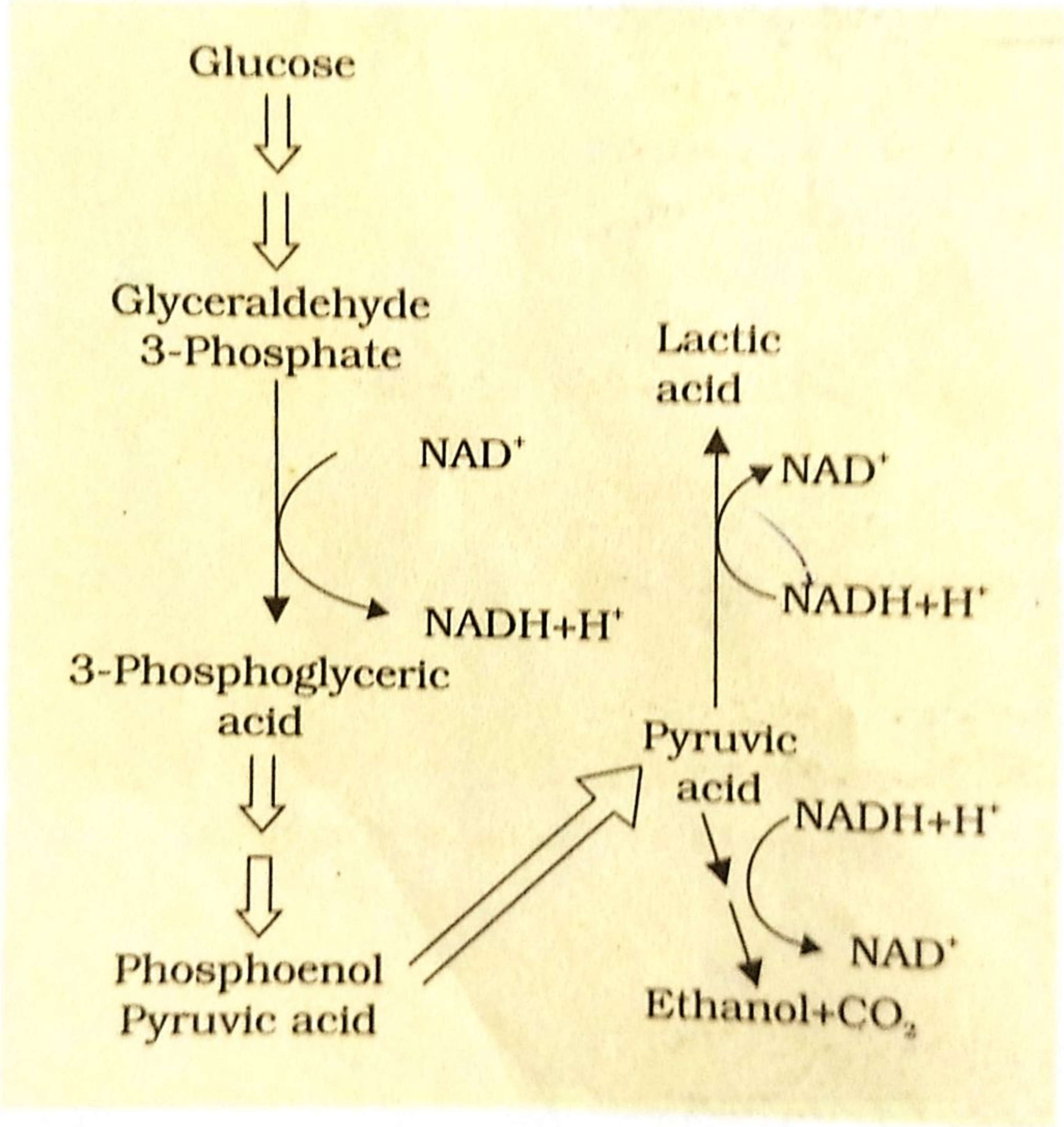

Figure 14.2 Major pathways of anaerobic respiration

- Lactic acid and alcohol fermentation less than seven percent of Energy in glucose is released.

- The process are hazardous - either or alcohol is produced.

- Yeast poison themselves to death when the concentration of alcohol reaches about 13 per cent.

AEROBIC RESPIRATION

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

* Crucial event in Aerobic Respiration are:-

[a] Complete Oxidation of Pyruvate by stepwise removel of all Hydrogen atom leaving 3 molecule of CO_2

[b] Passing on of electron removed as part of Hydrogen atom to molecular O_2 with simultaneous synthesis of CO_2

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- First process take place in Matrix of Mitochondria.

- Second process is located on inner membrane of Mitochondria.

- Pyruvate afters enters mitochondrial matrix Undergoes Oxidative decarboxylation.

- This reaction is Catalysed by Pyruvic dehydrogenase. It require participation of several Coenzymes, NAD^+ and Coenzyme A

$$\text{Pyruvic Acid} + \text{CoA} + NAD^+ \xrightarrow[\text{Pyruvate dehydrogenase}]{Mg^{2+}} \text{Acetyl CoA} + CO_2 + NADH + H^+$$

- Two molecules of NADH are produced from two molecules of pyruvic Acid.

- Acetyl CoA enters Tricarboxylic acid Cycle Commonly known as Kreb's Cycle after the scientist Hans Krebs

TRICARBOXYLIC ACID CYCLE

- 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.

- Citrate than isomerise to Isocitrate and followed by two Successive steps of decarboxylation lead to formation of α- ketoglutaric Acid. and then Succinyl- CoA.

- Succinyl - CoA is Oxidised to OAA.

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

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

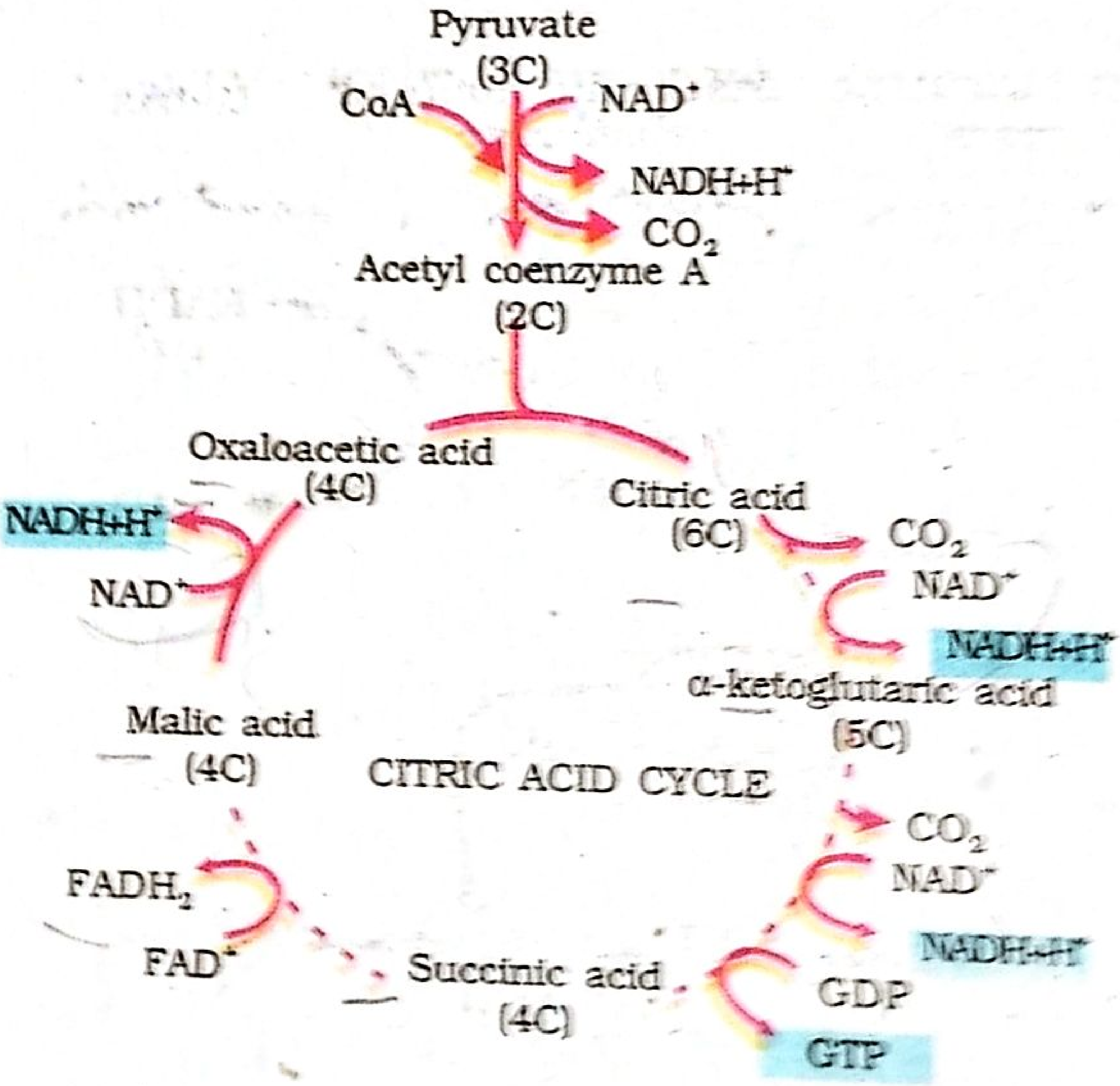

Figure 14.3 The Citric acid cycle

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- There are three point's in Cycle where NAD^+ is reduced to $NADH + H^+$ and One point where FAD^+ is reduced to FADH.

- Pyruvic Acid + $4NAD^+$ + FAD^+ + $2H_2O$ + ADP + Pi
 ↓ Mitochondrial matrix
$3CO_2$ + 4NADH + $4H^+$ + $FADH_2$ + ATP.

- Glucose has been broken down to release CO_2 and Eight molecules of $NADH + H^+$; Two of $FADH_2$ have been Synthesised beside just two molecule of ATP.

ELECTRON TRANSPORT SYSTEM [ETS] AND OXIDATIVE PHOSPHORYLATION.

- Metabolic pathway through which the electron Passes from One Carrier to Another is Called Electron Transport System.

- Present in inner Mitochondrial membrane.

- Electron from NADH produced in Mitochondrial Matrix during Citric Acid Cycle are Oxidised by an NADH dehydrogenase [Complex 1]

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- Ubiquinone [ubiquinol] is also receives reducing equivalent via $FADH_2$ [Complex II] that is genrate during oxidation of succinate in Citric Acid Cycle.

- Ubiquinone is then oxidise with the transfer of electrons to Cytochrome C via Cytochrome bC_1 Complex [Complex III].

- 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.

- Complex IV refers to Cytochrome C Oxidase Complex containing Cytochromes a and a_3 and two Copper Centres.

- 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.

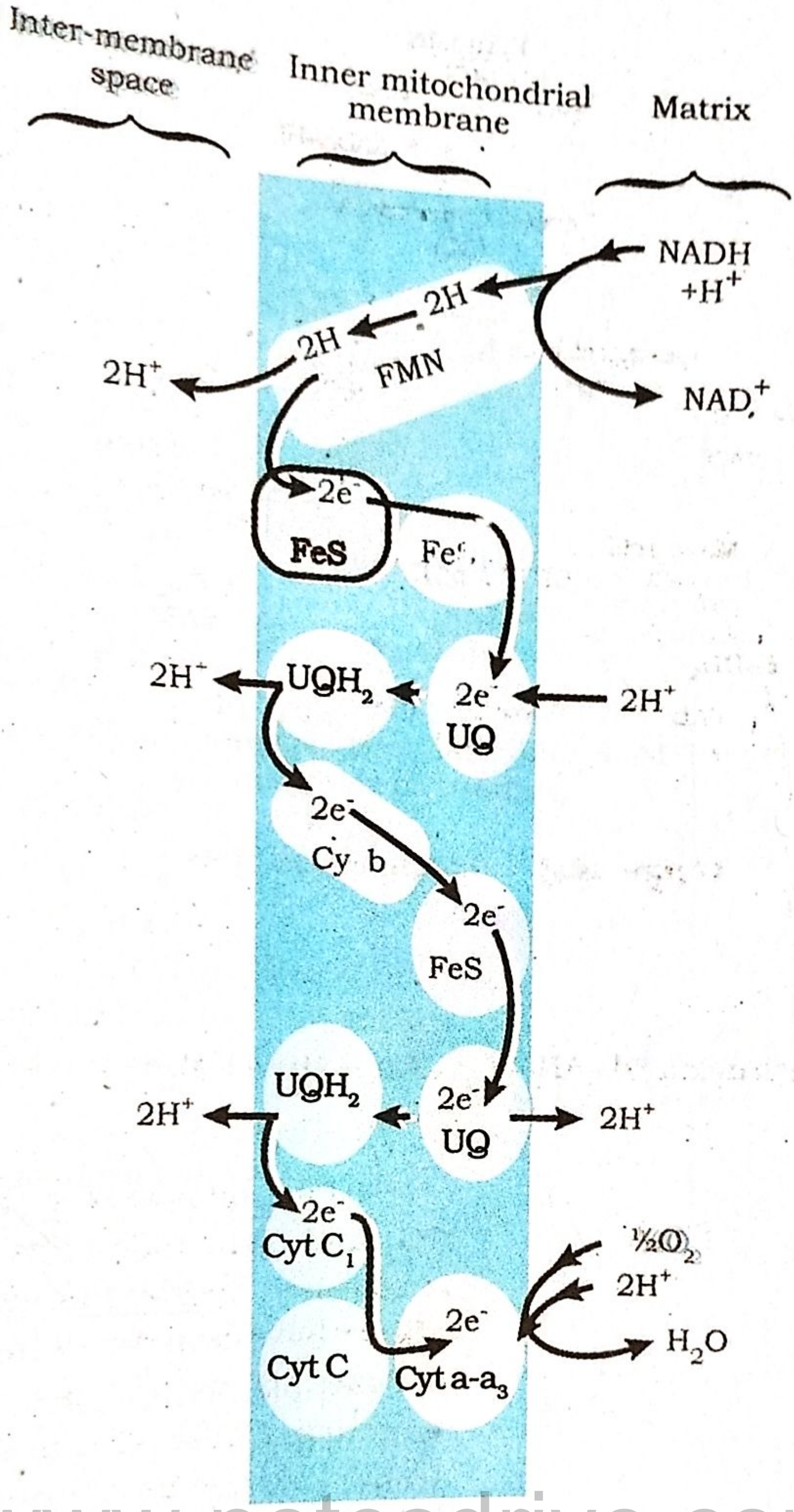

Figure 14.4 Electron Transport System (ETS)

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

One molecule of $FADH_2$ produce 2 molecules of ATP.

⊙ Necessary of Oxygen.

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

[b] Also act as final hydrogen acceptor.

⊙ In respiration energy of Oxidation - reduction Utilised for phosphorylation process. It is for reason that the process is Called Oxidative phosphorylation.

⊙ Energy released during electron transport System is Utilised in Synthising ATP with the help of ATP Synthase.

⊙ The F_1 headpiece is a peripheral membrane protein Complex and Contain the site for Synthesis of ATP from ADP and inorganic phosphate.

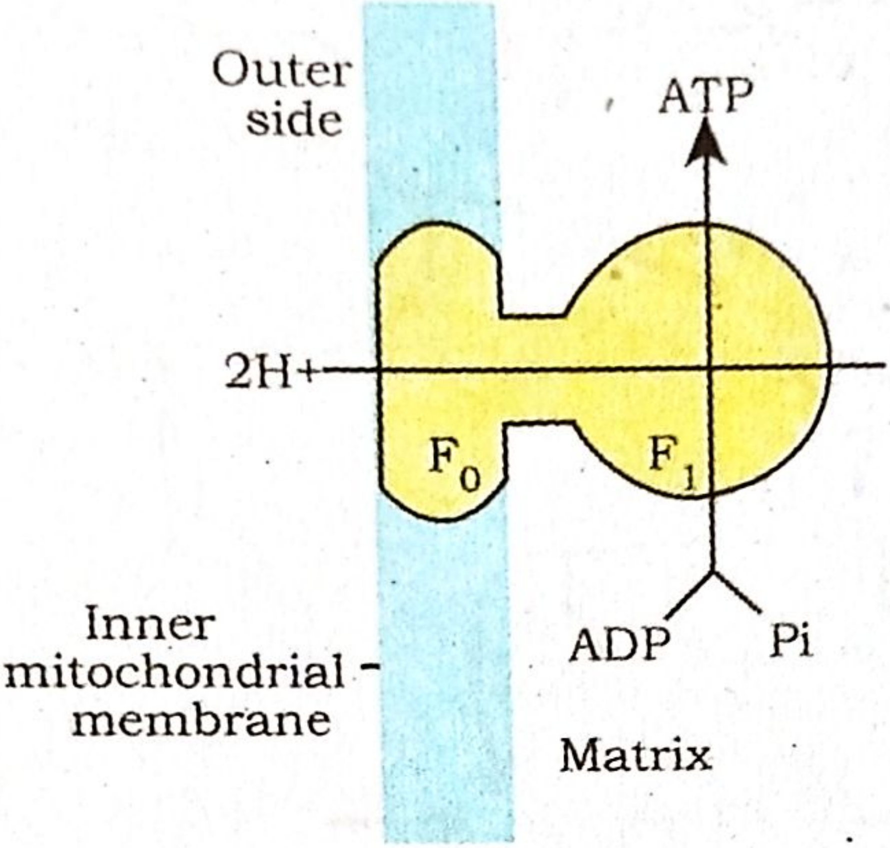

Figure 14.5 Diagramatic presentation of ATP synthesis in mitochondria

- F_0 is an integral membrane protein Complex that forms the channel through which proton cross the inner membrane.

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

THE RESPIRATORY BALANCE SHEET

- 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 Synthesised in glycolysis is transferred into Mitochondria and Undergoes Oxidative phosphorylation.

- Non of intermediates in pathway are Utilised to Synthesis any Other Compound.

- Only glucose is being respired - no Other alternative substrate are entering in pathway.

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⊙ 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
• Partial breakdown of glucose.	Complete breakdown of glucose in CO_2 and H_2O
• Net gain of 2 molecule of ATP	Net gain of 36 molecule of ATP.
• NADH is Oxidised to NAD^+ rather slowly	NADH is Oxidised to NAD^+ Very Vigorous.

AMPHIBOLIC PATHWAY

⊙ All ~~Eat~~ Cabohydrates first Converted into glucose before they are used for respiration.

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- Fats broken down into glycerol and fatty acid first.

- Fatty acid degraded to Acetyl CoA and Enters pathway.

- Glycerol enters the pathway after being Converted into PGAL.

- Protein degraded by Proteases and individual amino acid enter the pathway at some stage within Kreb's Cycle or even as pyruvate or Acetyl CoA.

- 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.

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

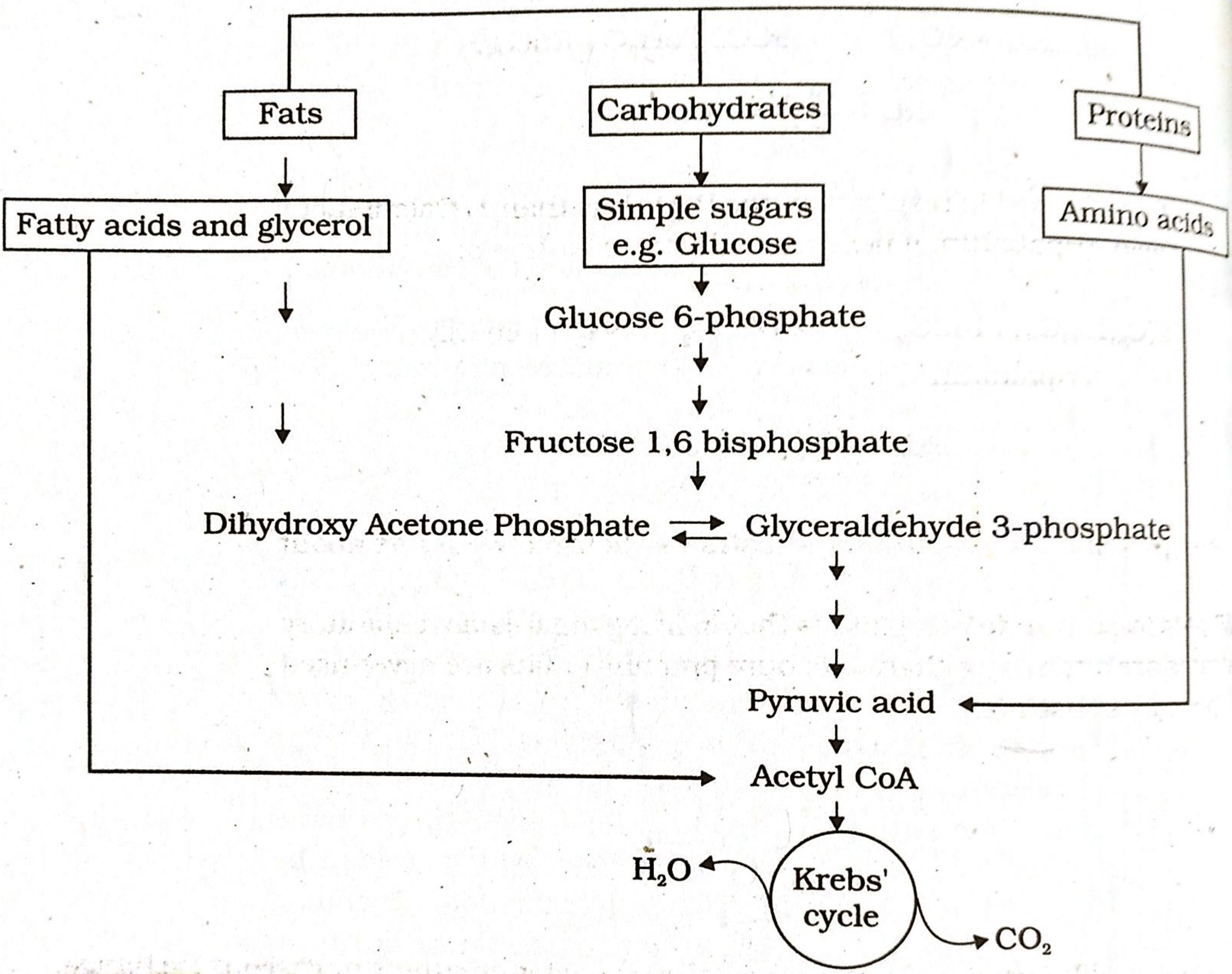

Figure 14.6 Interrelationship among metabolic pathways showing respiration mediated breakdown of different organic molecules to CO_2 and H_2O

RESPIRATORY QUOTIENT

- The ratio of Volume of CO_2 evolved to the Volume of O_2 Consumed in respiration is called Respiratory Quotient.

$$RQ = \frac{\text{Volume of } CO_2 \text{ Evolved}}{\text{Volume of } O_2 \text{ Consumed}}$$

[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.