* Respiration in Plants *

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The breaking of C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is calld **Respiration**

Energy is stored in the form of ATP.

The compounds that are oxidised during this process are known as Respiratory Substrates.

* Breathing in Plants.

Stomata- Exchange of gass takes place through stomata in leaves

Lenticels- Small pores present on bark of the stem which helps in gaseous exchange.

-> Each part takes care of its own gas exchange needs

-> The cells in the interior are dead and provide mechanical support

* Glycolysis also called (EMP Pathway) - Embden, Meyerhof Parnas -> discovered Pathway of Glycolysis

Glucose
↓ Partial Breakdown.
Pyruvic Acid.

- takes place in cytoplasm
- Occurs in all living org.
- 1st step of Respiration

In plants - Sucrose
↓ (Invertase)
Glucose + Fructose
↓
Glycolytic Pathway

* Formation of ATP called Phosphorylation
* Formn of ATP in presence of sunlight called photophosphorylation & occurs in Chloroplast

* Substrate level phosphorylation

$X-\text{P} + ADP \longrightarrow ATP$

cytoplasm (Glycolysis) & Matrix of mitochondria (Krebs cycle)

* Oxidative Phosphorylation → ATP formⁿ because of Oxdⁿ & Redⁿ
Oxdⁿ of ($NADH$ & $FADH_2$) occurs in mitochondrial inner memb.

Glycolysis → Respiratory phase → Requires ATP; 2 ATP Used.
Glycolysis → Pay off Phase → Formⁿ of ATP ; 4 ATP formed

Glucose (6c)

↓ Irreversible — ATP → ADP [Hexokinase] (Mg^{2+})

Glucose-6-Phosphate (6c)

↓

Fructose-6-Phosphate (6c)

↓ Irreversible — ATP → ADP [Phospho Fructo kinase] (Mg^{2+})

Fructose 1, 6- Bisphosphate (6c)

↙ ↘

Dihydroxy acetone Phosphate (DHAP) (3c) ⇌ 2x 3-Phosphoglyceraldehyde (PGAL) (3c)

↓ NAD^+ → $NADH + H^+$ x2

2 x 1,3 Bisphosphaglycerate (3c)

↓ ADP → ATP x 2 [Kinase]

2x 3- Phosphoglycerate (3c)

↓

2 x 2 - Phosphoglycerate (3c)

↓

2 x Phosphoenol Pyruvate (3c)

↓ Irreversible — ADP → ATP x2 [Pyruvate kinase]

2 x Pyruvate (3c)

In Glycolysis
ATP Used - 2 ATP
ATP formed - 4 ATP
Net ATP = 4-2=2
2 NADH

Glycolysis is Partial Oxidation

2 pyruvate $\xrightarrow{\text{Aerobic Resp}^n}$

2 pyruvate $\rightarrow$ Anaerobic Resp^n

Anaerobic Resp^n

Obligate Anaerobes	Facultative Anaerobes
→ Cannot grow in presence of O_2	→ can survive without Oxygen but grow better in presence of O_2
→ eg- Clostridium botulinum.	→ eg- Pseudomonas, klebsiella

* Fermentation (in cytoplasm)

Alcoholic — Lactic Acid

eg- Yeast

pyruvic acid $\xrightarrow[\boxed{\text{Pyruvic acid Decarboxylase}}]{}$ 2NADH + Acetaldehyde (2C) + CO_2

Acetaldehyde $\xrightarrow{\boxed{\text{Alcohol dehydrogenase}}}$ Ethanol

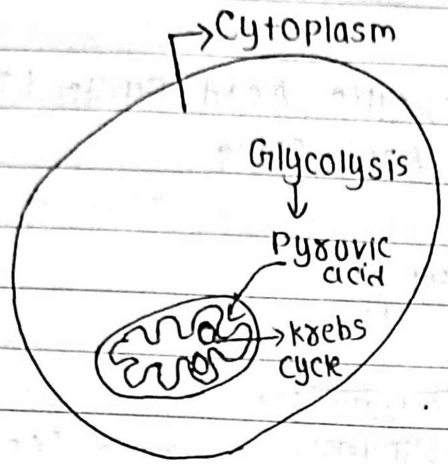
$NADH \xrightarrow[\text{Oxd}^n]{} NAD^+$

pyruvic acid + $2NADH + H^+$ $\xrightarrow{\boxed{\text{Lactate Dehydrogenase}}}$ Lactic Acid + $2NAD^+$

eg- Some bacteria

Animals muscles (exe

Yeast poison themself
to death when alcohol
conc^n is more than 13%.



* Aerobic Respiration.
  - → occurs in Mitochondria.
  - → in presence of O_2
  - → Energy + CO_2 + H_2O
  - → Complete Oxidation of Glucose

2x Pyruvic acid (3C)

$NAD^+ \rightarrow 2 \times NADH + H^+$

Mg²⁺ — Pyruvic dehydrogenase complex

↓

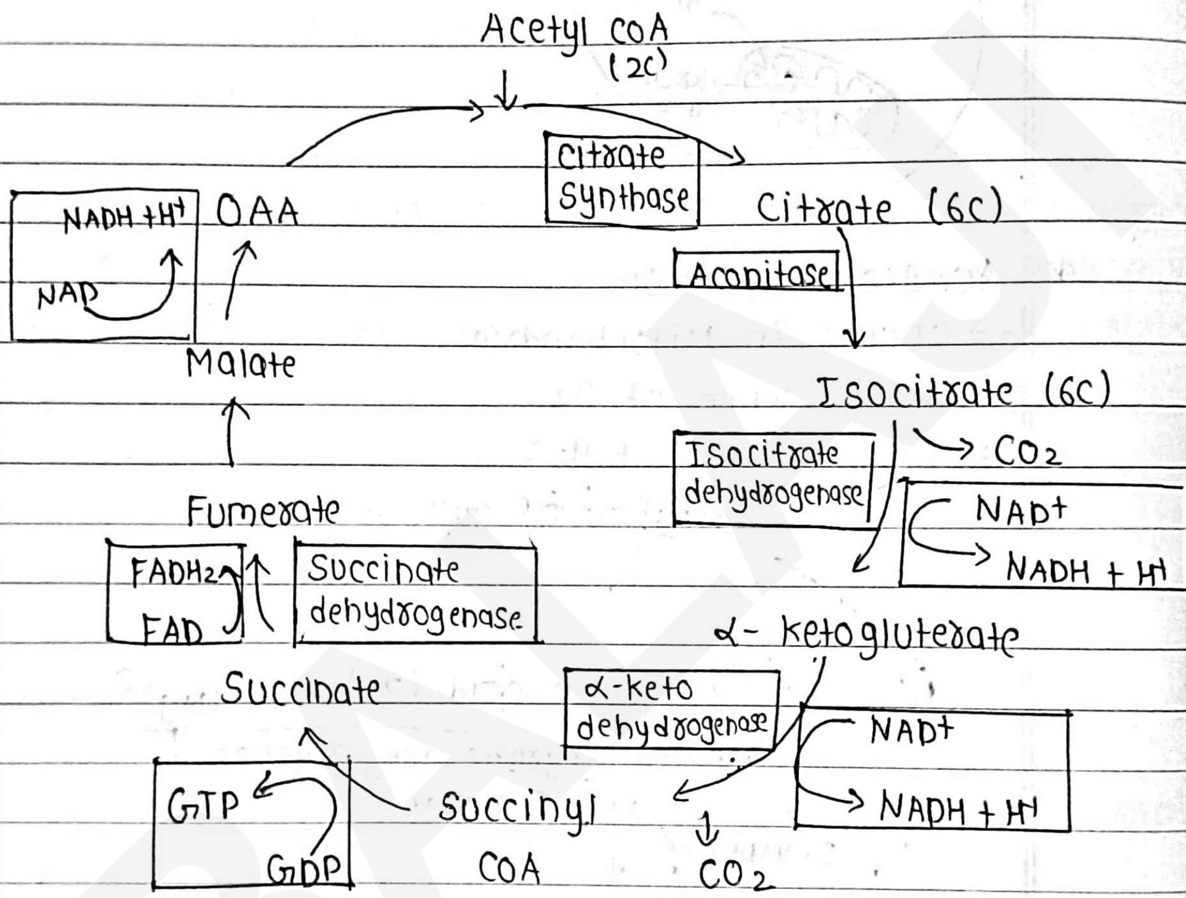
2x Acetyl COA + $CO_2^{\times 2}$ ↑
(2C)

Link Reaction
or
Oxidative decarboxylation

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

Krebs Cycle (Hans kreb)

- Also known as Tricarboxylic Acid cycle (TCA)
  - Citric Acid cycle



CO_2 Releases → 2
NADH form → 3
$FADH_2$ form → 1
GTP form → 1

} One cycle × 2

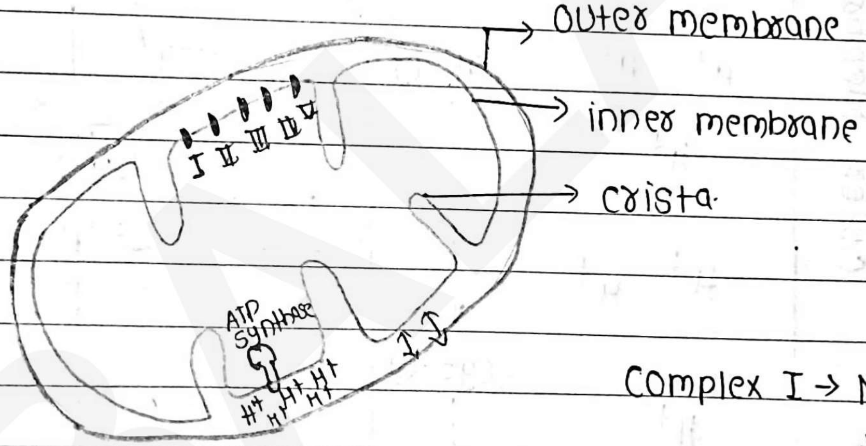
* Krebs Cycle

NADH → 3 × 2 = 6
$FADH_2$ → 1 × 2 = 2
GTP (ATP) → 1 × 2 = 2

Succinate dehydrogenase
↳ Present in inner mito membrane

Trick
Citrate - Citrate (6c)
Is - Isocitrate (6c)
krebs - ketogluterate (5c)
Starting - Succinyl CoA (4c)
Substrate - Succinate (4c)
For - Fumerate (4c)
making - malate (4c)
OAA - Oxaloacetate (4c)

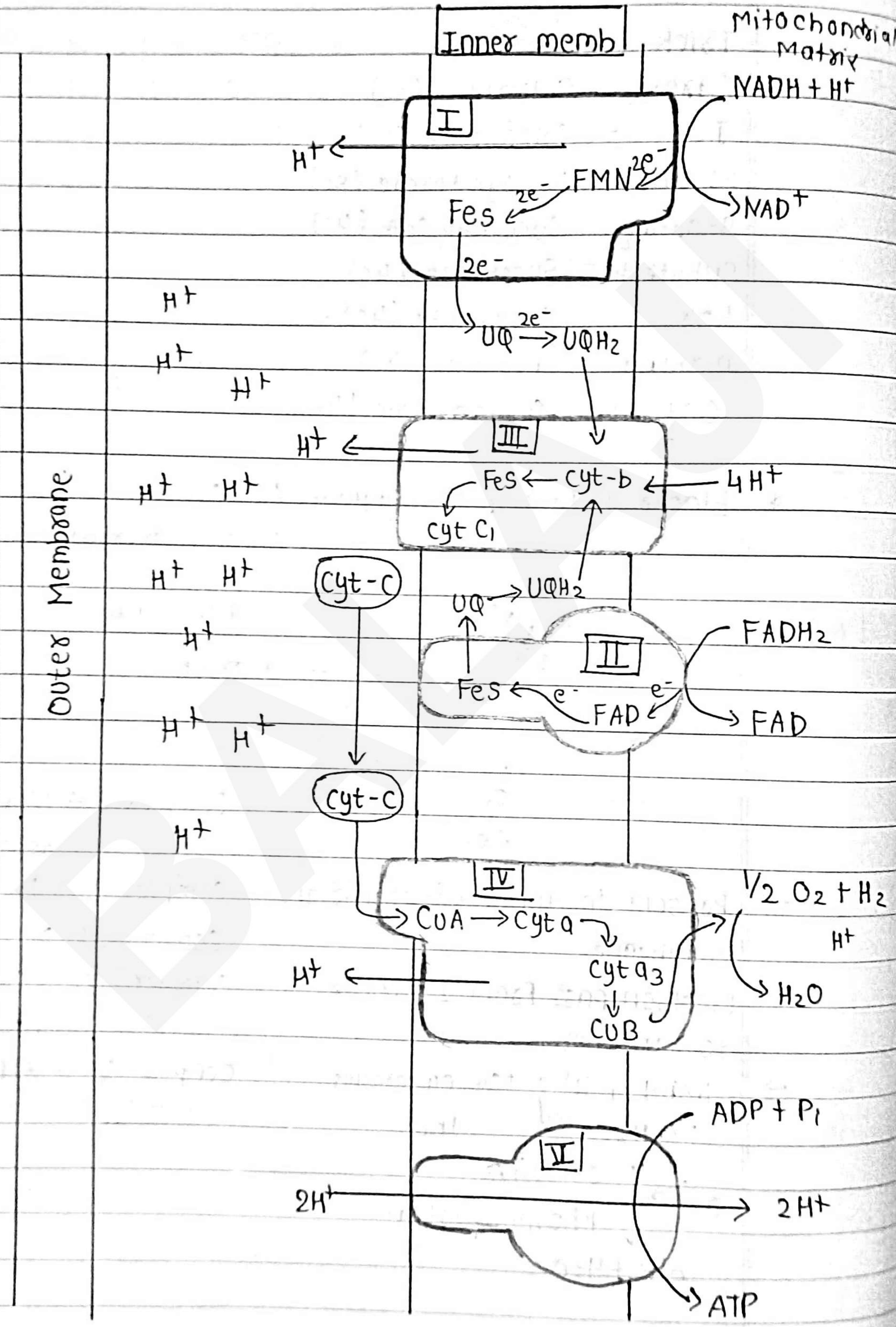
* Electron Transport System (ETS)



Complex I → NADH dehydrogenase
Complex II → $FADH_2$
Complex III → Cyt bc I
Complex IV → Cyt c oxidase
Complex V - ATP synthase

→ Present in inner mitochondrial membrane.
→ Electron pass from 1 carrier to another
→ $NADH + H^+$, $FADH_2$ } TCA cycle forms them

O_2 → ↓ oxidative Phosphorylation
$ATP + H_2O$



Inner memb
Mitochondrial Matrix
NADH + H+
I
H+
FMN
2e-
Fes
NAD+
H+
UQ
UQH2
III
Fes
cyt-b
4H+
cyt C1
Cyt-C
Outer Membrane
UQ
UQH2
II
FADH2
Fes
e-
FAD
FAD
IV
CuA
Cyt a
Cyt a3
CuB
1/2 O2 + H2
H2O
V
ADP + Pi
2H+
2H+
ATP

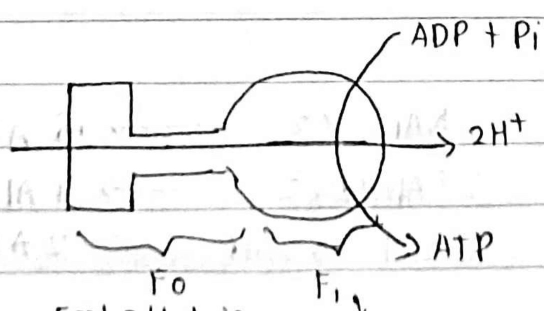
Complex I → NADH dehydrogenase
→ Oxidises NADH
→ Electron Acceptor
- FMN (Flavin mononucleotide)
- FeS

Complex II – Succinate dehydrogenase
→ Oxidises $FADH_2$
* It doesn't pump H^+ from matrix to inner mitochondrial memb. space
→ Electron acceptor
- FAD • FeS

Complex III – cyt bc I
→ Electron acceptor
- cyt b • FeS • Cyt C_1

Complex IV – cyt. C. oxidase
Electron acceptor
- CuA • cyt a • cyt a_3 • CuB

Complex V – ATP Synthase
→ 2 H^+ are required for synthesis of 1 ATP



Embedded in mitochondrial memb

Present towards the matrix

NADH → 3ATP
$FADH_2$ → 2 ATP

Electron transporters outside the complexes

1) UQ - Ubiquinone
→ Located within the inner memb.

$$UQ \xrightarrow[H^+]{e^-} UQH_2 \text{ (Ubiquinol)}$$

2) Cyt C - Mobile e^- carrier between complex III & IV
- Present at the outer surface of inner memb.

3) Oxygen - Acts as Final e^- and Hydrogen acceptor.
→ Not e^- carrier because it only accepts, not gives its e^- to another atom

* The Respiratory balance Sheet

Glycolysis	2 ATP directly	2 ATP
	2 molecules of NADH	6 ATP
Oxidative decarboxylation	2 NADH × 3	→ 6 ATP
TCA Cycle	6 NADH × 3	→ 18 ATP
	2 $FADH_2$ × 2	→ 4 ATP
	2 GTP → 2 ATP	→ 2 ATP

Total 38 ATP

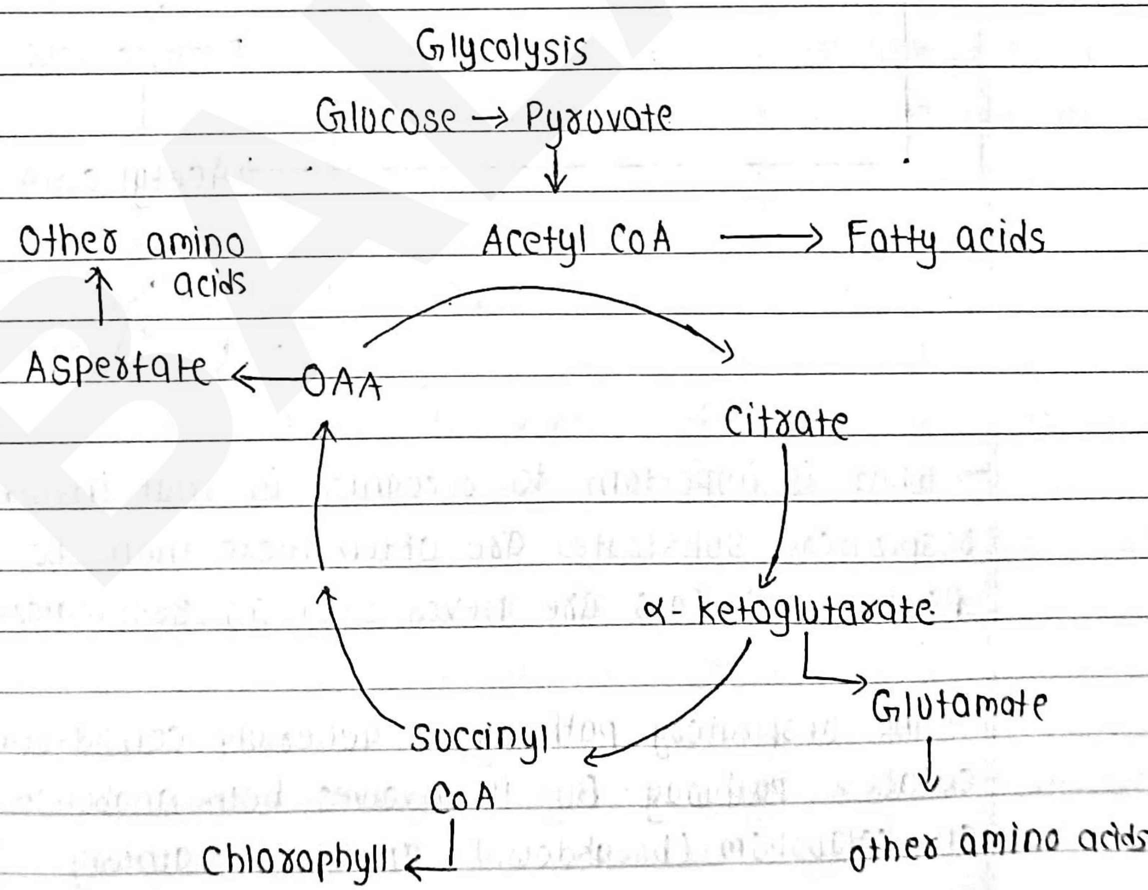
→ 2 ATP molecules are spent for transporting 2 NADH molecules formed during glycolysis to the mitochondria. Hence the net gain = 36 ATP

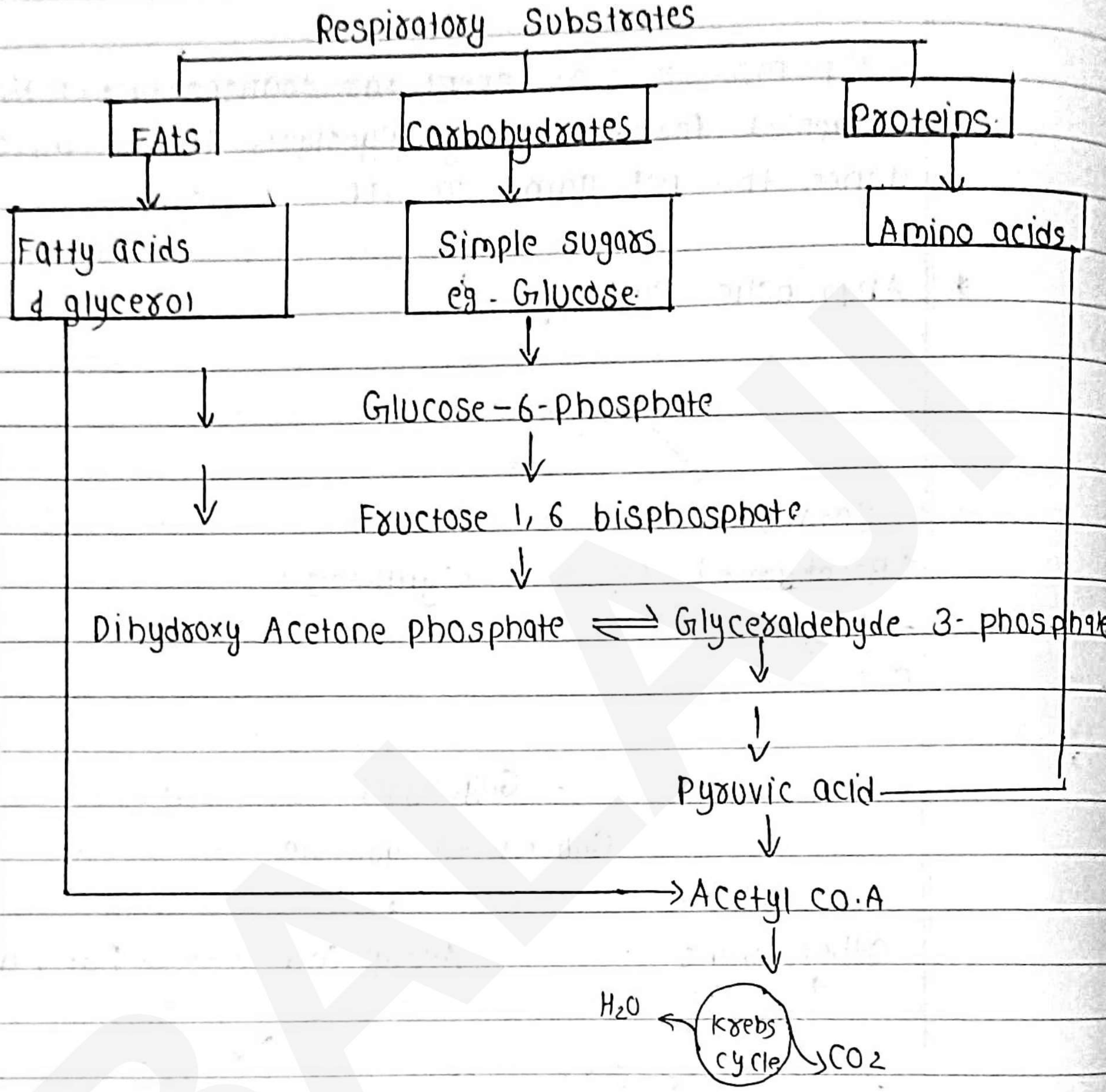
* Amphibolic Pathway.

Amphibolic

Catabolic
(Breakdown)
→ Respiration
C – C – C – C – C – C

Anabolic
(Synthesis)





→ What is important to recognise is that in living organisms respiratory. substrates are often more than one ; pure proteins or fats are never used as respiratory substrate

→ The respiratory pathway is generally considered as a catabolic pathway. But it involves both anabolism (synthesis) and catabolism (breakdown) - amphibolic pathway

→ eg - Fatty acids breakdown to acetyl CoA before entering the respiratory pathway. But when the organism needs to synthesise fatty acids, acetyl CoA withdraw from the respiratory pathway

→ Similarly during breakdown and synthesis of protein respiratory intermediates are involved

→ Fats breakdown into glycerol and fatty acids. Fatty acids are degraded to acetyl-CoA and enter the pathway. Glycerol is converted to PGAl and enters the pathway

→ Proteins are degraded by proteases into amino acids. Each amino acid (after deamination) enters the pathway at some stage in the krebs cycle or as pyruvate or acetyl CoA

* Respiratory Quotient (RQ)

RQ is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed in Respiration

$$\boxed{RQ = \frac{\text{volume of } CO_2 \text{ evolved}}{\text{volume of } O_2 \text{ consumed}}}$$

RQ depends upon the type of respiratory substrate.

RQ for carbohydrates = 1

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy

$$RQ = \frac{6CO_2}{6O_2} = 1$$

RQ for fats = <1

$2(C_{51}H_{98}O_6) + 145O_2 \rightarrow 102CO_2 + 98H_2O$ + energy

Tripalmitin

$$RQ = \frac{102CO_2}{145O_2} = 0.7$$

Substrate	RQ
Proteins	0.9
Organic acid	>1
a) Malic Acid	1.33
b) Oxalic Acid	4
Maturing fatty seeds	>1
CAM plants (succulents)	0
Anaerobic Respiration	Infinity