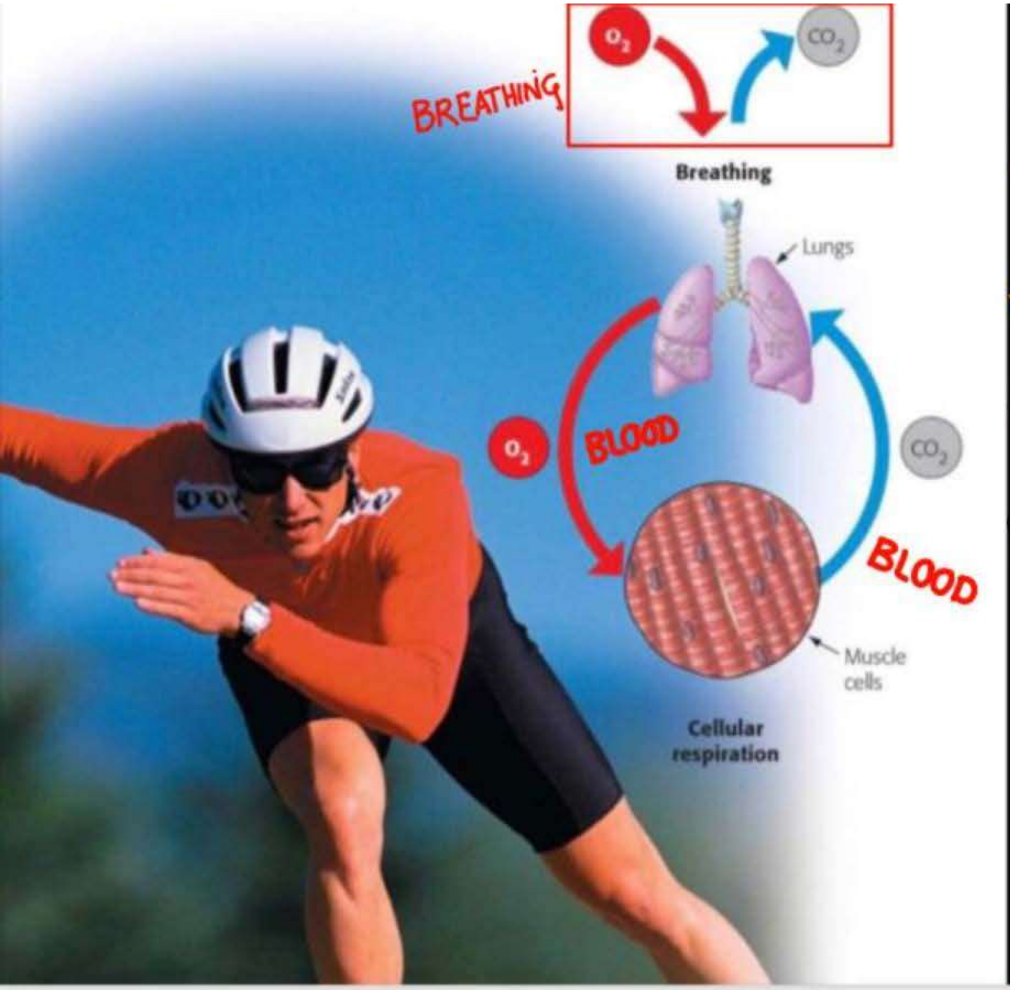



# What is Respiration

★ PLANT ⟶ PHOTOSYNTHESIS ⟶ GLUCOSE (Chemical Bonds : Energy present.

★ HUMAN ⟶ GLUCOSE TAKEN (OUTSIDE)

★ $O_2$ TAKEN ⟶ ENTER INTO LUNGS $\xrightarrow[\text{BLOOD}]{\text{Through}}$ $O_2$ ENTER INTO CELL

GLUCOSE + $O_2$
(BREAKDOWN)

$CO_2$ $H_2O$ Energy

Energy → Max → loss (Heat)

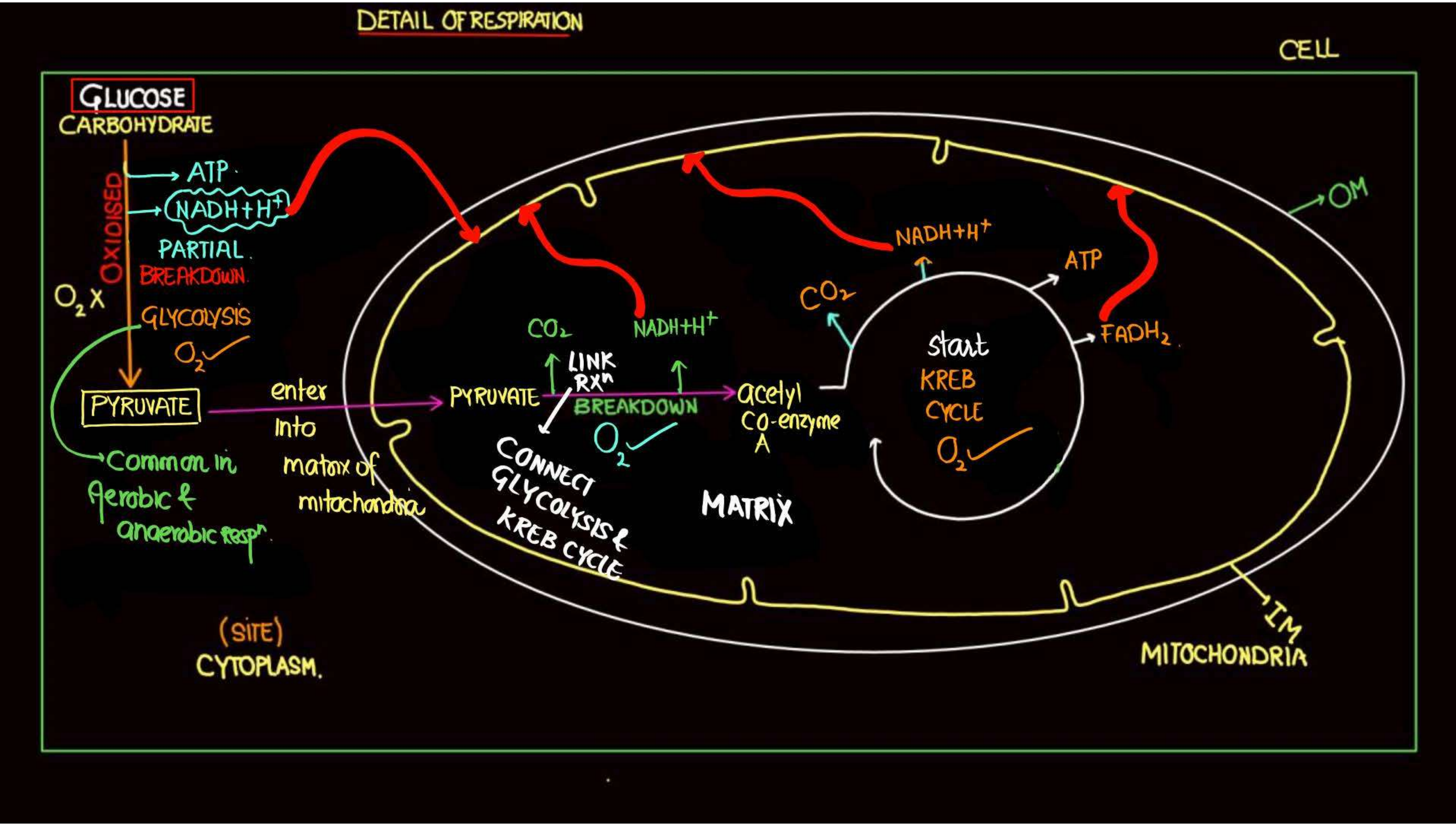
Energy → Stored → ATP

BREAKDOWN OF GLUCOSE IN PRESENSE OF $O_2$ to yield $CO_2$, $H_2O$, Energy.

↑

CELLULAR RESPIRATION.

OUTSIDE $\xleftarrow{CO_2}$ LUNGS $\xleftarrow{CO_2}$ BLOOD ⟵


DETAIL OF RESPIRATION
CELL
GLUCOSE
CARBOHYDRATE
OXIDISED
ATP
NADH+H+
PARTIAL
BREAKDOWN
O2 X
GLYCOLYSIS
O2 ✓
PYRUVATE
Common in
aerobic &
anaerobic respn
enter
into
matrix of
mitochondria
(SITE)
CYTOPLASM.
PYRUVATE
LINK
RXn
CO2
NADH+H+
BREAKDOWN
O2 ✓
CONNECT
GLYCOLYSIS &
KREB CYCLE
MATRIX
acetyl
CO-enzyme
A
CO2
NADH+H+
ATP
start
KREB
CYCLE
O2 ✓
FADH2
OM
IM
MITOCHONDRIA

* Glycolysis $O_2$ ✓, ATP, NADH, CYTOPLASM
* LINK RX^n $O_2$ ✓, NADH, MATRIX
* KREB CYCLE $O_2$ ✓, ATP, NADH, $FADH_2$, MATRIX

(O_2 PRESENT)

$\boxed{\text{AEROBIC RESPIRATION}}$

IM: INNER MEM. OF MITOCHOND.

Inner memb. of mitoch.

Participat in PROCESS.

ELECTRON TRANSPORT CHAIN

| | | |
|---|---|---|
| 1 NADH | $\longrightarrow$ | 3 ATP |
| 1 $FADH_2$ | $\longrightarrow$ | 2 ATP |

HOW ?

$O_2$ ⟶

# GLYCOLYSIS

- ★ SPLITTING OF GLUCOSE
- ★ PARTIAL BREAKDOW OF GLUCOSE.
- ★ GLUCOSE $\xrightarrow{\text{OXIDISED}}$ 2 PYRUVATE
  (1 mole : 6C) 1 mol : 3C
  2 mol × 3C = 6C
- ★ $CO_2$ : ABSENT
- ★ DISCOVERED: EMBDEN, MEYERHOFF, PARANAS (EMP) pathway.
- ★ CYTOPLASM → SITE → LIQUID REGION (CYTOSOL)
- ★ INDEPENDENT OF $O_2$.

GLUCOSE 1 mole, 6C

Hexokinase, $Mg^{+2}$ 1st ↓ ATP → ADP + ip (Energy consumed).

GLUCOSE-6-Phosphate 1 mole, 6C, 1P

2nd ↓

FRUCTOSE-6-PHOSPHATE 1 mole, 6C, 1P

PHOSPHOFRUCTOKINASE $Mg^{+2}$ 3rd. ↓ ATP → ADP + ip (Energy consumed).

FRUCTOSE 1,6 BIS PHOSPHATE 1 mole, 6C, 2P.

aldolase 4th.

Dihydroxyacetone phosphate $\overset{5th.}{\rightleftharpoons}$ 3-Phosphoglyceraldehyde.

3C, 1mol, 1P — 3C, 1mol, 1P

Energy Consuming PHASE / glucose activation phase

⇒ ATP CONSUMED: $\boxed{2}$

3 PHOSPHOGLYCERALDEHYDE , 2 mol, 3C+3C, 1P+1P.

$2H_3PO_4$ Oxidⁿ

2NAD⁺ → 2NADH + 2H⁺ 6th step.

SUBSTRATE ← 1,3 BISPHOSPHOGLYCERIC ACID 2 mol, 3C+3C, 2P+2P

2IP + 2ADP → 2ATP 7th step. SUBSTRATE LEVEL PHOSPHORYLATION

PRODUCT 3 PHOSPHOGLYCERIC ACID 2 mol, 3C+3C, 1P + 1P

8th step

2 PHOSPHOGLYCERIC ACID 2 mol, 3C+3C, 1P + 1P

9th

$H_2O$

PHOSPHOENOL PYRUVATE 2 mol, 3C+3C, 1P + 1P

Pyruvate kinase, $K^+$, $Mg^{+2}$.

2IP + 2ADP → 2ATP 10th step. SUBSTRATE LEVEL PHOSPHORYLATION

PYRUVATE 2 mol, 3C+3C, OP + OP

Q Total ATP in glycolysis (including ETC)

2+6 ⇒ $\boxed{8}$

---

★ 3 PGAL (1mol) ⟶ 2H ⇒ 2 Redox equivalent.

★ 3PGAL (2mol) ⟶ 2H + 2H

NAD⁺ NAD⁺

NADH + H⁺ NADH + H⁺

★ ADP + IP ⟶ ATP
PHOSPHORYLATION.

★ DIRECT ATP / SUBSTRATE LEVEL PHOSPHORYLATION ATP

⇒ $\boxed{4\text{ ATP}}$ → cytoplasm

★ CONSUMED: $\boxed{2\text{ ATP}}$

★ NET GAIN OF ATP: 4-2 = $\boxed{2\text{ ATP}}$

★ INDIRECT ATP/ETC:

2NADH X 3ATP : $\boxed{6\text{ATP}}$ → INNER MEMBRANE.

★ All steps are Reversible: 1st, 3rd, 10th.

SUMMARISE

G
↓ ATP → ADP
G6P
↓
F6P
↓ ATP → ADP
F 1,6 BISP

DHAP ← → 3-PGAL
↓ 2NADH
1,3 BISPGA
↓ 2ATP.
3PGA
↓
2PGA
↓
PEP
↓ 2ATP
PYRUVATE

FRUCTOSE → F6P
ATP → ADP
tip

Q ONE MOLECULE OF FRUCTOSE ENTER INTO GLYCOLYSIS

DIRECT ATP : 4

Q ATP CONSUMED: 2

Q INDIRECT ATP: 2NADHx3 = 6

Q NET GAIN : 4 – 2 : 2

NOTE : STORAGE CARBOHYDRATE
(STARCH)
↓
GLUCOSE.

NOTE : 2H : 2 REDOX EQUIVALENT

NOTE : COMMON PATHWAY FOR AEROBIC & ANAEROBIC RESP$^{N}$:

★ PHOTOSYNTHESIS : GLUCOSE FORMED
↓ CHANGE
SUCROSE
(END PRODUCT OF PHOTOSYNTHESIS)
INVERTASE
GLUCOSE ✓ FRUCTOSE ✓
BOTH ENTER READILY (FAST) INTO GLYCOLYSIS

## FATE OF PYRUVATE

$O_2$ LINK RXN. → Acetyl- Coenzyme A → KREB CYCLE

ETC

Aerobic RESPN.

$O_2$ X → ALCOHOL (ETHANOL)

Alcoholic fermentation

$O_2$ X. → Lactic acid

Lactate fermentation

3

(glycolysis)
PYRUVATE
(CYTOPLASM)

ENTER INTO MATRIX OF MITOCHONDRIA

# LINK $RX^N$ / OXIDATIVE DECARBOXYLATION ⟶ RELEASE OF $CO_2$.

$$2\text{PYRUVATE} + \boxed{\text{Coenzyme A} + 2NAD^+} \xrightarrow[\text{MULTISTEP REACTION.}]{\text{PYRUVATE DEHYDROGENASE, } Mg^{+2} \text{ (MULTIENZYME COMPLEX)}} 2\text{ ACETYL CO-A} + 2CO_2 + 2NADH + 2H^+$$

1mol : 3C
3C+3C : 6C

1mol : 2C
2C+2C : 4C

2C

*

1. DIRECT ATP FORMED: ZERO
   (SUBSTRATE LEVEL PHOSPHORYLATION)
2. INDIRECT ATP/ETC: 2NADH X 3ATP : $\boxed{6ATP}$
3. if one molecule of pyruvic acid enter into LINK $RX^n$
   - $CO_2 \rightarrow 1$
   - $NADH \rightarrow 1$
   - INDIRECT ATP ⟶ 3
   - ACETYl CO-A ⟶ 1.

# KREB CYCLE

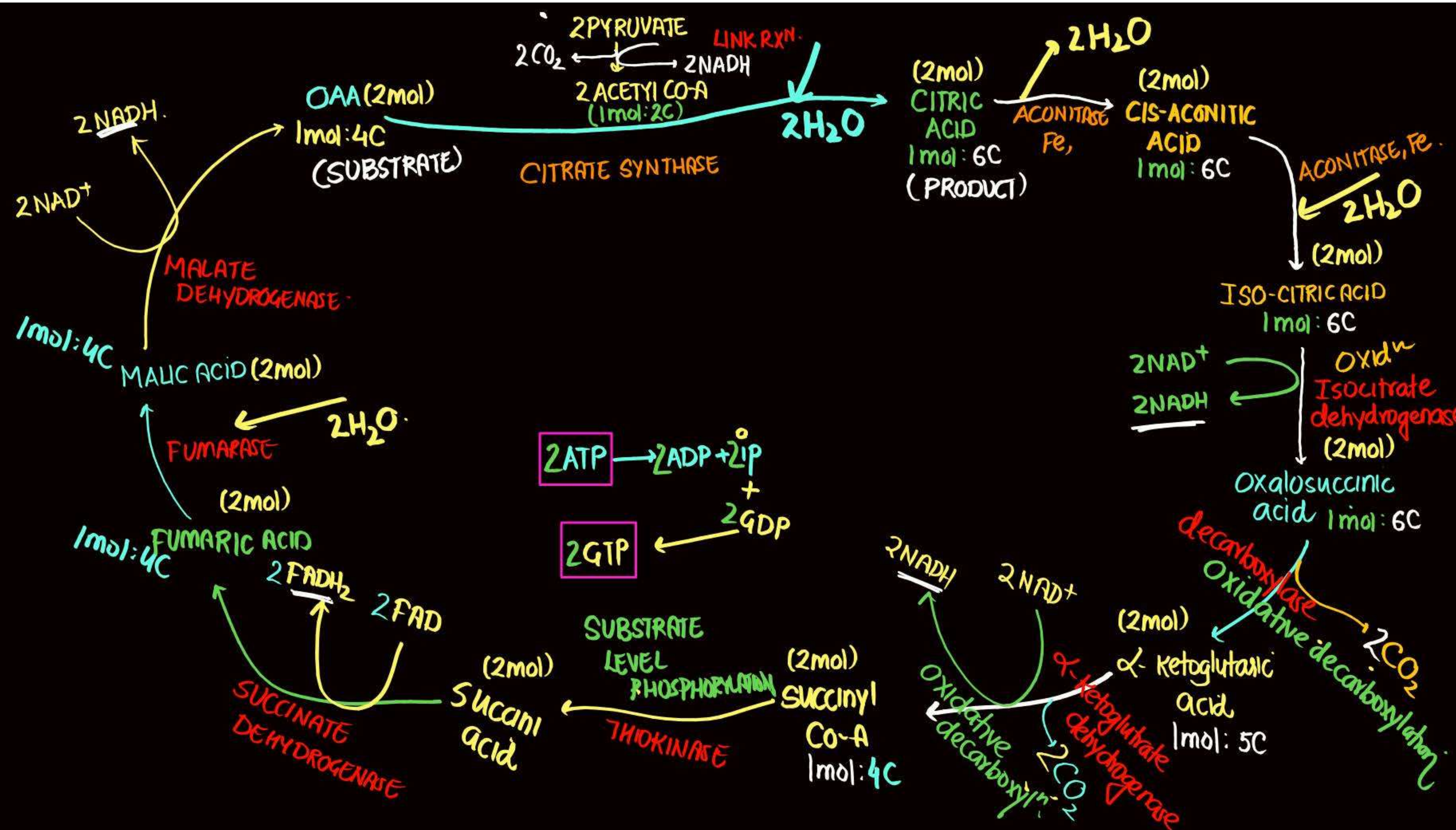
- MATRIX OF MITOCHONDRIA : SITE
- FIRST PRODUCT: CITRIC ACID = 6C. ⟶ 3COOH.
- CITRIC ACID CYCLE / TRICARBOXYLIC ACID CYCLE (TCA)
- All ENZYMES PRESENT IN MATRIX EXCEPT SUCCINATE DEHYDROGENASE ⟶ INNER MEMB.

- $\boxed{\text{FIRST STEP:}}$

$$\text{2 ACETYL CO-A} + \text{2 Oxaloacetic acid} \xrightarrow[\text{CITRATE SYNTHASE}]{\text{CONDENSATION REACTION}} \text{2 CITRIC ACID}$$

2 $H_2O$ CONSUMED.

| 2 ACETYL CO-A | 2 Oxaloacetic acid | 2 CITRIC ACID |
|---|---|---|
| 1 mol : 2C | 1 mol : 4C | 1 mol : 6C |
| 2C+2C : 4C | 4C+4C : 8C. | 6C+6C : 12C. |



2PYRUVATE
$2CO_2$
2NADH
2 ACETYL CO-A
(1mol: 2C)
LINK RXN.
OAA (2mol)
1mol: 4C
(SUBSTRATE)
CITRATE SYNTHASE
$2H_2O$
(2mol)
CITRIC ACID
1mol: 6C
(PRODUCT)
$2H_2O$
ACONITASE Fe,
(2mol)
CIS-ACONITIC ACID
1mol: 6C
ACONITASE, Fe.
$2H_2O$
(2mol)
ISO-CITRIC ACID
1mol: 6C
$2NAD^+$
2NADH
Oxidn
Isocitrate dehydrogenase
(2mol)
Oxalosuccinic acid 1mol: 6C
decarboxylase
Oxidative decarboxylation
$2CO_2$
(2mol)
α-Ketoglutaric acid
1mol: 5C
2NADH
$2NAD^+$
α-Ketoglutarate dehydrogenase
Oxidative decarboxyln
$2CO_2$
(2mol)
Succinyl Co-A
1mol: 4C
SUBSTRATE LEVEL PHOSPHORYLATION
THIOKINASE
(2mol)
Succini acid
2ATP → 2ADP + 2iP
+
2GDP
2GTP
2FAD
$2FADH_2$
SUCCINATE DEHYDROGENASE
(2mol)
FUMARIC ACID
1mol: 4C
FUMARASE
$2H_2O$.
MALIC ACID (2mol)
1mol: 4C
MALATE DEHYDROGENASE.
$2NAD^+$
2NADH.

★ DIRECT ATP/SUBSTRATE LEVEL PHOSPHORYLATION : 2 (MATRIX)

★ TOTAL NADH : $\boxed{6}$

★ TOTAL $FADH_2$ : 2

★ INDIRECT ATP (NADH) : 6 NADH X 3 ATP ⇒ 18 ATP

(FADH₂) : 2 $FADH_2$ X 2 ATP ⇒ 4 ATP

18 ATP + 4 ATP → 22 ATP (INNER MEM)

2 + 22 ATP → 24 ATP

★ TOTAL $CO_2$ : 4

★ If one molecule of Acetyl Co-A enter into Kreb cycle

NADH ⟶ 3

$FADH_2$ ⟶ 1

$CO_2$ ⟶ 2

ATP (DIRECT) ⟶ 1.

In addition it also requires regeneration of $NAD^+$ and $FAD^+$ from NADH and $FADH_2$ respectively. The summary equation for this phase of respiration may be written as follows:

NAD⁺
FAD⁺

$NADH + H^+ \xrightarrow{\text{oxidised}} NAD^+$

$FADH_2 \xrightarrow{\text{oxidised}} FAD^+$

Kreb cycle

$$\text{Pyruvic acid} + 4NAD^+ + FAD^+ + 2H_2O + ADP + Pi \xrightarrow{\text{Mitochondrial Matrix}} 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$

(1 molecu)

$6H_2O$

LINK RXⁿ
+KREB
CYCLE

6−2

$\Rightarrow \boxed{4H_2O}$

$2H_2O$

# CALCULATION OF ATP

**glycolysis**

TOTAL ATP / DIRECT ATP / SUBSTRATE LEVEL → 4

CONSUMED ATP → 2

NET GAIN OF ATP → 4 − 2 → $\boxed{2}$

INDIRECT ATP → 2NADH × 3 → $\boxed{6}$ ETC

cytoplasm

8

**LINK RX$^N$**

DIRECT / SUBSTRATE LEVEL → ZERO

INDIRECT ATP → 2NADH × 3 → $\boxed{6}$ ETC → 6

**KREB CYCLE**

DIRECT / SUBSTRATE LEVEL → $\boxed{2}$ → matrix

INDIRECT ATP → 6 NADH × 3 ATP → $\boxed{18}$ ETC

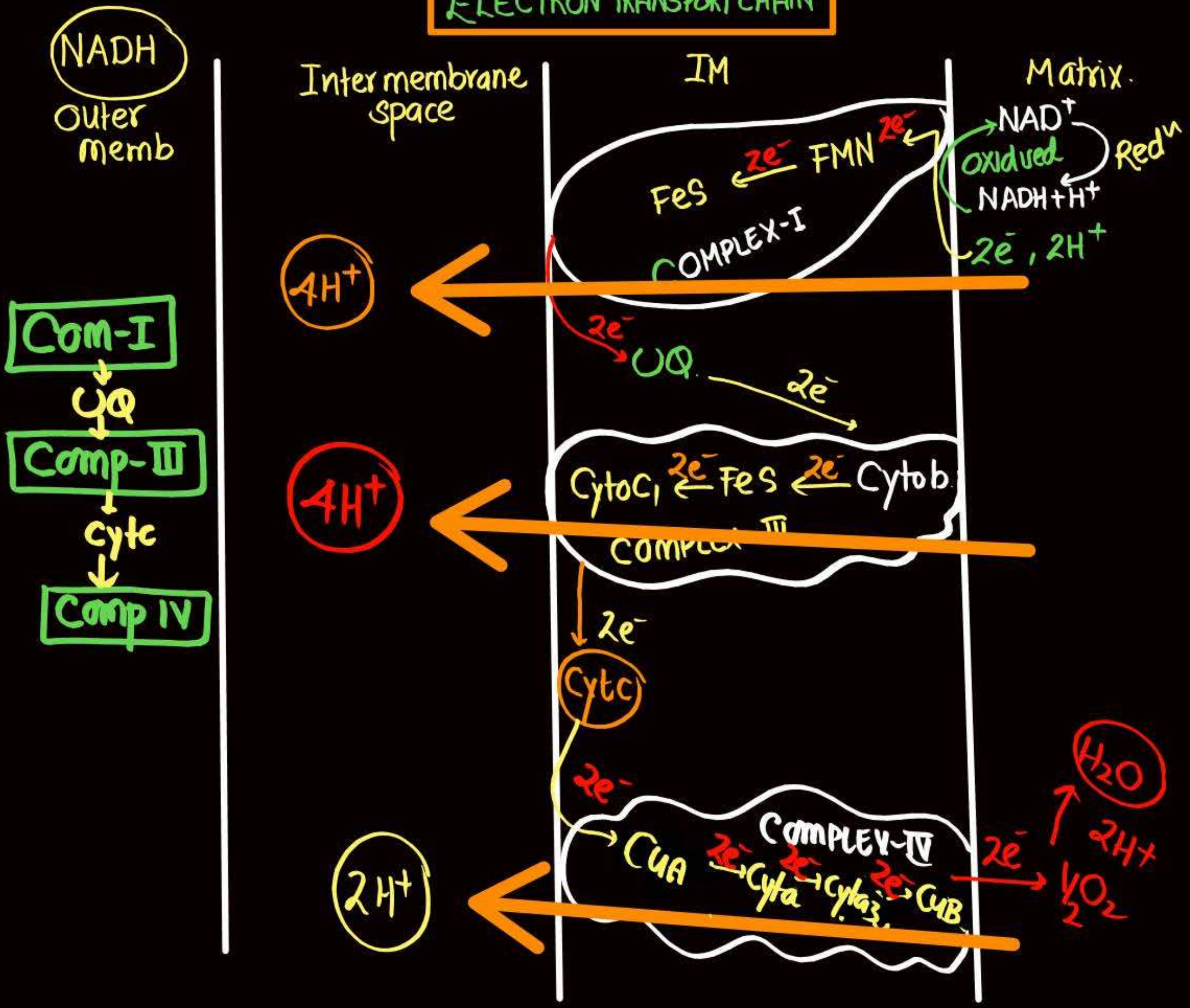
INDIRECT ATP → 2 $FADH_2$ × 2 ATP → $\boxed{4}$ ETC

24

38

1 mole of glucose in aerobic Resp$^n$.

# ELECTRON TRANSPORT CHAIN




⇒ FMN : FLAVIN MONO NUCLEOTIDE

⇒ COMPLEX : MAINLY PROTEIN. BUT HAVE NON PROTEIN PART ( FMN, FeS) / NADH DEHYDROGENASE

⇒ UQ / Coenzyme Q : mobile $e^-$ carrier, LIPID SOLUBLE

⇒ cytochrome : protein.

⇒ complex-III : Cyto $bc_1$ complex. / cyto c Reductase.

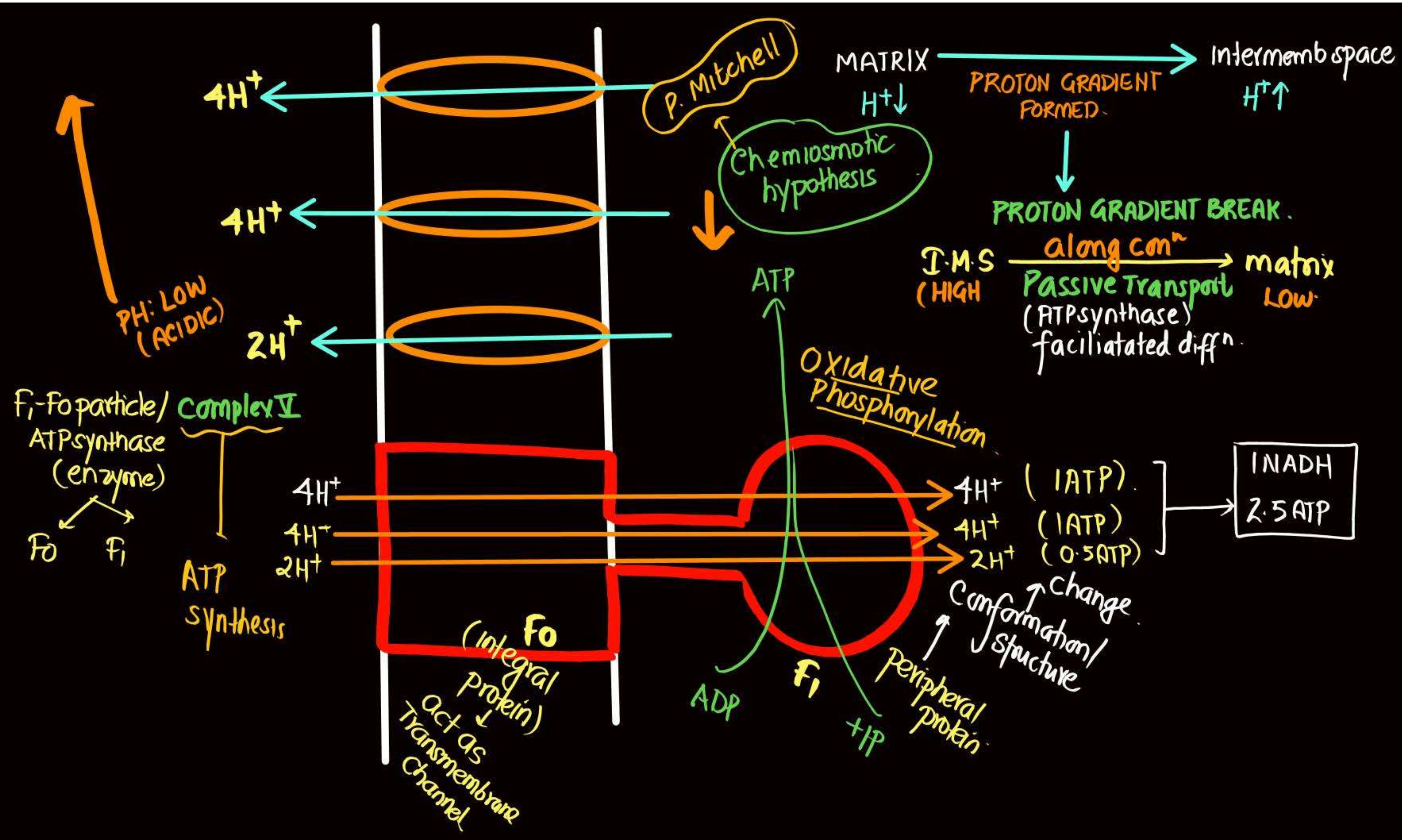
⇒ cyt c (protein) : Mobile $e^-$ carrier ( outer surface of inner membrane).

⇒ Final acceptor of $e^-$ : oxygen.

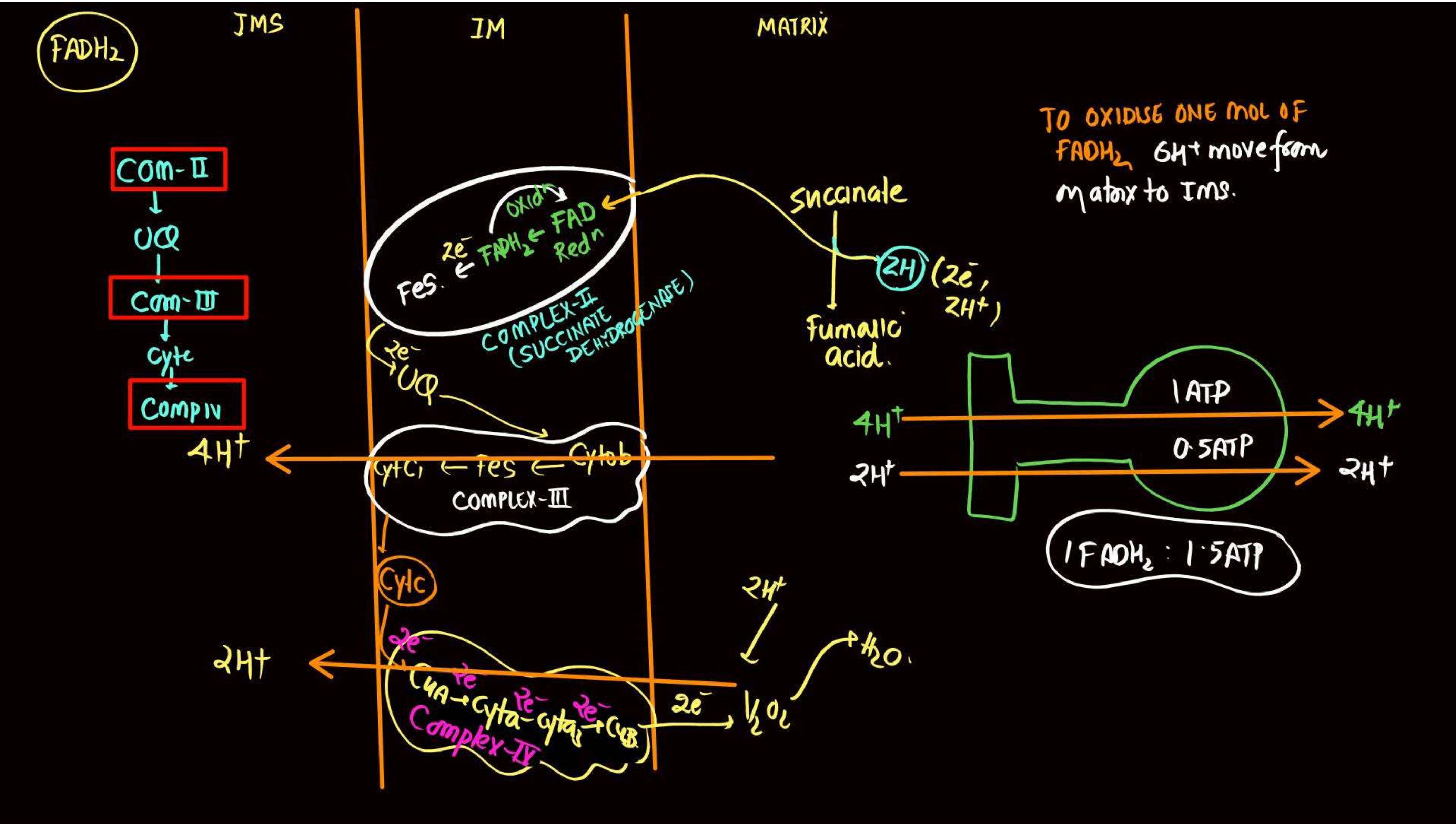
⇒ Complex IV / cytochrome C oxidase

⇒ NO. of proton moves from matrix to Intermembranous space to oxidise one molecule of NADH.

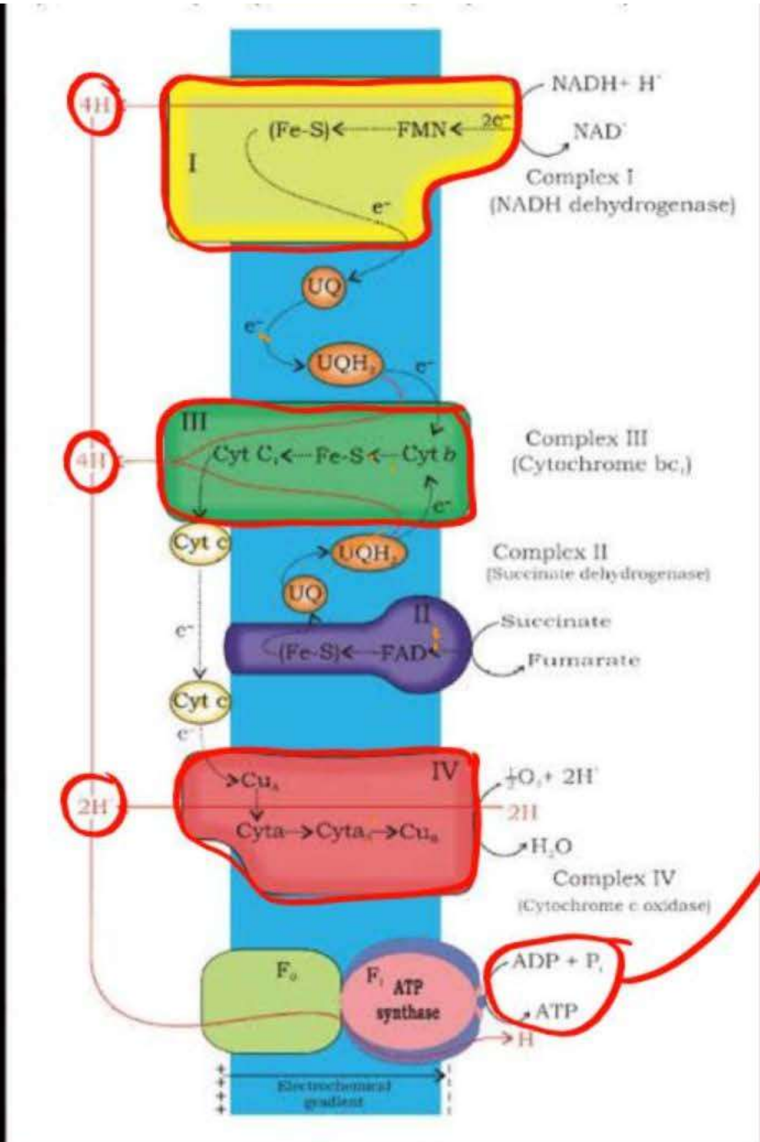
10



4H+
4H+
2H+
P. Mitchell
Chemiosmotic hypothesis
PH: LOW (ACIDIC)
MATRIX
H+↓
PROTON GRADIENT FORMED.
Intermemb space
H+↑
PROTON GRADIENT BREAK.
I.M.S (HIGH
along conn
Passive Transport
(ATPsynthase)
faciliatated diffn.
matrix LOW.
ATP
Oxidative Phosphorylation
F1-Fo particle/ ATPsynthase (enzyme)
Fo
F1
Complex V
ATP synthesis
4H+
4H+
2H+
4H+ (1ATP)
4H+ (1ATP)
2H+ (0.5ATP)
1NADH
2.5ATP
change
Conformation/ structure
Fo
(integral protein)
act as Transmembrane Channel
F1
ADP
+IP
peripheral protein



FADH2
IMS
IM
MATRIX
Com-II
UQ
Com-III
Cytc
Comp IV
TO OXIDISE ONE mol OF FADH2 6H+ move from matrix to Ims.
succinate
2H (2e-, 2H+)
Fumaric acid.
Oxidn
FAD
Redn
Fes. 2e- FADH2
COMPLEX-II (SUCCINATE DEHYDROGENASE)
2e-
UQ
4H+
CytC1 Fes Cytob
COMPLEX-III
Cytc
2H+
2e-
CuA Cyta Cyta3 CuB
Complex-IV
2e-
1/2 O2
2H+
H2O
4H+
1 ATP
4H+
2H+
0.5 ATP
2H+
1 FADH2 : 1.5 ATP




Oxidative phosphorylation

Electrochemical gradient

# FERMENTATION

- ★ INCOMPLETE OXID^N OF GLUCOSE IN ABSENSE OF $O_2$ (ANAEROBIC RESP^N).
- ★ $O_2$ absent, NADH ✓
- ★ BUT NADH do not enter ETC
- ★ ETC X. $O_2$ X.

★ NET GAIN OF ATP: 2

★ PARTIAL BREAKDOWN.

## ALCOHOLIC FERMENTATION

glucose

→ 4−2 ⇒ $\boxed{2ATP}$

ANAEROBIC GLYCOLYSIS ($O_2$ absent)

$2NAD^+$ → 2NADH. (Red^N).

2 PYRUVATE

1st step — PYRUVATE DECARBOXYLASE, $Mg^{+2}$

$2\ CH_3CHO + 2CO_2$

2nd step — ALCOHOL DEHYDROGENASE, $ZN^{+2}$

2 NADH → oxidised → $2NAD^+$

$2\ C_2H_5OH$

# LACTATE FERM$^N$

* NO PRODUCTION OF $CO_2$.

$O_2$ X

Anaerobic glycolysis

glucose

→ 4-2 ⇒ 2ATP

2NAD$^+$ → 2NADH

2 PYRUVATE

2NADH → 2NAD$^+$

1 step

LACTATE DEHYDROGENASE

2 Lactic acid

NET GAIN OF ATP: 2

NOTE:

NADH

FAST — OXIDISED — SLOW

NAD$^+$ → Aerobic Resp$^n$. $O_2$ ✓ ETC ✓

NAD$^+$ → Ferm$^n$ $O_2$ X ETC X

ETC

→ NADH

$\downarrow$ oxid$^n$.

NAD$^+$

Topic : NCERT BOOSTER

All of us breathe to live, but why is breathing so essential to life? What happens when we breathe? Also, do all living organisms, including plants and microbes, breathe? If so, how?

HUMAN: LUNGS

yes

gas diffusion through cell wall

$glucose + O_2 \xrightarrow[\text{Respn.}]{\text{cellular}} Energy.$

Stomata. (gaseous exchange)

All living organisms need energy for carrying out daily life activities, be it absorption, transport, movement, reproduction or even breathing. Where does all this energy come from? We know we eat food for energy – but how is this energy taken from food? How is this energy utilised? Do all foods give the same amount of energy? Do plants 'eat'? Where do plants get their energy from? And micro-organisms – for their energy requirements, do they eat 'food'?

FOOD

glucose + $O_2$ →

NO

Autotropsh. Food synthesis

Hetrotophs : feed on dead, decaying matter

(Saprophytic).

yes, Plant Photosynthesis

↓

glucose formed

energy ← Respiration

Breakdown

You may wonder at the several questions raised above – they may seem to be very disconnected. But in reality, the process of breathing is very much connected to the process of release of energy from food. Let us try and understand how this happens.

All the energy required for 'life' processes is obtained by oxidation of some macromolecules that we call 'food'. Only green plants and cyanobacteria can prepare their own food; by the process of photosynthesis they trap light energy and convert it into chemical energy that is stored in the bonds of carbohydrates like glucose, sucrose and starch. We must remember that in green plants too, not all cells, tissues and organs photosynthesise; only cells containing chloroplasts, that are most often located in the superficial layers, carry out photosynthesis. Hence, even in green plants all other organs, tissues and cells that are non-green, need food for oxidation.

Below epidermis
↓
Mesophyll cell.
(Chloroplast)

green cell $\xrightarrow[\text{MOVE}]{\text{FOOD}}$ Non green cell
(FOOD)
↓ oxidised
energy provide

Hence, food has to be translocated to all non-green parts. Animals are heterotrophic, i.e., they obtain food from plants directly (herbivores) or indirectly (carnivores). Saprophytes like fungi are dependent on dead and decaying matter. What is important to recognise is that ultimately all the food that is respired for life processes comes from photosynthesis. This chapter deals with **cellular respiration** or the mechanism of breakdown of food materials within the cell to release energy, and the trapping of this energy for synthesis of ATP.

glucose.

Photosynthesis, of course, takes place within the chloroplasts (in the eukaryotes), whereas the breakdown of complex molecules to yield energy takes place in the cytoplasm glycolysis and in the mitochondria LR, KC, ETC (also only in eukaryotes). The breaking of the C-C bonds of complex compounds (glucose) through oxidation within the cells, leading to release of considerable amount of energy is called **respiration**. The compounds that are oxidised during this process are known as **respiratory substrates.** Usually carbohydrates common substrate are oxidised to release energy, but proteins, fats and even organic acids can be used as respiratory substances in some plants, under certain conditions. During oxidation within a cell, all the energy contained in respiratory substrates is not released free into the cell, or in a single step.

(mitochondria absent).
PROKARYOTE
gly, LINK RXN,
KREB:
cytoplasm
ETC:
Cell membrane
(mesosome)

38 ATP

glucose → pyruvate → acetyl CoA → kreb cycle

ETC → 34 ATP FORMED.

It is released in a series of slow step-wise reactions controlled by enzymes, and it is trapped as chemical energy in the form of ATP. Hence, it is important to understand that the energy released by oxidation in respiration is not (or rather cannot be) used directly but is used to synthesise ATP, which is broken down whenever (and wherever) energy needs to be utilised. Hence, ATP acts as the energy currency of the cell. This energy trapped in ATP is utilised in various energy-requiring processes of the organisms, and the carbon skeleton produced during respiration is used as precursors for biosynthesis of other molecules in the cell.

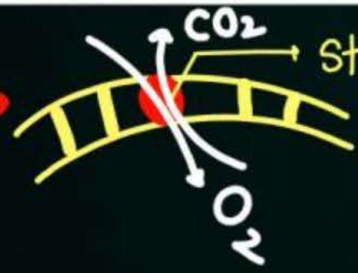
α-Ketoglutaric acid → glutamic acid

Succinyl coA → Chlorophyll

## 12.1 Do Plants Breathe?

Well, the answer to this question is not quite so direct. Yes, plants require $O_2$ for respiration to occur and they also give out $CO_2$. Hence, plants have systems in place that ensure the availability of $O_2$. Plants, unlike animals, → (LUNGS) have no specialised organs for gaseous exchange but they have stomata and lenticels for this purpose.

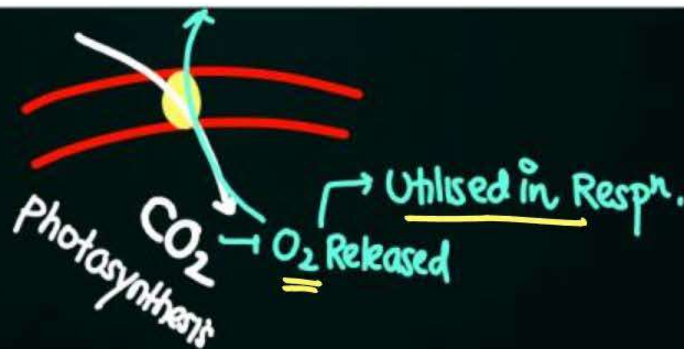
Leaf → epidermis → 
(Respiration).




→ Stomata (main Region !).

→ Openings : stem. (present)

There are several reasons why plants can get along without respiratory organs. First, each plant part takes care of its own gas-exchange needs. There is very little transport of gases from one plant part to another. Second, plants do not present great demands for gas exchange. Roots, stems and leaves respire at rates far lower than animals do. Only during photosynthesis are large volumes of gases exchanged and, each leaf is well adapted to take care of its own needs during these periods.

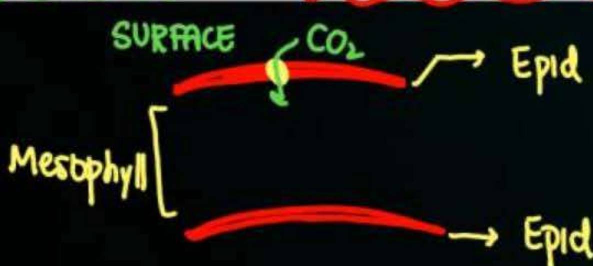



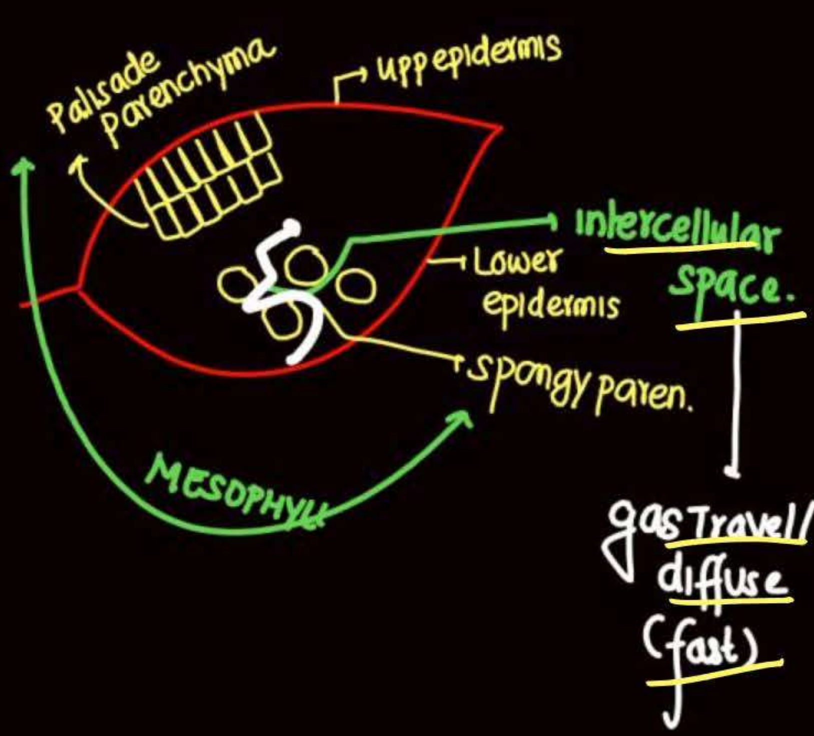
When cells photosynthesise, availability of $O_2$ is not a problem in these cells since $O_2$ is released within the cell. Third, the distance that gases must diffuse even in large, bulky plants is not great. Each living cell in a plant is located quite close to the surface of the plant. 'This is true for leaves', you may ask, 'but what about thick, woody stems and roots?' In stems, the 'living' cells are organised in thin layers inside and beneath the bark. They also have openings called lenticels. The cells in the interior are dead and provide only mechanical support. Thus, most cells of a plant have at least a part of their surface in contact with air. This is also facilitated by the loose packing of parenchyma cells in leaves, stems and roots, which provide an interconnected network of air spaces.

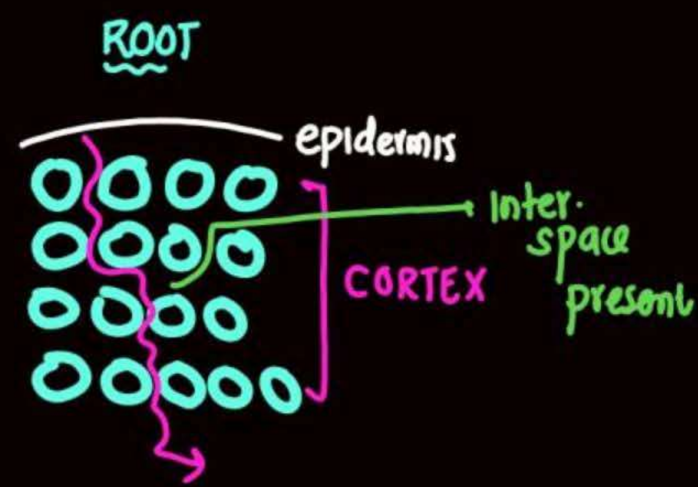
⇒ most of cell in TREE (DEAD).

Stem (openings) gaseous exchange.

mesophyll cell.





Palisade parenchyma
upp epidermis
intercellular space.
Lower epidermis
spongy paren.
MESOPHYLL
gas Travell/ diffuse (fast)


ROOT
epidermis
inter. space present
CORTEX

The complete combustion of glucose, which produces $CO_2$ and $H_2O$ as end products, yields energy most of which is given out as heat.

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

38 ATP

Heat loss.

If this energy is to be useful to the cell, it should be able to utilise it to synthesise other molecules that the cell requires. The strategy that the plant cell uses is to catabolise the glucose molecule in such a way that not all the liberated energy goes out as heat. The key is to oxidise glucose not in one step but in several small steps enabling some steps to be just large enough such that the energy released can be coupled to ATP synthesis. How this is done is, essentially, the story of respiration.

During the process of respiration, oxygen is utilised, and carbon dioxide, water and energy are released as products. The combustion reaction requires oxygen. But some cells live where oxygen may or may not be available. *Can you think of such situations (and organisms) where $O_2$ is not available?* There are sufficient reasons to believe that the first cells on this planet lived in an atmosphere that lacked oxygen. Even among present-day living organisms, we know of several that are adapted to anaerobic conditions. (yeast) Some of these organisms are facultative anaerobes, while in others the requirement for anaerobic condition is obligate. In any case, all living organisms retain the enzymatic machinery to partially oxidise glucose without the help of oxygen. This breakdown of glucose to pyruvic acid is called **glycolysis.**

fermentation
Bacteria, yeast.

NORMALLY LIVE IN PRESENSE OF OXYGEN BUT IF $O_2$ IS not available the they can live as anaerobe

Obligate anaerobe (only in absense of $O_2$ : SURVIVE)

$CO_2 + H_2S \xrightarrow[\text{Non-oxygenic Photosynthesis}]{\text{Bacteria}}$ $O_2$ was not present

## 12.3 Fermentation

alcoholic fermN.

In fermentation, say by yeast, the incomplete oxidation of glucose is achieved under anaerobic conditions by sets of reactions where pyruvic acid is converted to $CO_2$ and ethanol. The enzymes, pyruvic acid decarboxylase and alcohol dehydrogenase catalyse these reactions. Other organisms like some bacteria produce lactic acid from pyruvic acid. The steps involved are shown in Figure 12.2. In animal cells also, like muscles during exercise, when oxygen is inadequate for cellular respiration pyruvic acid is reduced to lactic acid by lactate dehydrogenase. The reducing agent is $NADH+H^+$ which is reoxidised to $\boxed{NAD^+}$ in both the processes.

LACTATE FERMN.

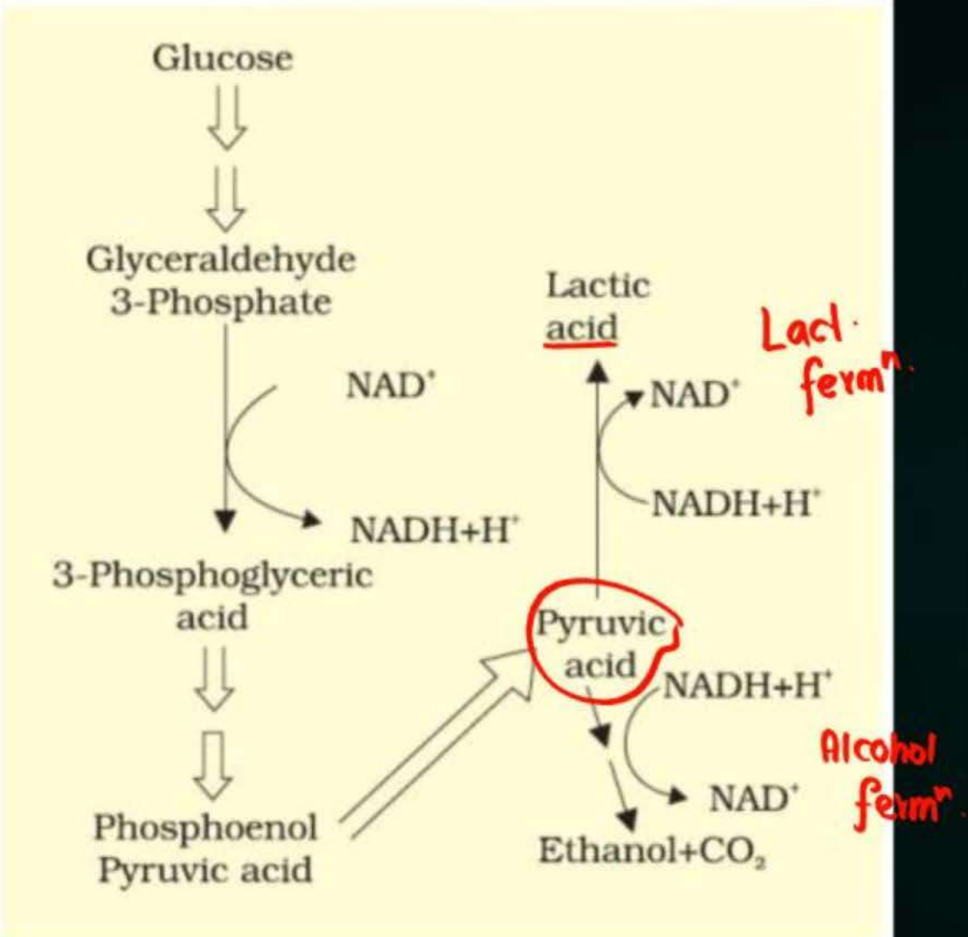



**Figure 12.2** Major pathways of anaerobic respiration

In both lactic acid and alcohol fermentation not much energy is released; less than seven per cent of the energy in glucose is released and not all of it is trapped as high energy bonds of ATP. Also, the processes are hazardous – either acid or alcohol is produced. What is the net ATPs that is synthesised (calculate how many ATP are synthesised and deduct the number of ATP utilised during glycolysis) when one molecule of glucose is fermented to alcohol or lactic acid?

2 ATP

2

4

–

2

→ 2 ATP

Yeasts poison themselves to death when the concentration of alcohol reaches about 13 per cent. ***What then would be the maximum concentration of alcohol in beverages that are naturally fermented?*** How do you think alcoholic beverages of alcohol content greater than this concentration are obtained?

13%

distillation process.

What then is the process by which organisms can carry out complete oxidation of glucose and extract the energy stored to synthesise a larger number of ATP molecules needed for cellular metabolism? In eukaryotes these steps take place within the mitochondria and this requires $O_2$. **Aerobic respiration** is the process that leads to a complete oxidation of organic substances in the presence of oxygen, and releases $CO_2$, water and a large amount of energy present in the substrate. This type of respiration is most common in higher organisms. We will look at these processes in the next section.

Aerobic Resp$^n$.
LR, KC, ETC.

glucose

$\boxed{686\text{ Kcalorie}}$

$$\text{glucose} + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \boxed{686\text{ Kcal}}$$

## 12.5 The Respiratory Balance Sheet

38 ATP

It is possible to make calculations of the net gain of ATP for every glucose molecule oxidised; but in reality this can remain only a theoretical exercise. These calculations can be made only on certain assumptions that:

all process occur simultanouly.

- There is a sequential, orderly pathway functioning, with one substrate forming the next and with glycolysis, TCA cycle and ETS pathway following one after another.

glycolysis → LINK RXn → KREB CYCLE → ETC. (all process occur one after other)

NADH

NADH

- The NADH synthesised in glycolysis is transferred into the mitochondria and undergoes oxidative phosphorylation.

NADH can enter into some other process.

- None of the intermediates in the pathway are utilised to synthesise any other compound.

acetyl CoA ⟶ Fatty acid
α-Ketog ⟶ glutamic
pyruvate ⟶ alanine
Succ.CoA ⟶ chlorophyll.

IT IS NOT CORRECT.

- Only glucose is being respired – no other alternative substrates are entering in the pathway at any of the intermediary stages.

IT IS NOT CORRECT

Protein, Fat } ⟶ can enter.

But this kind of assumptions are not really valid in a living system; all 1 pathways work simultaneously and do not take place one after another; substrates enter the pathways and are withdrawn from it as and when 3 necessary; ATP is utilised as and when needed; enzymatic rates are controlled by multiple means. Yet, it is useful to do this exercise to appreciate the beauty and efficiency of the living system in extraction and storing energy. Hence, there can be a net gain of 38 ATP molecules during aerobic respiration of one molecule of glucose.

Now let us compare fermentation and aerobic respiration:

- Fermentation accounts for only a partial breakdown of glucose whereas in aerobic respiration it is completely degraded to $CO_2$ and $H_2O$.
- In fermentation there is a net gain of only two molecules of ATP for each molecule of glucose degraded to pyruvic acid whereas many more molecules of ATP are generated under aerobic conditions. 38
- ETC absent

  NADH is oxidised to $NAD^+$ rather slowly in fermentation, however the reaction is very vigorous in case of aerobic respiration. ETC present.

  Fast

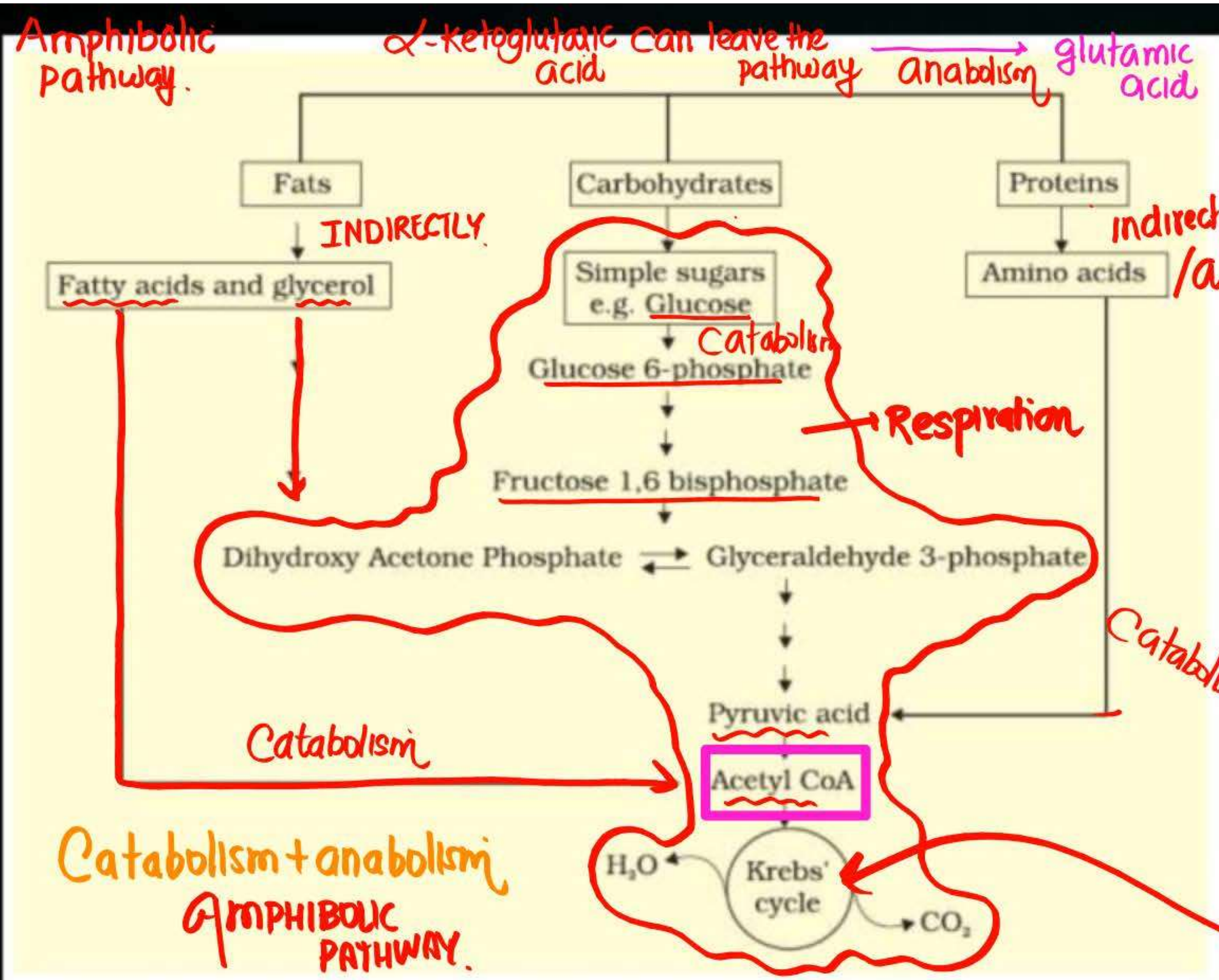



**Figure 12.6** Interrelationship among metabolic pathways showing respiration mediated breakdown of different organic molecules to $CO_2$ and $H_2O$

⇒ fatty acid can enter in Resp^n

⇒ Acetyl CoA leave Respiration

↓ anabolism

Fatty acid

⇒ SUBSTRATE CAN ENTER / EXIT THE RESP^N.

PROTEIN

↓ PROTEASE

amino acid (glutamic acid)

deamination

$-NH_2$

α-ketoglutaric acid

enter into Respiratory pathway. (Krebcycle)

## 12.7 Respiratory Quotient

Let us now look at another aspect of respiration. As you know, during aerobic respiration, $O_2$ is consumed and $CO_2$ is released. The ratio of the volume of $CO_2$ evolved to the volume of $O_2$ consumed in respiration is called the **respiratory quotient** (RQ) or respiratory ratio.

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

The respiratory quotient depends upon the type of respiratory substrate used during respiration.

When carbohydrates are used as substrate and are completely oxidised, the RQ will be 1, because equal amounts of $CO_2$ and $O_2$ are evolved and consumed, respectively, as shown in the equation below :

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy} \quad 686\,\text{kcal}$$

glucose

carbohydrate

$$RQ = \frac{6CO_2}{6O_2} = 1.0$$

$$C \longrightarrow F \longrightarrow P$$

(common Respiratory substrate)

When fats are used in respiration, the RQ is less than 1. Calculations for a fatty acid, tripalmitin, if used as a substrate is shown:

$$\underset{\text{Tripalmitin}}{2(C_{51}H_{98}O_6)} + 145O_2 \longrightarrow 102CO_2 + 98H_2O + \text{energy}$$

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

$2C_2H_5OH + 2CO_2$

Anaerobic Resp$^n$. $\Rightarrow \frac{2CO_2}{0} = \infty$

When proteins are respiratory substrates the ratio would be about 0.9.

Organic acid: More than 1

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 substrates.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QUESTION

Match List I with List II (2024)

Choose the correct answer from the options given below:

| | List I | | List II |
|---|---|---|---|
| A. | Citric acid cycle | I. | Cytoplasm |
| B. | Glycolysis | II. | Mitochondrial matrix |
| C. | Electron transport system | III. | Intermembrane space of mitochondria |
| D. | Proton gradient | IV. | Inner mitochondrial membrane |

(1) A-I, B-II, C-III, D-IV

(2) A-II, B-I, C-IV, D-III

(3) A-III, B-IV, C-I, D-II

(4) A-IV, B-III, C-II, D-I

**QUESTION**

Identify the step in tricarboxylic acid cycle, which does not involve oxidation of substrate.

(2024)

NADH, $FADH_2$ : oxidⁿ.

1. Malic acid → Oxaloacetic acid
2. Succinic acid → Malic acid
3. Succinyl-CoA → Succinic acid
4. Isocitrate → α -ketoglutaric acid

## QUESTION

**A :** ATP is used at two steps in glycolysis

**R :** First ATP is used in converting glucose into glucose-6-phosphate and second ATP is used in conversion of fructose-6-phosphate into fructose-1,6-diphosphate (2023)

1. Both A and R are true but R is not correct explanation of A
2. A is true but R is false
3. A is false but R is true
4. Both A and R are true and R is correct explanation of A

QUESTION

Match List I with List II : (2023)

| | List I | | List II |
|---|---|---|---|
| A. | Oxidative decarboxylation (LR) | I. | Citrate synthase |
| B. | Glycolysis | II. | Pyruvate dehydrogenase |
| C. | Oxidative phosphorylation | III. | ETS |
| D. | TCA cycle | IV. | EMP pathway |

Choose the correct answer from the options given below:

1. A-II, B-IV, C-I, D-III
2. A-III, B-I, C-II, D-IV
3. A-II, B-IV, C-III, D-I
4. A-III, B-IV, C-II, D-I

**QUESTION**

What is the net gain of ATP when each molecule of glucose is converted to two molecules of pyruvic acid? (2022)

4-2

1. Eight
2. Four
3. Six
4. Two

QUESTION

What amount of energy is released from glucose during lactic acid fermentation? (2022)

1. Less than 7%
2. Approximately 15%
3. More than 18%
4. About 10%

**QUESTION**

Conversion of glucose to glucose-6-phosphate, the first irreversible reaction of glycolysis, is catalysed by (2019)

1. Aldolase
2. Hexokinase
3. Enolase
4. Phosphofructokinase

QUESTION

In which one of the following processes $CO_2$ is not released? (2014)

1. Lactate fermentation
2. Aerobic respiration in plants ✓
3. Aerobic respiration in animals ✓
4. Alcoholic fermentation ✓

QUESTION

Which of the following statements is incorrect? 3 (2021)

1. In ETC (Electron Transport Chain), one molecule of NADH + $H^+$ gives rise to ~~2~~ 3 ATP molecules, and one $FADH_2$ gives rise to ~~3~~ 2 ATP molecules.

2. ATP is synthesized through complex V.

3. Oxidation - reduction reactions produce proton gradient in respiration,

4. During aerobic respiration, role of oxygen is limited to the terminal stage.

**QUESTION**

Pyruvate dehydrogenase activity during aerobic respiration requires: (2020-Covid)

1. Iron
2. Cobalt
3. Magnesium
4. Calcium

QUESTION

What is the role of $NAD^+$ in cellular respiration? (2018)

1. It functions as an enzyme
2. It functions as an electron carrier
3. It is a nucleotide source for ATP synthesis
4. It is the final electron acceptor for anaerobic respiration

## QUESTION

Which of these statements is incorrect? (2018)

1. Enzymes of TCA cycle are present in mitochondrial matrix. C
2. Glycolysis occurs in cytosol. C
   NADH
3. Glycolysis operates as long as it is supplied with NAD that can pick up hydrogen atoms.
4. Oxidative phosphorylation takes place in ~~outer~~ mitochondrial membrane.
   (ETC) inner

## QUESTION

Which statement is wrong for Krebs' cycle? (2017-Delhi)

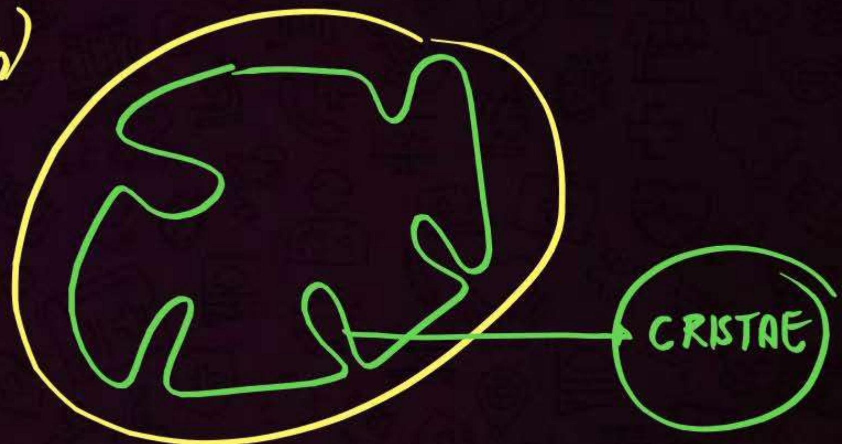
1. There are three points in the cycle where $NAD^+$ is reduced to $NADH + H^+$
2. There is one point in the cycle where $FAD^+$ is reduced to $FADH_2$
3. During conversion of succinyl CoA to succinic acid, a molecule of GTP is synthesised
4. The cycle starts with condensation of acetyl group (acetyl CoA) with ~~pyruvic~~ acid to yield citric acid

OAA.

**QUESTION**

Cytochromes are found in: (2015)

1. Cristae of mitochondria (Inner memb)
2. Lysosomes
3. Matrix of mitochondria
4. Outer wall of mitochondria



**QUESTION**

Which of the following biomolecules is common to respiration-mediated breakdown of fats, carbohydrates and proteins? (2016 - II, 2003)

1. Pyruvic acid
2. Acetyl CoA ✓
3. Glucose-6-phosphate
4. Fructose 1,6-bisphosphate

QUESTION

Respiratory Quotient (RQ) value of tripalmitin is (2019)

1. 0.9
2. 0.7
3. 0.07
4. 0.09