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NEET- 2020- 45 Days Crash Course

Date : 17th August 2020

Chapter Name : Rerspiration in Plants

CELLULAR RESPIRATION , TYPES
STEPS – GLYCOLYSIS , KREBS CYCLE , ETS
AMPHIBOLIC PATHWAY
ETS

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

- 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 and in the mitochondria (also only in eukaryotes).

- The breaking of the C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy, is called respiration.

- The compounds that are oxidized during this process are known as **respiratory substrates**.
- Some of the important respiratory substrates which yield energy in respiration are…

Carbohydrates are the principal respiratory substrates in plants.

Carbohydrates
Proteins

Fats

Organic acids

- ❖ **Carbohydrates are oxidized to release energy, but proteins, fats, organic acids can be used as respiratory substrates in some plants.**

- Energy released by oxidation in respiration is not used directly but is used to synthesize ATP.

ATP acts as the energy currency of the cell.

ATP is broken down whenever energy needs to be utilized.

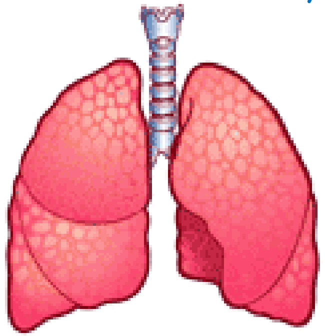
ATP Hydrolysis

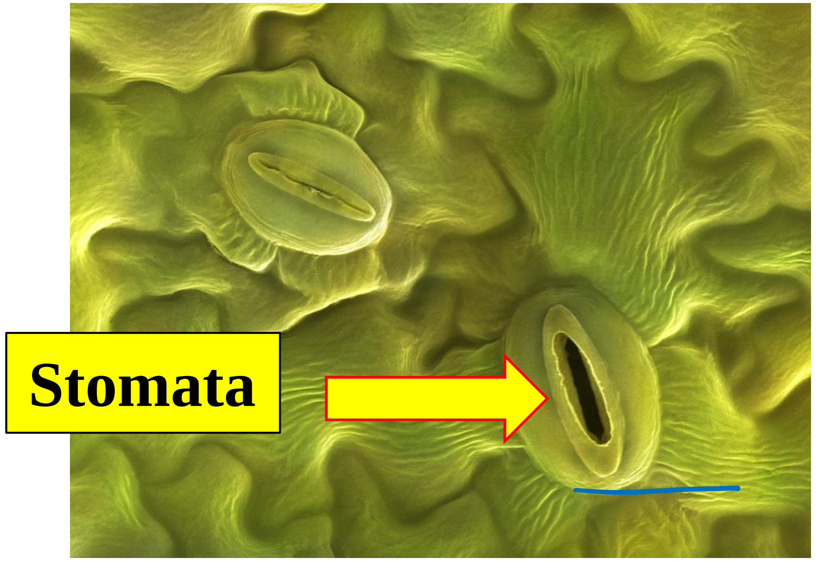
$$ATP \longrightarrow ADP + P_i$$

Energy

ADP + ip ⇌ ATP

❖ **Plants unlike animals do not have any specialized organs for gaseous exchange but they have stomata and lenticels for this purpose.**





- There are several reasons why plants can get along without respiratory organs.

(i) Each plant part takes care of its own gas-exchange needs.

(ii) Plants do not present great demands for gas exchange.

- Roots, stems and leaves respire at rates far lower than animals.

- **Only during photosynthesis large volumes of gases are exchanged and, each leaf is well adapted to take care of its own needs during these periods.**
- **When cells photosynthesise, availability of oxygen is not a problem in these cells since, oxygen is release within the cell.**

- 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.

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

sugar (glucose) | oxygen | carbon dioxide | water

(ATP) → 36/38

aerobic Respiration

- If this energy is to be useful to the cell, it should be able to utilise it to synthesize other molecules that the cell requires.
- The strategy that the plant cell uses is to catabolize the glucose molecule in such a way that not all the liberated energy goes out as heat.
- The key is to oxidize 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.

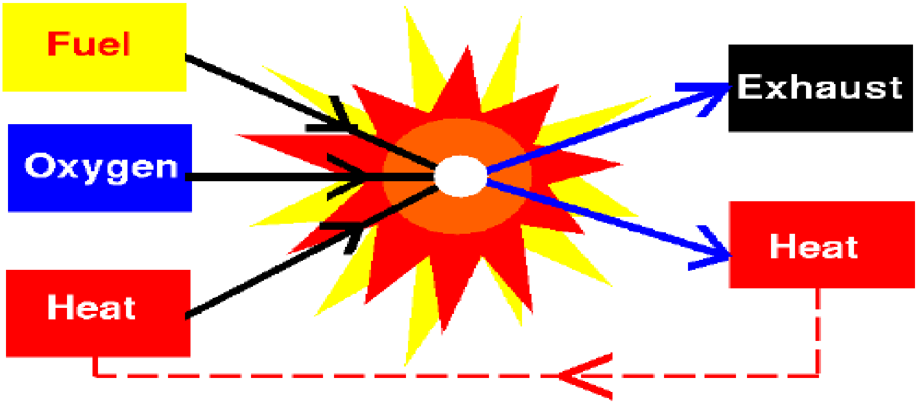
→ Glycolysis
→ Oxidative Decarboxylation
→ Kreb's cycle
→ ETC – ATP Synthesis

- During the process of respiration, oxygen is utilised, and CO_2 and H_2O, energy are released as products.

- The combustion reaction requires oxygen.

What is combustion?

The process of burning something or rapid chemical combinations of a substance with oxygen involving production of heat and light.



Several organisms adapted to anaerobic conditions: some are facultative and others are Obligate anaerobes.

Microorganism tha[t] ... and grow ... molecul[...]

An organism that can grow only in the complete absence of molecular oxygen. → Obligate anaerobe

→ QNEET

Facultative anaerobe → can also survive in the presence of O_2.

- **Pyruvic acid is then the key product of glycolysis.**
- **There are three major ways ... ent cells handle pyruvic acid produced by gl...**
- **These are lactic ... ic fermentation and aerobic respiration.**

What is the metabolic fate of pyruvate?

This depends on the cellular need.

FERMENTATION

anaerobic Resp in microorganisms

- **Fermentation takes place under anaerobic conditions in many prokaryotes and unicellular eukaryotes.**
- **For the complete oxidation of glucose to CO_2 and H_2O, however, organisms adopt Krebs' cycle which is also called as aerobic respiration.**

This required O_2 supply.

Alcoholic Fermentation

- In fermentation, say by yeast, the incomplete oxidation of glucose is achieved under anaerobic conditions by set of reactions where pyruvic acid is converted to CO_2 and ethanol.

- The enzymes, pyruvic acid decarboxylase and alcohol dehydrogenase catalyse these reactions.

  * * → Remove CO_2

- In some bacteria lactic acid formed from pyruvic acid in presence of lactate dehydrogenase. [No decarboxylation] → ** a NEET

- The reducing agent is NADH+H^+.

alcoholic or lactic acid

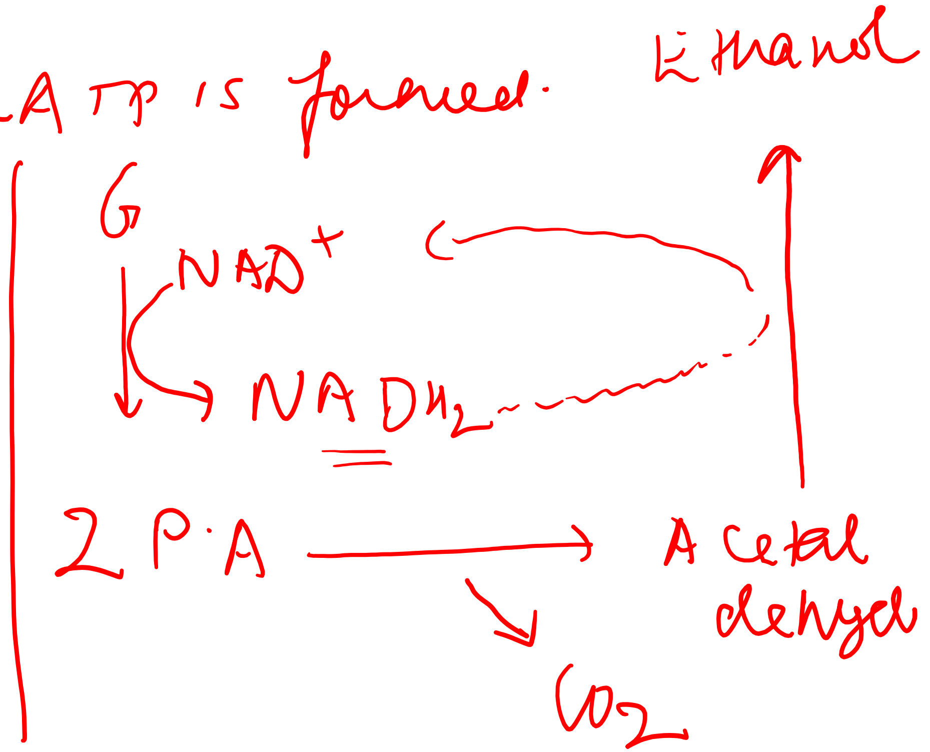
- ❖ In both fermentations not much energy is released; less than **seven percent** of the energy in glucose is released and not all of it is trapped as high energy bonds of ATP.

- ❖ When one molecule of glucose is fermented to alcohol or lactic acid only two molecules of ATP are formed.

→ only 2 ATP is formed.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + CO_2 + 2ATP$$

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + 2ATP$$

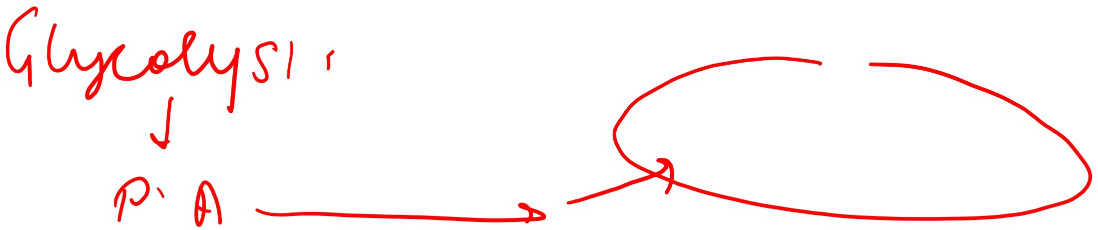


NEET Q

Representation:

Yeast poison themselves to death when the concentration of alcohol reaches about 13%.

- **What then is t… carry out complete oxidation o… ed to synthesise a large numbe… ular metabolism?**
- **In eukaryotes these steps ta… within the mitochondria and this required O_2.**
- **Aerobic respiration is the process that leads to a complete oxidation of organic substances in the presence of oxygen, and release CO_2, water and a large amount of energy present in the substrate.**
- **This type of respiration is most common in higher organisms.**

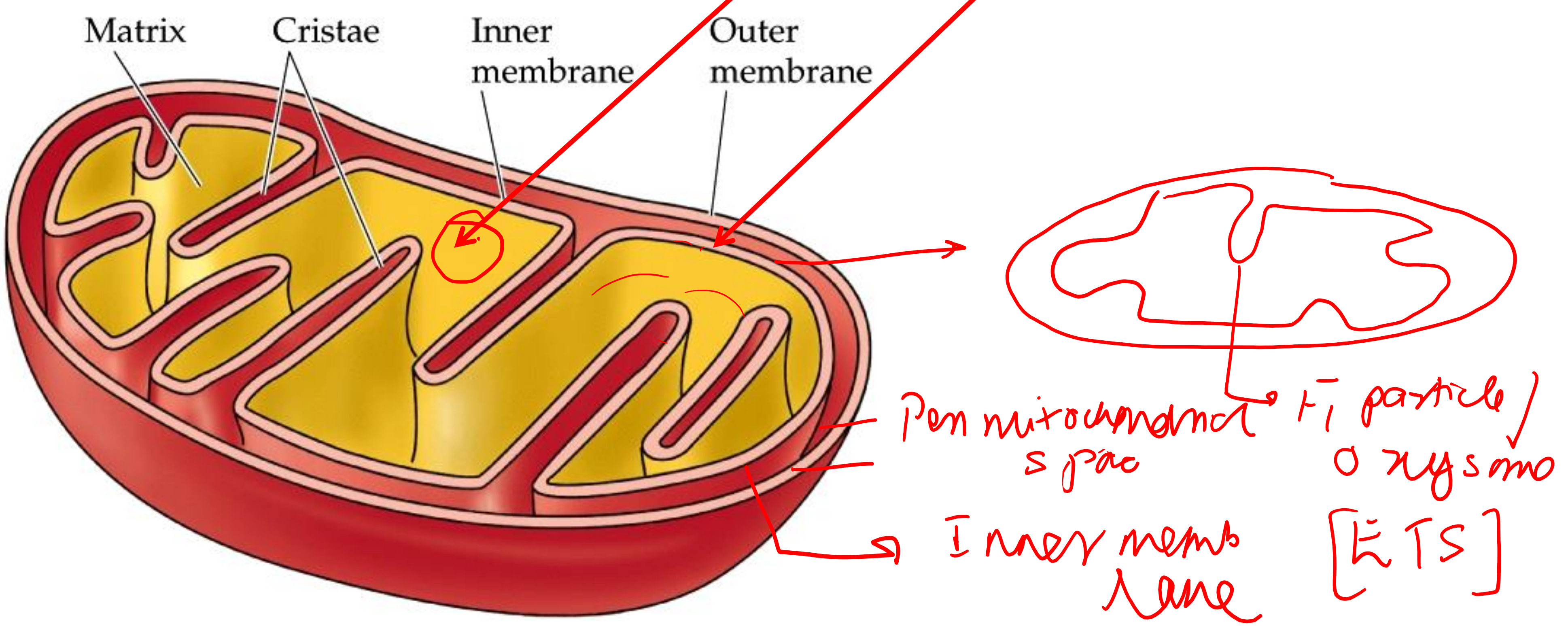


Aerobic respiration

- **Aerobic respiration takes place within mitochondria.**
- **Pyruvic acid is transported from the cytoplasm to the mitochondria.**
- **The important events in aerobic respiration are :**

1. **The complete oxidation of pyruvic acid by the stepwise removal of all the hydrogen atoms, leaving three molecules of CO_2.** Kreb's cycle
2. **The passing of the electrons removed as a part of hydrogen atoms to molecular O_2 with simultaneous synthesis of ATP.** ETS

- The 1st event takes place in the matrix of the mitochondria. Kreb's cycle
- The 2nd event takes place on the inner membrane of the mitochondria.



GLYCOLYSIS

GLYCOLYSIS

Means

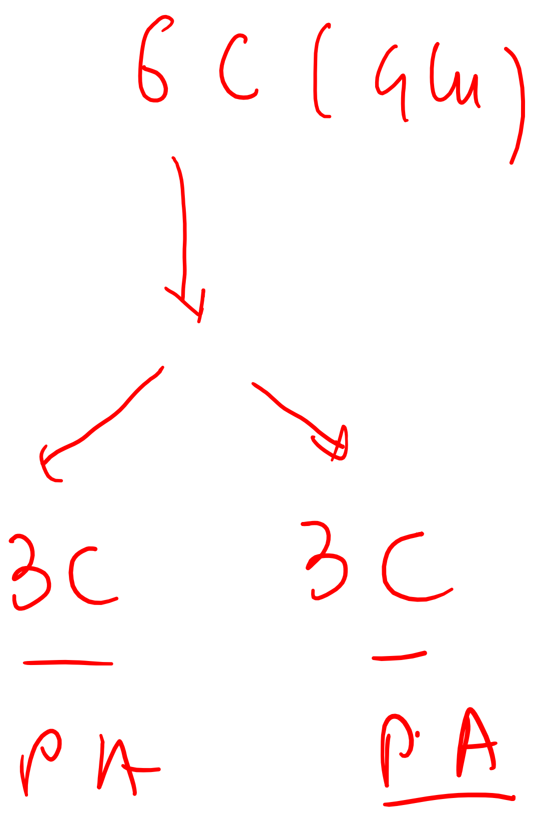
In Greek words

Glycos = Sugar
Lysis = Splitting

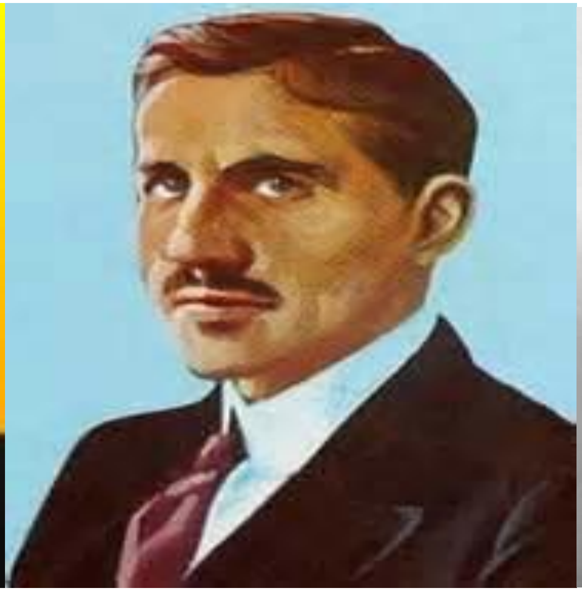
GLYCOLYSIS

- Glycolysis is the fir stage of respiratory metabolism in which hexose sugar undergoes part oxidation to form two molecules of Pyruvic acid (3 carbon comp

Glycolysis is the common step for both aerobic and anaerobic respiration and occurs in the cytosol.



❖ **The sequence of reactions in glycolysis were traced out by German scientists Embden, Meyerhoff and Paranas, it is known after them as "EMP pathway".**


Embden **Meyerhoff** **Paranas**

Dissacharide

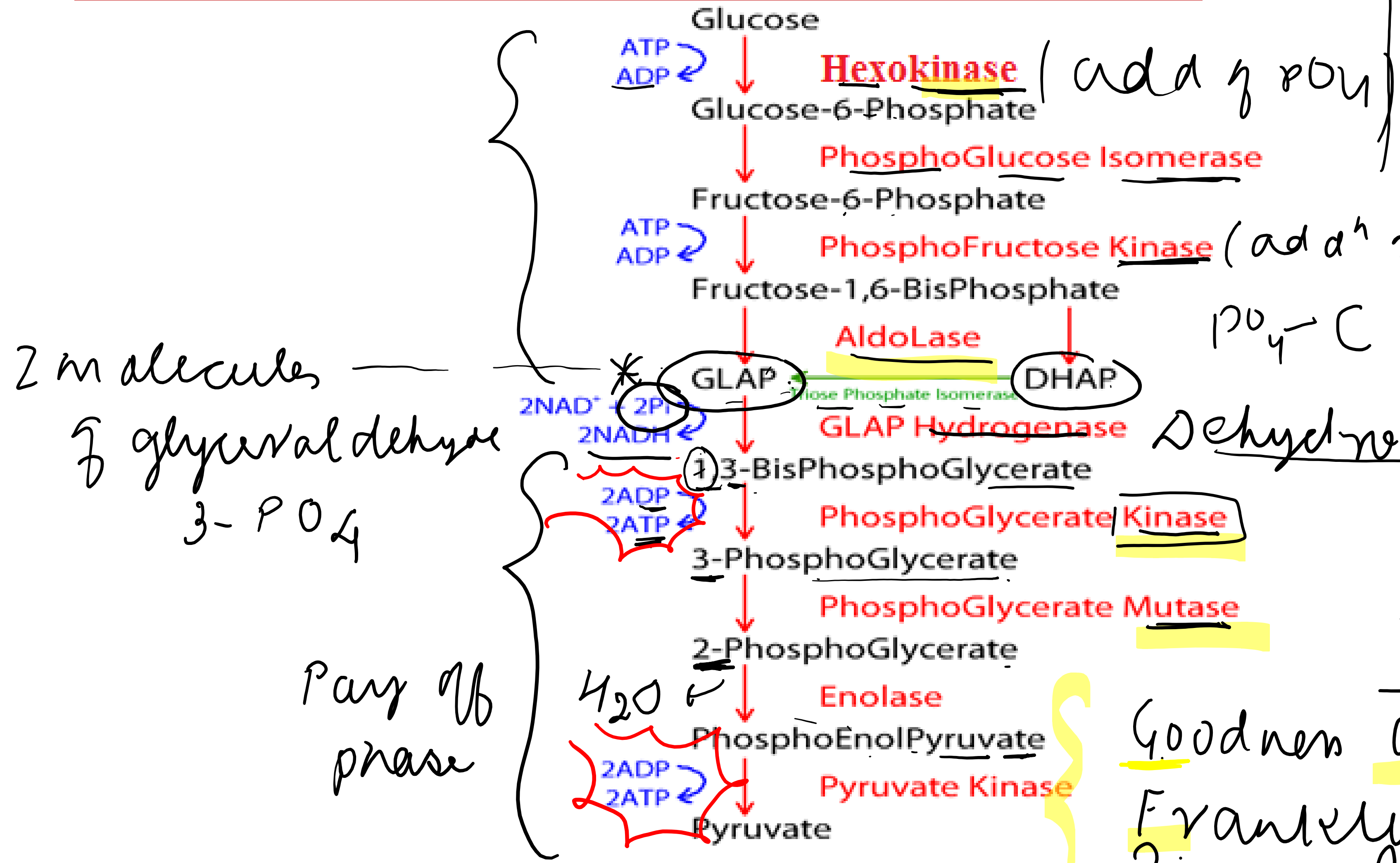
- **Sucrose is converted into glucose and fructose by the enzyme invertase, and these two monosaccharides readily enter the glycolytic pathway.**
- **Glucose and fructose are phosphorylated to give rise to glucose-6-phosphate in presence of hexokinase.**
- **Glucose-6-phospahte is isomerised to fructose-6-phosphate, in presence of hexose phosphate isomerase.**

$C_{12}H_{22}O_{11}$ → Sucrase

$C_6H_{12}O_6$ Glu

$C_6H_{12}O_6$ F-ruc

Reactions of the Glycolytic sequence



2 PA

ATP produced → 4ATP
ATP utilized → 2ATP
Net gain → 2ATP
2NADH2 → 6ATP
Gross ATP → 8ATP

PO4 – C – C – C + C – C – C – PO4

TRICK

Goodness Gracious Father, Franklin Did go By Picking Pumpkins (to) Prepare Pies

- **Fructose-6-phosphate reacts with ATP to form fructose 1, 6-bisphosphate, enzyme is phosphofructokinase.**
- **The fructose 1, 6-bisphosphate is split into DHAP and PGAL.**
- **This reaction is catalyzed by aldolase.**
- **DHAP is also isomerized to PGAL, this reaction is catalyzed by triose phosphate isomerase.**
- **PGAL is oxidised and with inorganic phosphate get converted into BPGA(1, 3 bisphosphoglycerate).**

- **This oxidation gives $2NADH_2$.**
- **This reaction is catalyzed by glyceraldehyde-3-phosphate dehydrogenase.**
- **The conversion of BPGA to PGA is also an energy yielding process.**
- **This energy is trapped in the form of ATP.**
- **Another ATP is synthesized during the conversion of PEP to pyruvic acid.**

- Pyruvic acid is then the key product of glycolysis.
- There are three major ways … ent cells handle pyruvic acid produced by gl…
- These are lactic … ic fermentation and aerobic respiration.

What is the metabolic fate of pyruvate?

This depends on the cellular need.

- **Fermentation takes place under anaerobic conditions in many prokaryotes and unicellular eukaryotes.**
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This required O_2 supply.

Oxidative decarboxylation of Pyruvic acid

Occurs in the Mitochondrial matrix.

- **Pyruvate which is formed by the glycolytic catabolism of carbohydrates in the cytosol, after entering mitochondrial matrix, undergoes oxidative decarboxylation by a complex set of reactions catalysed by pyruvic dehydrogenase.**

- **The reactions catalysed by pyruvic dehydrogenase require the participation of several coenzymes, including NAD^+ and Coenzyme A.**

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

- **During this process, two molecules of NADH are produced from the metabolism of two molecules of pyruvic acid (produced from one glucose molecule during glycolysis).**

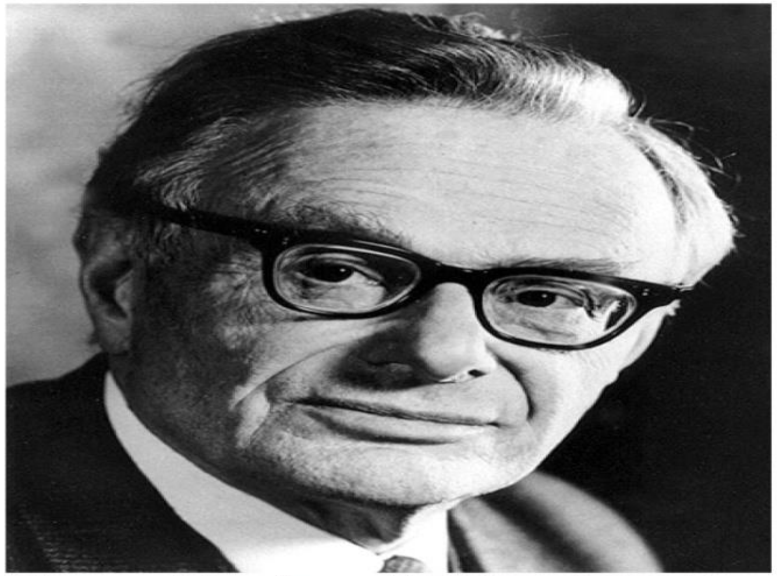
- **The acetyl CoA then enters a cyclic pathway, TCA cycle, more commonly called Krebs-cycle.**

AEROBIC RESPIRATION- TRICARBOXYLIC ACID CYCLE

Citric Acid cycle or Tricarboxylic Acid cycle or Krebs Cycle

- **In 1937 English Biochemist Sir Hans Krebs postulated the cycle of reactions which describe the oxidation of pyruvate to CO_2 and came to be known as Citric acid cycle.**

- **In 1953, Krebs was awarded Nobel prize, and the cycle is frequently referred to as Krebs cycle in his honour.**



Hans Krebs, 1900–1981

Citric Acid cycle or Tricarboxylic Acid cycle or Krebs Cycle

- **The TCA cycle starts with the condensation of acetyl group with OAA and water to yield citric acid.**
- **This reaction is catalised by citrate synthase and a molecule of CoA is released.**
- **Citrate is then isomerised to isocitrate.**
- **It is followed by two successive steps of decarboxylation, leading to the formation of α-Ketoglutaric acid and then succinyl-CoA.**

- **During the conversion of Succinyl CoA to Succinic acid a molecule of GTP is synthesized. This is a substrate level phosphorylation.**

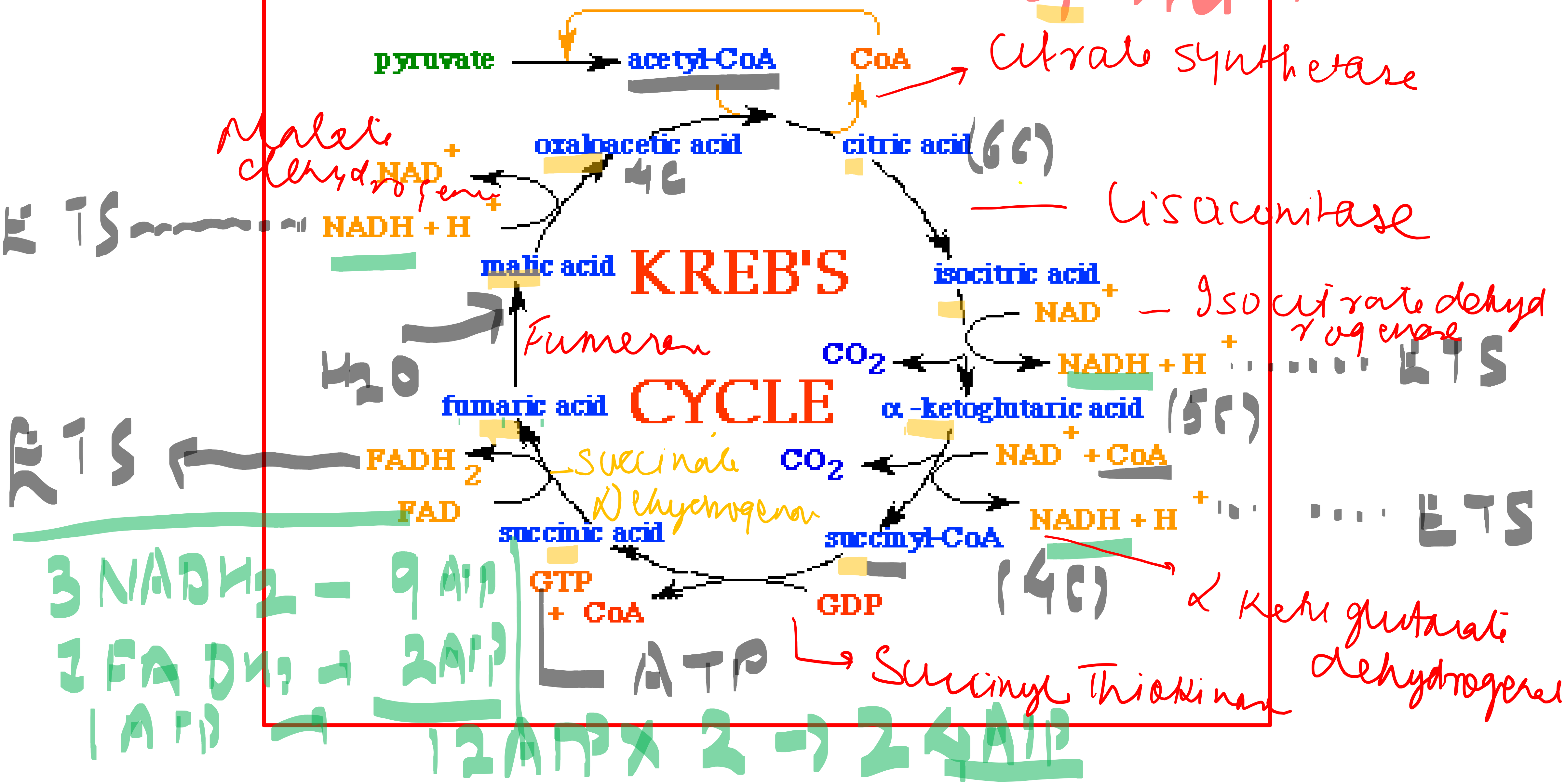
- **In a coupled reaction GTP is converted to GDP with the simultaneous synthesis of ATP from ADP.**

- **At 3 points NAD^+ is reduced to NADH + H^+ and at one point FAD^+ is reduced to $FADH_2$.**

- **The continued oxidation of acetyl CoA via the TCA cycle requires the continued replenishment of oxaloacetic acid, the first member of the cycle.**

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

"C I know Some Simple Formula making Optimal"



Sequence of Krebs cycle is :

1. CONDENSATION

OAA + Acetyl CoA+H_2O —Citric synthetase→ Citric acid + CoA

2. DEHYDRATION

Citric acid —Aconitase→ Cis-aconitic acid + H_2O

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2. DEHYDRATION

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3. HYDRATION

Cis-aconitic acid $\xrightarrow{\text{Aconitase}}$ Isocitric acid

4. OXIDATION -I

Isocitric acid + NAD^+ $\xrightarrow{\text{Isocitric dehydrogenase}}$ Oxalosuccnic acid+NADH+H^+

5. DECARBOXYLATION

Oxalosuccnic acid $\xrightarrow{\text{Oxalosuccinic decarboxylase}}$ α-Ketoglutaric acid +CO_2

6. OXIDATIVE DECARBOXYLATION(OXIDATION II)

α-Ketoglutaric acid +NAD^+ + Coenzyme A $\xrightarrow{\text{α-Ketoglutaric dehydrogenase}}$ Succinyl coenzyme A + NADH+H^++CO_2

7. CLEAVAGE

Succinyl coenzyme A + ADP+ Pi $\xrightarrow{\text{Succinic thiokinase}}$ Succinic acid + ATP+ CoA

8. OXIDATION III

Succinic acid +FAD^+ $\xrightarrow[\text{dehydrogenase}]{\text{Succinic}}$ Fumaric acid + $FADH_2$

9. HYDRATION

Fumaric acid + H_2O —Fumerase→ Malic acid

10. OXIDATION IV

Malic acid + NAD^+ —Malic dehydrogenase→ Oxaloacetic acid + $NADH + H^+$

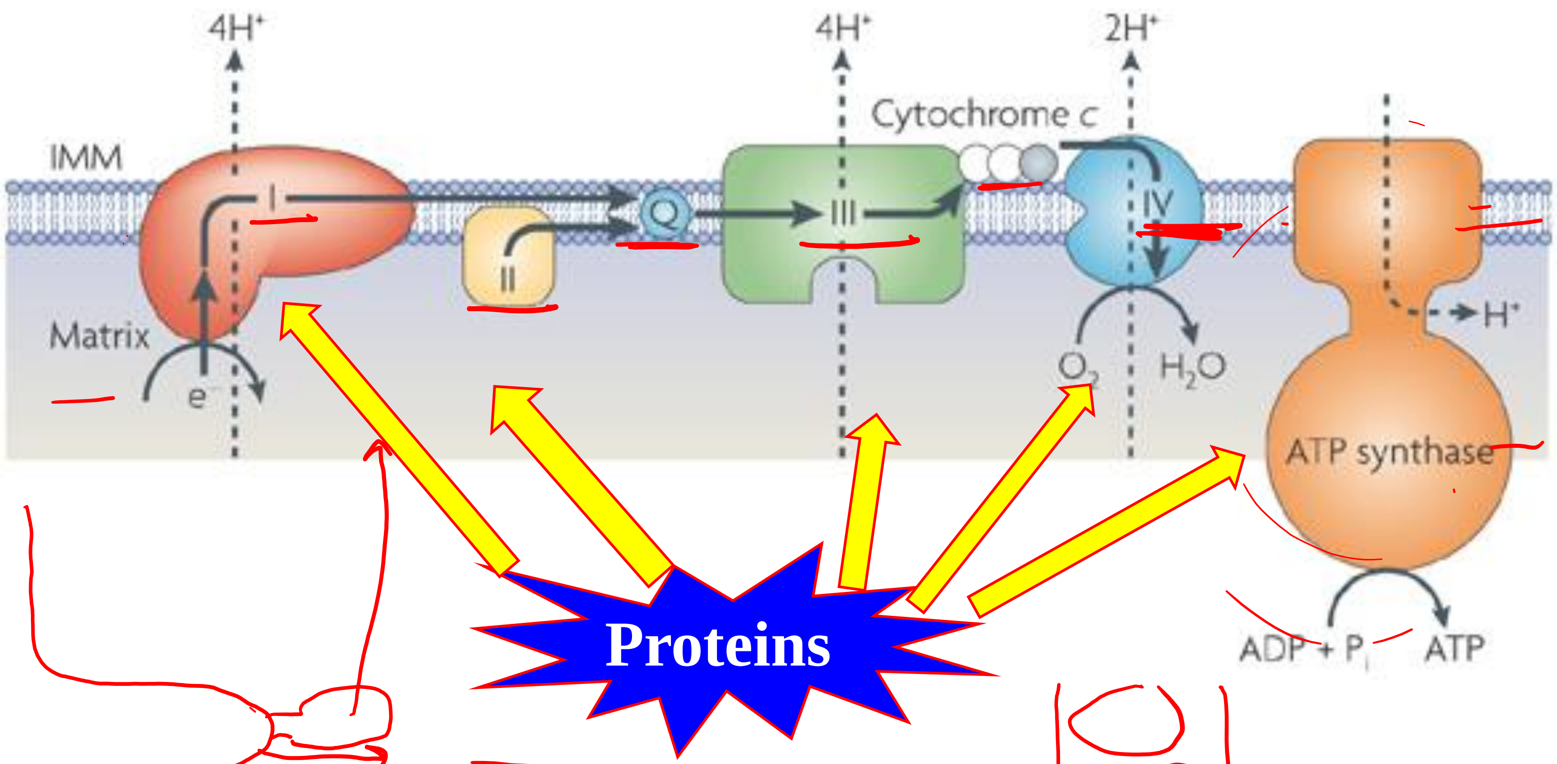
Summary equation for the oxidation of pyruvic acid in mitochondrion is:

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

Final Rxn of Krebs cycle

ELECTRON TRANSPORT SYSTEM AND OXIDATIVE PHOSPHORYLATION

Electron Transport System and Oxidative Phosphorylation



❖ Series of proteins in the mitochondria helps transfer electrons (e⁻) from NADH to Oxygen.

Most energy from Redox reactions

❖ Electrons during metabolic reactions sent to NAD and FAD.

Electron transport sy

❖ 5 Multiprotein co

❖ 2 mobile Carriers: Ubi ochrome 'C'.

**QNEET

No . of $NADH/FADH_2$ produced at various levels of aerobic respiration.

Complex I (NADH – dehydrogenase)

- It transfers electrons from NADH to Ubiquinone.

Ubiquinone located within the inner membrane.

Ubiquinone is the mobile carrier between complexes I and III and also between II and III.

Complex II (Succinate dehydrogenase)

❖ **Transfers electrons from Succinate to Ubiquinone ($FADH_2$ to Ubiquinone).**

Complex III (Cytochrome "c" reductase/cytochrome bc_1 complex)

❖ **Catalyse the reduction of Cytochrome c by the transfer of electrons from Ubiquinol.**

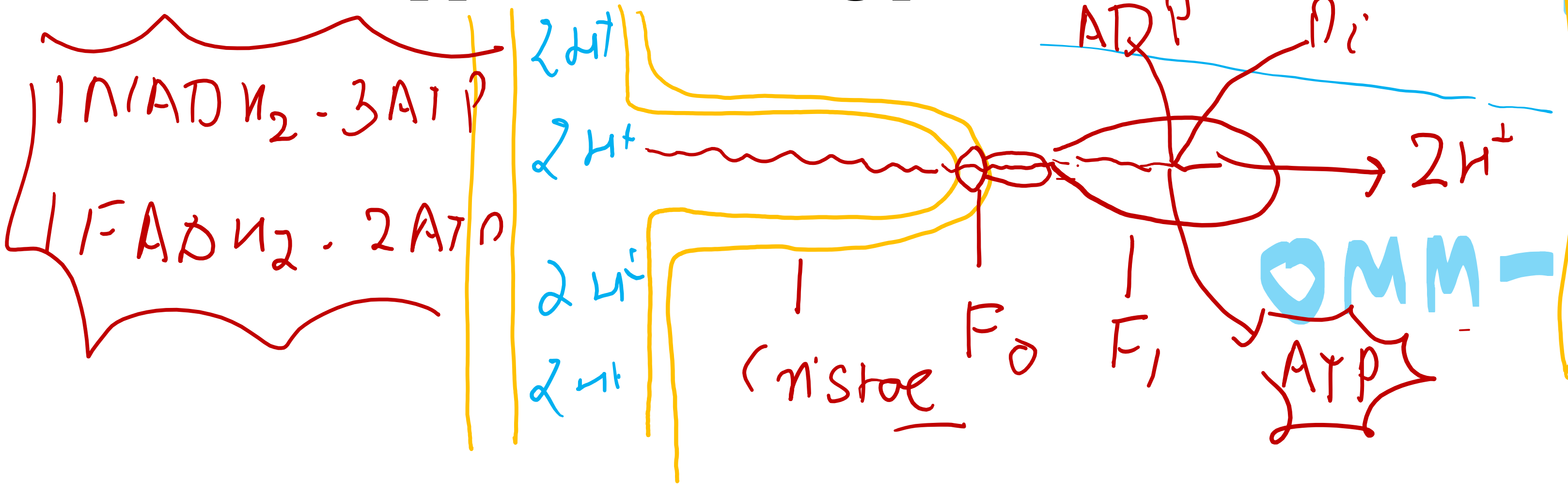
Cytochrome "c" is a small protein attached to the outer surface of the inner membrane.

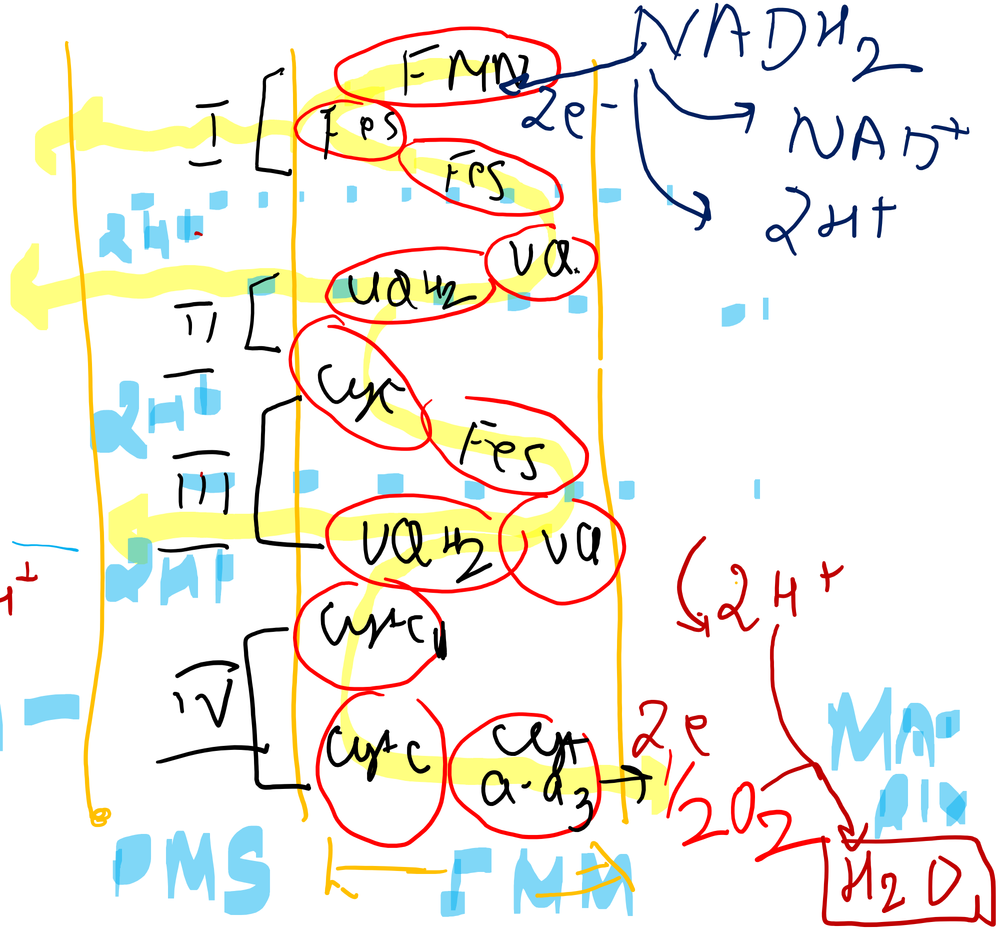
Complex IV (Cytochrome “c” oxidase)

- ❖ **Transfers electrons from reduced cytochrome ‘c’ to molecular oxygen.**

It Contain four units :

- ❖ **Cytochrome ‘a’**
- ❖ **Cytochrome ‘a_3’**
- ❖ **2 copper containing proteins**





Respiratory Balance sheet:

- **It is possible to make calculations of the net gain of ATP for every glucose molecule oxidized; but in reality this can remain only theoretical exercise.**

- **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.**

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

- None of the intermediates in the pathway is utilized to synthesize any other compound.

➢ But thes… …lid in a living system.

➢ All… …ake place one after the…

➢ Subs… …ithdrawn from it as and when necess… …nd when needed.

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

- **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 extracting and storing energy.**

- **Hence, there can be a net gain of 36 ATP molecules during aerobic respiration of one molecule of glucose.**

- ❖ **Now, let us compare fermentation and aerobic respiration.**

Fermentation	Aerobic respiration
i)Partial oxidation of glucose takes place	Complete oxidation of glucose takes place
ii)Net gain of ATP is 2	36 molecules (Net) of ATP is formed
iii)NADH is oxidised to NAD slowly	It is vigorous

Balance sheet of ATP production in aerobic oxidation of glucose

1) Glycolysis

i) ATP produced by substrate level phosphorylation

- ❖ 1,3- bisphosphoglyceric acid to 3- phosphoglyceric acid $2 \times 1 = 2$ ATP
- ❖ Phosphoenol pyruvic acid to pyruvic acid $2 \times 1 = 2$ ATP

4 ATP

ATP Consumed

- ❖ Glucose to Glucose – 6 - phosphate - 1 ATP
- ❖ Fructose – 6- phosphate to Fructose , 1,6- bisphosphate - 1 ATP

+ 4 ATP

Net gain of ATP (4 - 2) +2 ATP

* Imp NET

2. ATP from NADH generated in glycolysis:

- G-3-P to BPGA (2NADH, each worth 2 ATP) 2×2 ATP = 4 ATP
- ATP gain from glycolysis in the presence of O_2

6 ATP

------------------------ (a)

↳ $NADH_2$ via ETS

II. Oxidative decarboxylation of Pyruvic acid

Pyruvic acid to acetyl CoA (2NADH, each worth 3ATP)

From 2NADH (2 × 3 ATP) =6ATP ------------------------ (b)

→ via ETS

III Krebs (citric acid) cycle

i. ATP produced by substrate level phosphorylation

Succinyl Co A to Succinic acid **2 × 1 ATP= 2 ATP**

ii. From NADH

- Isocitric acid to Oxalosuccinic acid $2 \times 3ATP = 6\ ATP$
- α-Ketoglutaric acid to Succinyl CoA $2 \times 3ATP = 6\ ATP$
- Malic acid to Oxaloacetic acid $2 \times 3ATP = 6\ ATP$

iii. From $FADH_2$

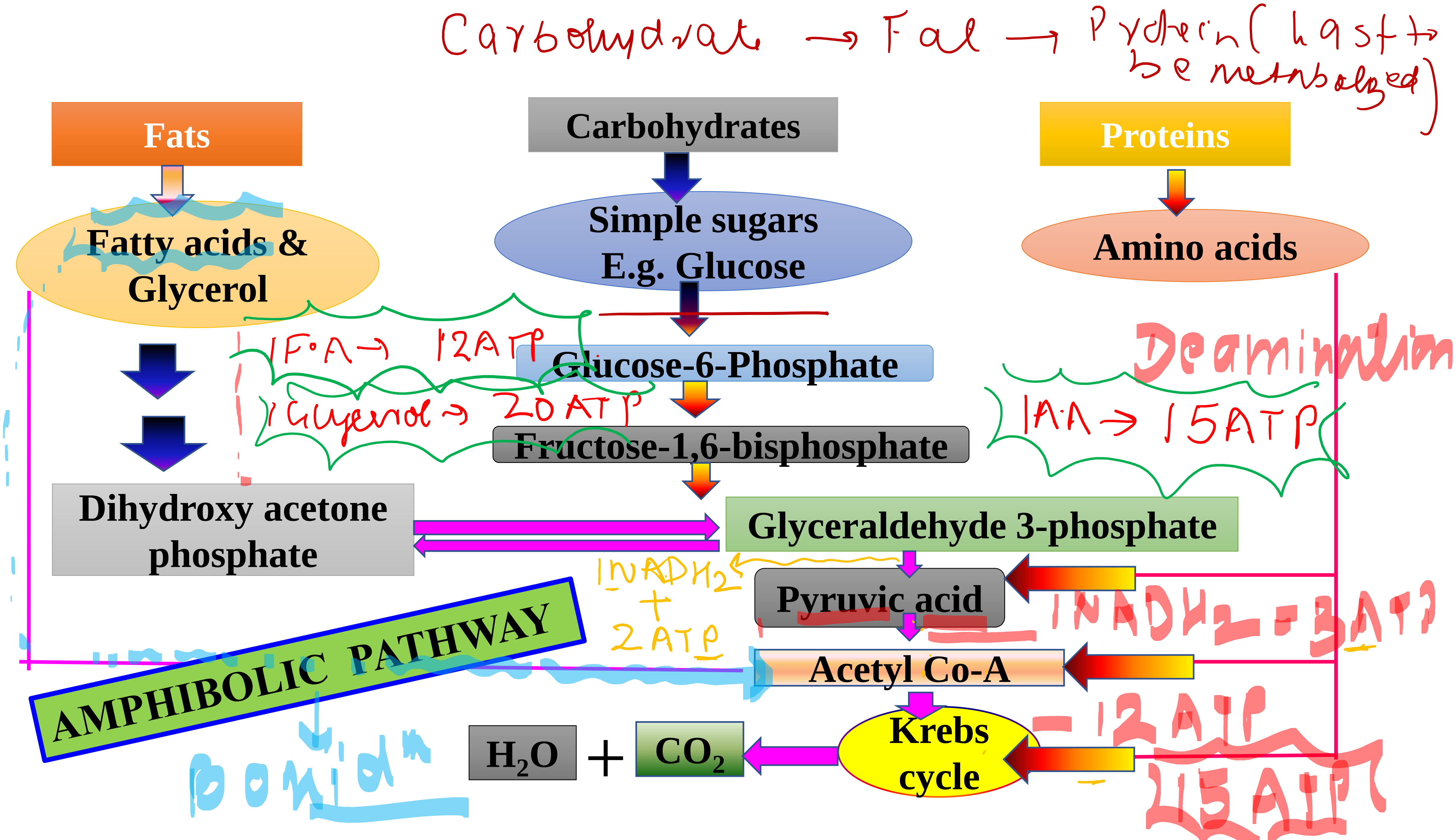
Succinic acid to Fumaric acid $2 \times 2ATP = 4$ ATP

ATP value of Kreb cycle(i+ii+iii) 24 ATP ---------------- (c)

Net gain of ATP in aerobic respiration per mole of glucose(a+b+c) 36 ATP

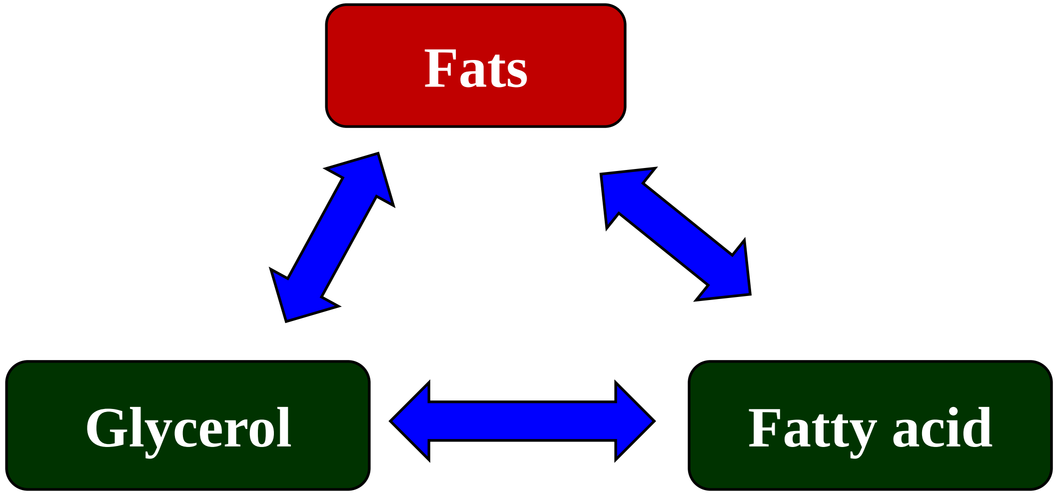
From Kreb's cycle

AMPHIBOLIC PATHWAY


Fats
Carbohydrates
Proteins
Fatty acids & Glycerol
Simple sugars E.g. Glucose
Amino acids
Glucose-6-Phosphate
Fructose-1,6-bisphosphate
Dihydroxy acetone phosphate
Glyceraldehyde 3-phosphate
Pyruvic acid
Acetyl Co-A
AMPHIBOLIC PATHWAY
Krebs cycle
H_2O + CO_2
Deamination
1 F.A → 12 ATP
1 Glycerol → 20 ATP
1 A.A → 15 ATP
1 NADH2 + 2 ATP
Carbohydrate → Fat → Protein (last to be metabolized)

- Glucose is the most favoured substrate for respiration.
- All carbohydrates are converted into glucose before they are used for respiration.
- Entry of different substrates in respiratory pathway:

Fats:



- If fatty acids to be respired first it would be degraded to acetyl Co-A.

  Fatty acids → Acetyl Co-A

- Glycerol enter the pathway after being converted to PGAL.

  Glycerol → PGAL

- Proteins degraded by Proteases and the individual amino acids (after deamination).

- **Respiration involves the breakdown of substrates, the respiratory process has traditionally been considered as Catabolic process and respiratory pathway as a catabolic pathway.**
- **Hence, fatty acids would be broken down to Acetyl CoA before entering the respiratory pathway when it is used as a substrate.**
- **But when the organism needs to synthesize fatty acids, Acetyl CoA would be withdrawn from the respiratory pathway for it.**
- **Hence, respiratory pathway comes into the picture both during the breakdown and synthesis of fatty acids, similarly breakdown and synthesis of proteins too.**

- **The breaking down process within the living organisms constitute Catabolism, while the synthesis is Anabolism.**

The respiratory pathway is involved in both anabolism and catabolism.

The respiratory pathway is considered as Amphibolic pathway rather than catabolic process.

RQ = RESPIRATORY QUOTIENT

- "The ratio between the volume of **Carbondioxide given out** and **oxygen taken** in respiration.

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

provides idea of the substrate being used.

- RQ is an index of type of substrate being respired.

Different respiratory substrates yield different RQ values.

Respiratory substrates

- Carbohydrates
- Proteins
- Fats
- Organic acids

Carbohydrates:

RQ value "1"

- **When carbohydrates are used as substrate and are completely oxidised, the RQ is 1.**

e.g. **Glucose**

CO_2 evolved = O_2 consumed

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

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

R.Q = 6/6 = 1

Fats:

- 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 below:

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

Tripalmitin

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

RQ value is "0.7"

→ Fats & protein R·Q is less than one

Protiens :

- When proteins are respiratory substrates the ratio would be about 0.9.
- What is important to recognise is that in living organisms respiratory substrates have RQ value more than 1.

Pure proteins or fats are never used as respiratory substrates.

For anaerobic Respiration

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

$R.Q = \frac{2}{0} = \infty$

Succulent plants — Malic Acid

$C_6H_{12}O_6 + 3O_2 \rightarrow C_4H_6O_5 + H_2O$

$\frac{0}{3O_2} = 0$