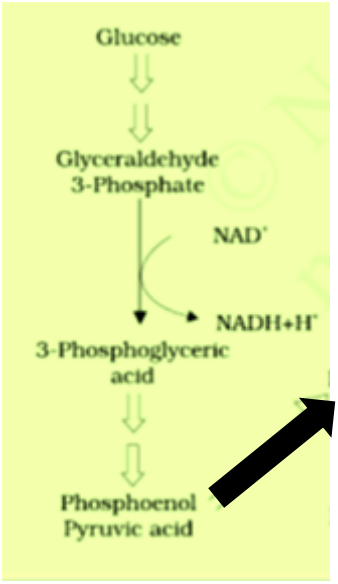
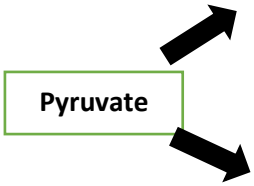
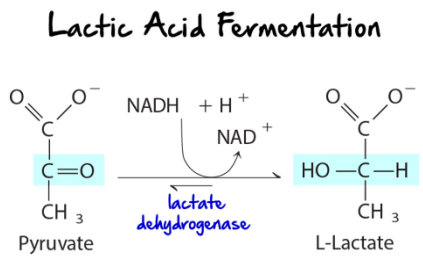
$C_6H_{12}O_6 + 2\ NAD^+ + 2\ ADP + 2\ Pi \longrightarrow 2\ Pyruvate + 2\ NADH + 2\ H^+ + 2\ ATP + 2\ H_2O$

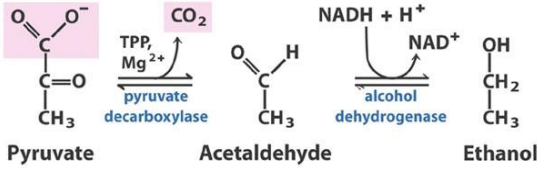
Fermentation

- In animal cells, like muscles during exercise, when oxygen is insufficient for aerobic respiration, pyruvic acid is reduced to **Lactic acid** by enzyme lactate dehydrogenase due to reoxidation of $NADH_2$ to NAD^+







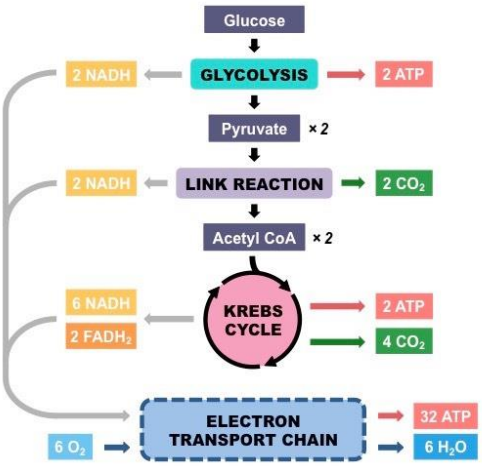


- In fermentation by yeast, pyruvic acid is converted to **Ethanol** and **CO2**. The enzyme involved is pyruvic acid decarboxylase and alcohol dehydrogenase catalyse this reaction.
- In both lactic acid and alcohol fermentation very less amount i.e. less than 7% of energy (**2ATP only**) in Glucose is released & the processes are hazardous.
- Yeasts poison themselves to death if concentration of alcohol reaches above 13%.
- All naturally fermented beverages contain maximum up to 13% alcohol concentration.
- Alcoholic beverages greater that 13% concentration are obtained through fractional distillation.

SN	Beverages	Concentration	Fermentation of Substrate
1	Beer	4-6%	Barley, wheat etc
2	Wine	10-13%	Fruits (grapes)
3	Champagne	12-13%	Grapes
4	Whisky	40-60%	Distillate Drinks from Wheat, Barley, fruits etc
5	Vodka	35-90%	
6	Rum	40-80%	
7	Brandy	40-80%	
8	Tequila	40-80%	

Aerobic Respiration

- Final product of glycolysis, pyruvate is transported from the cytoplasm into mitochondria for further breakdown.

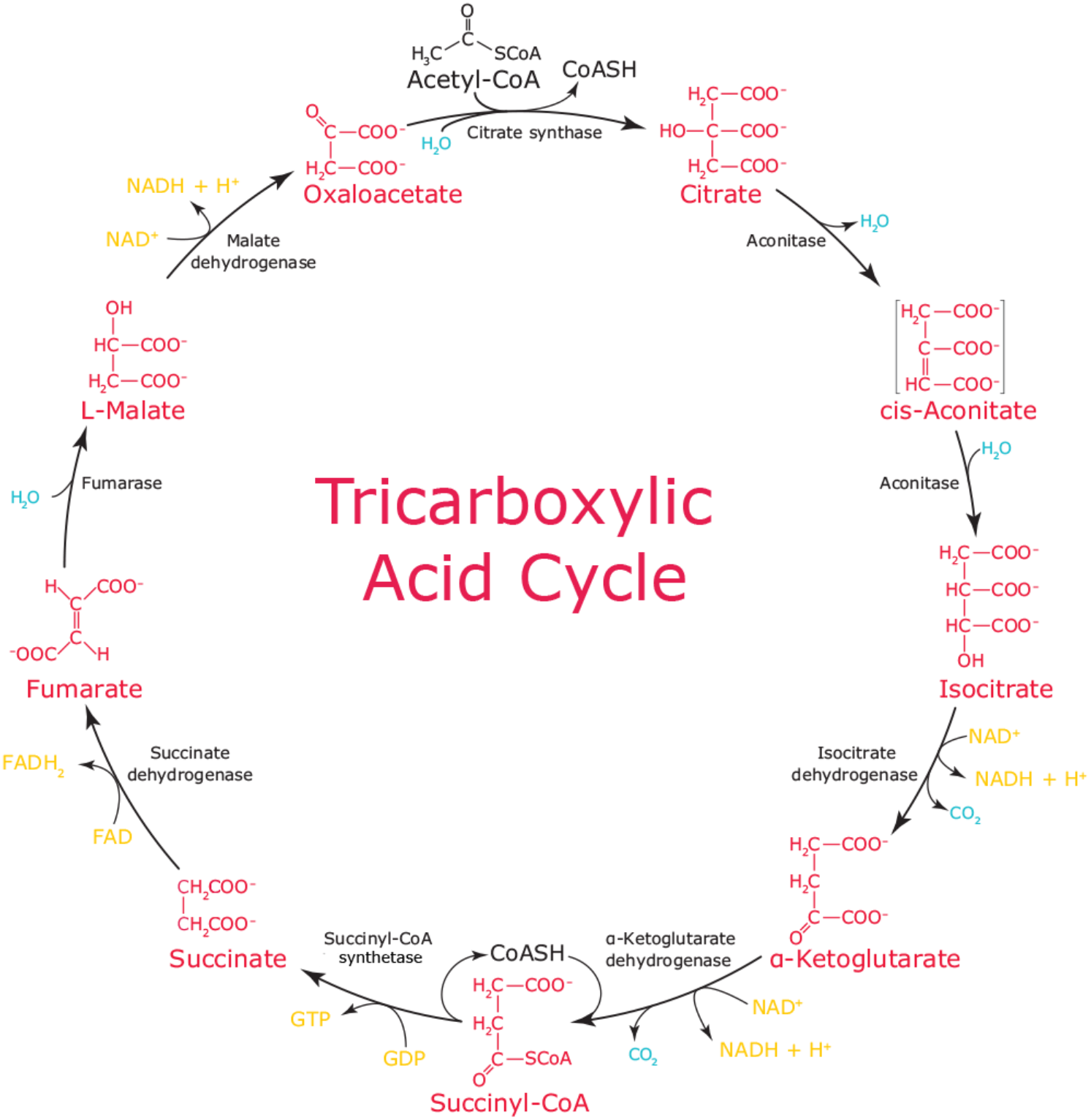


Link Reaction- Take place in matrix of mitochondria

- Pyruvate (3C) oxidised to Acetyl-CoA (2C) to produce CO2 and $NADH_2$. Catalysed by pyruvic dehydrogenase & Coenzymes including NAD+ participate.
- Acetyl CoA enters a cyclic pathway called TCA cycle or **Kreb's cycle**.

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

Tricarboxylic Acid (TCA) Cycle /Krebs Cycle : Discovered by Hans Krebs in 1940. Also known as citric acid cycle as first product is citric acid.



Trick to Learn				
Can	Citrate	Kerb's / TCA Cycle	Clever	Citrate Synthetase
Competent	Cis- Aconitate		Ants	Aconitase
Intelligent	Isocitrate		And	Aconitase
Karan	Alpha-ketoglutaric Acid		Intelligent	Isocitrate dehydrogenase
Solve	Succinyl CoA		Kangaroo	A-ketoglutarate dehydrogenase
Some	Succinate		Swiftly	Succinyl CoA Synthetase
Foreign	Fumerate		Skip	Succinate dehydrogenase
Mafia	Malic Acid		Fun	Fumarase
Operation	OxaloAcitic Acid		Mountains	Malate Dehydrogenase

Step 1: **Condensation or Formation of Citrate**

Acetyl-CoA (2C) + Oxaloacetate (4C) —*Citrate Synthase*→ Citrate (6C)

Step 2: **Isomerization of Citrate to Isocitrate**

Citrate (6C) ⇄ *Aconitase / Fe^{++}* ⇄ Cis-Aconitate (6C) ⇄ *Aconitase / Fe^{++}* ⇄ Isocitrate (6C)

(Cis- Aconitate is an intermediate product formed by removal of water and gets converted in Isocitrate by addition of water)

Step 3: **Oxidation Decarboxylation of Isocitrate to Alpha-Ketoglutarate**

Isocitrate (6C) + NAD^+ ⇄ *Isocitrate Dehydrogenase / Mn^{++}* ⇄ Alpha-Ketoglutarate (5C) + NADH + H^+ + CO_2

(Oxalosuccinate is an intermediate product formed during the reaction)

Step 4: **Oxidation Decarboxylation of Alpha-Ketoglutarate to Succinyl-CoA**

Alpha-Ketoglutarate (5C) + NAD^+ + CoA —*α-Ketoglutarate Dehydrogenase*→ Succinyl-CoA (4C) + NADH + H^+ + CO_2

(*α-Ketoglutarate Dehydrogenase complex contains Thiamine Pyrophosphate (TPP), Lipoic acid, Mg^{++} and transsuccinytase)*

Step 5: **Substrate-level phosphorylation of Succinyl-CoA to Succinate**

Succinyl-CoA (4C) + GDP + Pi —*Succinyl-CoA Synthetase*→ Succinate (4C) + GTP + CoA

Step 6: **Dehydrogenation or Oxidation of Succinate to Fumarate**

Succinate (4C) + FAD ⇄ *Succinate Dehydrogenase* ⇄ Fumarate (4C) + $FADH_2$

Step 7: **Hydration of Fumarate to Malate**

Fumarate (4C) + H_2O ⇄ Fumarase ⇄ Malate (4C)

Step 8: **Dehydrogenation or Oxidation of Malate to Oxaloacetate**

Malate (4C) + NAD^+ ⇄ Malate Dehydrogenase ⇄ Oxaloacetate (4C) + NADH + H^+

Combined Reaction (Link & Krebs Cycle) for one molecule of Pyruvate

Pyruvate + $4NAD^+$ + FAD^+ + $2H_2O$ + GDP + Pi —*Mitochondrial Matrix*→ $3CO_2$ + 4 NADH + $4H^+$ + $FADH_2$ + GTP

Glycolysis	2 ATP directly	= 2 ATP	
	2 molecules of NADH	= 6 ATP	Total 8 ATP
Pyruvic acid to acetyl Co-A	2 molecules of NADH	= 6 ATP	
Citric acid cycle	6 molecules of NADH	= 18 ATP	
	2 molecules of FADH	= 4 ATP	
	2 molecules of GTP	= 2 ATP	Total 24 ATP
	Total	**38 ATP**	