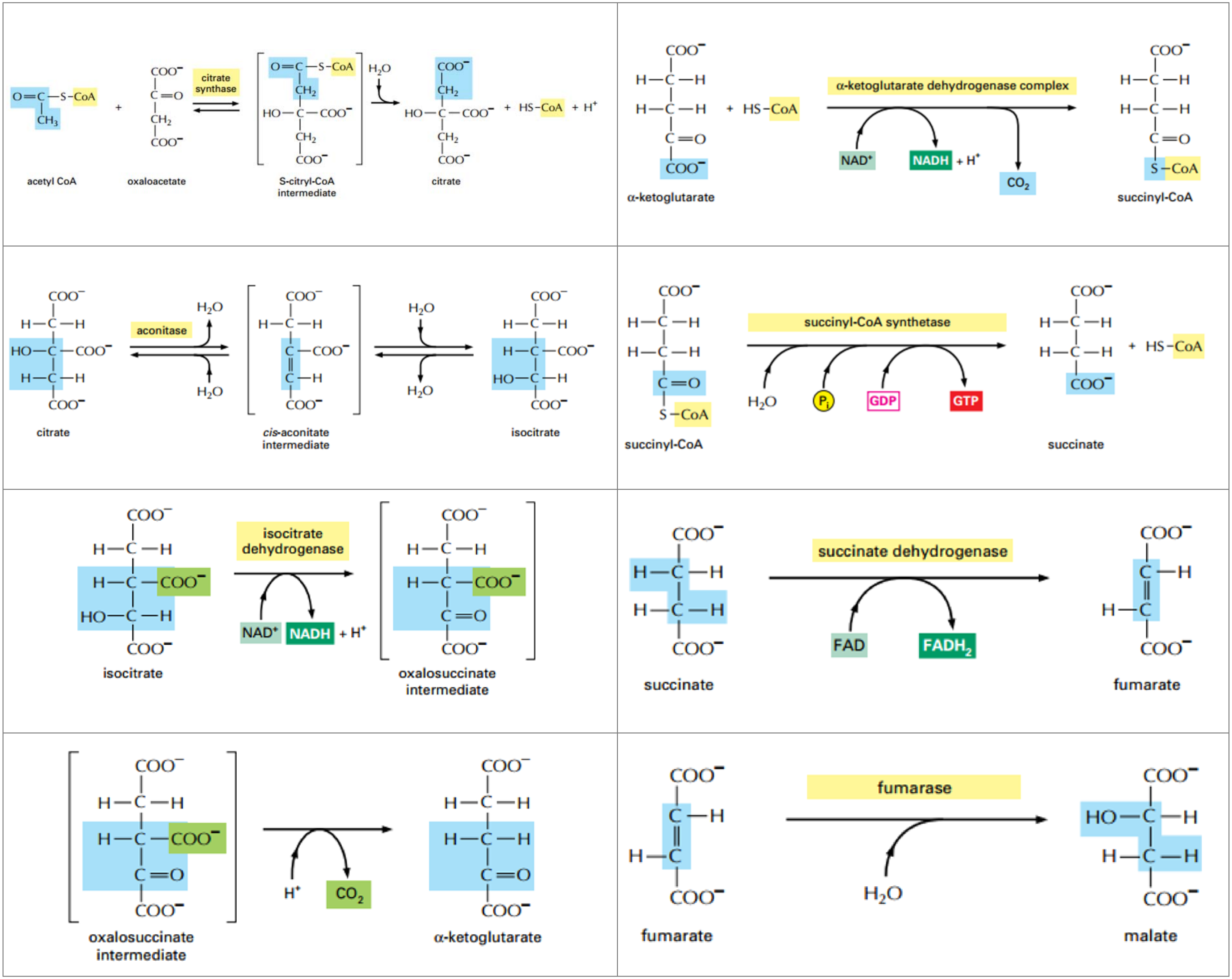
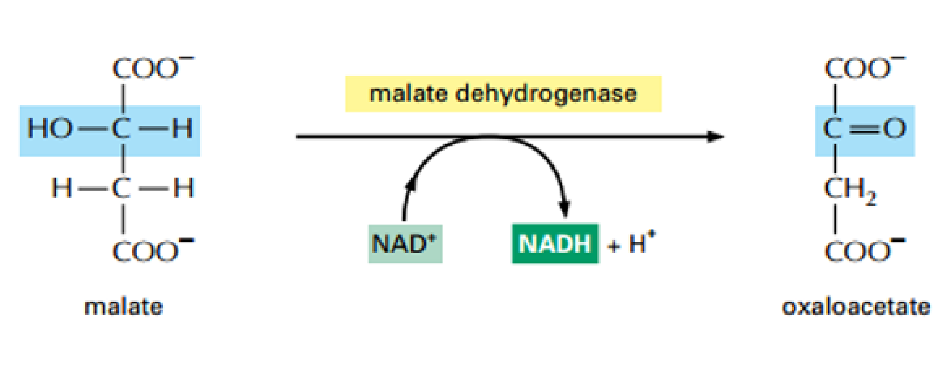
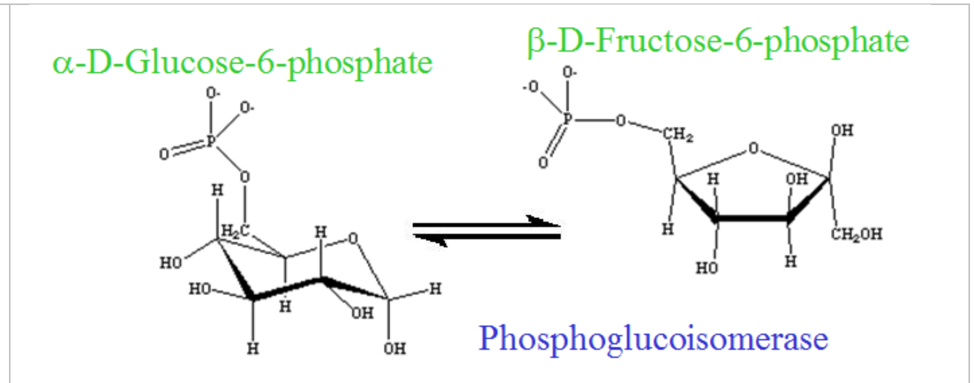
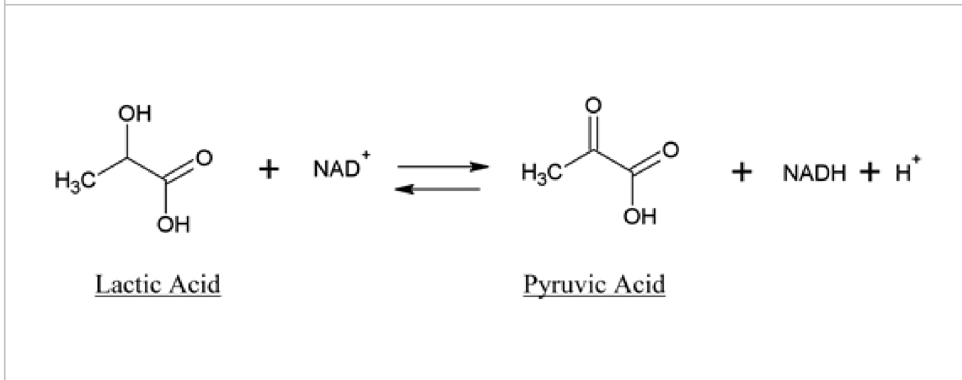
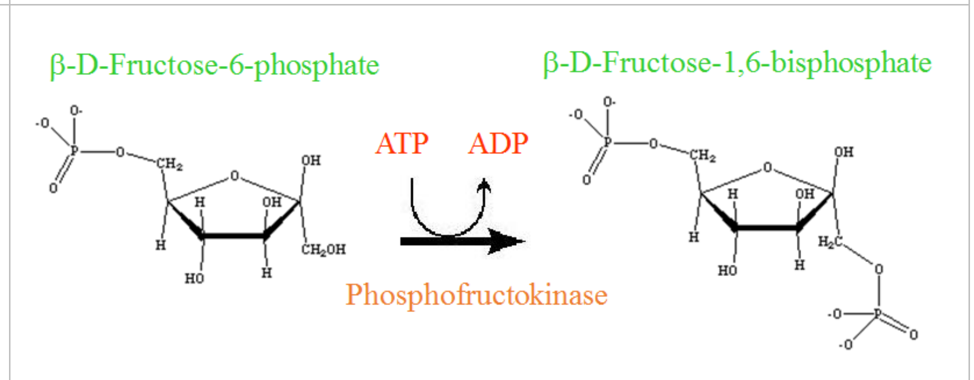

citrate synthase
acetyl CoA
oxaloacetate
S-citryl-CoA intermediate
citrate
H_2O
HS–CoA + H^+
α-ketoglutarate dehydrogenase complex
α-ketoglutarate
HS–CoA
NAD^+
NADH + H^+
CO_2
succinyl-CoA
aconitase
citrate
cis-aconitate intermediate
isocitrate
succinyl-CoA synthetase
H_2O
P_i
GDP
GTP
succinyl-CoA
succinate
isocitrate dehydrogenase
isocitrate
NAD^+
NADH + H^+
oxalosuccinate intermediate
succinate dehydrogenase
FAD
$FADH_2$
succinate
fumarate
oxalosuccinate intermediate
H^+
CO_2
α-ketoglutarate
fumarase
H_2O
fumarate
malate

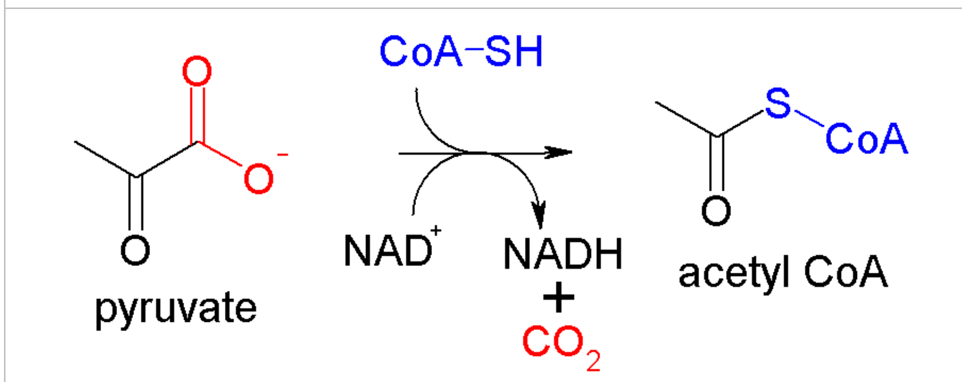
Type: Decarboxylation (-CO_2) Energy: Neutral – no redox coenzymes or ATP used or generated	Reaction: Hydration (+H_2O). An Alkene → 2° Alcohol Energy: Neutral – no redox coenzymes or ATP used or generated
Type: Dehydrogenation (-H_2)/Redox or Alcohol → Ketone Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: Molecule because a Alcohol is oxidized to form a Ketone or because lost bond to hydrogen and gained a bond to oxygen Energy: Cell gains energy because NAD^+ is reduced to form NADH	Reaction: Dehydrogenation (-H_2) "dehydrogenase" AND Redox. An Alkane → Alkene Reduced: The FAD is reduced to form $FADH_2$ Oxidized: The molecule loses two bonds to hydrogen. Energy: Cell gains energy because FAD is reduced to form $FADH_2$
Reaction 1 Type: Dehydration (-H_2O) or 2° Alcohol → Alkene Energy: Neutral – no redox coenzymes or ATP generated **Reaction 2** Type: Hydration (+H_2O) or Alkene → 2° Alcohol Energy: Neutral – no redox coenzymes or ATP used or generated	Reaction: Substrate Level Phosphorylation (SLP). The molecules loses the CoAS, temporarily gains a PO_4 group and transfers it to GDP to make GTP Energy: Cell gains energy by gaining a High Energy Phosphate Bond (HEPB) by converting GDP to GTP (equivalent to ATP)
Reaction 1 Type: Aldol Condensation (Ketone + Ketone →Aldol) Energy: Neutral – no redox coenzymes or ATP generated **Reaction 2** Type: Hydrolysis (+H_2O) of Thioester (S) bond Energy: Neutral – no redox coenzymes or ATP used or generated	Reaction: Decarboxylation (-CO_2) AND Redox Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: Molecule gains a bond to Sulfur (same as gaining bond to Oxygen) or Oxidation number of bottom carbon (COO^-) = +3 goes to (CO_2) = +4 or Oxidation number of Ketone carbon goes from +2 to +4 Energy: Cell gains energy because NAD^+ is reduced to form NADH

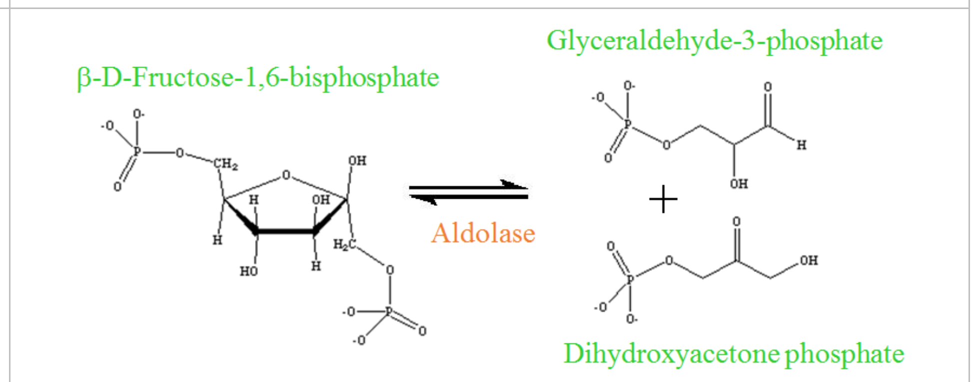

malate dehydrogenase
NAD+
NADH + H+
malate
oxaloacetate

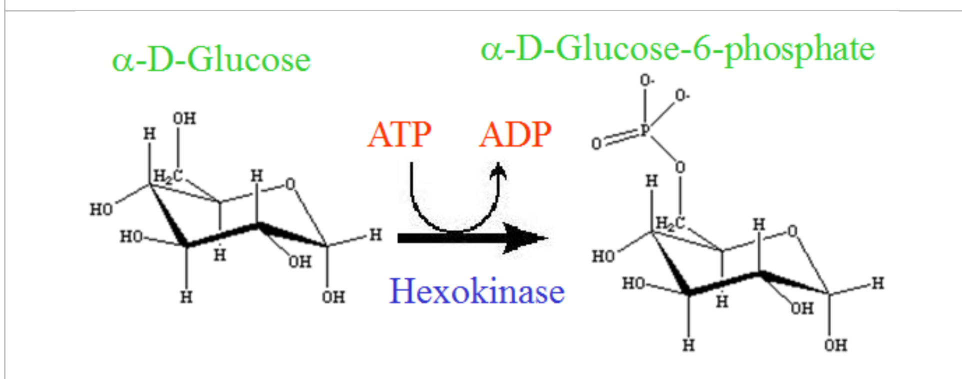

α-D-Glucose-6-phosphate
β-D-Fructose-6-phosphate
Phosphoglucoisomerase

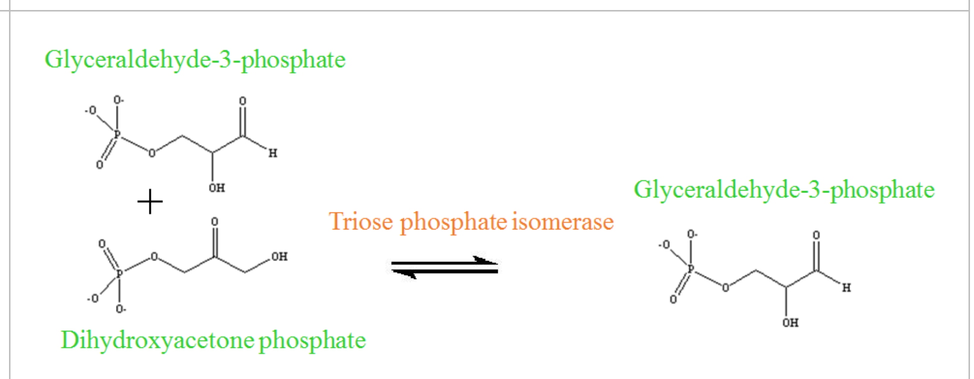

NAD+
NADH + H+
Lactic Acid
Pyruvic Acid


β-D-Fructose-6-phosphate
β-D-Fructose-1,6-bisphosphate
ATP
ADP
Phosphofructokinase

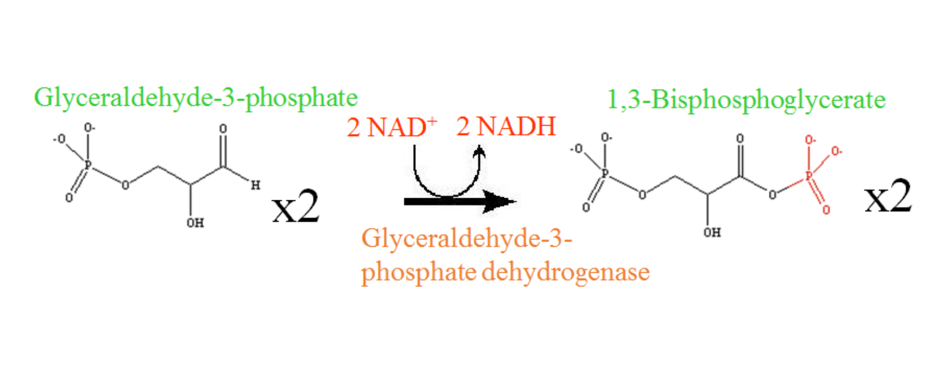

CoA–SH
NAD+
NADH
+
CO2
pyruvate
acetyl CoA

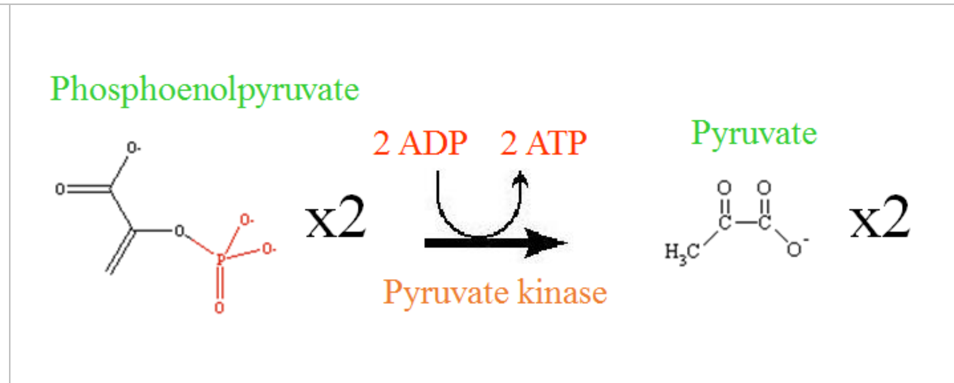

β-D-Fructose-1,6-bisphosphate
Glyceraldehyde-3-phosphate
Aldolase
Dihydroxyacetone phosphate

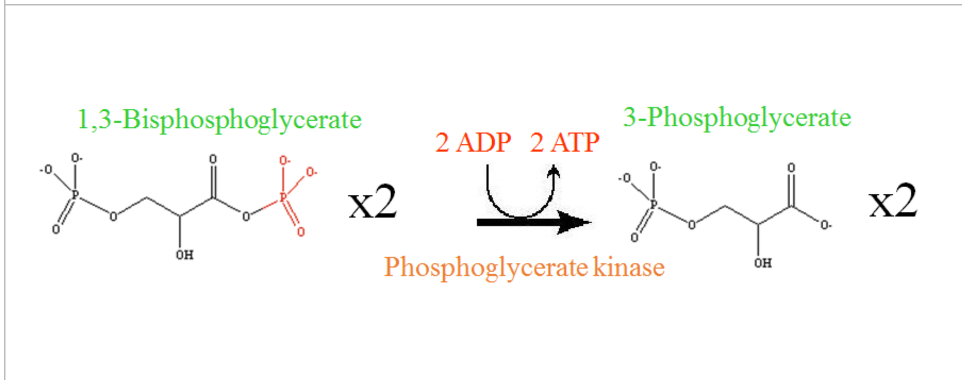

α-D-Glucose
α-D-Glucose-6-phosphate
ATP
ADP
Hexokinase

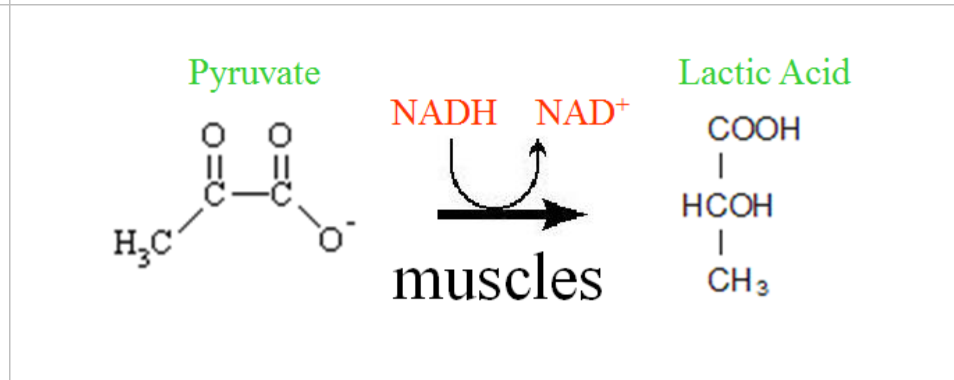

Glyceraldehyde-3-phosphate
Dihydroxyacetone phosphate
Triose phosphate isomerase
Glyceraldehyde-3-phosphate

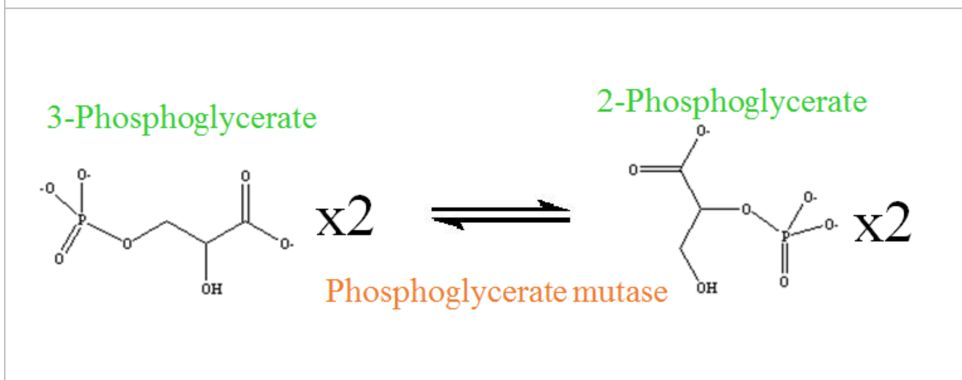
Reaction: Transfer of a PO_4 group from ATP to Molecule Energy: Cell <u>loses</u> energy, a HEPB is broken when ATP is converted to ADP	Reaction: The bottom molecule undergoes an isomerization "isomerase" reaction to make a second Glyceraldehyde-3-phosphate molecule Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated Misc: Instead of having 2 different molecules and requiring 2 different metabolic pathways, this reaction converts one molecule into the other thus combining the 2 metabolic pathways into 1.
Reaction: Decarboxylation ($-CO_2$) AND REDOX (or thioesterfication) Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: The molecule is oxidized, it gains a bond to Sulfur (equivalent to Oxygen). The oxidation number of the last carbon (COO^-) = +3 goes to (CO_2) = +4 or Oxidation number of Ketone carbon goes from +2 to +4 Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Molecule "explodes" (technically there is no name for this reaction) but you should describe it. The molecules is split into two smaller molecules by a Lysase reaction Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated
Reaction: Redox or a 2° Alcohol → Ketone Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: The molecule loses a bond to H and gains a bond to oxygen or a 2° Alcohol is oxidized to a Ketone Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Transfer of a PO_4 group from ATP to Molecule Energy: Cell <u>loses</u> energy, a HEPB is broken when ATP is converted to ADP
Reaction: Dehydrogenation ($-H_2$) "dehydrogenase" AND Redox. A 2° Alcohol → Ketone Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: The molecule loses a bond to H and gains a bond to oxygen or a 2° Alcohol is oxidized to a Ketone Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Isomerization "isomerase". (same formula different structure) Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated Misc: Allows fructose to enter the glycolysis pathway (control mechanism/links two pathways together)

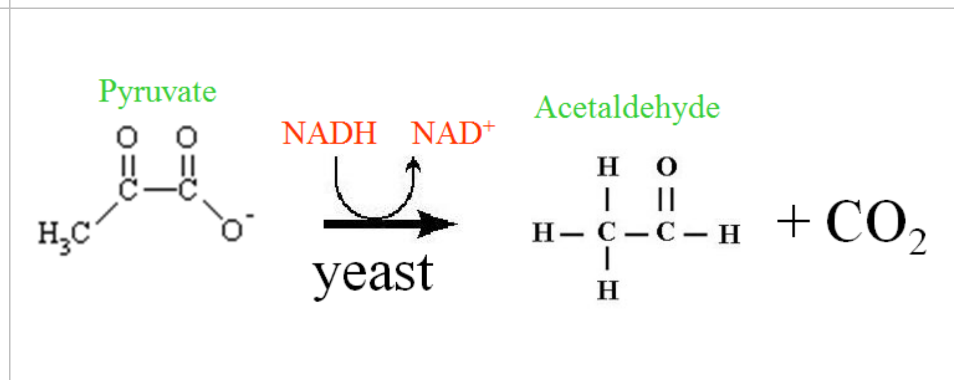

Glyceraldehyde-3-phosphate
x2
2 NAD+
2 NADH
Glyceraldehyde-3-phosphate dehydrogenase
1,3-Bisphosphoglycerate
x2

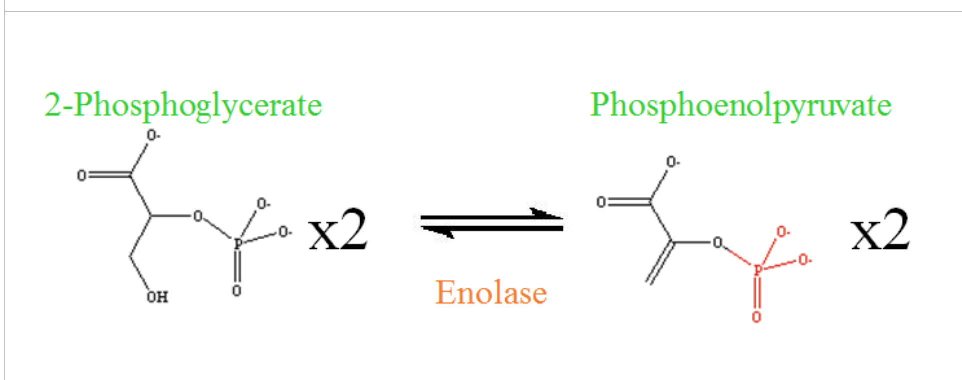

Phosphoenolpyruvate
x2
2 ADP
2 ATP
Pyruvate kinase
Pyruvate
x2

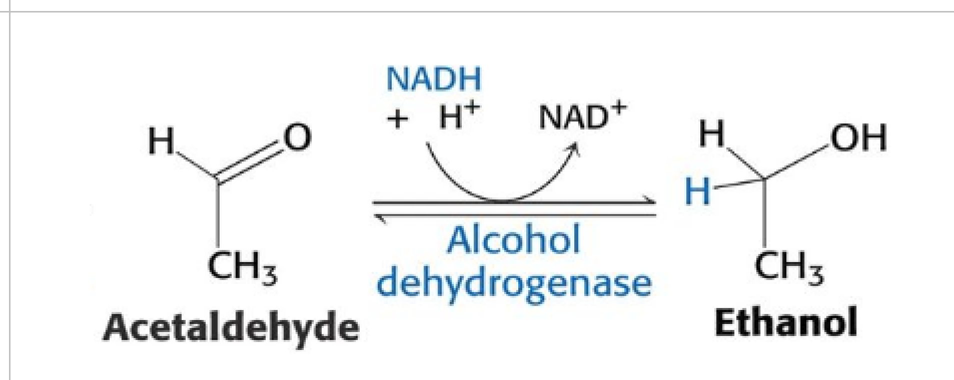

1,3-Bisphosphoglycerate
x2
2 ADP
2 ATP
Phosphoglycerate kinase
3-Phosphoglycerate
x2


Pyruvate
NADH
NAD+
muscles
Lactic Acid
COOH
HCOH
CH3

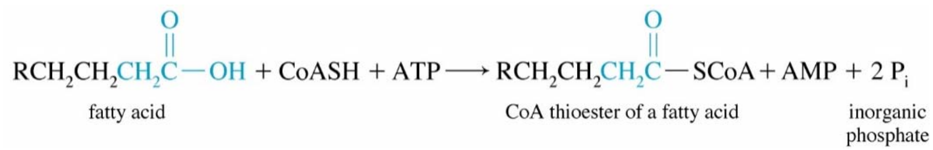

3-Phosphoglycerate
x2
Phosphoglycerate mutase
2-Phosphoglycerate
x2

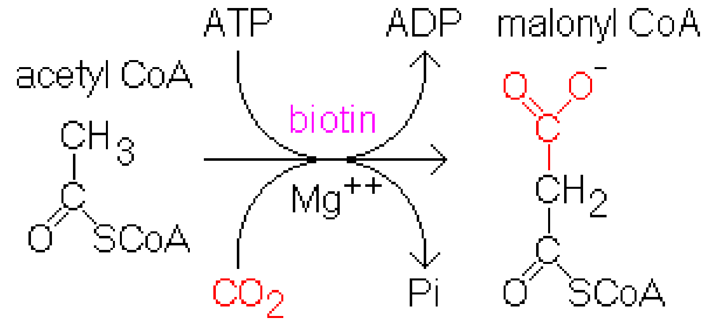

Pyruvate
NADH
NAD+
yeast
Acetaldehyde
+ CO2

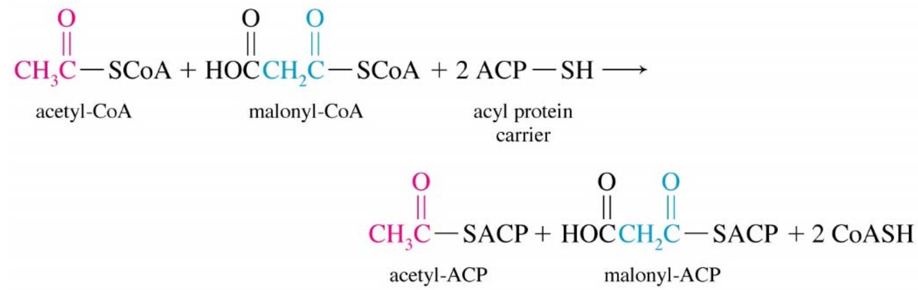

2-Phosphoglycerate
x2
Enolase
Phosphoenolpyruvate
x2

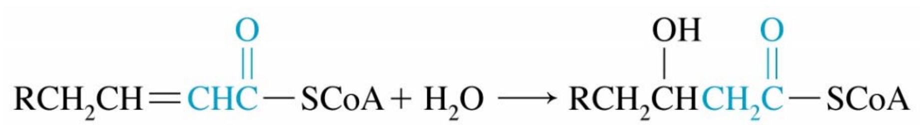

NADH
+ H+
NAD+
Alcohol dehydrogenase
Acetaldehyde
Ethanol

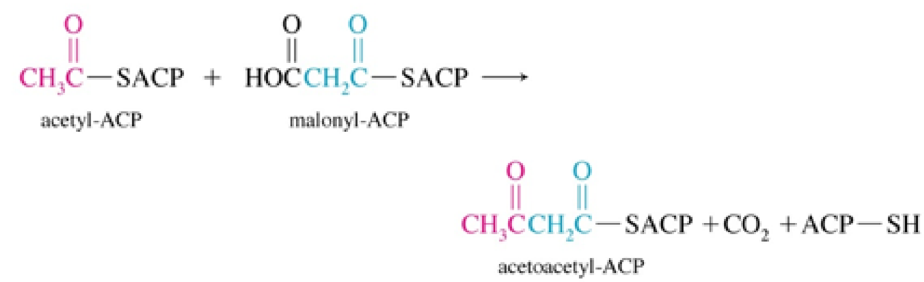
Reaction: Elimination ($-H_2O$) or Dehydration or 1° Alcohol → Alkene Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated	Reaction: Hydrogenation ($+H_2$) AND Redox. Aldehyde → 1° Alcohol Reduction: The aldehyde function group is reduced to form an alcohol. The oxidation number changes from +1 to -1 Oxidized: The redox co-enzyme is oxidized from NADH to NAD^+
Reaction: Isomerization reaction "mutase". The –OH and PO_4 groups swap places (same formula different structure) Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated	Reaction: Decarboxylation ($-CO_2$) AND Redox. Reduction: The second carbon is reduced from a Ketone to an Aldehyde and gained a bond to H. Oxidized: The redox co-enzyme is oxidized from NADH to NAD^+ Energy: Cell <u>loses</u> energy because NADH is oxidized to form NAD^+
Reaction: Substrate Level Phosphorylation (SLP). The molecules loses a PO_4 group and transfers it to ADP to make ATP Energy: Cell <u>gains</u> energy by gaining a High Energy Phosphate Bond (HEPB) by converting ADP to ATP	Reaction: Redox. On the middle carbon the Ketone → 2° Alcohol Reduction: The molecule is reduced, a Ketone is reduced to a 2° Alcohol. The molecule lost a bond to oxygen and gained a bond to H. Oxidized: The redox co-enzyme is oxidized from NADH to NAD^+ Energy: Cell <u>loses</u> energy because NADH is oxidized to form NAD^+
Reaction: Dehydrogenation ($-H_2$) + Redox. Aldehyde loses bond to hydrogen and gains a bond to the oxygen in the phosphate group (Ald -> CA). Reduction: The NAD^+ is reduced because it gained a bond to H. Oxidized: Aldehyde loses a bond to H and gains a bond to Oxygen Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Substrate Level Phosphorylation (SLP). The molecules loses a PO_4 group and transfers it to ADP to make ATP Energy: Cell <u>gains</u> energy by gaining a High Energy Phosphate Bond (HEPB) by converting ADP to ATP

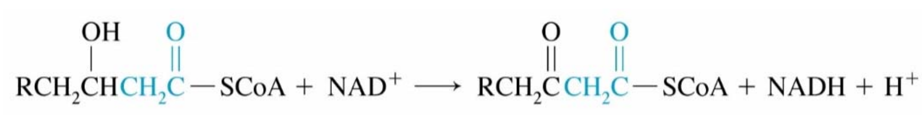

fatty acid
CoA thioester of a fatty acid
inorganic phosphate

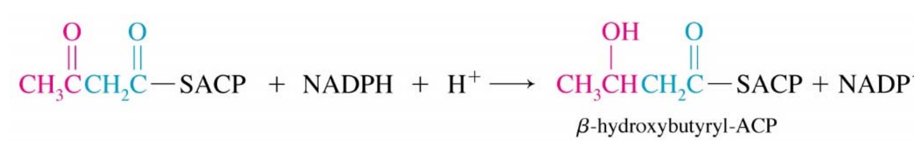

acetyl CoA
ATP
ADP
malonyl CoA
biotin
Mg++
CO2
Pi


acetyl-CoA
malonyl-CoA
acyl protein carrier
acetyl-ACP
malonyl-ACP

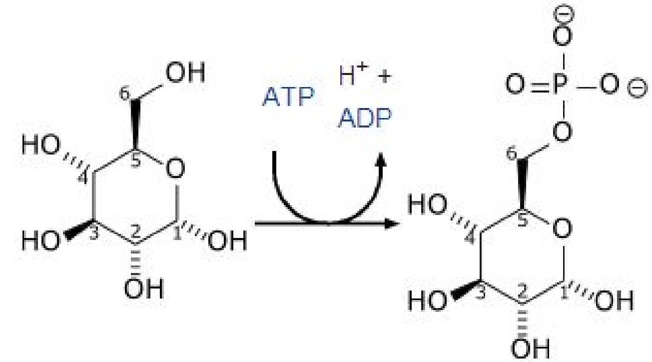
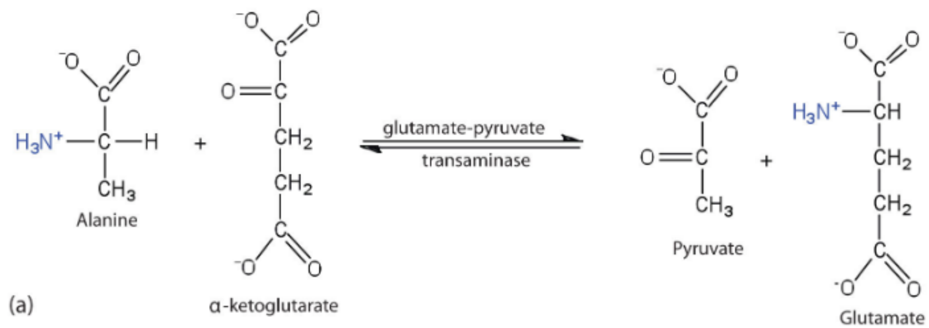
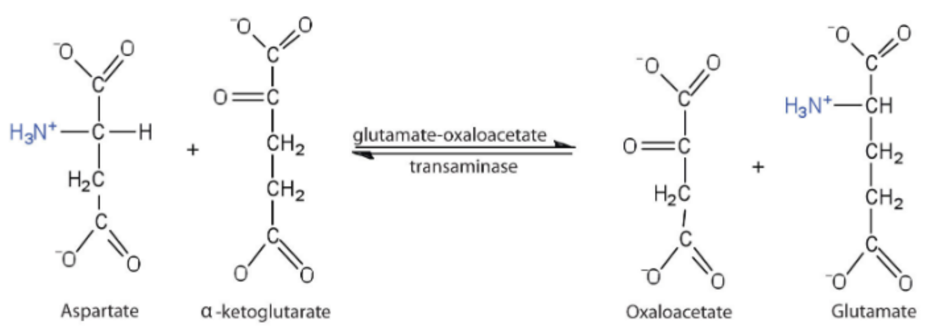



acetyl-ACP
malonyl-ACP
acetoacetyl-ACP

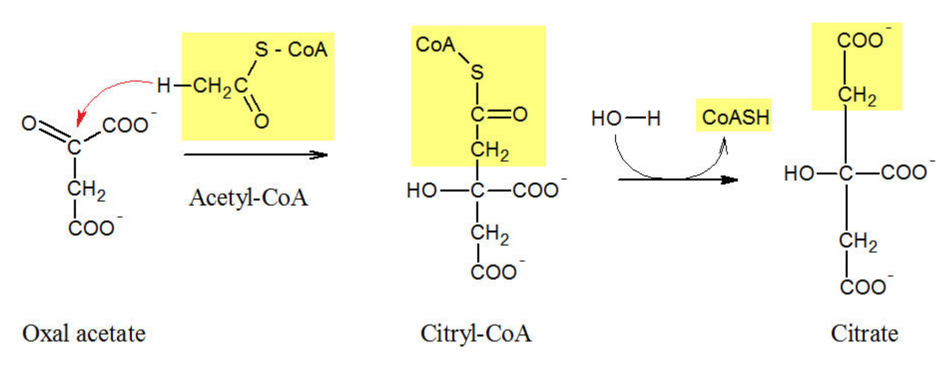


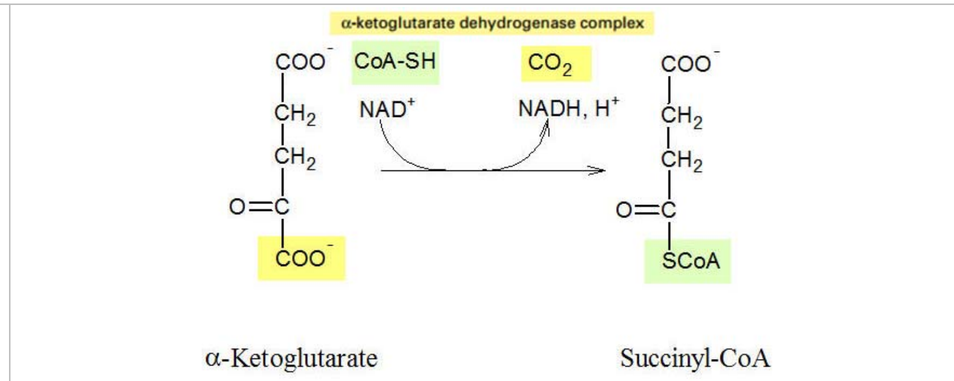

β-hydroxybutyryl-ACP

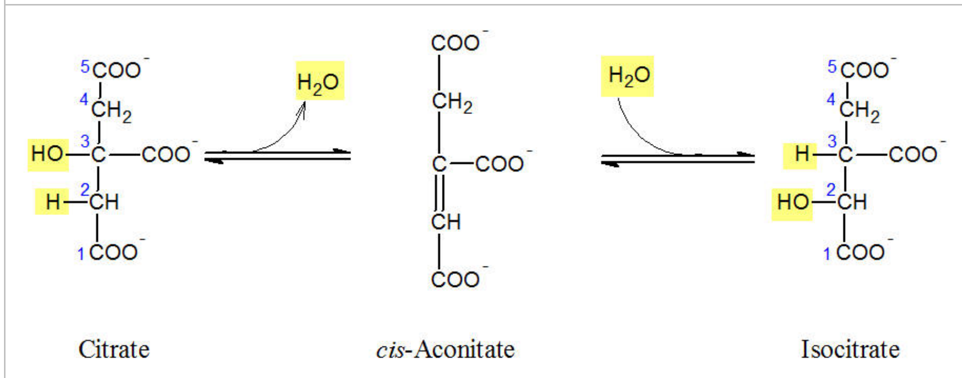
Reaction: Dehydrogenation ($-H_2$) AND Redox. 2° Alcohol → Ketone Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: The molecule loses two bonds to hydrogen and gains a bond to oxygen. A secondary alcohol is oxidized to a ketone. Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Hydrogenation AND Redox. Hydrogen is added across the C=O bond. Ketone → Alcohol Reduced: The molecule is reduced, it lost a bond to oxygen and gained 2 bonds to hydrogen. A ketone reduced to form an alcohol. Oxidized: The redox co-enzyme is oxidized from NADPH to $NADP^+$ Energy: Cell <u>loses</u> energy because NADPH is oxidized to form $NADP^+$
Reaction: Hydration ($+H_2O$)/Addition. Alkene → 2° Alcohol Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated	Reaction: Condensation (2 molecules → 1 molecule) AND a Decarboxylation ($-CO_2$). Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated
Reaction: Dehydrogenation ($-H_2$) or Elimination AND Redox. Alkane → Alkene. Reduced: The FAD is reduced to form $FADH_2$ Oxidized: The molecule loses two bonds to hydrogen. An alkane is reduced to an Alkene. Energy: Cell <u>gains</u> energy because FAD is reduced to form $FADH_2$	Reaction: Transfer reaction – SACP and CoASH swap places. Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated Misc: The reaction takes a molecule tagged as being used in the CAC cycle (it has CoASH attached) to being tagged as being used in Lipogenesis (it has SACP) attached.
Reaction: Dehydration ($-H_2O$). CA + Alcohol/Thiol → Ester (Thioester). Energy: Cell <u>loses</u> energy, a HEPB is broken when ATP is converted to AMP	Reaction: Reverse of Decarboxylation Energy: Cell <u>loses</u> energy, a HEPB is broken when ATP is converted to ADP

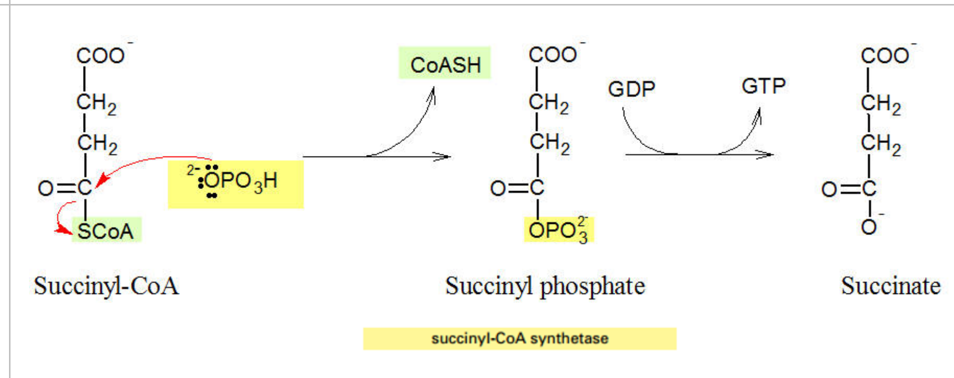
$CH_3CH(OH)CH_2C(=O)-SACP \longrightarrow CH_3CH{=}CHC(=O)-SACP + H_2O$ crotonyl-ACP	
$CH_3CH{=}CHC(=O)-SACP + NADPH + H^+ \longrightarrow CH_3CH_2CH_2C(=O)-SACP + NADP^+$ butyryl-ACP	
	
	

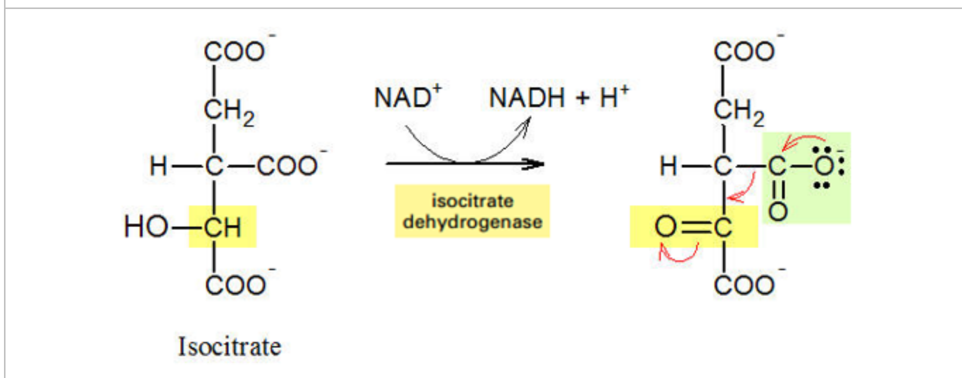
Reaction: Transamination (swap Amine and Ketone groups) Energy: Neutral – no redox coenzymes or ATP used or generated	
Reaction: Transamination (swap Amine and Ketone groups) Energy: Neutral – no redox coenzymes or ATP used or generated	
Reaction: Hydrogenation (+H_2) AND Redox. Alkene → Alkane Reduced: The molecule is reduced, it gained 2 bonds to hydrogen. A alkene is reduced to form an alkane Oxidized: The redox co-enzyme is oxidized from NADPH to $NADP^+$ Energy: Cell loses energy because NADPH is oxidized to form $NADP^+$	
Reaction: Dehydration (-H_2O). Alcohol → Alkene Energy: Neutral – no redox coenzymes or ATP used or generated	Reaction: Transfer of a PO_4 group from ATP to Molecule Energy: Cell loses energy, a HEPB is broken when ATP is converted to ADP

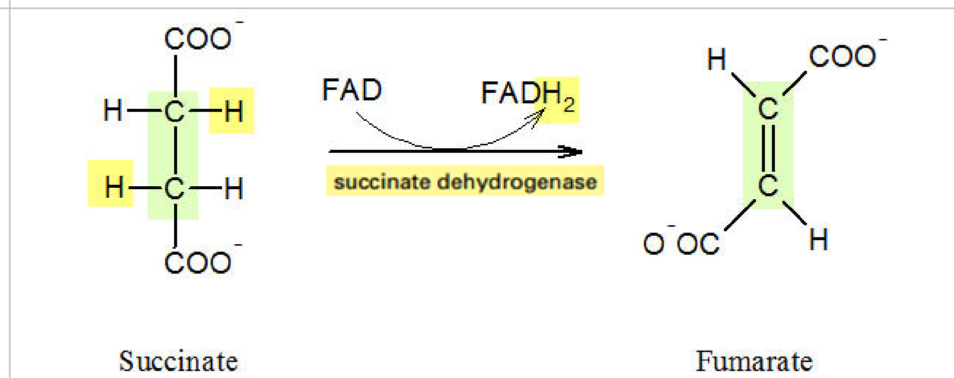

S - CoA
Acetyl-CoA
CoASH
Oxal acetate
Citryl-CoA
Citrate

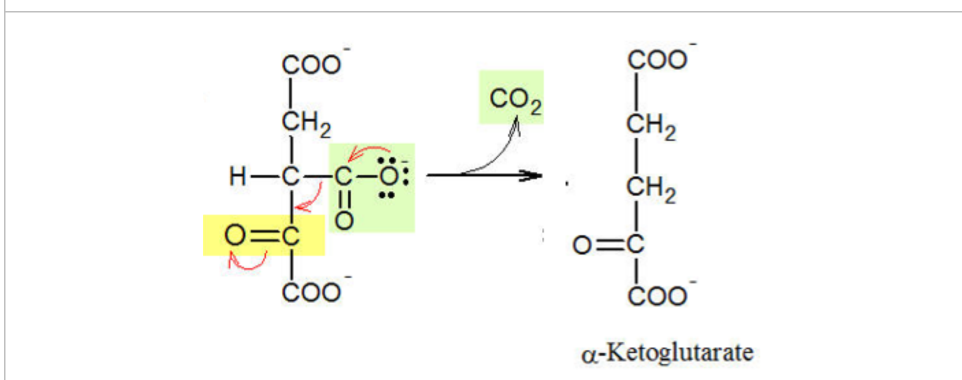

α-ketoglutarate dehydrogenase complex
CoA-SH
CO2
NAD+
NADH, H+
SCoA
α-Ketoglutarate
Succinyl-CoA

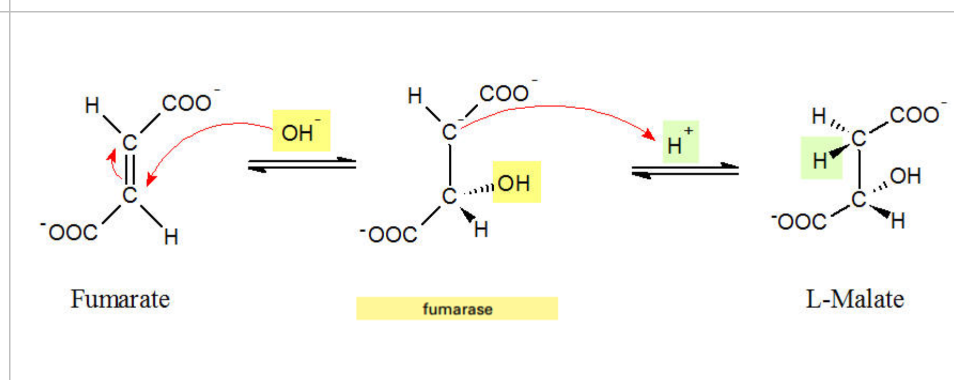

H2O
H2O
Citrate
cis-Aconitate
Isocitrate


CoASH
GDP
GTP
SCoA
OPO3H
Succinyl-CoA
Succinyl phosphate
Succinate
succinyl-CoA synthetase

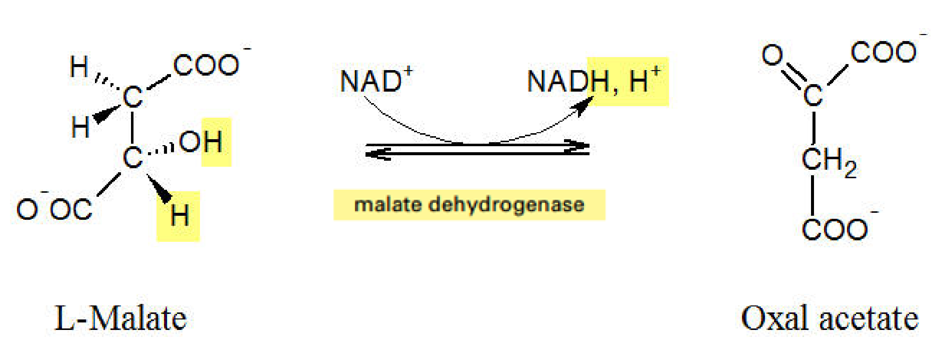

NAD+
NADH + H+
isocitrate dehydrogenase
Isocitrate


FAD
FADH2
succinate dehydrogenase
Succinate
Fumarate

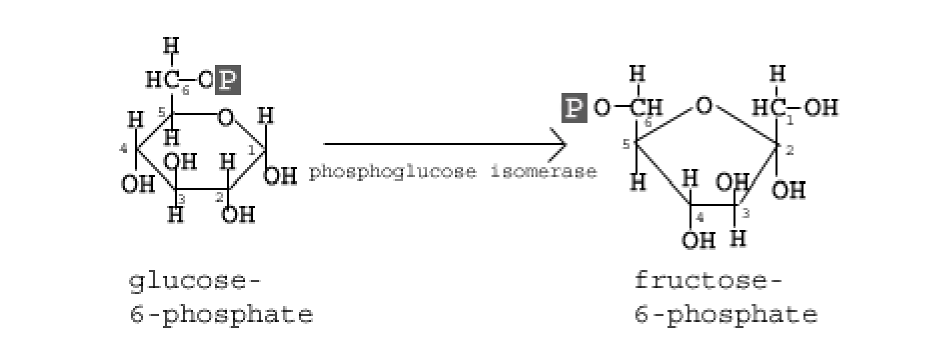

CO2
α-Ketoglutarate


OH-
H+
Fumarate
fumarase
L-Malate

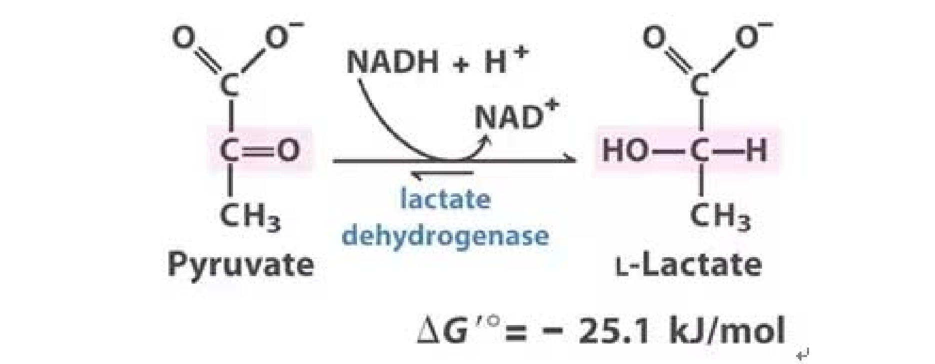
Type: Decarboxylation (-CO_2) Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated	Reaction: Hydration (+H_2O). An Alkene → 2° Alcohol Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated
Type: Dehydrogenation (-H_2)/Redox or Alcohol → Ketone Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: Molecule because a Alcohol is oxidized to form a Ketone or because lost bond to hydrogen and gained a bond to oxygen Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Dehydrogenation (-H_2) "dehydrogenase" AND Redox. An Alkane → Alkene Reduced: The FAD is reduced to form $FADH_2$ Oxidized: The molecule loses two bonds to hydrogen. Energy: Cell <u>gains</u> energy because FAD is reduced to form $FADH_2$
Reaction 1 Type: Dehydration (-H_2O) or 2° Alcohol → Alkene Energy: <u>Neutral</u> – no redox coenzymes or ATP generated **Reaction 2** Type: Hydration (+H_2O) or Alkene → 2° Alcohol Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated	Reaction: Substrate Level Phosphorylation (SLP). The molecules loses the CoAS, temporarily gains a PO_4 group and transfers it to GDP to make GTP Energy: Cell <u>gains</u> energy by gaining a High Energy Phosphate Bond (HEPB) by converting GDP to GTP (equivalent to ATP)
Reaction 1 Type: Aldol Condensation (Ketone + Ketone →Aldol) Energy: <u>Neutral</u> – no redox coenzymes or ATP generated **Reaction 2** Type: Hydrolysis (+H_2O) of Thioester (S) bond Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated	Reaction: Decarboxylation (-CO_2) AND Redox Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: Molecule gains a bond to Sulfur (same as gaining bond to Oxygen) or Oxidation number of bottom carbon (COO^-) = +3 goes to (CO_2) = +4 or Oxidation number of Ketone carbon goes from +2 to +4 Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH



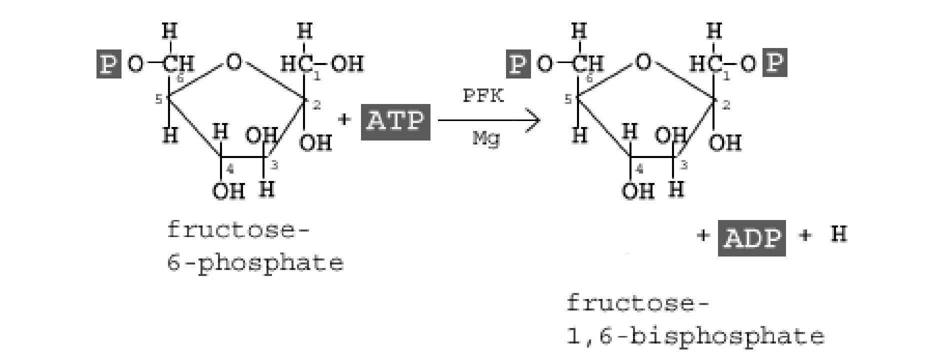
NAD+
NADH, H+
malate dehydrogenase
L-Malate
Oxal acetate



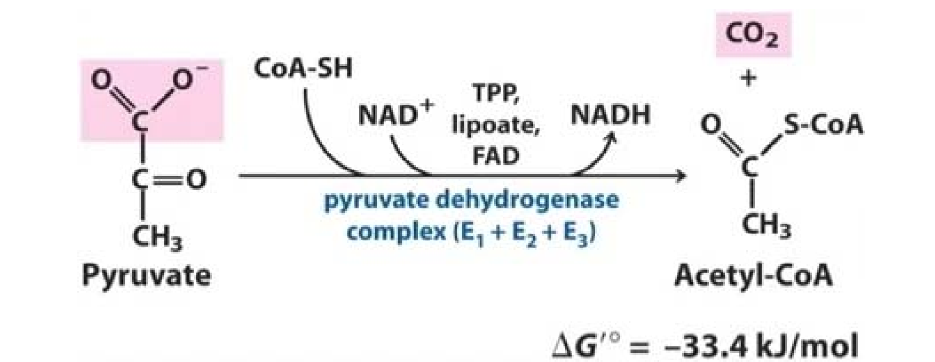
phosphoglucose isomerase
glucose-6-phosphate
fructose-6-phosphate



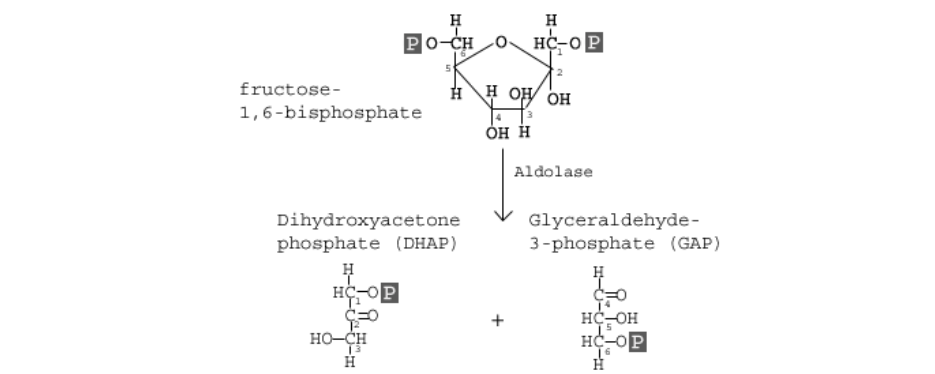
NADH + H+
NAD+
lactate dehydrogenase
Pyruvate
L-Lactate
ΔG′° = − 25.1 kJ/mol



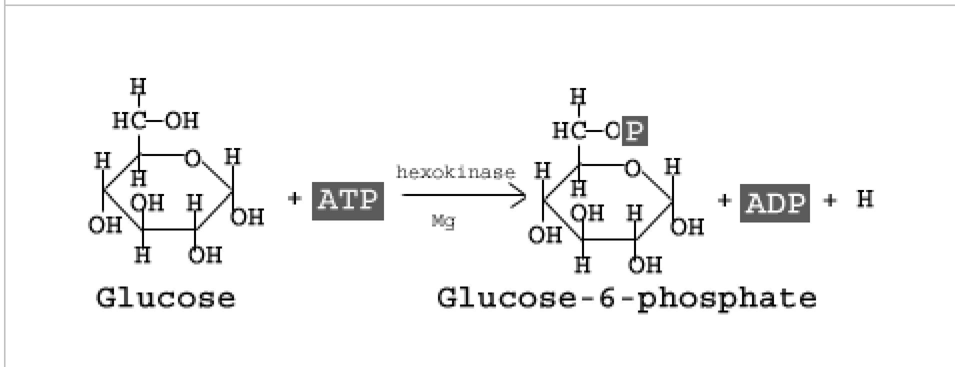
ATP
PFK
Mg
ADP
fructose-6-phosphate
fructose-1,6-bisphosphate



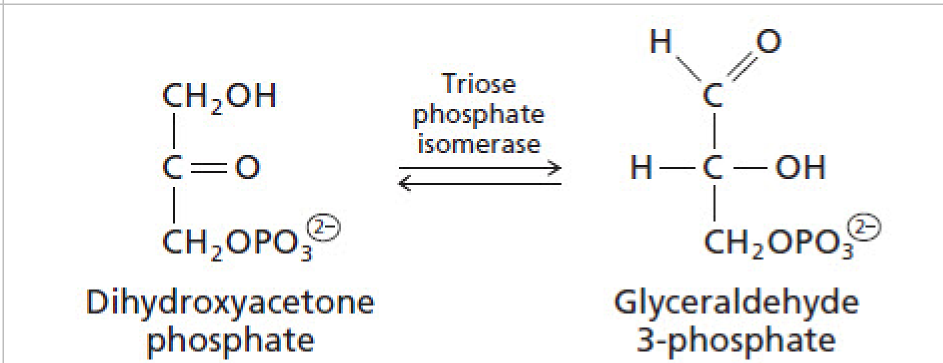
CoA-SH
NAD+
TPP, lipoate, FAD
NADH
CO2
pyruvate dehydrogenase complex (E1 + E2 + E3)
Pyruvate
Acetyl-CoA
ΔG′° = −33.4 kJ/mol



fructose-1,6-bisphosphate
Aldolase
Dihydroxyacetone phosphate (DHAP)
Glyceraldehyde-3-phosphate (GAP)

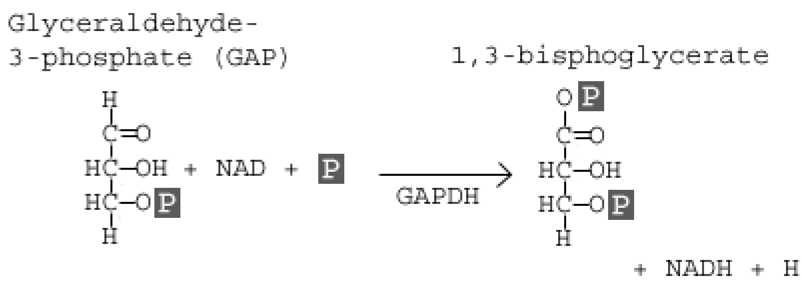


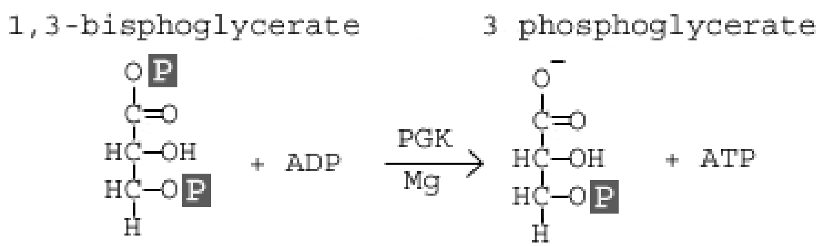
ATP
hexokinase
Mg
ADP
Glucose
Glucose-6-phosphate

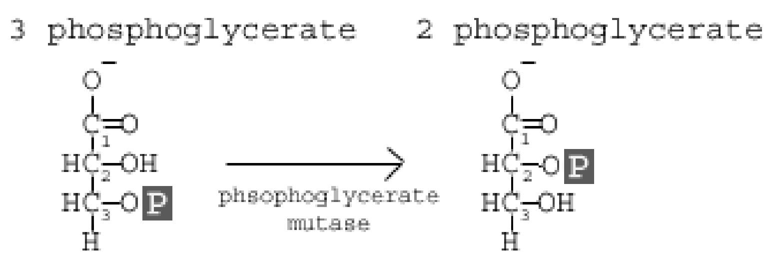


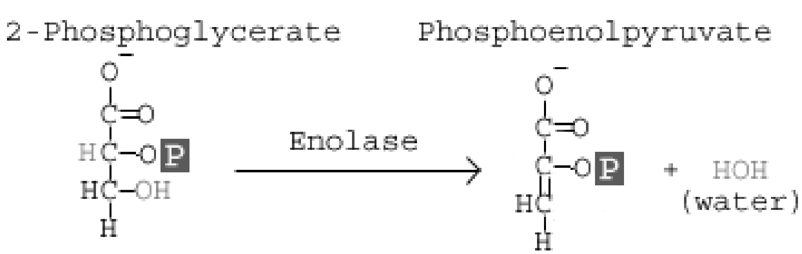
Triose phosphate isomerase
Dihydroxyacetone phosphate
Glyceraldehyde 3-phosphate

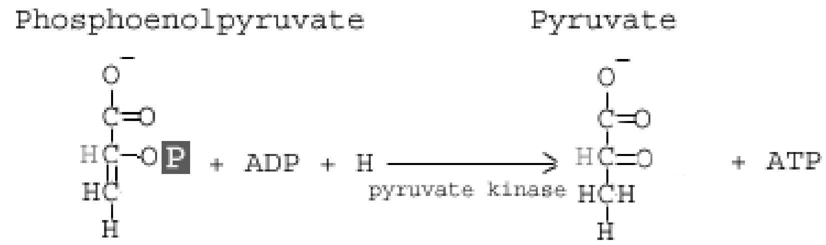
Reaction: Transfer of a PO_4 group from ATP to Molecule Energy: Cell <u>loses</u> energy, a HEPB is broken when ATP is converted to ADP	Reaction: The bottom molecule undergoes an isomerization "isomerase" reaction to make a second Glyceraldehyde-3-phosphate molecule Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated Misc: Instead of having 2 different molecules and requiring 2 different metabolic pathways, this reaction converts one molecule into the other thus combining the 2 metabolic pathways into 1.
Reaction: Decarboxylation ($-CO_2$) AND REDOX (or thioesterfication) Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: The molecule is oxidized, it gains a bond to Sulfur (equivalent to Oxygen). The oxidation number of the last carbon (COO^-) = +3 goes to (CO_2) = +4 or Oxidation number of Ketone carbon goes from +2 to +4 Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Molecule "explodes" (technically there is no name for this reaction) but you should describe it. The molecules is split into two smaller molecules by a Lysase reaction Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated
Reaction: Hydrogenation ($+H_2$), AND Redox, a Ketone → 2° Alcohol Reduced: The molecule gains 2 bonds to H and loses a bond to oxygen or a Ketone is reduced to a 2° Alcohol Oxidized: The $NADH^+$ is oxidized because it loses a bond to H. Energy: Cell <u>loses</u> energy because NADH is oxidized to form NAD^+	Reaction: Transfer of a PO_4 group from ATP to Molecule Energy: Cell <u>loses</u> energy, a HEPB is broken when ATP is converted to ADP
Reaction: Dehydrogenation ($-H_2$) "dehydrogenase" AND Redox. A 2° Alcohol → Ketone Reduced: The NAD^+ is reduced because it gained a bond to H. Oxidized: The molecule loses a bond to H and gains a bond to oxygen or a 2° Alcohol is oxidized to a Ketone Energy: Cell <u>gains</u> energy because NAD^+ is reduced to form NADH	Reaction: Isomerization "isomerase". (same formula different structure) Energy: <u>Neutral</u> – no redox coenzymes or ATP used or generated Misc: Allows fructose to enter the glycolysis pathway (control mechanism/links two pathways together)

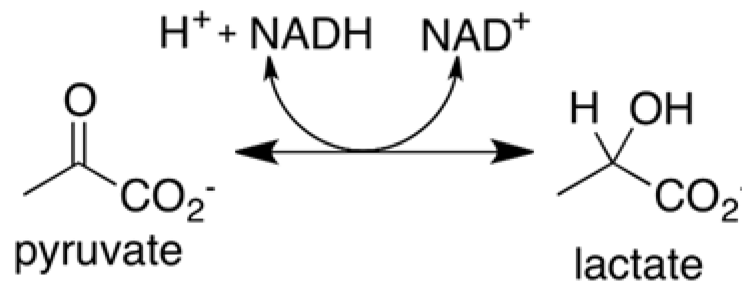

Glyceraldehyde-
3-phosphate (GAP)
1,3-bisphoglycerate
+ NAD + P
GAPDH
+ NADH + H

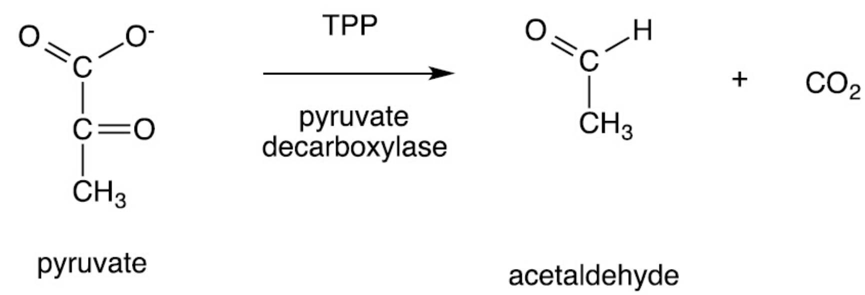

1,3-bisphoglycerate
3 phosphoglycerate
+ ADP
PGK
Mg
+ ATP

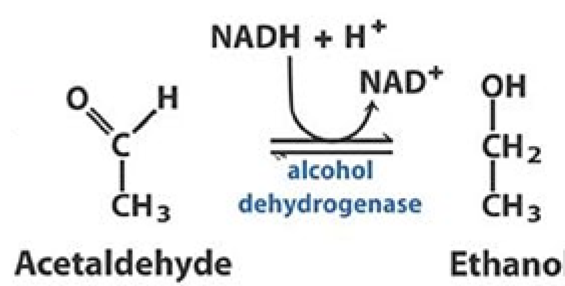

3 phosphoglycerate
2 phosphoglycerate
phsophoglycerate
mutase


2-Phosphoglycerate
Phosphoenolpyruvate
Enolase
+ HOH
(water)


Phosphoenolpyruvate
Pyruvate
+ ADP + H
pyruvate kinase
+ ATP


H+ + NADH
NAD+
pyruvate
lactate


TPP
pyruvate
decarboxylase
+
CO2
pyruvate
acetaldehyde


NADH + H+
NAD+
alcohol
dehydrogenase
Acetaldehyde
Ethanol

Reaction: Elimination ($-H_2O$) or Dehydration or 1° Alcohol → Alkene Energy: Neutral – no redox coenzymes or ATP used or generated	Reaction: Hydrogenation ($+H_2$) AND Redox. Aldehyde → 1° Alcohol Reduction: The aldehyde function group is reduced to form an alcohol. The oxidation number changes from +1 to -1 Oxidized: The redox co-enzyme is oxidized from NADH to NAD^+
Reaction: Isomerization reaction "mutase". The –OH and PO_4 groups swap places (same formula different structure) Energy: Neutral – no redox coenzymes or ATP used or generated	Reaction: Decarboxylation ($-CO_2$) Energy: Neutral – no redox coenzymes or ATP used or generated
Reaction: Substrate Level Phosphorylation (SLP). The molecules loses a PO_4 group and transfers it to ADP to make ATP Energy: Cell gains energy by gaining a High Energy Phosphate Bond (HEPB) by converting ADP to ATP	Reaction: Redox. On the middle carbon the Ketone → 2° Alcohol Reduction: The molecule is reduced, a Ketone is reduced to a 2° Alcohol. The molecule lost a bond to oxygen and gained a bond to H. Oxidized: The redox co-enzyme is oxidized from NADH to NAD^+ Energy: Cell loses energy because NADH is oxidized to form NAD^+
Reaction: Dehydrogenation ($-H_2$) + Redox. Aldehyde loses bond to hydrogen and gains a bond to the oxygen in the phosphate group (Ald -> CA). Reduction: The NAD^+ is reduced because it gained a bond to H. Oxidized: Aldehyde loses a bond to H and gains a bond to Oxygen Energy: Cell gains energy because NAD^+ is reduced to form NADH	Reaction: Substrate Level Phosphorylation (SLP). The molecules loses a PO_4 group and transfers it to ADP to make ATP Energy: Cell gains energy by gaining a High Energy Phosphate Bond (HEPB) by converting ADP to ATP