of isocitrate and α-ketoglutarate.

The energy released by these oxidations was conserved in the reduction of three NAD$^+$ and one FAD and the production of ATP or GTP. At the end of the cycle a molecule of oxaloacetate was regenerated. Note that the two carbon atoms appearing as CO$_2$ are not the same two carbons that entered in the form of acetyl group.

**Biosynthesis of Amino Acids:**

All amino acids are derived from intermediates in glycolysis, citric acid cycle, or the pentose phosphate pathway.

The following arebiosynthesis process of some amino acids:

- **3-phosphoglycerate** from glycolysis

\[
\begin{align*}
\text{C}_3\text{H}_4\text{O}_4\text{P} \rightarrow \text{C}_3\text{H}_4\text{O}_3 \rightarrow \text{C}_3\text{H}_2\text{O}_3\text{P}
\end{align*}
\]

- **NAD$^+$**

\[
\begin{align*}
\text{NAD}^+ & \rightarrow \text{NADH} + \text{H}^+
\end{align*}
\]
Overall flow of nitrogen in amino acid catabolism.
Biosynthesis of Nutritionally non-essential amino acids

Biomedical importance: All 20 a.a. present in proteins are essential for health. A.a. deficiency cause disorders like "kwashiorkor, marasmus" both a-a. and Caloric intake are deficient.

Humans can synthesize 12 of the 20 a.a. From the intermediate of glycolysis and citric acid cycle. (9) of them are from amphibolic intermediate and 3 a.a. from nutritionally essential a.a. (cysteine, tyrosin, hydroxylysine)

\[
\begin{align*}
\text{Pyruvate} & \xrightarrow{\text{decarboxylation}} \text{α-ketoglutarate} \\
\text{α-ketoglutarate} & \xrightarrow{\text{oxidation}} \text{Glutamate} \\
\text{Glutamate} & \xrightarrow{\text{decarboxylation}} \text{Glutaminine} \\
\text{Glutaminine} & \xrightarrow{\text{transamination}} \text{Alanine} \\
\end{align*}
\]
Steps 1, 3, 4 are irreversible in the cell, so the acetyl groups are fed into the citric acid cycle which enzymatically oxidizes them to CO₂. The energy released is conserved in the reduced electron carriers NADH and FADH₂. A two carbon acetyl group entered the cycle by combining with oxaloacetate. Two carbon atoms emerged from the cycle as CO₂ from the oxidation of isocitrate and α-ketoglutarate.

The energy released by these oxidations was conserved in the reduction of three NAD⁺ and one FAD and the production of ATP or GTP. At the end of the cycle, one molecule of oxaloacetate was regenerated. Note that the two carbon atoms appearing as CO₂ are not the same two carbons that entered in the form of acetyl group.

**Biosynthesis of Amino Acids:**

All amino acids are derived from intermediates in glycolysis, the citric acid cycle, or the pentose phosphate pathway.

The following are biosynthesis processes of some amino acids:

\[
\begin{align*}
\text{C}_4O_6H_8O_7^- & \xrightarrow{\text{3-phosphoglycerate dehydrogenase}} \text{C}_4O_6H_8O_7^+ \\
\text{NAD}^+ & \xrightarrow{\text{NADH} + H^+} \text{NAD}^+
\end{align*}
\]

3-phosphoglycerate from glycolysis

\[
\begin{align*}
\text{C}_4O_6H_8O_7^- & \xrightarrow{\text{Phosphoglycerate dehydrogenase}} \text{C}_4O_6H_8O_7^+ \\
\text{NAD}^+ & \xrightarrow{\text{NADH} + H^+} \text{NAD}^+
\end{align*}
\]

3-phospho-hydroxy pyruvate