# Metabolic pathway for the biosynthesis of industrial microbiology products

In order to be able to manipulate microorganisms to produce maximally materials of economic importance to humans, but at minimal costs, it is important that the physiology of the organisms be understood as much as is possible.

The series of chemical reactions involved in converting a chemical (or a metabolite) in the organism into a final product is known as a **metabolic pathway.**

When the reactions lead to the formation of a more complex substance, that particular form of metabolism is known as **anabolism** and the pathway an anabolic pathway. When the series of reactions lead to less complex compounds the metabolism is described as **catabolism** Figure 1. The compounds involved in a metabolic pathway are called **intermediates** and the final product is known as the **end-product.**

Catabolic reactions have been mostly studied with glucose. Four pathways of glucose breakdown to pyruvic acid (or glycolysis) are currently recognized. They will be discussed later. Catabolic reactions often furnish energy in the form of ATP and other high energy compounds, which are used for biosynthetic reactions. A second function of catabolic reactions is to provide the carbon skeleton for biosynthesis. Anabolic reactions lead to the formation of larger molecules some of which are constituents of the cell.

Although anabolism and catabolism are distinct phenomena some pathways have elements of both kinds Metabolic intermediates which are derived from catabolism and which are also available for anabolism are known as **amphibolic intermediates**.

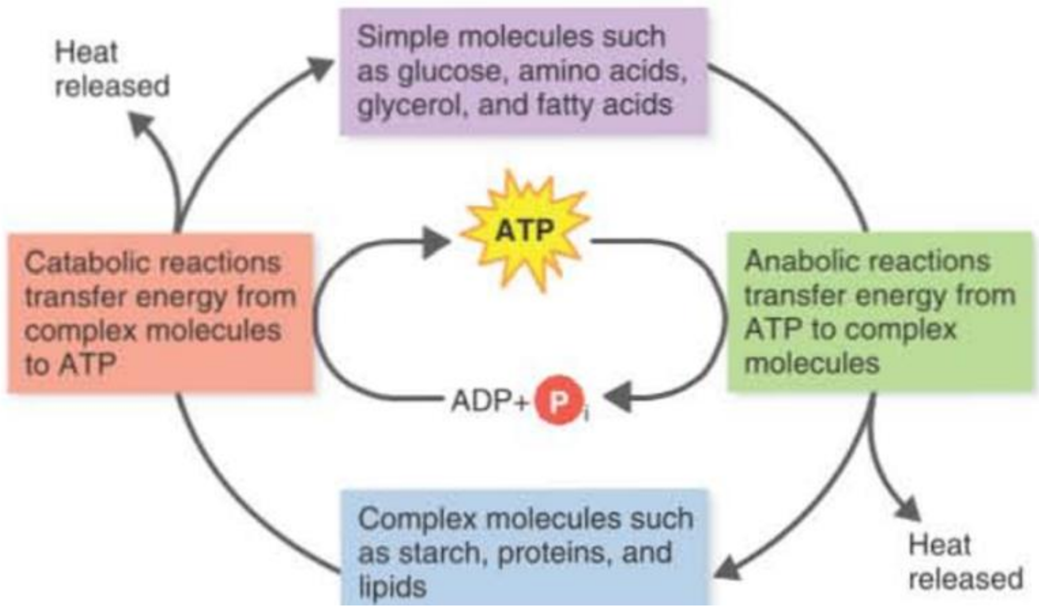


Figure 1: Metabolic pathway

## Industrial microbiological products as primary and secondary metabolites

### Products of Primary Metabolism

Primary metabolism is the inter-related group of reactions within a microorganism which are associated with growth and the maintenance of life. Primary metabolism is essentially the same in all living things and is concerned with the release of energy, and the synthesis of important macromolecules such as proteins, nucleic acids and other cell constituents. When primary metabolism is stopped the organism dies. Products of primary metabolism are associated with growth and their maximum production occurs in the logarithmic phase of growth in a batch culture. Primary catabolic products include ethanol, lactic acid, and butanol while anabolic products include amino-acids, enzymes and nucleic acids. Single-cell proteins and yeasts would also be regarded as primary products (Table:1)

Table (1): primary metabolites

| *Anabolic Products* | *Catabolic Products* |
|---|---|
| 1. Enzymes | 1. Ethanol and ethanol-containing products, e.g. wines |
| 2. Amino acids | 2. Butanol |
| 3. Vitamins | 3. Acetone |
| 4. Polysaccharides | 4. Lactic acid |
| 5. Yeast cells | 5. Acetic acid (vinegar) |
| 6. Single cell protein | |
| 7. Nucleic acids | |
| 8. Citric acid | |

## Products of Secondary Metabolism

In contrast to primary metabolism which is associated with the growth of the cell and the continued existence of the organism, secondary metabolism, which was first observed in higher plants, has the following characteristics

(i) Secondary metabolism has no apparent function in the organism. The organism continues to exist if secondary metabolism is blocked by a suitable biochemical means. On the other hand it would die if primary metabolism were stopped.

(ii) Secondary metabolites are produced in response to a restriction in nutrients. They are therefore produced after the growth phase, at the end of the logarithmic phase of growth and in the stationary phase (in a batch culture). They can be more precisely controlled in a continuous culture.

(iii) Secondary metabolism appears to be restricted to some species of plants and microorganisms (and in a few cases to animals). The products of secondary metabolism also appear to be characteristic of the species.

Table 2: secondary metabolites

| *Product* | *Organism* | *Use/Importance* |
|---|---|---|
| *Antibiotics* | | |
| Penicillin | *Penicillium chrysogenum* | Clinical use |
| Streptomycin | *Streptomyces griseus* | Clinical use |
| *Anti-tumor Agents* | | |
| Actinomyin | *Streptomyces antibioticus* | Clinical use |
| Bleomycin | *Streptomyces verticulus* | Clinical use |
| *Toxins* | | |
| Aflatoxin | *Aspergiulus flavous* | Food toxin |
| Amanitine | *Amanita* sp | Food toxin |
| *Alkaloids* | | |
| Ergot alkaloids | *Claviceps purpurea* | Pharmaceutical |
| *Miscellaneous* | | |
| Gibberellic acid | *Gibberalla fujikuroi* | Plant growth hormone |
| Kojic acid | *Aspergillus flavus* | Food flavor |
| Muscarine | *Clitocybe rivalosa* | Pharmaceutical |
| Patulin | *Penicillium urticae* | Anti-microbial agent |

## Pathways for the synthesis of primary and secondary metabolites of industrial importance

### Catabolism of Carbohydrates

Four pathways for the catabolism of carbohydrates up to pyruvic acid are known. All four pathways exist in bacteria, actinomycetes and fungi, including yeasts. The four pathways are the **Embden-Meyerhof**, **the Pentose Phosphate Pathways**, **the Entner Duodoroff pathway and the Phosphoketolase.** Although these pathways are for the breakdown of glucose. Other carbohydrates easily fit into the cycles.

### 1- The Embden-Meyerhof (EMP Pathways):

The net effect of this pathway is to reduce glucose (C6) to pyruvate (C3) Figure 2.

The system can operate under both aerobic and anaerobic conditions. Under aerobic conditions it usually functions with the tricarboxylic acid cycle which can oxidize pyruvate to $CO_2$ and $H_2O$. Under anaerobic conditions, pyruvate is fermented to a wide range of fermentation products, many of which are of industrial importance.

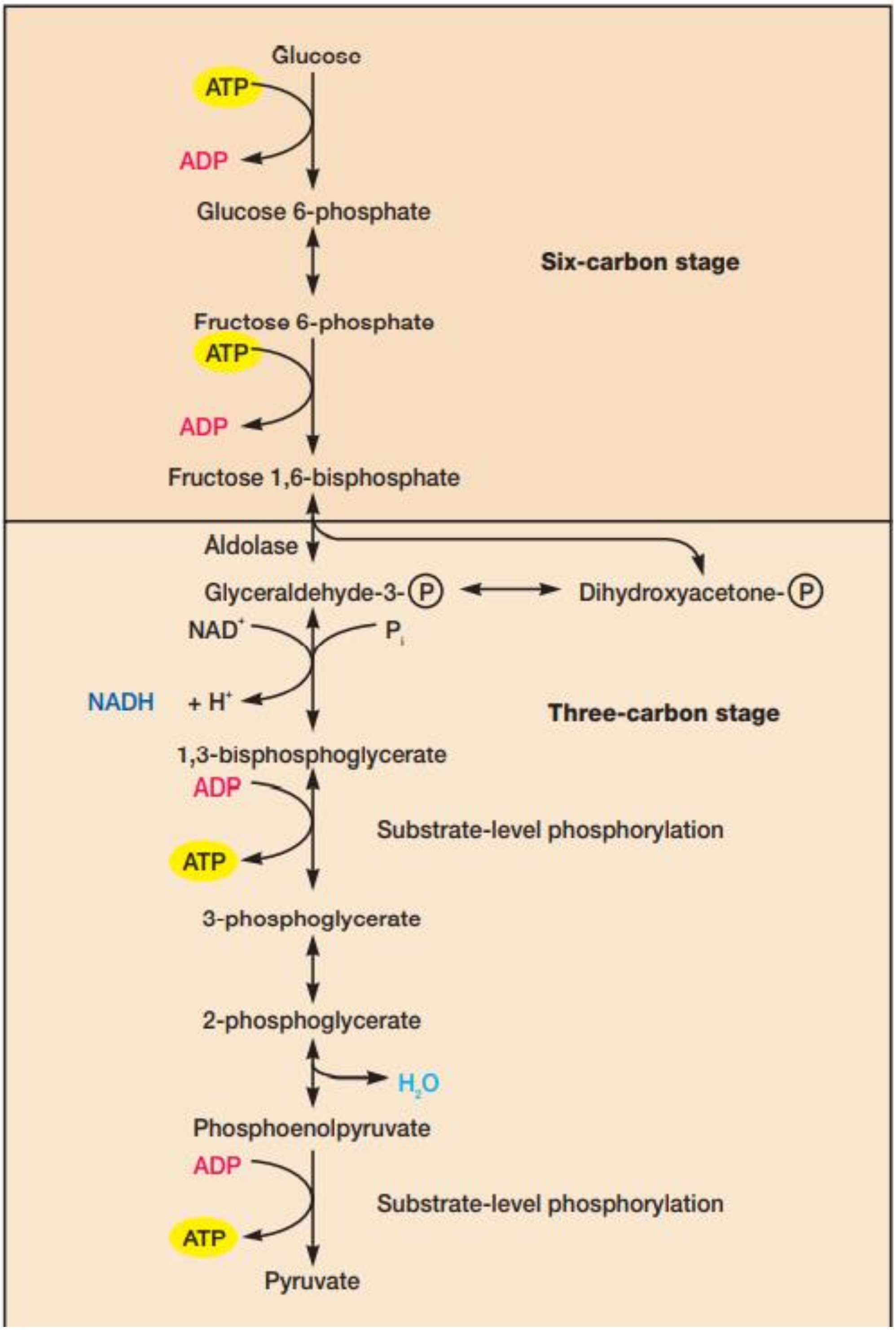


Figure 2: The Embden-Meyerhof pathway