Transamination and transamidation.

By

W. D. Loomis and P. K. Stumpf.

With 2 figures.

Transamination represents a class of reaction wherein the amino nitrogen of an amino acid (donor) is transferred to aminate the carbonyl group of a keto acid (acceptor). The acceptor now becomes an amino acid whereas the donor becomes a keto acid. Transamination involves the transfer of $-\text{NH}_2$ from a carboxamide group to a suitable acceptor. Transamination is far better understood than transamidation, but both types of transfer reaction appear to be of general importance in the metabolism of plants and other organisms. The role of transamination in amino acid synthesis is discussed in the chapter "The synthesis of amino acids in plants", p. 224.

Transamination.

The general formula for most of the observed transamination reactions is as follows:

$$R\cdot \text{CHNH}_2\cdot \text{COOH} + R'\cdot \text{CO}\cdot \text{COOH} \rightleftharpoons R\cdot \text{CO}\cdot \text{COOH} + R'\cdot \text{CHNH}_2\cdot \text{COOH}. \quad (1)$$

In some cases amino or carbonyl groups which are not in the $\alpha$-position to a carboxyl group may also participate. Examples are the amino group of adenine and the $\delta$-amino group of ornithine.

Enzymatic transamination was first demonstrated by Braunstein and Kritzmann (1937) in animal preparations. Early reports of transamination in plants were made by Virtanen and Laine (1938), Kritzmann (1939), Adler and coworkers (1938), and Cedrangolo and Carandante (1940). Subsequent investigations have shown that the phenomenon is widespread in all types of organisms, and that most, if not all, of the known natural amino acids can participate. There are several excellent reviews of the earlier work on both plant and animal transaminations (Braunstein 1947, Cohen 1951, Bonner 1950). More recent work has been reviewed by Cohen (1954), Burris (1953), and Meister (1955).

The enzymes which catalyze transamination reactions are known as "transaminases" or "aminopherases". Although the term "aminopherase" suggested by Braunstein and Kritzmann (Braunstein 1947) is the older, "transaminase" is commoner usage in English language publications and will therefore be used here.

Glutamic-aspartic and glutamic-alanine transaminases.

In plants as well as in other organisms the best known transaminations are the glutamic-aspartic and the glutamic alanine reactions:

$$\text{Glutamic acid} + \text{oxalacetic acid} \rightleftharpoons \alpha\text{-ketoglutaric acid} + \text{aspartic acid}, \quad (2)$$

$$\text{Glutamic acid} + \text{pyruvic acid} \rightleftharpoons \alpha\text{-ketoglutaric acid} + \text{alanine}. \quad (3)$$
A third commonly observed transamination system, aspartic-alanine,

$$\text{Aspartic acid } + \text{pyruvic acid } \rightleftharpoons \text{oxalacetic acid } + \text{alanine},$$  \hspace{1cm} (4)

was shown with purified enzymes from animal sources to be actually the summation of reactions (2) and (3) and to require the presence of two separate enzymes (Green, Leloir and Nocito 1945). In most cases of reported aspartic-alanine activity in plants, the data are consistent with this interpretation, but no detailed investigation appears to have been made.

Virtanen and Laine (1941) investigated the transamination reactions of crushed pea plants and demonstrated glutamic-aspartic, glutamic-alanine, aspartic-alanine, and glutamic-leucine activity. Glutamine and asparagine were considerably less active than the corresponding free amino acids. It was concluded that these amides first were hydrolyzed to the corresponding amino acids before they participated in transamination. The activity of the glutamic-aspartic system in germinating oats was studied by Albaum and Cohen (1943), who reported that transaminase activity increased more rapidly at first than did the total protein content of the seedling. The activity of the transaminase when based on protein content of the tissue increased steadily until, after 96 hours, it was twice that of the most active animal source. On the other hand, activity calculated on total-dry-weight basis decreased with age. The authors point out that the large amounts of structural materials such as cellulose in plants lead to erroneous interpretations if dry weight is used as a basis for comparisons. They concluded that transamination may be important in protein synthesis.

Rautanen (1946, 1948) demonstrated and partially characterized glutamic-alanine, glutamic-aspartic, and aspartic-alanine transamination as well as a weaker valine-\(\alpha\)-ketoglutaric reaction in crushed pea seedlings. The glutamic-aspartic reaction was observed in all portions of the two-day old seedling. Glutamic-aspartic transaminase was demonstrated in all but a few of the 22 plant species, mostly cultivated vegetables, tested by Leonard and Burris (1947). In addition, in wheat germ they found a very active glutamic-alanine transaminase. In most of the species examined, the greatest activity, expressed on a nitrogen basis, was found in the roots. Nodules of legumes were also highly active. No significant activity could be shown in the green fruit of tomato and apple, or in leaves of maple and pine.

Giri and coworkers (1952), using quantitative paper chromatographic methods, studied transamination in legumes. With extracts from green gram seed, they were able to demonstrate transamination with glutamic acid, aspartic acid, and alanine but with none of the other amino acids tested. Activity of the glutamic-alanine transaminase increased on 24-hours germination of the seed. It was found that the antibiotic pterygospermin at 1/20,000 concentration strongly inhibited glutamic-alanine transaminase, but had little or no effect on the glutamic-aspartic reaction.

Studies on the glutamic-aspartic transaminase of pea and horse bean were reported by Ruggieri (1953). He demonstrated the reversibility of the reaction and showed that although all parts of the plant contained the enzyme, highest activity was in the nodules.

Recently, investigations of transamination in sunflower crown gall tissue cultures were reported by Eberts et al. (1954). They had found that certain amino acids at about \(10^{-3}\) M concentration act as growth inhibitors of the tissue culture, whereas the same amino acids are stimulatory at either higher or lower concentrations. To test whether this could be related to transamination, cultures were grown with alanine, aspartate, or glutamate at different levels, and the