VIVEKANANDA COLLEGE
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NAAC ACCREDITED ‘A’ GRADE

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Auxin

The term auxin was first used by Frits Went in 1926, who discovered that some unidentified compound probably caused curvature of oat coleoptiles toward light. He demonstrated that a substance present in the tips could diffuse from them into a tiny block agar.

The activity of this auxin was detected by the curvature of the coleoptile caused by enhanced elongation on the side to which the agar block was applied. This Avena-curvature test, first developed by F. W. Went is not only the first but to-date the best bioassay for auxin.

The test centres around two important aspects of auxin-action (a) the transport of auxin is strictly polar, diffusing from the morphological top to a morphological base (b) the degree of curvature is proportional to the amount of auxin.

Thimann (1948) defined an auxin as "an organic substance which promotes growth along the longitudinal axis when applied in low concentrations to shoots of plants freed as far as possible from their own inherent growth-promoting substances."

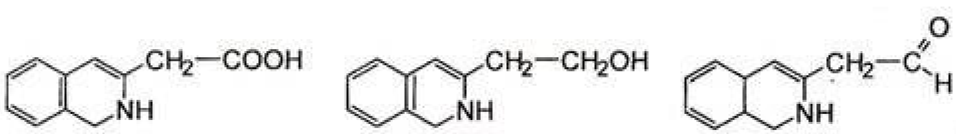
Auxin Distribution in Plants:

Thimann (1934) working on etiolated seedlings of Avena found that the auxins occurred in their highest concentrations in the shoot tip; the root tips contained the least amounts. Thimann and Skoog found that in light-grown plants apical buds contained most auxin, young leaves contained lesser quantities and mature leaves, the lowest quantities. Auxin is synthesised in shoot apices, leaf primordia and developing seeds and it is now believed that the auxins-synthesis may take place in all parts of the plant.

Types of Auxins:

1. Natural auxin:

Recently several substances showing auxin-action have been isolated from plant materials.



indole acetic acid   indole ethanol   indole acetaldehyde

Fig : Naturally occurring auxins

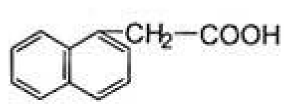
Indole 3-Acetic Acid (IAA) is the universal natural auxin. It was discovered by Kogl et al (1934). Related chemicals are indole 3-acetaldehyde, indole 3-acetonitrile, phenylacetic acid and 4-chloro indole acetic acid. But in a majority of plants, Indole-3-acetic acid (IAA) is found to be present in much larger quantities than any other auxin.

Auxins generally occur as complexes, usually bound with an amino acid or sugar. These complexes serve as precursor substances and six different precursor molecules for auxins have been reported. Many workers, including Thimann, reported that the amino acid, Tryptophan, figures prominently in the auxin formation. Many Indole compounds too serve as precursors of auxins.

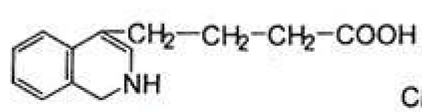
Auxin synthesis is conditioned by the presence of light and zinc. Too high or too low temperatures are found inimical to IAA formation. It is thus suggested that auxin synthesis is an enzyme- mediated process.

Synthetic Auxins:

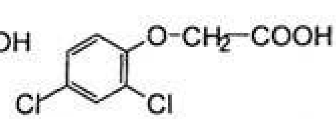
Many synthetic auxins cause many of the physiological responses common to IAA and are generally considered to be auxins. Of these **Naphthalene acetic acid (NAA), Indole butyric acid (IBA), 2,4-dichloro-phenoxyaectic acid (2,4-D), 2-methyl-4-chloro-phenoxyaectic acid (MCPA) and 2,4,5-trichloro- phenoxyacetic acid** are the best known.



napthalene acetic acid



indole butyric acid



2, 4-dichorophenoxyacetic acid (2, 4-D)

Anti auxins:

Anti Auxins are a group of chemicals that can prevent auxin-action in plants. They were first discovered by Skoog (1942). **Trans Cinnamic acid, ascorbic acid, 7-phenyl butyric acid are some of these antiauxins**. Probably, an antiauxin competes with an auxin for the same site of reaction and thus inhibits auxin-action.

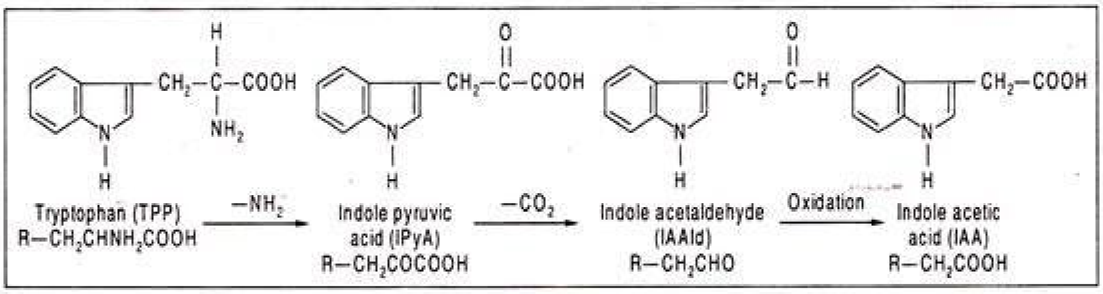
- **Biosynthesis of Indole-3-Acetic Acid:**

Indole-3-acetic acid (IAA) is structurally related to the aromatic amino acid tryptophan. It is considered that tryptophan is the probable precursor of IAA.

Plants convert tryptophan to IAA by several pathways which are described below:

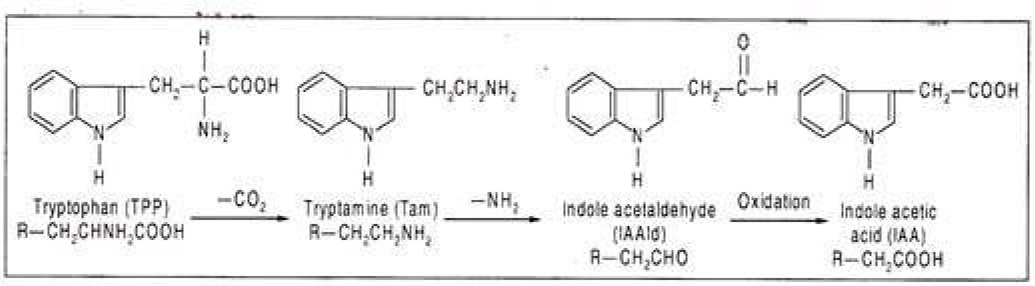
(a) Indole Pyruvic Acid (IpyA) Pathway:

The first step involves transamination or deamination of TPP by TPP aminotransferase. Second enzyme is IpyA decarboxylase by which IpyA is converted to lAAld. The last step is catalyzed by IAAld dehydrogenase or oxidase in which lAAld is oxidized to IAA. This pathway is known as indole pyruvic acid pathway.



(b) Tryptamine (Tam) Pathway:

This pathway is known as tryptamine (Tam) pathway. First reaction is catalysed by TPP decarboxylase by which TPP is converted to tryptamine. Then tryptamine is deaminated by tryptamine deaminase to indole acetaldehyde (lAAId), which is then oxidized to IAA either by an oxidase or a dehydrogenase. Thus, the indole acetaldehyde (lAAId) is the immediate precursor of indole acetic acid (IAA) by both routes.



(c) Indole Acetaldoxime (lAOx) Pathway:

In this pathway, tryptophan (TPP) is first converted to tryptamine (Tam) by decarboxylase reaction. Then by oxidation of this primary amine, Tam will be converted to lAOx by means of a mono-oxygenase.

In this case, one atom of the oxygen molecule is directly inserted into the product IAOx and the other atom of oxygen is reduced to water.

IAOx is converted to indole acetonitrile (**IAN**) by IAOx hydro-lyase in which H_2O is removed. Then the nitrilase enzyme acts on IAN in a two-step reaction. In the first step, one molecule of water is added to IAN and indole acetamide (IAM) is formed as an intermediate. In the second step, the second water is added to IAM and IAA is produced together with NH_3.

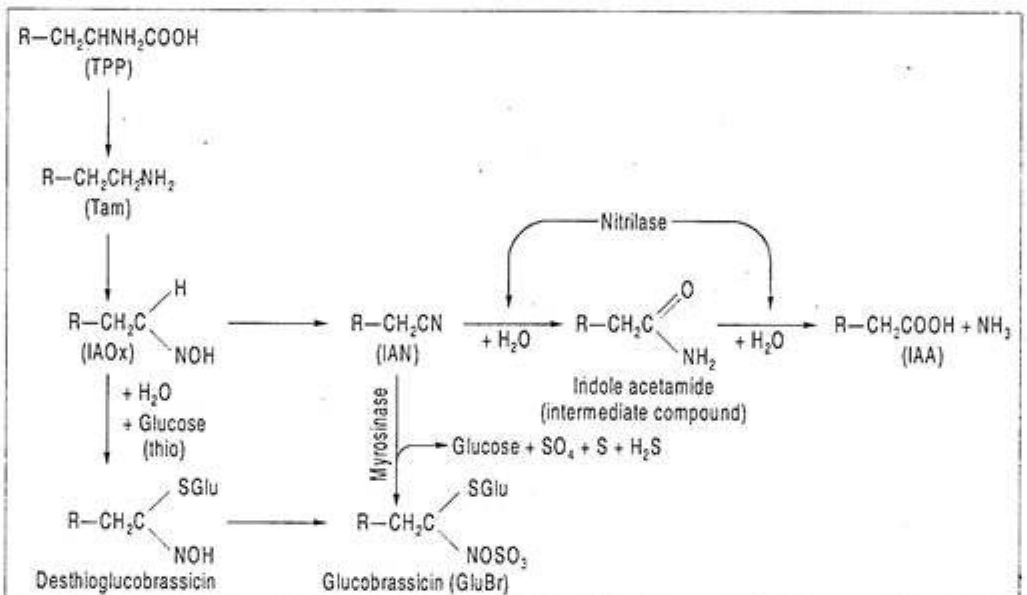


Fig. 13.2 : Indole acetaldoxime (IAOx) pathway of IAA synthesis

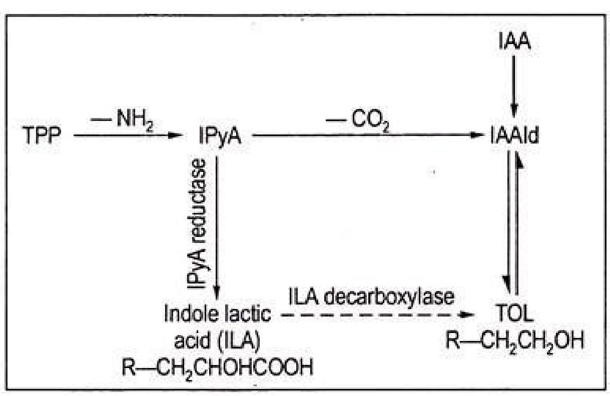
The above pathway is found in non-Cruciferous plants. In Cruciferous plants, IAOx is converted to glucobrassicin, a thioglucoside of IAOx, by an additional reaction with thioglucose (SGIu) and sulphate, in which the intermediate compound is desthio glucobrassicin (GluBr).

Then GluBr is acted upon by myrosinase and IAN is produced which is ultimately converted to IAA by nitrilase.

(d) Tryptophol (TOL) Pathway:

It is actually a modification of the first, i.e., IPyA pathway. The first and second reactions are similar to those of IPyA pathway, i.e., deamination followed by decarboxylation. The last reaction, which involves oxidation or reduction of lAAld, may engage either dehydrogenase or oxidase or dismutase.

It is possible that metabolism of IAAld to IAA and TOL may be catalysed by a dismutase, i.e., coupled enzyme reactions involving pyridine nucleotides leading to oxidation to form IAA and reduction to form TOL. On the other hand, two separate dehydrogenases, viz., acetaldehyde dehydrogenase and alcohol dehydrogenase, may also function. In addition, TOL oxidase has also been identified (TOL → IAAld).



In some plants, IPyA may undergo reduction to indole lactic acid (ILA) by IPyA reductase. It has been suggested that in some cases, ILA acts as the direct precursor of TOL through ILA decarboxylase. Since ILA decarboxylase has not generally been detected and isolated, this conversion (ILA → TOL) seems unlikely.

(e)Tryptophan-Independent Pathway of Auxin Biosynthesis:

In some plants, IAA is also synthesized either from indole or from indole-3-glyceroL phosphate. In studies with Arabidopsis mutants, which are blocked in tryptophan biosynthesis, it has been shown that IAN accumulates to a much higher level compared to the wild type.

In tomato, IPyA has been shown to be synthesized without the involvement of tryptophan. Depending on the species, either IAN or IPyA may be synthesized from either indole-3-glycerol phosphate or indoles respectively, which are ultimately converted to IAA. The suggested branch points from tryptophan-dependent pathways are at IGP or at indole, whereby IAN and IPyA are two possible intermediates.

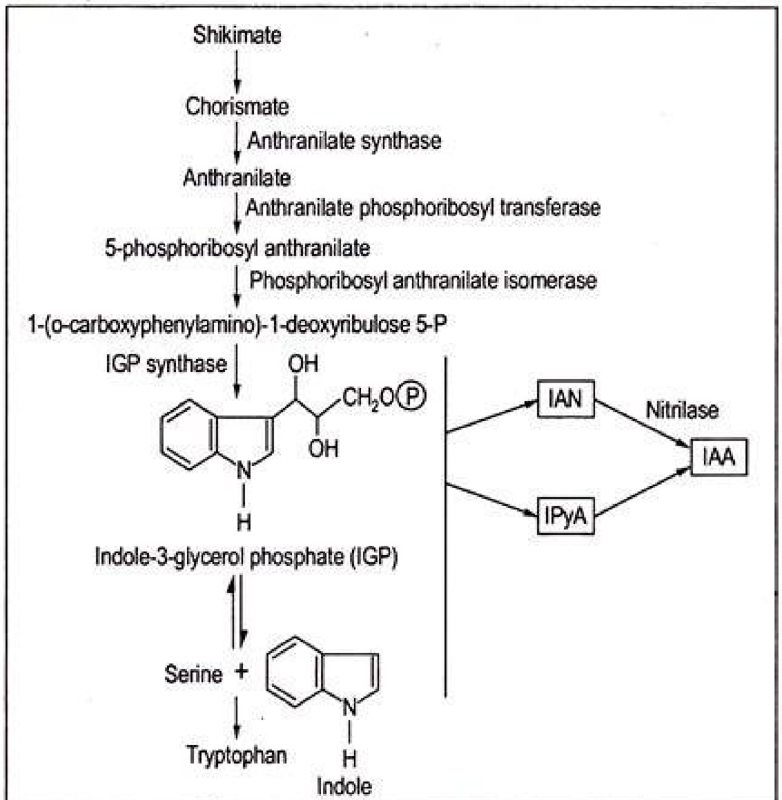


Fig. 13.3 : Tryptophan-independent pathway of IAA synthesis

Physiological Responses of Plants to Auxins:

(a) Cell Enlargement:

Auxins induce rapid cell elongation in isolated stem and coleoptile sections. The time-course of auxin-induced cell enlargement shows that there is a lag of at least eight minutes before the growth. Then the rate rises until a maximum of 5-10 fold is reached after 30-60 min which remains constant for hours or even days.

Initiation of **auxin-induced growth requires** the continued presence of auxin, **a continued supply of ATP and active ATPase's**, **protein synthesis and sufficient cell turgor** so that the cells are in a state of tension.

Although the initial rate of auxin-induced growth is independent of the presence or absence of absorbable solutes like sucrose, continual rapid elongation requires sucrose.

Since auxin-induced cell enlargement is an energy-requiring process, all inhibitors of ATP synthesis (e.g., KCN, DNP, and azide) or of ATPase activity (e.g., vanadate, DCCD, DES) block the process. All inhibitors of protein and RNA synthesis likewise inhibit auxin-induced growth.

(b) Cell Division:

In an intact system, auxin stimulates cell division in the cambium and formation of new phloem and xylem. In cultured tissues, auxins usually in combination with cytokinins promote cell division. For instance, in tissue culture, when auxin level is higher than cytokinin, roots form.When cytokinin is higher than auxin, shoots are produced. When the concentrations are about the same, a callus mass is produced. Thus by adjusting auxin-cytokinin ratios, either shoot or root formation can be initiated.

(c) Vascular Tissue Differentiation:

Auxin indole-3-acetic acid (IAA) is the main limiting and controlling factor for both phloem and xylem differentiation.

One of the major signals produced by the young leaves is auxin which moves in a polar fashion towards the roots. Vascular tissue differentiation occurs along the polar flow of auxin from leaves to roots. There is evidence that low auxin levels induce phloem with no xylem whereas both xylem and phloem differentiations take place at higher auxin levels.

(d) Root Initiation:

Root initiation is generally regulated by auxin. The localization of root generation at the basal end of stem cuttings is due to polar movement of auxin toward the physiologically lower end that was nearer the root tip of the intact plant.

Synthetic auxins like NAA and IBA added from outside to the root end of the freshly excised stem cutting have been found to initiate root initiation and thus can be used as rooting hormones in horticultural practice.

(e) Tropic Responses:

Auxin mediates the tropistic (bending) response of shoots and roots to light (phototropism) and to gravity (gravitropism). Shoots grow toward unilateral light sources showing positive phototropic response. Roots generally bend away from unilateral light sources and are negatively phototropic.

In the phototropic response mechanism of higher plants, the Cholodny-Went hypothesis says that auxin becomes asymmetrically distributed with more accumulating on the shaded side than on the illuminated side and this produces the bending response.

The prostrated seedlings lying in a horizontal manner are said to be gravitropically (geotropically) stimulated whereby shoots and roots show opposite gravitropic curvature.

The Cholodny-Went hypothesis says that hormone asymmetry which is the essential component of the process results from basipetal transport of IAA from the upper to the lower sides of gravistimulated roots and shoots whereby cell elongation is inhibited in the former and stimulated in the latter.

Nowadays, the Cholodny-Went hypothesis, however, is open to question and has been challenged as the sole mechanism for explaining both types of tropic responses.

(f) Apical Dominance:

The concept of apical dominance is based on domination of the apical region of shoot axis over the lateral buds which are also termed correlative inhibition. In a broad sense, this means complete or partial inhibition of initiation and development of lateral (usually axillary) buds by an actively growing apical region.

IAA formed in apex has a distinct role in lateral bud inhibition. Surgical experiments have shown that the shoot apical region appears to be the main source of lateral bud inhibition.

It has been shown that removal of the tip portion of shoot (i.e., decapitation) releases apical dominance and consequently lateral bud formation is stimulated. Auxin applied on decapitated stump acts to replace the tip and appears to re-establish apical dominance and prevents lateral bud growth.

The phenomenon of apical dominance is broad ranging, encompassing at least four themes:

1. Complete or partial inhibition of development of lateral (usually axillary, but occasionally adventitious) buds by an actively-growing apical region on the same or a different shoot axis.

The apex may also control the initiation of buds. Domination of the apical region over the lateral buds is termed **‘correlative inhibition’**. It is seen especially in etiolated shoots but also in leafy and modified shoots (tubers, rhizomes, stolons, bulbs, corms, etc.).

2. The suppressive influence of one dominant shoot upon one or more subordinate shoots.

3. Influence of the apex on the development and positioning of leaves, axillary shoots, stolons, tubers, rhizomes and roots. An inflorescence apex can modify the positioning and development of the floral and derived structures.

4. Influence of the apex on the transport of nutrients and cellular differentiation in the stem or root axes. Thimann and Skoog originally proposed that auxin from the shoot apex inhibited the growth of the axillary bud directly. This is called direct-inhibition theory. According to the theory, the optimal auxin concentration for bud growth is much lower than the auxin concentration normally found in the stem.

(g) <u>Leaf and Fruit Abscission:</u>

In the intact plant, IAA present in the leaf blade inhibits its abscission but when the supply of IAA becomes low either by normal aging or by artificial de-blading abscission occurs. In the isolated system, a de-blade petiole is found to abscise faster. In de-bladed leaves, IAA when applied to the proximal end of the petiole can substitute for leaf blade and retard abscission of the petiole.

It is a common experience that mature fruits of apple, pear, lemon and grape are frequently found to drop before the time of commercial harvest resulting in lower quality fruits. The auxins like 2,4,5-trichlorophenoxy propionic acid (2, 4, 5-TP) and the dichlorophenoxy analogs (2, 4-DP), NAA, 2, 4-D, when applied during the mid-states of fruit growth have been found to prevent abscission of mature fruit.

The role of auxin in fruit abscission is rather complex. The auxins are frequently used both for the prevention of fruit drop as well as for the chemical thinning of young fruits. It is a common orchard management practice that the fruit-growers tend to remove excessive numbers of young fruits.

(h) Fruit Setting, Fruit Growth and Fruit Ripening:

An auxin like 4-chlorophenoxyacetic acid (4-CPA) is used to increase fruit set and growth of tomato.

Although no clear relation has been found between fruit ripening and endogenous auxin content, it has been suggested that ripening may be related to a decline in auxin. An auxin like 2,4-D has been shown to cause a dual effect on ripening, viz., stimulates ripening through ethylene production but may also cause delay in ripening.

(i) Flowering:

Auxins like NAA and IAA promote flowering in the members of the Bromeliaceae and this effect is due to auxin-induced ethylene production. Nevertheless, the proposed role of auxin in the control of flower formation is not universal since auxin application tends to be inhibitory to flower formation in most plants. It now appears that these inhibitory effects are also due to auxin-induced ethylene production.

(j) Assimilate Movement:

Hormones in general are involved in the regulation of source-sink relations. The maximum amount of hormones occurs in seeds during the time of rapid dry-matter accumulation. It appears that assimilate movement is enhanced towards an auxin source possibly by an effect on phloem transport.

(k) <u>Changing Sex Expression:</u>

Perfect flowers are those which contain both stamens and pistils. In Cucurbits like Cucumis, perfect flowers are initiated but one sex organ fails to develop which leads to the development of monecious plants having staminate and pistillate flowers. Application of auxin to flower buds at the bisexual stage leads to the formation of female flowers. It now appears that IAA acts through ethylene in this process.