

Auxins



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DISCOVERY

Coleoptiles

The protective sheath round the first leaf of a grass embryo.

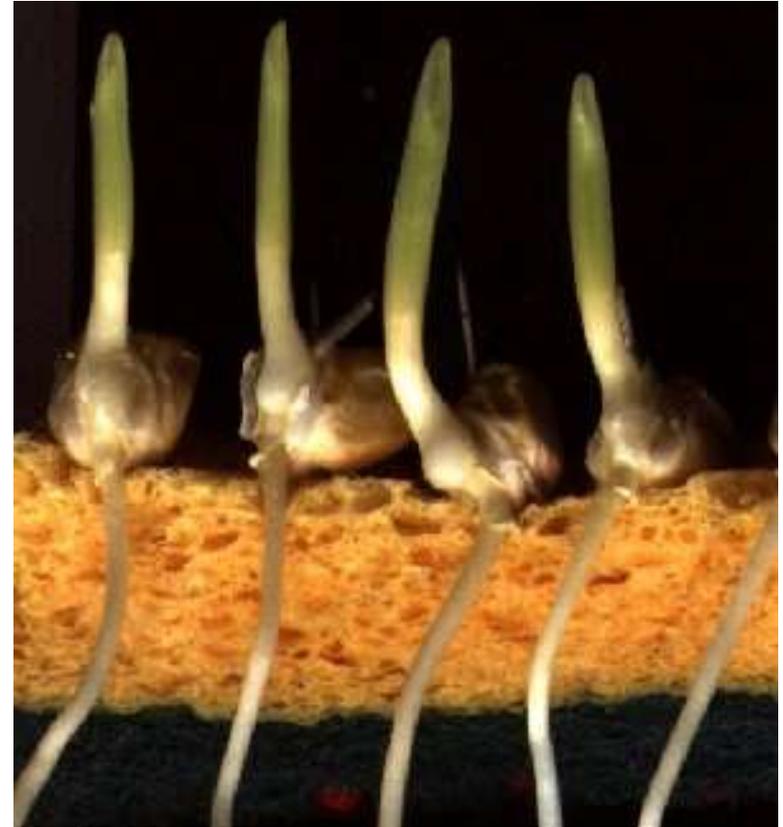
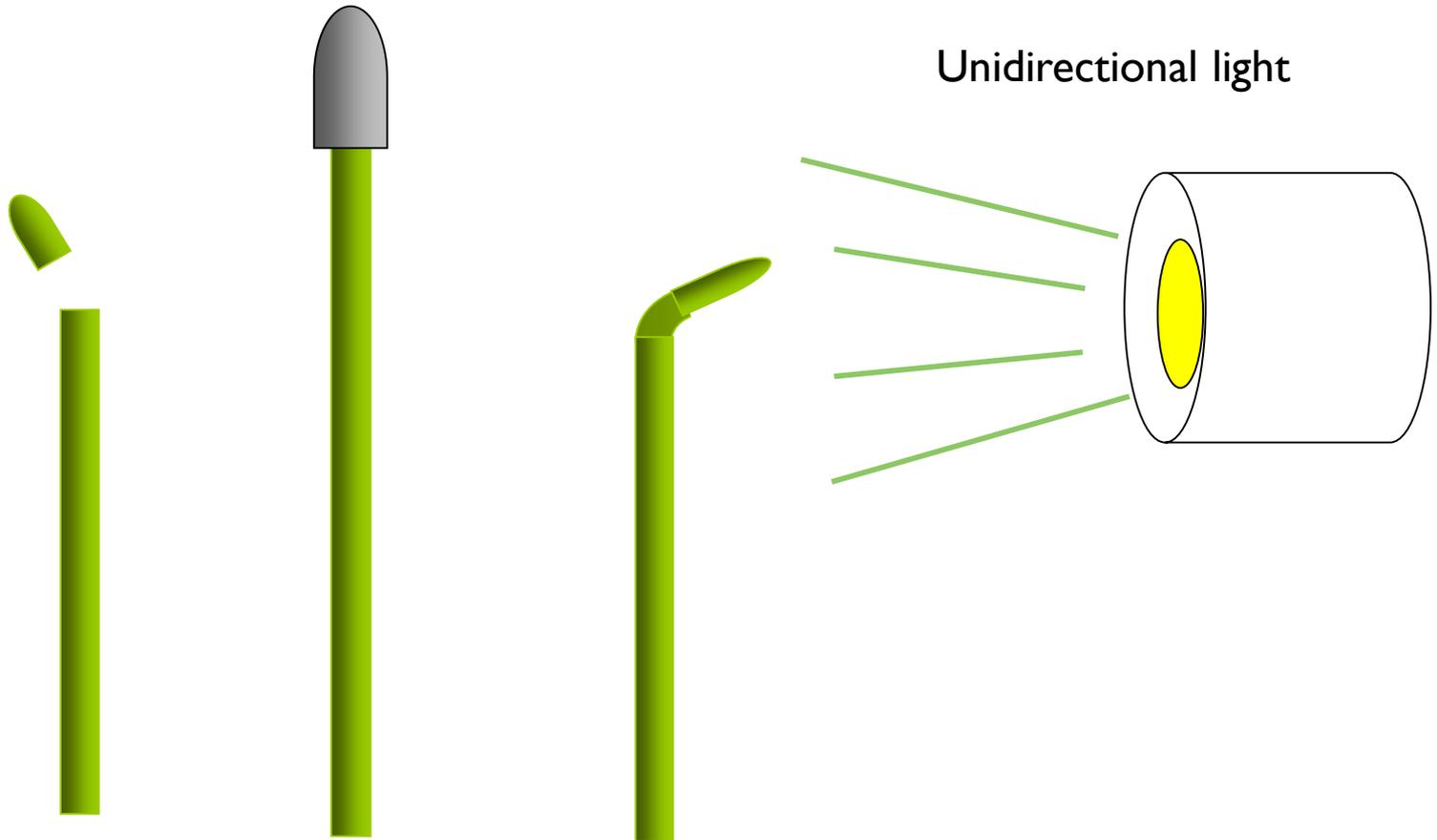
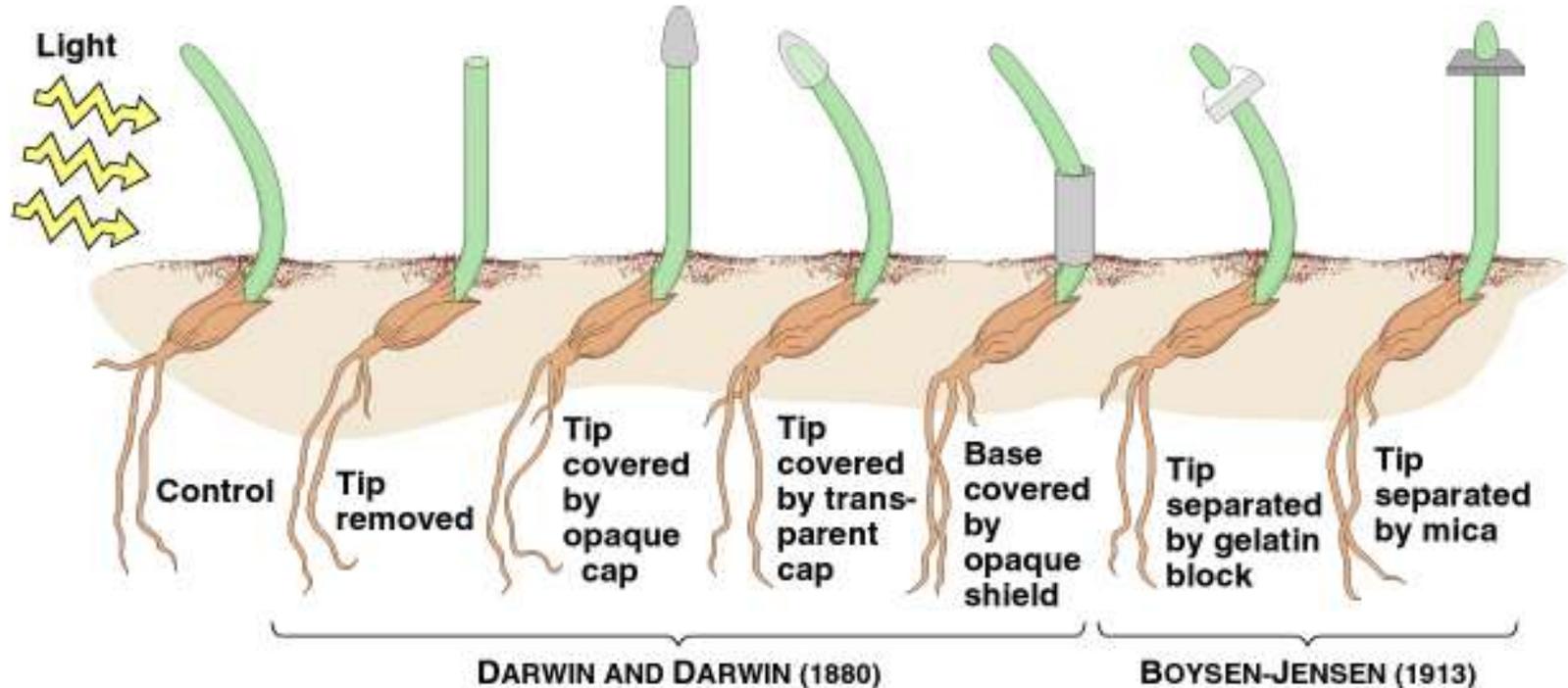


Image Credit: [Oat coleoptiles \(Avena\)](#)

Charles Darwin 1880



EARLY EXPERIMENTS ON PHOTOTROPISM SHOWED THAT A STIMULUS (LIGHT) RELEASED CHEMICALS THAT INFLUENCED GROWTH



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Results on growth of coleoptiles of canary grass and oats suggested that the reception of light in the tip of the shoot stimulated a bending toward light source.

Charles Darwin 1880

- Coleoptile tips are **positively phototropic**
- Bends behind the tip = zone of cell elongation
- Tip is the location of the **sensor**
- The zone of cell elongation is the **effector**
- Covered tips = taller growth
- Tip removed = no growth.

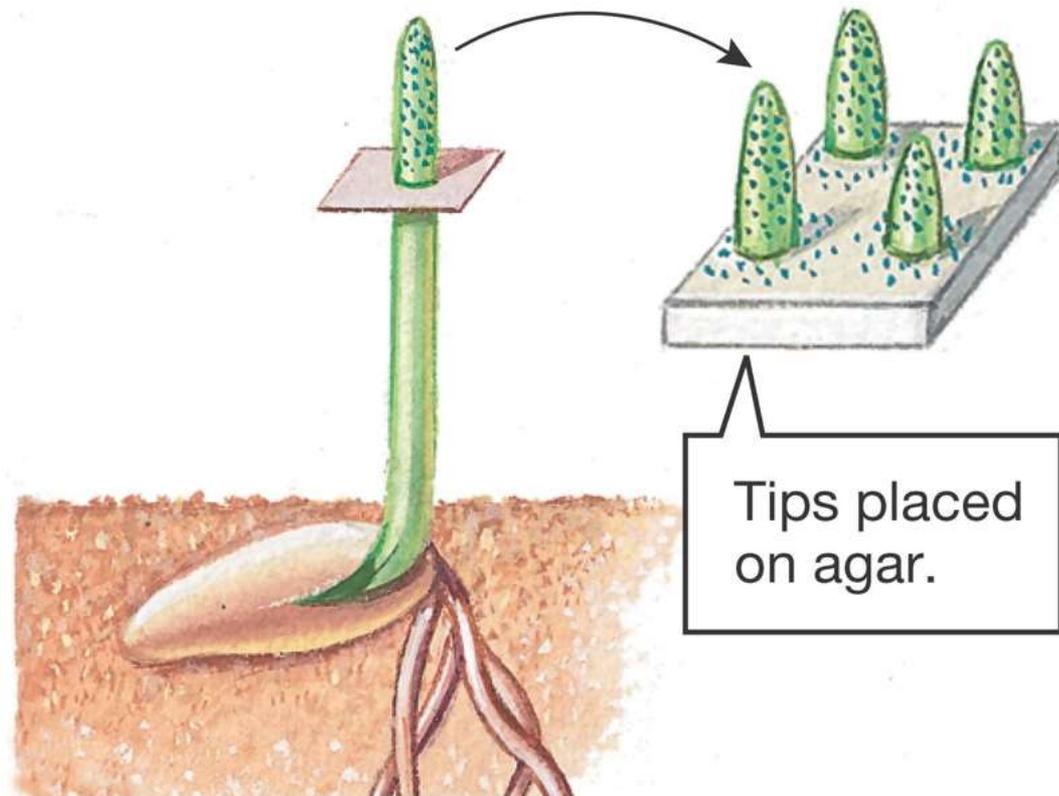
F.W.Went

- In the early 20th century, F.W.Went worked on identifying the factor that was causing plants to bend toward the light.
- By building on the work of the Darwins and Boysen-Jensen, Went was able to isolate the factor and show how it worked.



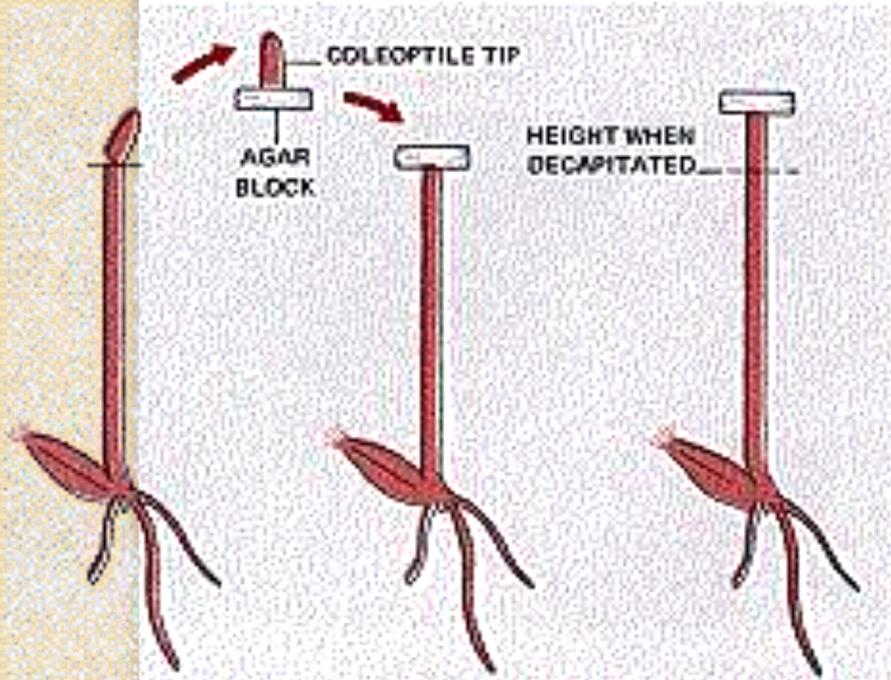
F.W.Went

Went first cut the tips off of oat coleoptiles and placed them on a block of agar and allowed juices from the tip to diffuse into the agar.



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Went then cut blocks from the agar. If he cut a tip from an oat coleoptile and placed an agar block on top, then put the coleoptile in the dark, it grew just as it would if the tip were intact.

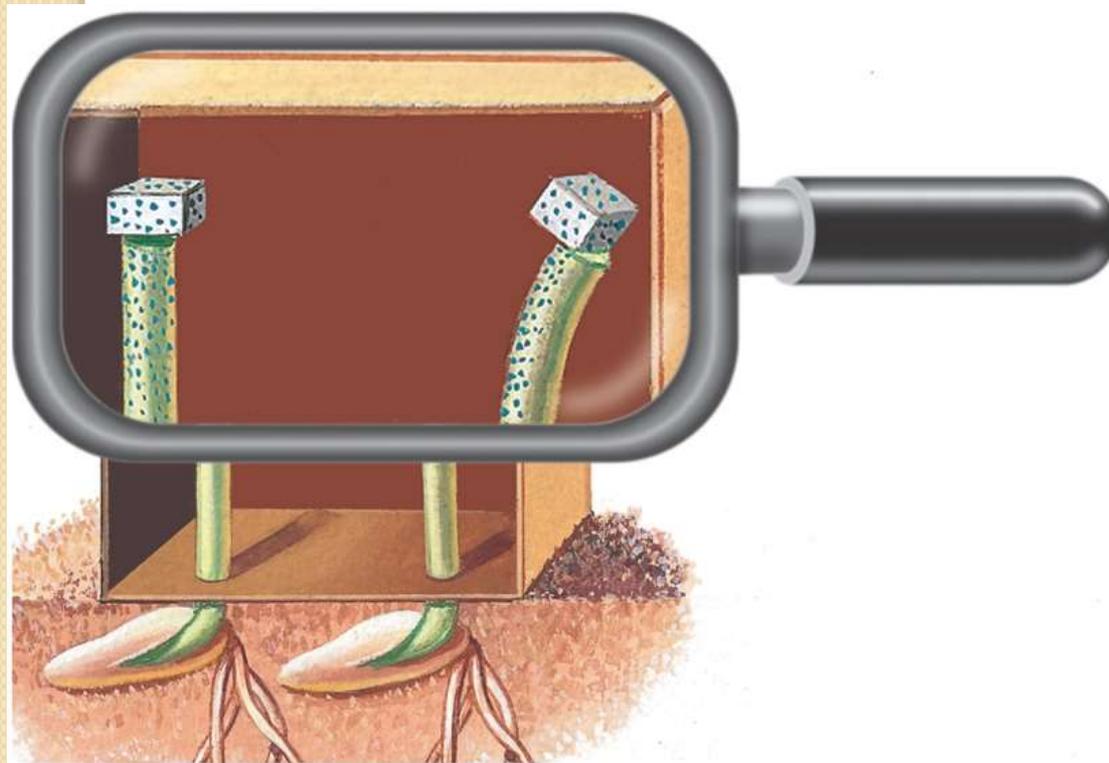


Questions:

Why use the agar block infused with plant juice instead of just cutting and replacing the tip?

Why place the plants in the dark instead of shining light on one side as in the other experiments?

Went also compared what happened when he placed an agar block squarely on top of a clipped coleoptile versus what happened when he set the block on one side of the cut tip. In the first case, the coleoptile grew straight up. In the second, it bent.



Questions:

What does this tell us about the role of juice from the coleoptile tip in plant growth?

What effect do you think the juice is having at the cellular level?

The Mystery Factor

- Eventually, F.W. Went was able to isolate a chemical from coleoptile juice: Indole acetic acid (IAA), one chemical in a class of plant hormones called auxins.

Introduction to Auxin

- First growth hormone to be studied in plants
- Play important role in growth and development of plant
- Developmental processes like stem elongation, apical dominance, root initiation, fruit development, meristem development is controlled by auxin

Auxin

- Auxin and cytokinin are required for viability of the plant embryo
- Whereas other hormones act as regulators of discrete developmental processes

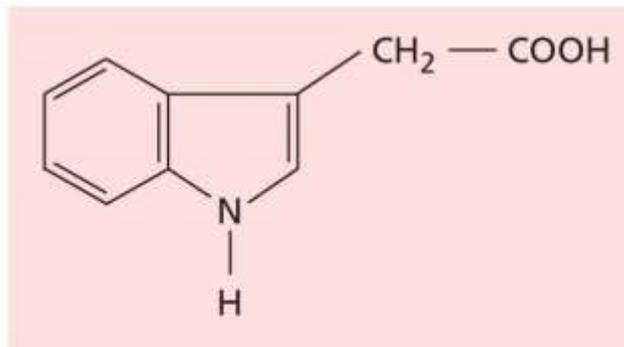
phototropic response.

- Occurs in very low concentrations.
 - Isolated from human urine, ($40\text{mg } 33 \text{ gals}^{-1}$)
 - In coleoptiles ($1\text{g } 20,000 \text{ tons}^{-1}$)
- Differential response depending on dose.

Natural Auxin

The term auxin is derived from the Greek word auxein which means to grow. Compounds are generally considered auxins if they can be characterized by their ability to induce cell elongation in stems and otherwise resemble indoleacetic acid (the first auxin isolated) in physiological activity.

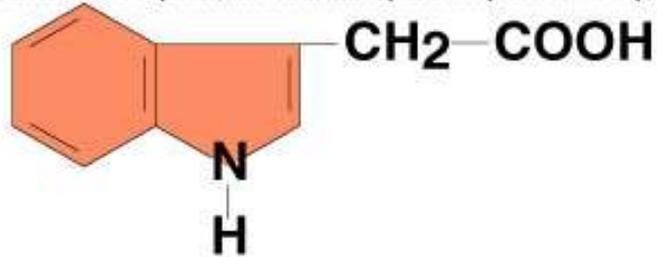
- I. Endogenous
- Indole Acetic Acid



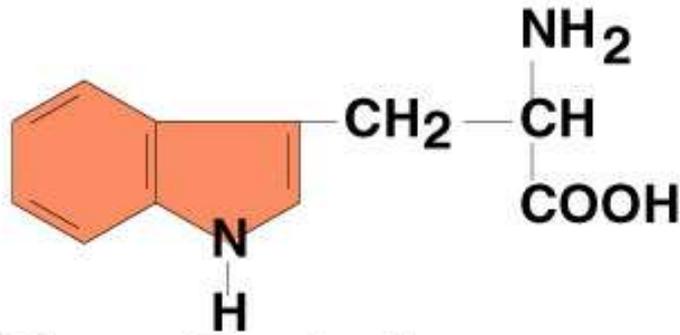
Indole-3-acetic acid
(IAA)

Auxins

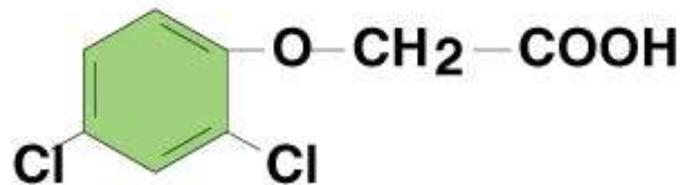
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(a) IAA (Indoleacetic acid)



(b) Tryptophan

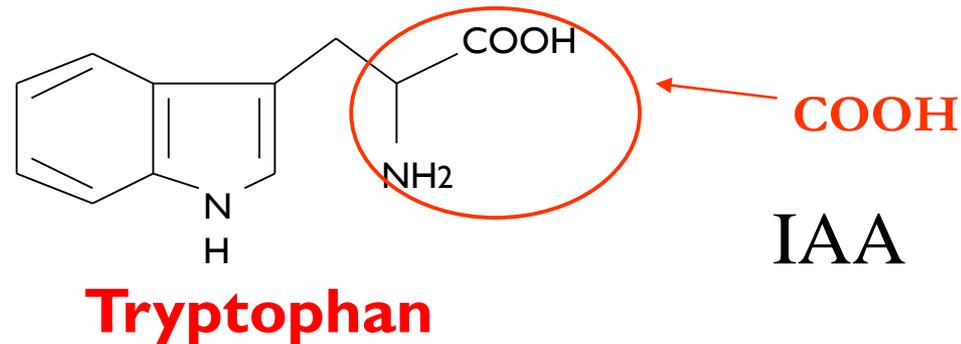


(c) Dichlorophenoxyacetic acid (2,4-D)

BIOSYNTHESIS

- IAA biosynthesis is associated with rapidly dividing and growing tissues
- Primary site of auxin synthesis are shoot apical meristem and young leaves
- Root apical meristem also synthesizes auxin
- Young fruits and seeds also have high level of auxin

Biosynthetic pathway of IAA :- Tryptophan dependent pathway



- The IPA pathway (indole-3-pyruvic acid)
- The TAM pathway (tryptamine)
- The IAN pathway (indole-3-acetonitrile)
- The IAM pathway (indole-3-acetamide)

Indole-3-pyruvic acid pathway

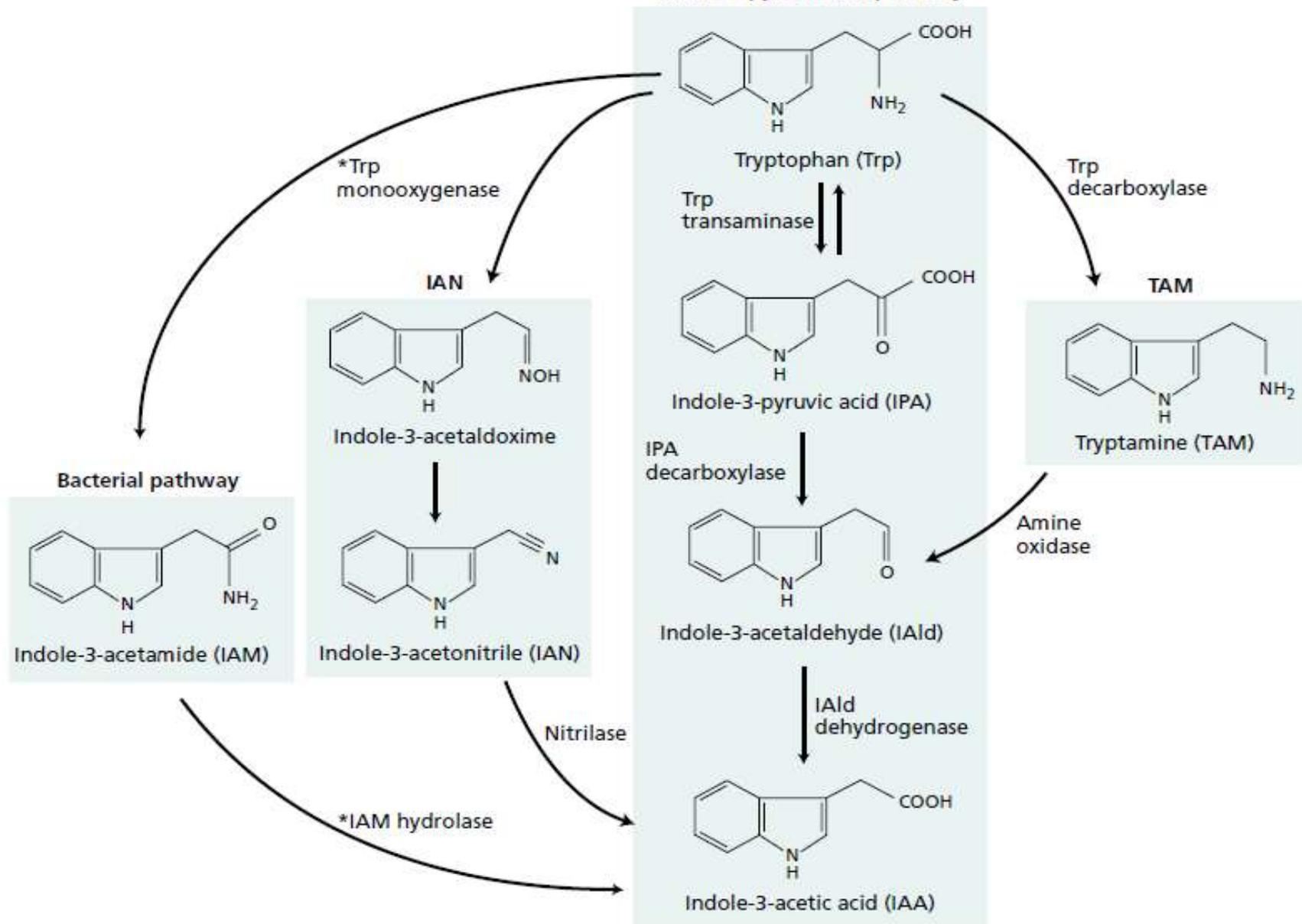
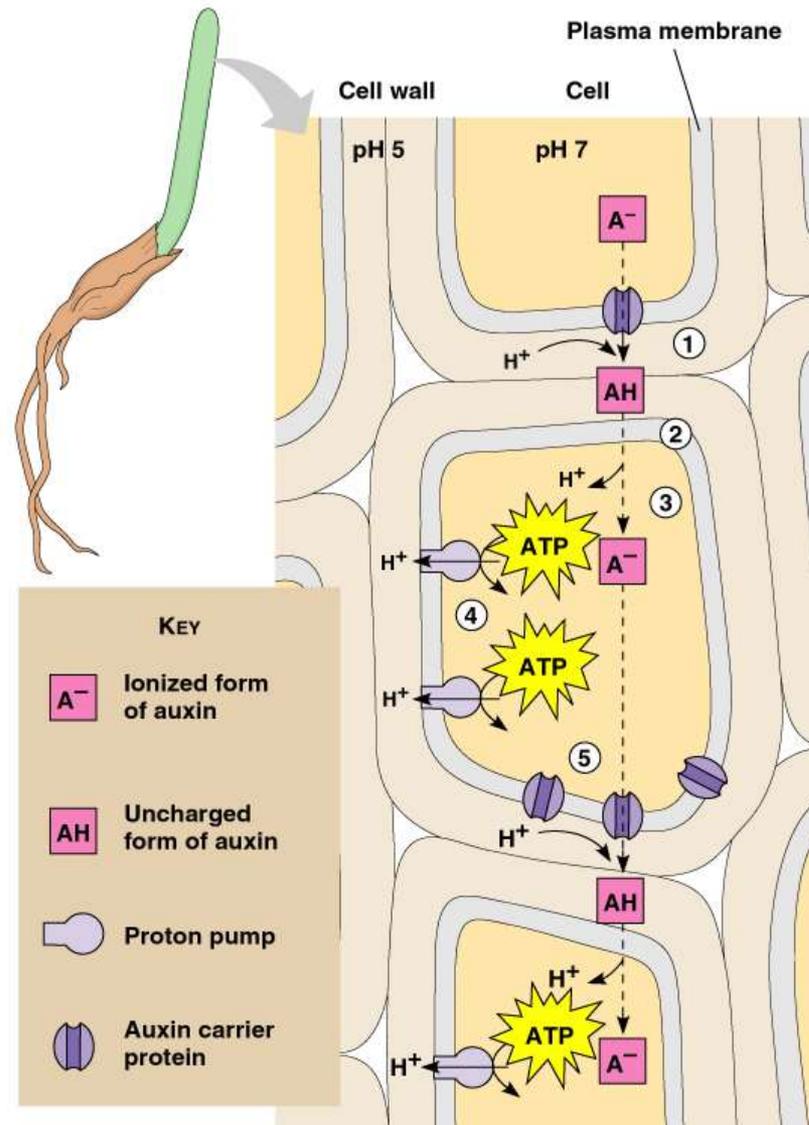


FIGURE 19.6 Tryptophan-dependent pathways of IAA biosynthesis in plants and bacteria. The enzymes that are present only in bacteria are marked with an asterisk. (After Bartel 1997.)

Polar transport of Auxin



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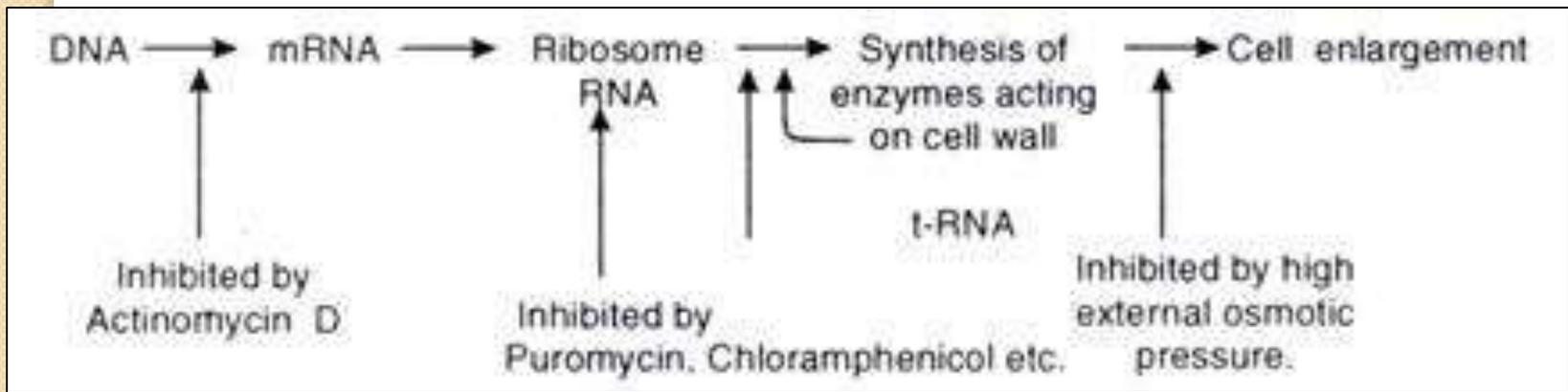
I. Cell Elongation

The primary physiological effect of auxin in plants is to stimulate the elongation of cells in shoot. A very common example of this can be observed in phototropic curvatures where the unilateral light unequally distributes the auxin in the stem tip (*i.e.*, more auxin on shaded side than on illuminated side).

The higher concentration of auxin on the shaded side causes the cells on that side to elongate more rapidly resulting in bending of the stem tip towards the unilateral light.

Accordingly, the auxin causes cell elongation probably:

- (i) By increasing the osmotic solutes of the cells,
- (ii) By reducing the wall pressure,
- (iii) By increasing the permeability of cells to water,
- (iv) By an increase in the wall synthesis and
- (v) By inducing the synthesis of specific DNA dependent new m-RNA and specific enzymic proteins. The latter bringing about an increase in cell plasticity and extension resulting ultimately in cell enlargement.



INDUCES CELL DIVISION: Auxin also induces / promotes cell division within the cambial region.

The action of auxin at the cellular level

- The regulation of gene expression – slow response
- Auxin affects about 10 genes that determine cell growth
- Acts at the transcription of these genes.

2. Apical Dominance

It has been a common observation in many vascular plants especially the tall and sparsely branched ones that if the terminal bud is intact and growing, the growth of the lateral buds just below it remained suppressed. Removal of the apical bud results in the rapid growth of the lateral buds. This phenomenon in which the apical bud dominates over the lateral buds and does not allow the latter to grow is called as **apical dominance**.

Skoog and Thimann (1934) first pointed out that the apical dominance might be under the control of auxin produced at the terminal bud and which is transported downward through the stem to the lateral buds and hinders their growth. They removed the apical bud of broad bean plant and replaced it with agar block. This resulted in rapid growth of lateral buds. But, when they replaced the apical bud with agar block containing auxin, the lateral buds remained suppressed and did not grow.

Apical Dominance



- ❖ Lateral branch growth are inhibited near the shoot apex, but less so farther from the tip.
- ❖ Apical dominance is disrupted in some plants by removing the shoot tip, causing the plant to become bushy.

Thinking question

- How does pinching back a plant, such as this chrysanthemum, cause it to become more bushy?



3. Root Initiation

In contrast to the stem, the higher concentration of auxin inhibits the elongation of root but the number of lateral branch roots is considerably increased i.e., the higher conc. of auxin initiates more lateral branch roots.

Application of IAA in lanolin paste to the cut end of a young stem resulted in an early and extensive rooting. This fact is of great practical importance and has been widely utilized to promote root formation in economically useful plants which are propagated by cuttings.

Adventitious roots

- Adventitious roots are those growing out of places where roots don't normally grow.
- Auxins stimulate root growth on the end of a houseplant cutting..



Thinking question

- When people grow new plants from cuttings, they often dip the end of the cutting in rooting compound to stimulate root growth.
 - ***What hormone is in the compound?***
 - ***How does it work?***

4. Prevention of Abscission

Natural auxins have controlling influence on the **abscission of leaves**, fruits etc.

5. Parthenocarpy

- Auxin can induce the formation of parthenocarpic fruits. In nature also, this phenomenon is common and in such cases the concentration of auxins in the ovaries has been found to be higher than in the ovaries of plants which produce fruits only after fertilization.
- In the latter cases, the concentration of the auxin in ovaries increases after pollination and fertilization.



Normal development



Seeds removed



Seeds removed; auxin applied

6. Respiration

It has been established that the auxin stimulates respiration and there is a correlation between auxin induced growth and an increased respiration rate.

According to French and Beevers (1953), the auxin may increase the rate of respiration indirectly through increased supply of ADP (Adenosine diphosphate) by rapidly utilizing the ATP in the expanding cells.

7. Callus Formation

- Besides cell elongation the auxin may also be active in cell division.
- In fact, in many tissue cultures where the callus growth is quite normal, the continued growth of such callus takes place only after the addition of auxin.

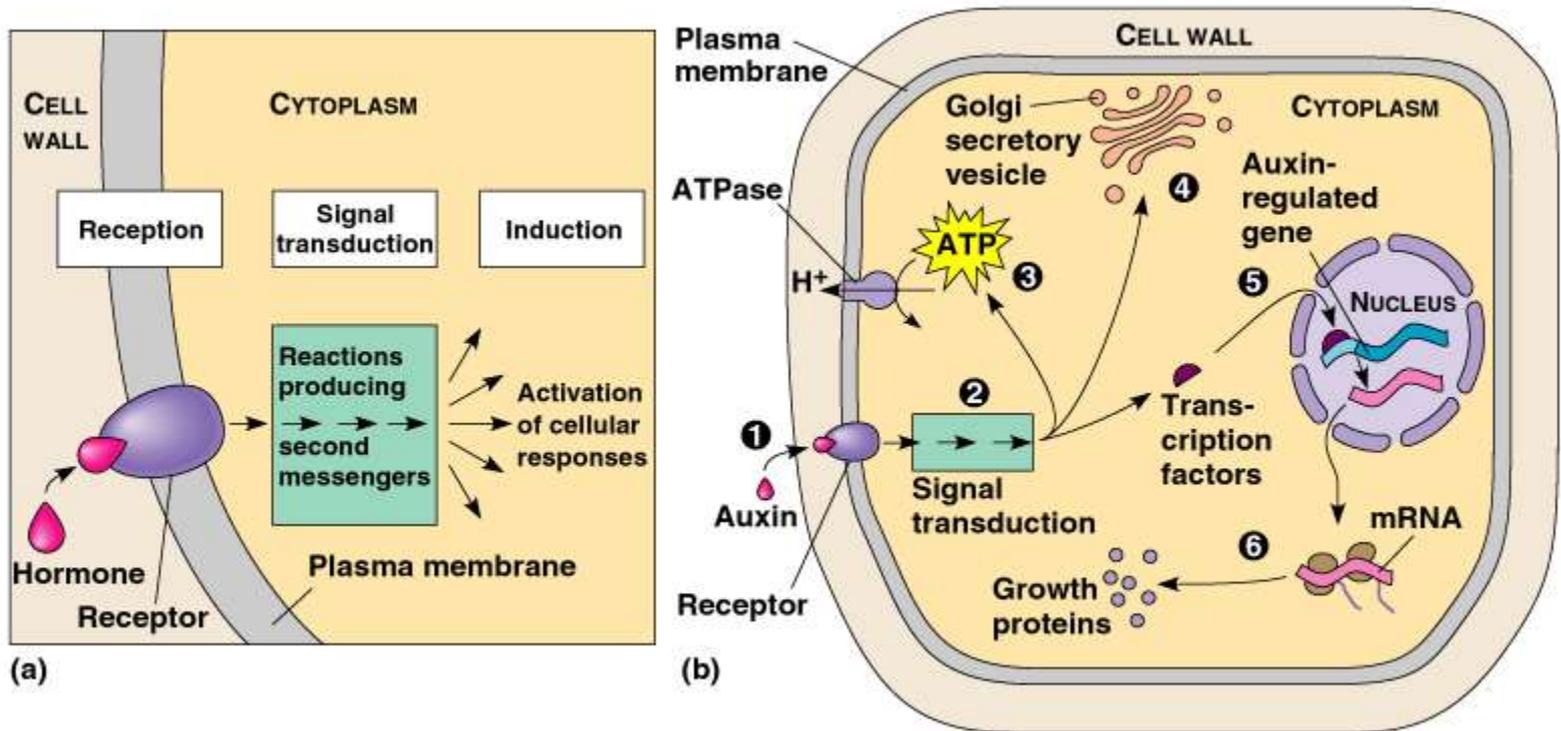
8. Vascular Differentiation

- Auxin induces vascular differentiation in plants.
- This has been confirmed in tissue culture experiments and from studies with transgenic plants.
- Cytokinins are also known to participate in differentiation of vascular tissues and it is believed that vascular differentiation in plants is probably under the control of both auxin and cytokinins.

Additional responses to auxin

- **Abscission - loss of leaves:** Abscission does not occur when auxin content is high on distal end and low in the proximal end of abscission zone.
- **Sex expression:** Auxin induced the changing of sex ratio of flowers towards femaleness, i.e. increase the number of female flowers.
- **Callus Formation:** Undifferentiated mass of parenchymatous tissue is known as callus. • Application of IAA causes cells to elongate & adventitious root.
- **Fruit development**
- **Flower initiation**
- **Parthenocarpy:** Auxin induces Parthenocarpy.

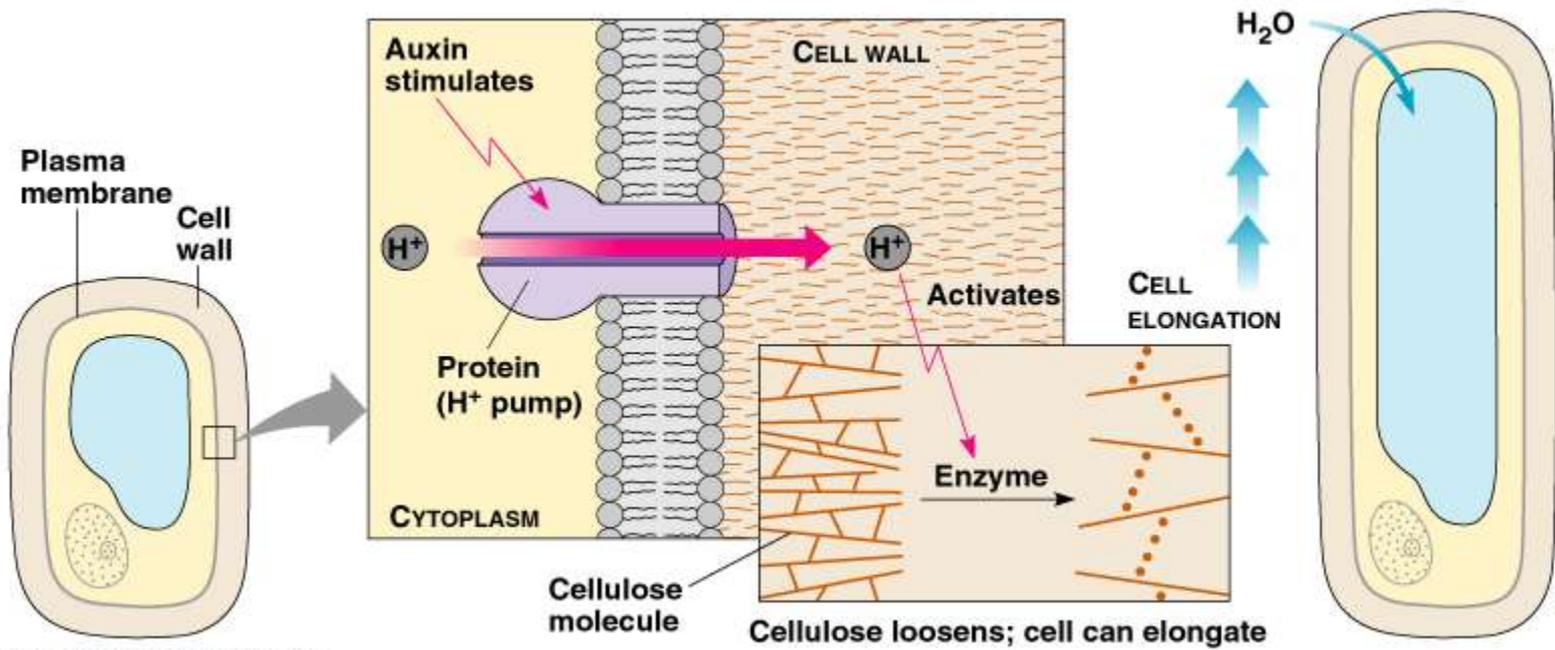
Signal-transduction pathways in plants



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Auxin interacts with calcium ions which in turn calmodulin, a protein, which regulates many processes in plants, animals, and microbes.

Loosening of cell wall



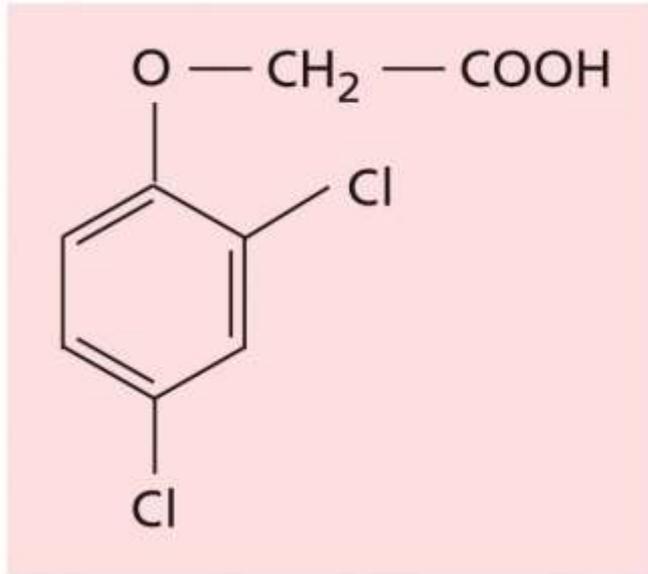
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The action of auxin at the cellular level

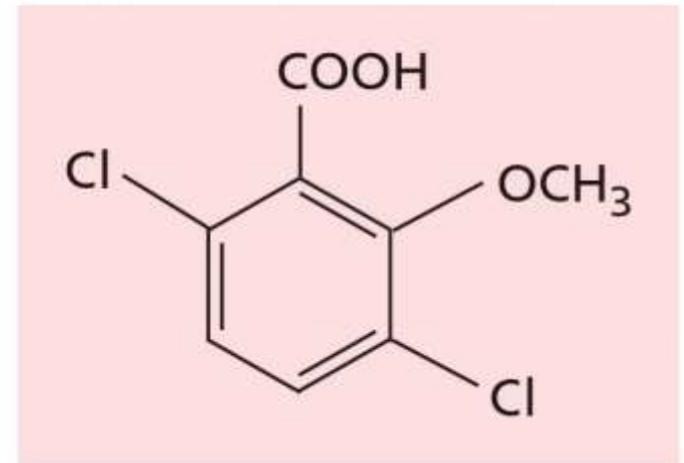
Acid growth hypothesis – rapid response

- Causes rapid pumping of H^+ out of the plasma membrane
- Acidifies cell wall
- Hydrolyses bonds between cellulose fibrils
- Loosens cell wall
- Cell swells under turgor pressure.

Synthetic Auxins



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



2-Methoxy-3,6-dichlorobenzoic acid (dicamba)

PLANT PHYSIOLOGY, Third Edition, Figure 19.4 © 2002 Sinauer Associates, Inc.

Auxin

- Synthetic auxins
 - ❖ widely used in agriculture and horticulture
 - ❖ prevent leaf abscission
 - ❖ prevent fruit drop
 - ❖ promote flowering and fruiting
 - ❖ control weeds
 - ❖ Agent Orange - 1:1 ratio of 2,4-D and 2,4,5-T used to defoliate trees in Vietnam War.
 - ❖ Dioxin usually contaminates 2,4,5-T, which is linked to miscarriages, birth defects, leukemia, and other types of cancer.

Use of Auxin in Agriculture

➤ Rooting of Cuttings

- Application of NAA (in Mango) and IBA (in Guava) in stem cutting causes **100% success** in vegetative propagation.

➤ Prevention of Sprouting

- In case of Potato – Methyl ester of NAA (MENA)
- In case of Onion – Maleic Hydrazide (MH)

➤ Seedless Fruit Production (Parthenocarpy)

- In case of Banana, Grapes, Strawberry, Brinjal, Grapes – Application of IAA, IBA, and NAA show 100% success.

Use of Auxin in Agriculture

➤ Promotion of Flowering

- Application NAA causes uniform flowering in Pineapple leading to development of uniform sized fruits.
- 2, 4 -D is also used to increase the femaleness in monoecious Cucurbits.

➤ Prevention of Premature Dropping of Fruits

- In case of Apple and Cotton - NAA
- In case of Citrus fruits – 2,4–D/ 2,4,5-T

➤ Germination

- IAA, IBA, is most widely used in soaking seeds for germination.

Use of Auxin in Agriculture

➤ Fruit Setting

- 2, 4, 5-T is used for improved fruit setting in berries.

➤ Thinning of Flower, Fruit and Leaves

- 2, 4-D is used for defoliation of Cotton plant before boll harvesting.
- NAA is used for fruit thinning in Apple.

➤ Prevention of Lodging in Cereals

- 30-40% Yield loss in traditional tall varieties. Alpha naphthalene acetamide is used to prevent lodging in cereals.

Use of Auxin in Agriculture

➤ Weedicide

- 2, 4-D, MCPA (Methyl Chloro-Phenoxy Acetic Acid) are weed killer.
- 2,4-D is highly toxic to broad leaved plants or dicotyledons.

➤ Tissue Culture

- Auxin along with cytokinin shows successful callus formation, root-shoot differentiation etc.



THANK YOU ALL

Dr. Suranjana Sarkar, SNC