Plant Hormones - Outline
1. Discovery
2. Chemical structure
3. Biological effects
4. Mechanism of action
5. Agricultural applications if any

Types of Plant Hormones
1. Auxin
2. Cytokinins
3. Gibberellins
4. Abscisic Acid
5. Ethylene
6. Brassinosteroids

What are plant hormones?
1. Chemical messengers that regulate plant growth
2. Endocrine (often) → transported to target tissue
3. Interact with protein receptors

Auxin – The Growth Hormone
Agricultural Applications
1. Rooting of cuttings
2. Prevention of premature fruit drop
3. Promotion of flowering in pineapple
4. Parthenocarpic, seedless fruit development
5. Herbicides for dicot or broadleaf weeds
   - 2,4-D
   - Dicamba
   - 2,4,5-T

Auxin – Oat Coleoptile Curvature Bioassay

Auxin Bioassay: Oat Coleoptile Elongation Assay

Auxins – Discovery
1. Darwin & phototropism: Canary grass coleoptiles.
2. 1913: Boysen-Jensen: Growth stimulus passes through gelatin but not impermeable material.
3. 1919: Paul: Growth stimulus was a chemical.
4. 1926: Fritz Went: Conclusive evidence growth stimulus was a chemical.
Dose-response curve for IAA-induced growth

What is auxin?

Auxin = indole-3-acetic acid

0.5nm distance is important for auxin activity

IAA Site of Synthesis

1. Rapidly growing tissues
   - Shoot meristems
   - Root meristems
   - Young leaves
   - Developing fruits

Other auxins: Natural & Synthetic

Naturally Occurring Auxins
- Indole-3-Acetic Acid
- 4-Chloro-indole-3-acetic Acid
- Indole-3-butyric Acid

Synthetic Auxins
- 2,4-Dichlorophenoxy Acetic Acid
- 2-Methoxy-3,6-Dichlorobenzoic Acid (Dicamba)

Auxin Detection

1. Bioassay: 0.02mg l⁻¹ = 0.02ppm
   ≈ 0.000000001 g in a 1 drop sample
   ≈ 1 billionth of a gram

2. GCMC: detects 10⁻¹² g
   ≈ 1000 times > bioassay
   ≈ amt in a single stem tip

Visualizing IAA Distribution in Tissue

IAA responsive DNA promoter
+ GUS
+ Ti plasmid

GUS reporter gene fused to auxin response element synthesizes GUS enzyme to react with substrate producing a blue color
Reveals sites of auxin production.

Recombinant Plant DNA

Differentiating xylem

Auxin diffusion trail
≈ auxin gradient

Site of auxin synthesis
• Start wed 4/1/09

**Auxin Transport is Polar & Basipetal**
1. Auxin transport is polar and basipetal = apex to base
2. Polar transport is gravity independent
3. Polar transport is cell to cell, but not through the symplast
4. Polar transport is slow: 5-20cm hr⁻¹ faster than diffusion, slower than translocation
5. Site of polar transport in stems & leaves is vascular parenchyma

**Relevance of Polar Auxin Transport**
- Auxin synthesis in leaves
- Longitudinal gradient down stem... or to roots
- Developmental processes affected: stem elongation, apical dominance, leaf senescence, root development

**Chemiosmotic Model of Auxin Influx**
Proton efflux into cell wall then entrance into cytoplasm by two mechanisms
1. Passive diffusion of protonated IAAH into cytoplasm
2. Permease 2H⁺ - IAA⁻ symporter = Secondary active transport of IAA

**Cellular Mechanism for Polar Auxin Transport**
- **Auxin Efflux**
  1. Anionic form to IAA predominates in cytoplasm
  2. Anionic IAA (IAA⁻) exits cell via auxin anion efflux carriers at basal end of cell

- **PIN protein in plasma membrane**
  1. Located asymmetrically in plasma membrane
  2. 10-20 transmembrane regions
  3. Rapidly cycled to and from plasma membrane
**Cellular Mechanism for NONPolar Auxin Transport**

P-Glycoproteins are:
1. ATP-dependent transporters
2. Function as hydrophobic anion carriers
3. Function independently to catalyze nondirectional auxin transport
4. Function cooperatively with PIN proteins for directional auxin transport

![Auxin Transport Model in Meristematic Cells](image)

W = wild type
br2 = Brachytic 2 mutant in corn

**How does cell elongation growth occur?**

1. Osmotic uptake of water
2. Increase in turgor pressure
3. Biochemical wall loosening

**Auxin mechanism**

**Auxin acid-growth hypothesis**

**Auxin Transport Model in Meristematic Cells**

**How does auxin induce growth?**

Cell Elongation Growth
1. Stimulated in Stems & coleoptiles
2. Inhibited in roots

**Cell elongation after IAA treatment**

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Cell length (μm)</th>
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<tbody>
<tr>
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<tr>
<td>45</td>
<td>125</td>
</tr>
<tr>
<td>60</td>
<td>150</td>
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**Auxin Acid-Growth Hypothesis**

**Supporting Evidence**

1. Acid buffers promote short term growth.
2. Auxin increases rate of proton extrusion.
4. Fusicoccin (promotes proton extrusion) & stimulates growth.
5. Cell walls protein expansins respond optimally at acid pH. Expansins loosen hydrogen bonds between cell wall polysaccharides

**Auxin-Molecular Mechanism of Action**

**Activation and Synthesis Hypotheses**

1. Direct activation of plasma membrane H^+ - ATPase by auxin-binding protein
2. Gene activation & synthesis of new H^+ - ATPases on plasma membrane
Model for IAA-induced Proton Extrusion by Gene Repression

1. Auxin inhibits transcriptional repressor.
2. Auxin enhances ATPase traffic to plasma membrane
3. Auxin stabilizes ATPase at plasma membrane

Physiological Effects of Auxin - Tropisms

1. Tropisms
   a. Phototropism
   b. Gravitropism
   c. Thigmotropism

Physiological Effects of Auxin - Phototropism

1. Light-stimulated growth response
2. Cholodny-Went Model of Phototropism
   a. Auxin production alinear the apex
   b. Perception of unilateral light
   c. Lateral IAA transport
3. Perception of unilateral light
   a. Blue-light activation
   b. Flavoproteins called phototropins (1 & 2) sense blue light
   c. Phosphorylation gradient induces lateral auxin movement
4. After lateral transport, auxin moves basipetally to stimulate growth.

Physiological Effects of Auxin - Gravitropism in Coleoptiles

Gravitropism in Roots

Starch Statolith Hypothesis

Gravitropism in Roots Root cap produces an inhibitor

Starch sheath in stem required for gravitropism in shoots.
Physiological Effects of Auxin

Gravitropism in Roots

1. Auxin inhibits lateral bud development
2. Related to AXR1 protein in xylem and sclerenchyma between vascular bundles.
3. Possible involvement of a carotenoid cleavage product from the root

Other Physiological Effects of Auxin

1. Delays onset of Abscission
2. Promotes fruit development
3. Induces Vascular Differentiation

Synthesis of 2,4,5-T … a synthetic auxin

Other "dioxins" may have from 1 to 8 chlorine atoms attached