Unit 5 · Plant Hormones

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Plant Physiology (Units 2–6 together): 11 of 75 marks; 3 MCQs (knowledge, application, higher ability) and 1 long question (8 marks: knowledge 1, understanding 3, application 2, higher ability 2)
- **The paper:** Botany 37 + Zoology 38; each part: MCQs × 1 (5 Botany, 6 Zoology) · 4 short × 4 · 2 long × 8; one OR in each short and long group; 3 hours; 1 mark per expected point
- **CDC's model paper:** short (OR): plant growth hormones; the functions of auxin and the harm of using too much of it
- **MCQ (1 mark)**
  - natural auxin IAA; made in shoot and root apices
  - pinching the apical bud interrupts auxin
  - most gibberellin in immature seeds
  - cytokinin delays leaf senescence; kinetin divides callus cells
  - lateral buds grow with low auxin, high cytokinin
- **Short and long (in parts)**
  - what a phytohormone is
  - roles of auxin; of gibberellin; of cytokinin
  - callus stops growing: which hormones to add, why
  - fruit dropping in wind: which regulator, how it works
  - commercial uses of cytokinins

Key terms

Phytohormone (Thimann, 1948): natural organic substance, made in one part, acting **elsewhere** in **very small amounts** to control growth.

Endogenous: made inside the organism.

Plant growth regulator: any organic compound, **not a nutrient**, changing growth in low concentration: **natural and synthetic**.

Classic five: auxins, gibberellins, cytokinins, abscisic acid, ethylene (since added: brassinosteroids, jasmonates, salicylic acid, strigolactones).

Coleoptile: hollow sheath round a grass seedling's first leaf.

Bioassay: measuring a substance by its effect on a living thing (Avena curvature test).

Polar (basipetal) transport: auxin moves only from the shoot tip **down**.

Apical dominance: the apical bud keeps the lateral buds below it dormant.

Abscission: shedding of leaves, flowers or fruits at the **abscission layer**.

Parthenocarpy: fruit without fertilization, seedless.

Callus: lump of undifferentiated dividing cells in tissue culture.

Anti-auxin: blocks auxin's movement (TIBA).

Bolting: sudden lengthening of a rosette's stem into a flowering axis.

Senescence: aging; leaf loses chlorophyll and protein, turns yellow.

Richmond–Lang effect (1957): kinetin keeps detached leaves green.

Plant hormones

- every plant hormone is a regulator; not every regulator (2,4-D) is a hormone
- **ethylene**: a gas, acts near where made; still a hormone
- unlike animal hormones: made in **many tissues**; **one hormone, many effects**; act in **balance** (a **ratio** decides)
- hard to pin down: many responses; different hormones give similar ones; varies with variety, age, development, nutrition; several proposed modes
- receptors found since the 1990s: TIR1 (auxin), GID1 (gibberellin), 2005; most switch genes on

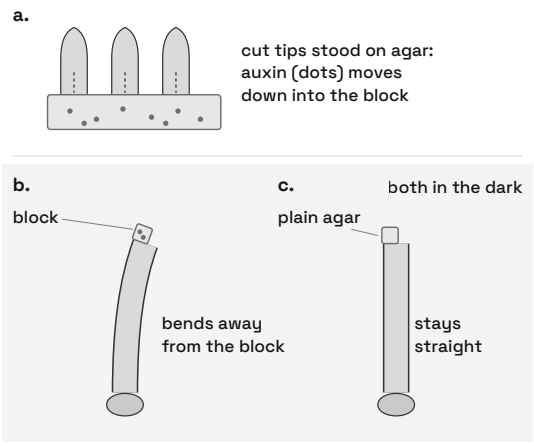
Group	Defined by	Main effect
auxins	like **IAA**; lengthen coleoptiles	cell elongation
gibberellins	**diterpenoids** (20C); lengthen dwarf, rosette stems	stem elongation
cytokinins	**substituted adenines**, like **zeatin**; divide tobacco cells	cell division
ethylene	gas, C_2H_4; seedlings grow thicker	ripening, abscission
abscisic acid	15C terpenoid	dormancy, stomata close

Auxins

- Greek *auxein*, to grow; made in **shoot tips** (apical bud, young leaves), root tips; act in the **zone of elongation**
- named by **Kögl and Haagen-Smit** (1931), from human urine
- Darwins (1880): coleoptile bends to light only with its tip

Went's Avena curvature test (1926–28, oat, *Avena sativa*)

1. coleoptile tips on **agar** → auxin diffuses in
2. block on **one side** of a cut stump, in the dark
3. stump **bends away** from the block; plain agar: no bend
4. angle ∝ auxin → first **bioassay**; "no growth without growth substance"



Went's Avena curvature test.

- natural: **IAA** (from tryptophan), in every plant; also 4-chloro-IAA, PAA, IBA in some
- **free** auxins move out readily; **bound** (to sugars, amino acids): released by hydrolysis
- **polar transport**: shoot tip → base, cell to cell, by carriers; cuttings root at the lower end

Synthetic auxin	Use
IBA (indole-3-butyric acid)	rooting cuttings
NAA (naphthalene acetic acid)	rooting; stops fruit drop
MENA	stops stored potatoes sprouting
MCPA, 2,4-D	weedkillers
2,4,5-T	weedkiller (now banned)

- synthetics last longer: plant enzymes can't break them; **TIBA** = anti-auxin

Physiological effects

1. **cell elongation**: acid loosens the wall, cell takes in water; also cambium divides → secondary growth, xylem and phloem
2. **apical dominance**: auxin from the apex keeps lateral buds dormant; tip removed → branches; auxin paste on the stump → still dormant; pinching tea, hedges, chrysanthemums
3. **root initiation**: many roots on stems (IAA in **lanolin**, IBA, NAA powders); high auxin **inhibits root elongation**
4. **prevents abscission**: NAA, 2,4-D at low strength stop **premature fruit drop** (apple, orange, mango)
5. **parthenocarpy**: seedless tomato, cucumber, brinjal
6. **respiration** ↑ (more ADP)
7. **callus** growth in tissue culture (with cytokinin)
8. **weedkiller**: high 2,4-D, 2,4,5-T kill broad-leaved plants; monocots (wheat, rice) less affected
9. **flowering**: mostly inhibits; **pineapple**: uniform flowering (via ethylene); cucurbits: more **female** flowers

- **too much**: inhibits root growth; at high doses kills plants (weedkiller); 2,4,5-T banned
- cuttings with rooting powder root sooner, more, at the lower end

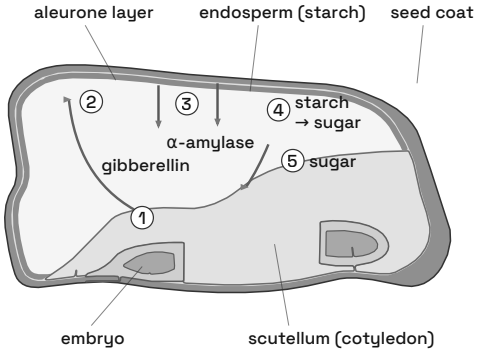
Gibberellins

- **bakanae** ("foolish seedling") of rice: tall, thin, pale, no grain
- **Kurosawa** (1926): fungus *Gibberella fujikuroi* filtrate; **Yabuta** named it (1935); crystals with **Sumiki** (1938)
- 130+ known (GA_1, GA_2 ...); **GA_3** (gibberellic acid) sold for farm use
- **biosynthesis**: acetate + CoA → acetyl CoA → mevalonic acid → MVA pyrophosphate → **isopentenyl pyrophosphate** (5C) → geranyl PP (10C) → **GGPP** (20C) → **ent-kaurene** (plastids) → gibberellins
- in all parts; reproductive > vegetative; **immature seeds** richest; **free** and **bound** (glycosides)

Physiological effects

1. **seed germination**: replaces light need of lettuce, tobacco seeds

2. **breaks dormancy** of buds; potato tubers sprout → two crops a year
3. **roots**: little effect; inhibits roots on cuttings
4. **internode elongation**: overcomes **genetic dwarfism** (pea, maize)
5. **bolting and flowering**: rosettes (cabbage, lettuce, radish, henbane) bolt and flower in short days; long-day plants flower sooner
6. **parthenocarpy, fruit growth**: pollen germination; pome (apple, pear) and stone fruits where auxin fails; bigger seedless grapes
7. **α-amylase**: embryo → GA → **aleurone layer** → α-amylase genes on → endosperm starch → sugar → embryo; faster malting



Gibberellin and the aleurone layer.

Cytokinins

- **Skoog, Miller** (Wisconsin, 1955): tobacco pith divided with old herring sperm DNA → **kinetin** (6-furfurylaminopurine); from DNA breakdown, not a main plant hormone
- **purines**: adenine with a side chain at N-6
- **zeatin**: first natural one, maize grains (**Letham**, 1963); coconut milk factor; in some **tRNA**
- sources: coconut milk, tomato juice, apple, pear, plum fruits; cambium of pine, *Eucalyptus*, tobacco; immature maize, walnut, banana; *Ginkgo* gametophytes; peach seeds; pea seedlings; sunflower root exudates; tobacco tumors; $\geq$ 7 natural ones by 1970
- **made** from adenine nucleotides + isopentenyl chain, mainly in **root tips** (also seeds, cambium); move **up in xylem** (Kende, 1965), also down; auxin speeds their movement

Physiological effects

1. **cell division** with auxin: tobacco pith callus, carrot, soybean, pea
2. **cell enlargement**: bean leaves, pumpkin cotyledons
3. **counteracts apical dominance**: lateral bud grows; auxin : cytokinin balance decides
4. **breaks seed dormancy** (lettuce, tobacco)
5. **delays senescence**: **Richmond–Lang effect** (*Xanthium*); a treated spot stays green, nutrients drawn to it
6. **flowering** in some short-day plants
7. **morphogenesis** (Skoog and Miller, 1957): **high auxin** → **roots; high cytokinin** → **shoot buds**; equal → callus grows
8. **solutes** drawn in and moved in phloem to the treated part
9. **protein synthesis** ↑ (Osborne, 1962)
10. resistance to heat, cold, disease; enzymes of photosynthesis
11. **commercial**: shelf life of cut flowers, leafy vegetables, fruits; shoots in tissue culture; yield, oil of groundnut

- callus stopped: add **auxin and cytokinin** (cells divide only with both); shoots wanted: more cytokinin

Ethylene and abscisic acid

Ethylene (C_2H_4)

- gas from almost all parts; most from **ripening fruits**, aging flowers and leaves, wounds
- **ripens fruit** (one ripe mango ripens the box); ripening rooms; **ethephon** releases it
- calcium carbide (acetylene): illegal ripening, harmful traces
- **abscission** of leaves, fruits; fading flowers; **triple response** (shorter, thicker stem, bent tip)

Abscisic acid (ABA): "stress hormone"

- water short → ABA → **stomata close** in minutes
- keeps **seeds and buds dormant**; stops sprouting in the fruit; works against gibberellin
- named for cotton fruit abscission; ethylene is the main cause

COMMON MISTAKES

✗ Hormones and growth regulators are the same
✓ regulators include **synthetic** ones (2,4-D).

✗ A plant hormone does one job
✓ one hormone, **many effects**; ratios matter.

✗ In Went's test the stump bends towards the block
✓ **away** from it.

✗ Auxin moves up from the roots
✓ shoot tip **down** (polar).

✗ High auxin helps roots grow longer
✓ it **inhibits** root elongation; it starts roots on stems.

✗ Auxin causes fruit drop
✓ auxin **prevents** it; ethylene causes abscission.

✗ Gibberellins come from the fungus only
✓ plants make them; the fungus makes too much.

✗ Kinetin is the plant's main cytokinin
✓ **zeatin**; kinetin from DNA breakdown.

✗ High cytokinin gives roots
✓ **shoots**; high auxin gives roots.