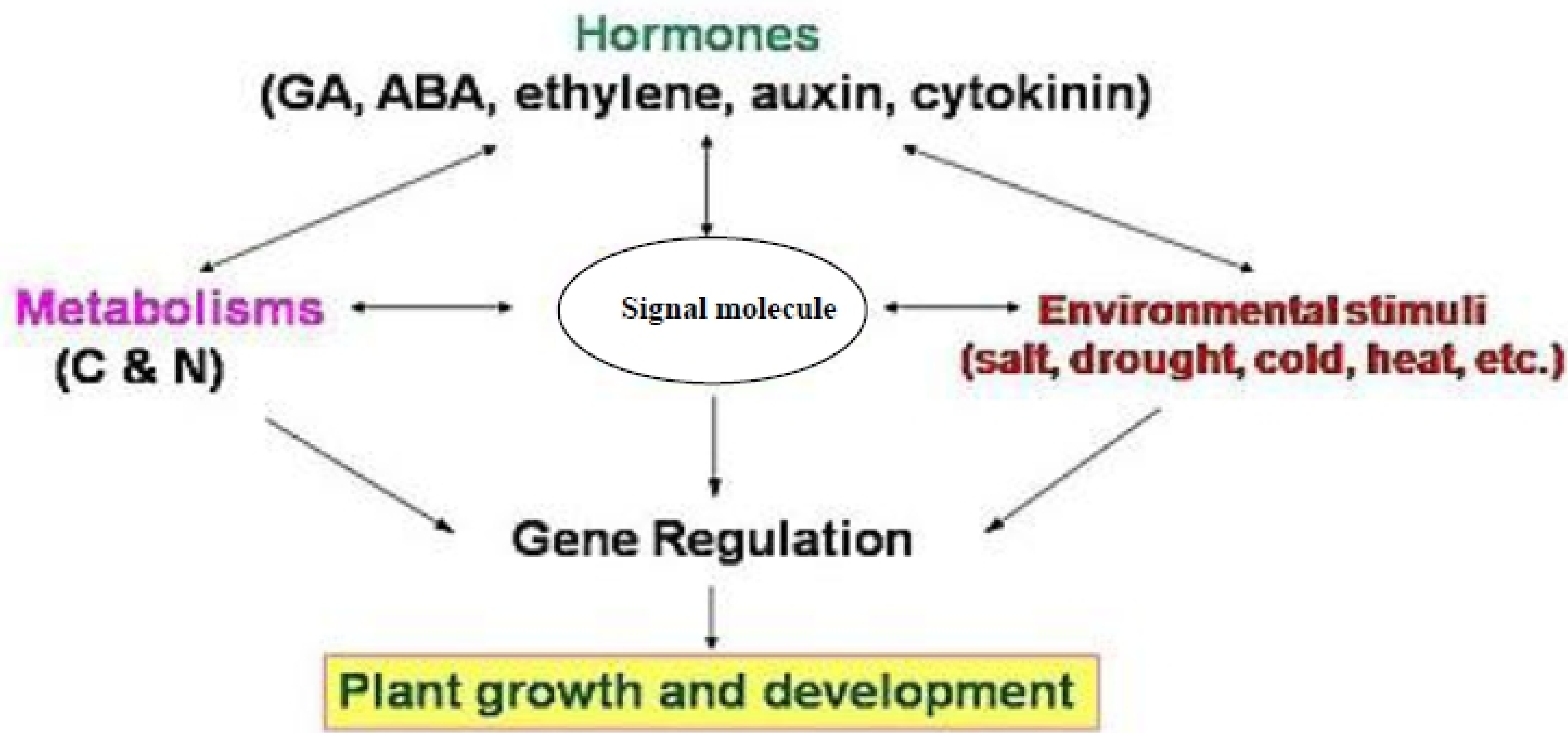

PLANT GROWTH REGULATORS

THE FORM AND FUNCTION of multicellular organism would not be possible without efficient communication among cells, tissues, and organs.

In higher plants, regulation and coordination of metabolism, growth, and morphogenesis often depend on chemical signals from one part of the plant to another.

This idea originated in the nineteenth century with the German botanist Julius von Sachs (1832–1897)

Sachs proposed that chemical messengers are responsible for the formation and growth of different plant organs


Hormones
(GA, ABA, ethylene, auxin, cytokinin)
Metabolisms
(C & N)
Signal molecule
Environmental stimuli
(salt, drought, cold, heat, etc.)
Gene Regulation
Plant growth and development

Plant growth hormone

What they are?

- organic compounds;
- synthesized by the plant;
- active in low concentration ($<10^{-6}$);
- promote or inhibit growth and developmental responses;
- often show a separation of the site of production and the site of action

Plant hormones differ from animal hormones in that:

- No evidence that the fundamental actions of plant and animal hormones are the same.
- Unlike animal hormones, plant hormones are not made in tissues specialized for hormone production. (e.g., sex hormones made in the gonads, human growth hormone - pituitary gland)
- Unlike animal hormones, plant hormones do not have definite target areas (e.g., auxins can stimulate adventitious root development in a cut shoot, or shoot elongation or apical dominance, or differentiation of vascular tissue, etc.).

Plant Growth Regulators –

Both naturally occurring and synthetic growth substances which control growth, and development

Growth promoters and Growth retardents

Mechanism of hormone action

Thus, for a response to occur:

the hormone must be present in sufficient quantity;

the target tissue must be sensitive (sensitized) to the hormone;

the target tissue recognizes the hormone (i.e., there must be a receptor to which the hormone can bind);

the binding of the hormone/receptor should initiate a change in the receptor (amplification).

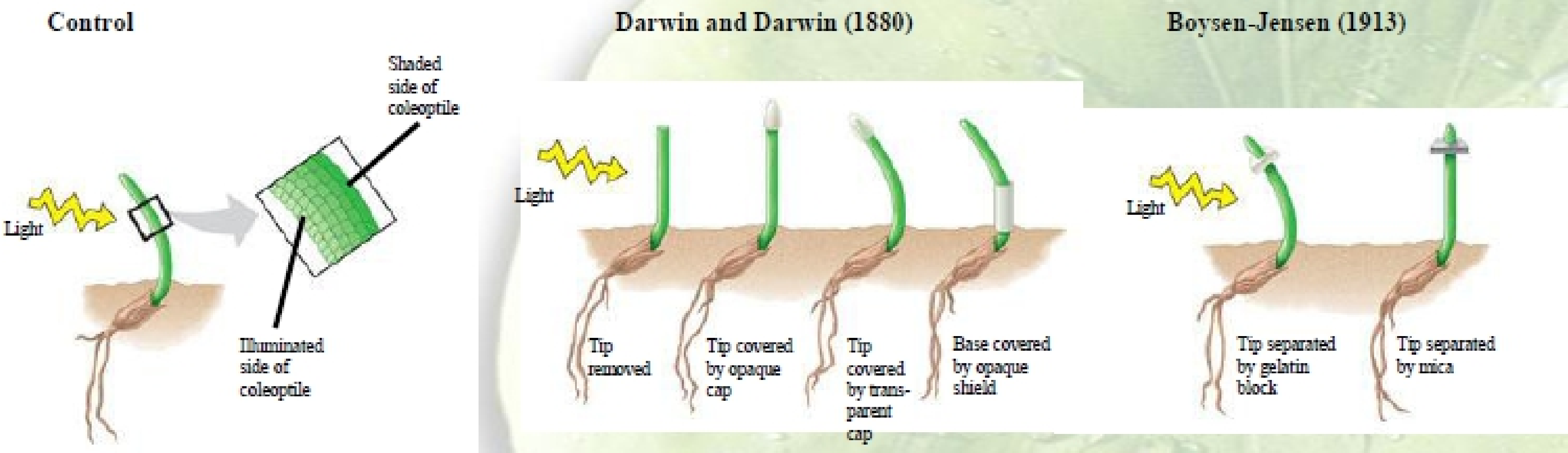
the activated receptor initiates a physiological response

Auxins

- History
- Biosynthesis
- Biological role
- Commercial application

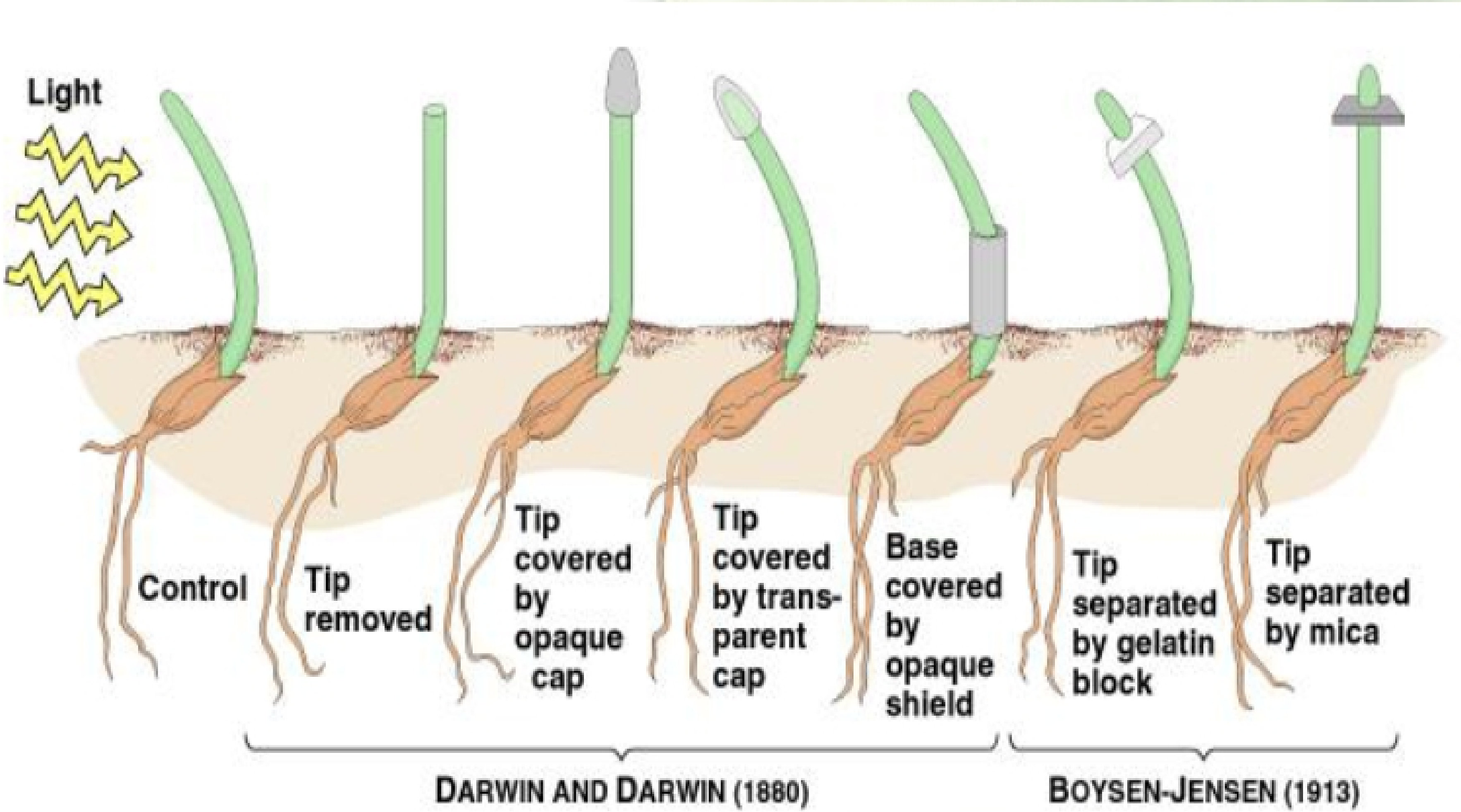
EXPERIMENT In 1880, Charles Darwin and his son Francis designed an experiment to determine what part of the coleoptile senses light. In 1913, Peter Boysen-Jensen conducted an experiment to determine how the signal for phototropism is transmitted.

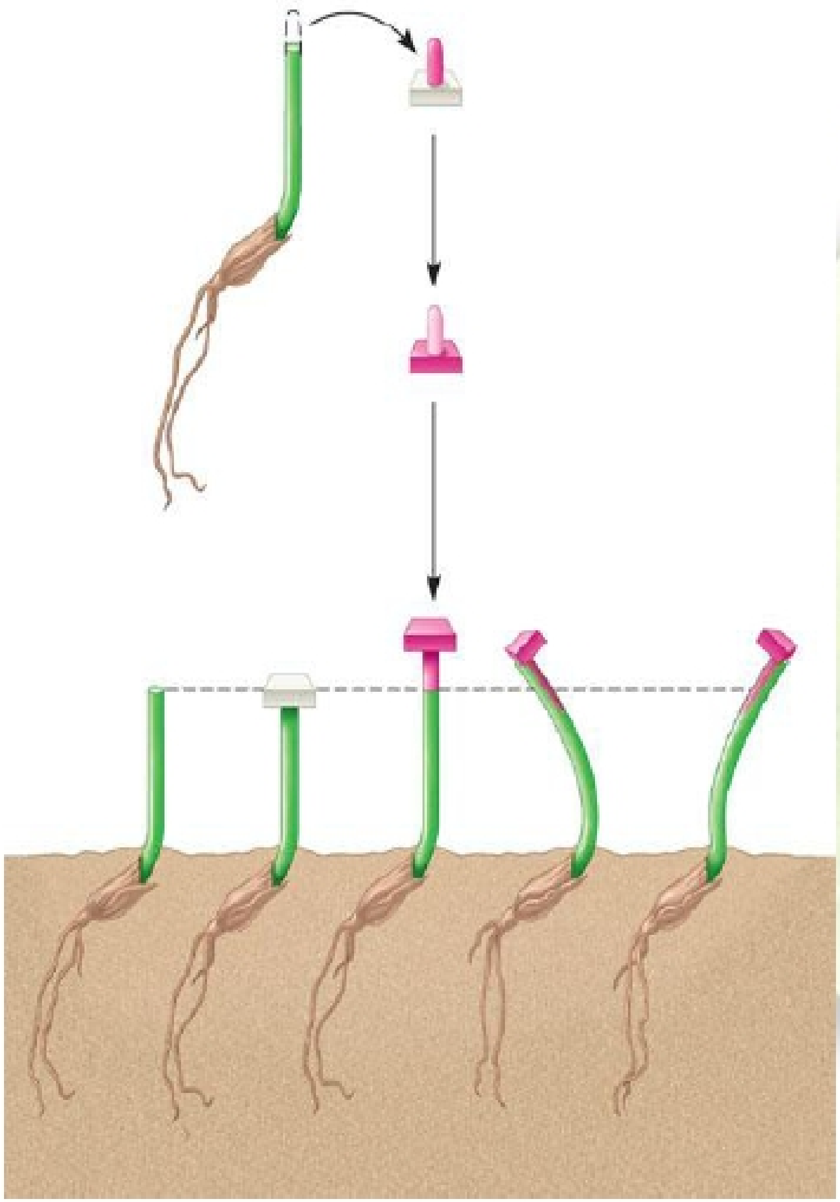
RESULTS



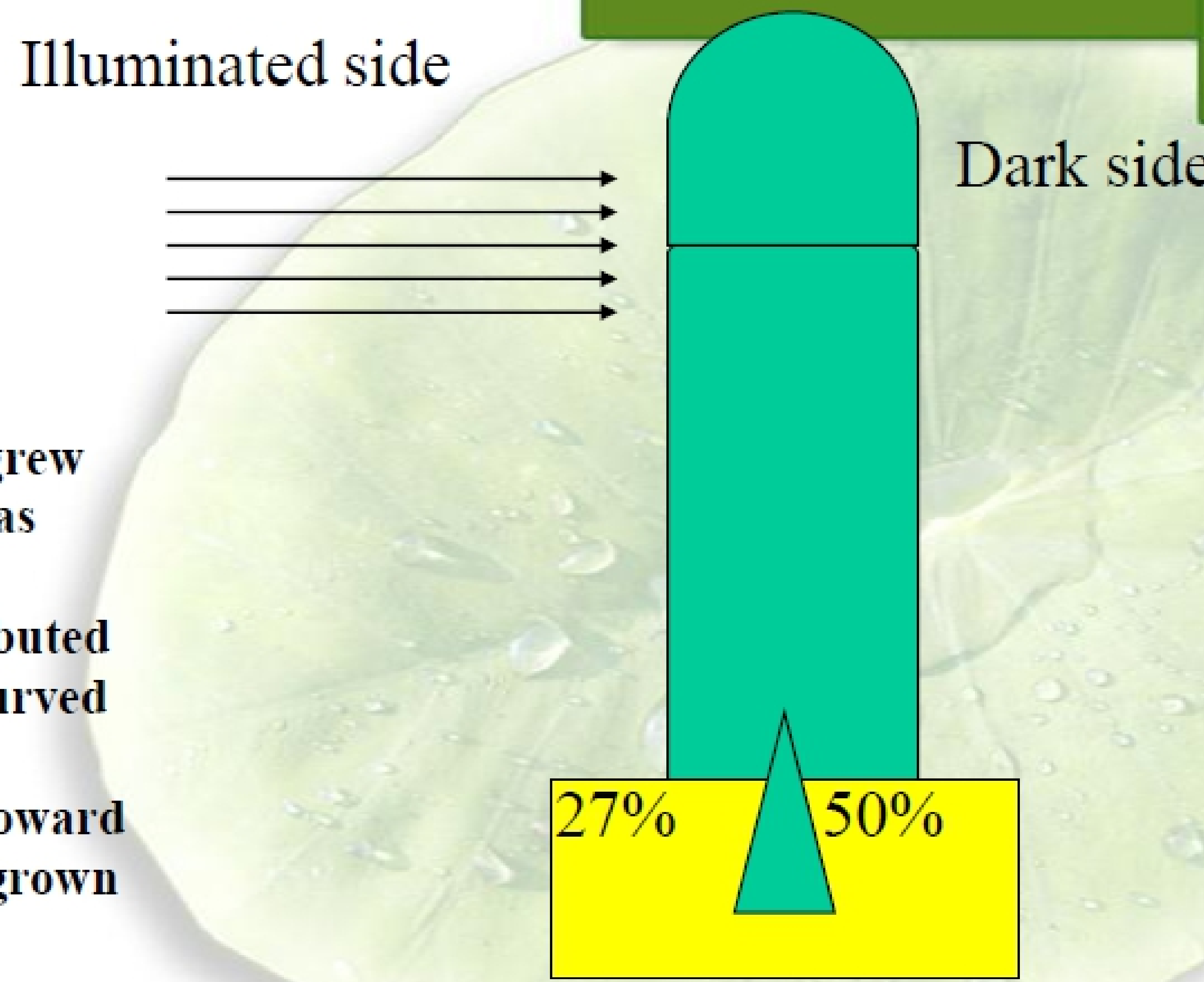
CONCLUSION In the Darwins' experiment, a phototropic response occurred only when light could reach the tip of coleoptile. Therefore, they concluded that only the tip senses light. Boysen-Jensen observed that a phototropic response occurred if the tip was separated by a permeable barrier (gelatin) but not if separated by an impermeable solid barrier (a mineral called mica). These results suggested that the signal is a light-activated mobile chemical.

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





In 1926, Frits Went's experiment identified how a growth-promoting chemical causes a coleoptile to grow toward light. He placed coleoptiles in the dark and removed their tips, putting some tips on agar blocks that he predicted would absorb the chemical. On a control coleoptile, he placed a block that lacked the chemical. On others, he placed blocks containing the chemical, either centered on top of the coleoptile to distribute the chemical evenly or offset to increase the concentration on one side.



The coleoptile grew straight if the chemical was distributed evenly.
If the chemical was distributed unevenly, the coleoptile curved away from the side with the block, as if growing toward light, even though it was grown in the dark.

Went concluded that a coleoptile curved toward light because its dark side had a higher concentration of the growth-promoting chemical, which he named auxin.

Hypothesis for effect of unilateral illumination on distribution of auxin in a coleoptile

Biosynthesis of Auxins :

Site :

Auxin is synthesized in actively growing tissue which includes young leaves, fruits, and especially the shoot apex. Made in cytosol of cells

Biosynthesis

1. Indole pyruvic acid pathway

Tryptophan → Indolepyruvic acid → Indoleacetaldehyde → IAA

2. Tryptamine pathway

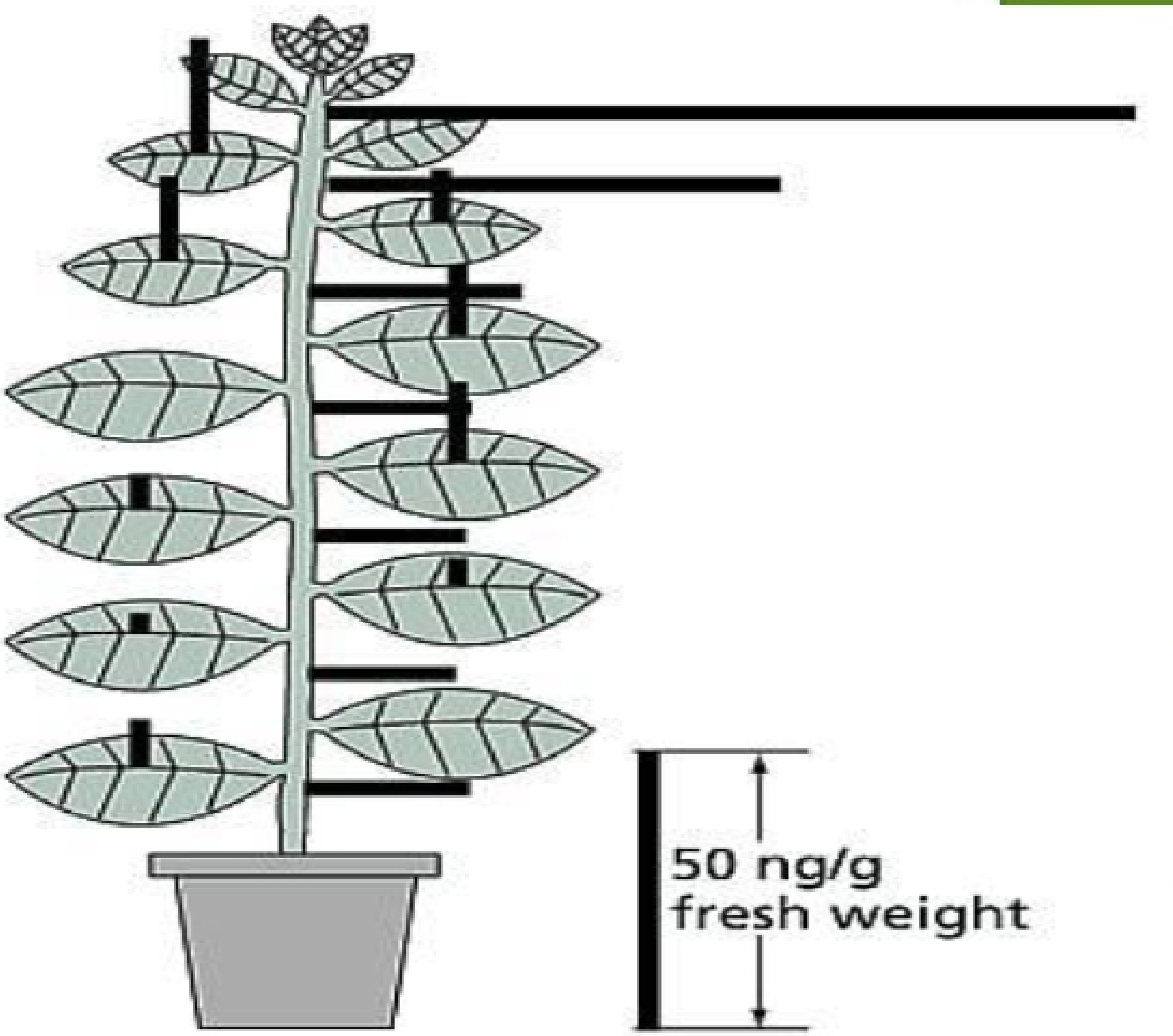
Trypthophan → Tryptamine → Indoleacetaldehyde → IAA

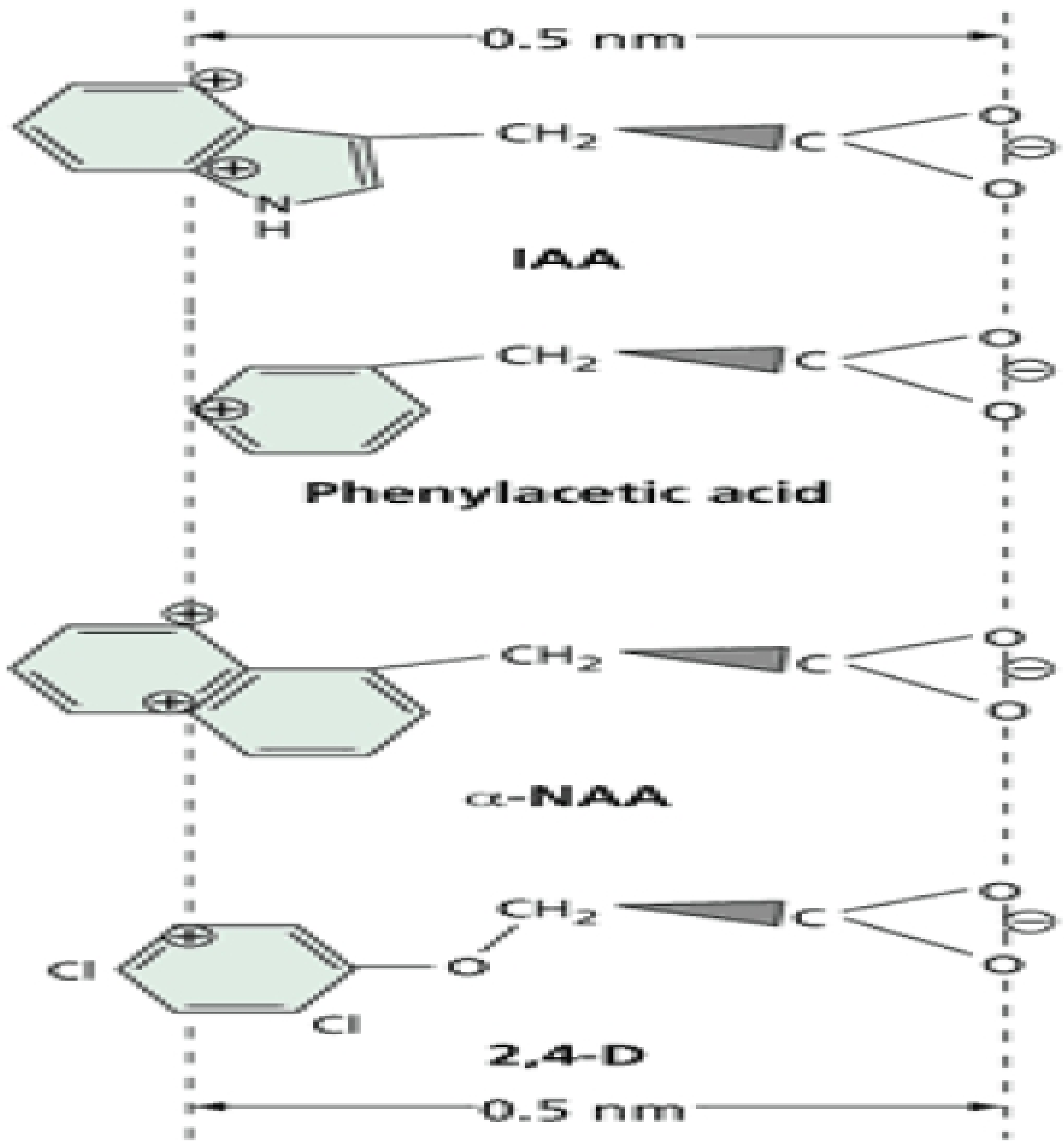
3. Indoleacetonitrile pathway

Trypthophan → Indoleacetaldoxime → Glucobrassicin →

Indoleacetonitrile → IAA

Polar transport of auxin- basipetally





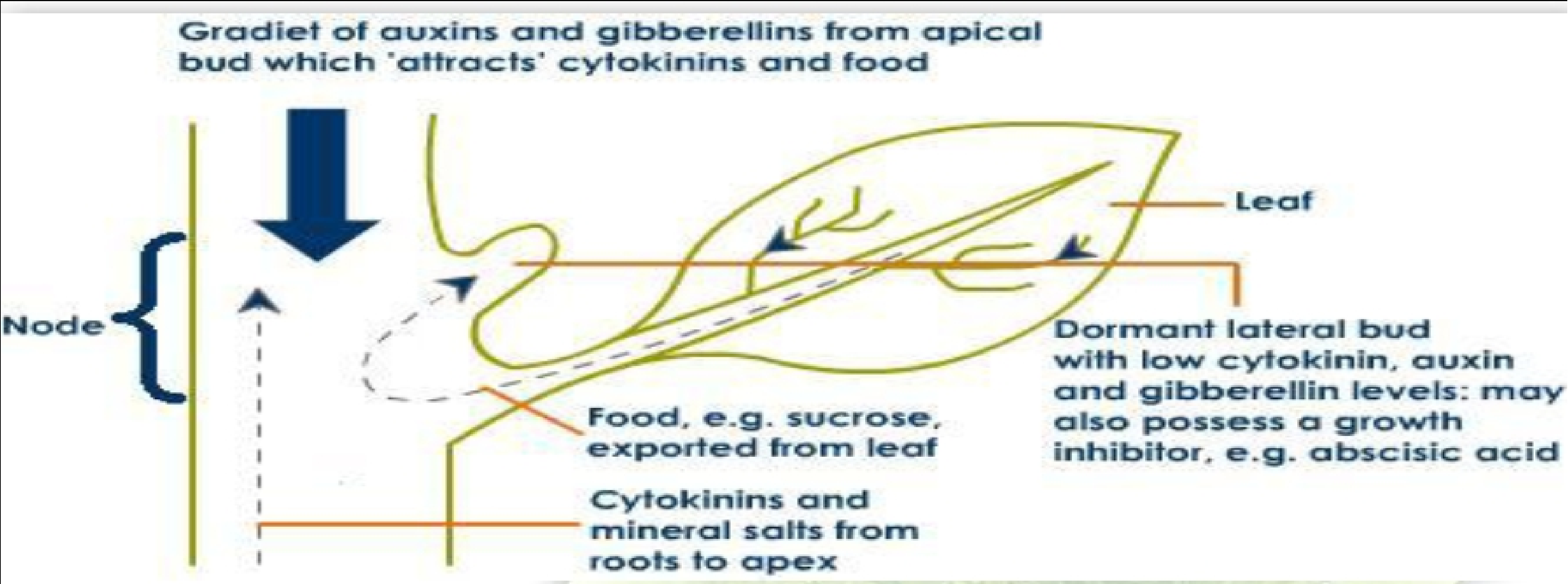
0.5 nm
CH2
C
O
N
H
IAA
Phenylacetic acid
α-NAA
Cl
2,4-D
0.5 nm

Role of Auxins

Apical Dominance

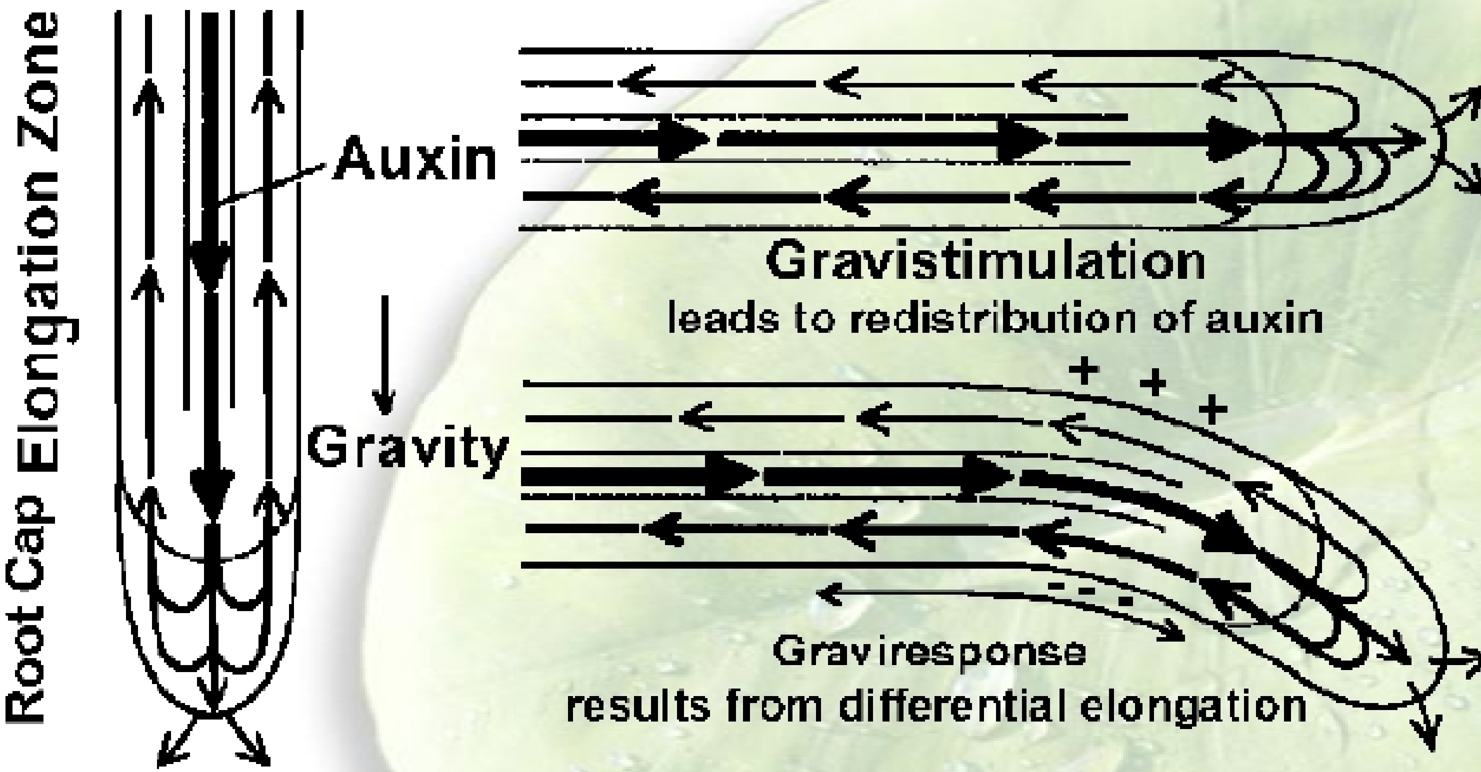
- Cytokinins, auxin, and other factors interact in the control of apical dominance
  - The ability of a terminal bud to suppress development of axillary buds

- If the terminal bud is removed
  - Plants become bushier


Gradiet of auxins and gibberellins from apical bud which 'attracts' cytokinins and food
Leaf
Node
Dormant lateral bud with low cytokinin, auxin and gibberellin levels: may also possess a growth inhibitor, e.g. abscisic acid
Food, e.g. sucrose, exported from leaf
Cytokinins and mineral salts from roots to apex

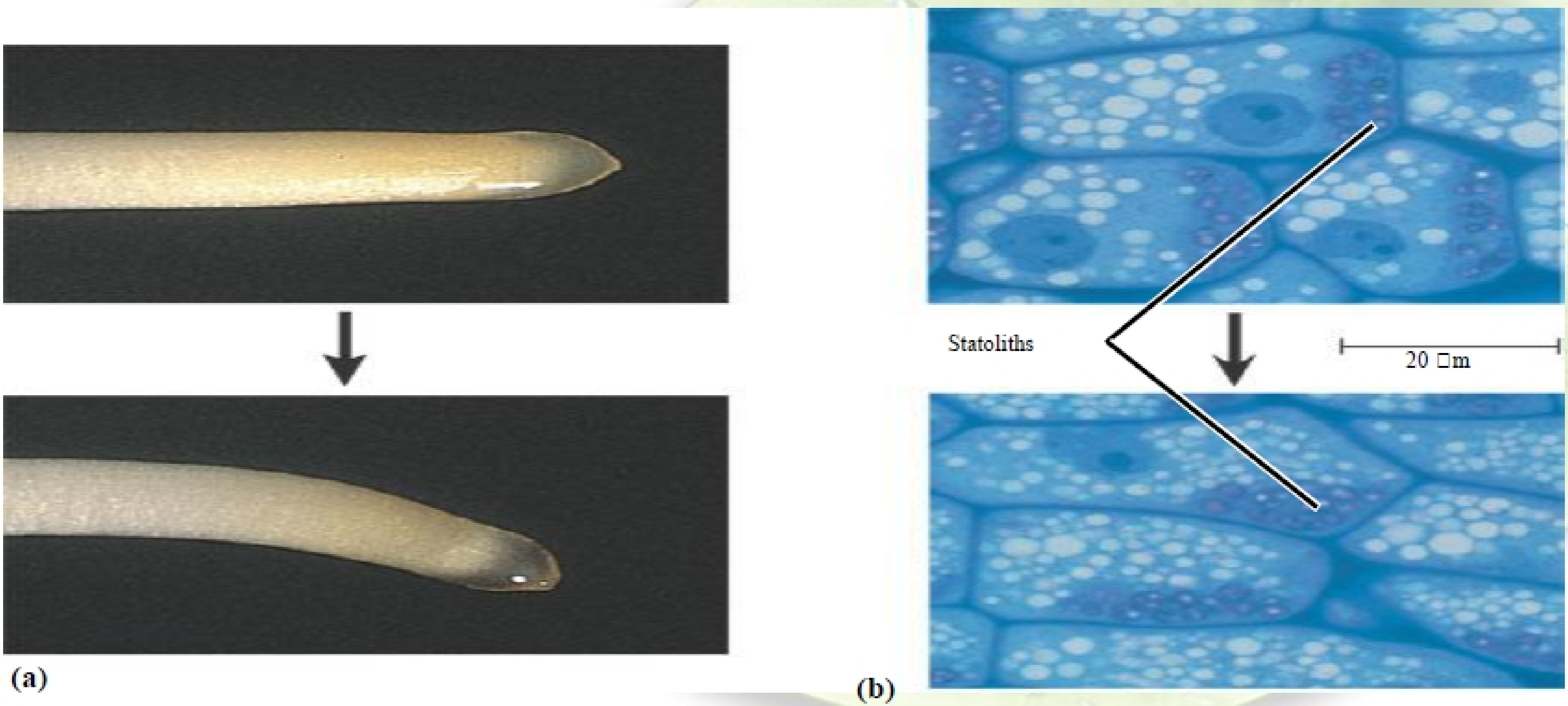

Removal of apical bud
Leaf
Lateral bud becomes active and produces own cytokinin, auxin and gibberellin; growth inhibitor, if present, inactivated
Food, from leaf
Cytokinins and mineral salts

Cell expansion
Lateral root initiation
Promote Shoot growth and inhibit root growth
Tropism
Xylem differentiation
Fruit development
Abscission



Root Cap Elongation Zone
Auxin
Gravity
Gravistimulation
leads to redistribution of auxin
+ + +
- - -
Graviresponse
results from differential elongation

- Plants may detect gravity by the settling of statoliths
  - Specialized plastids containing dense starch grains



Commercial application of auxins:

Propagation of plant by auxin treatment of cutting scions

Prevention of pre harvest drop of fruits

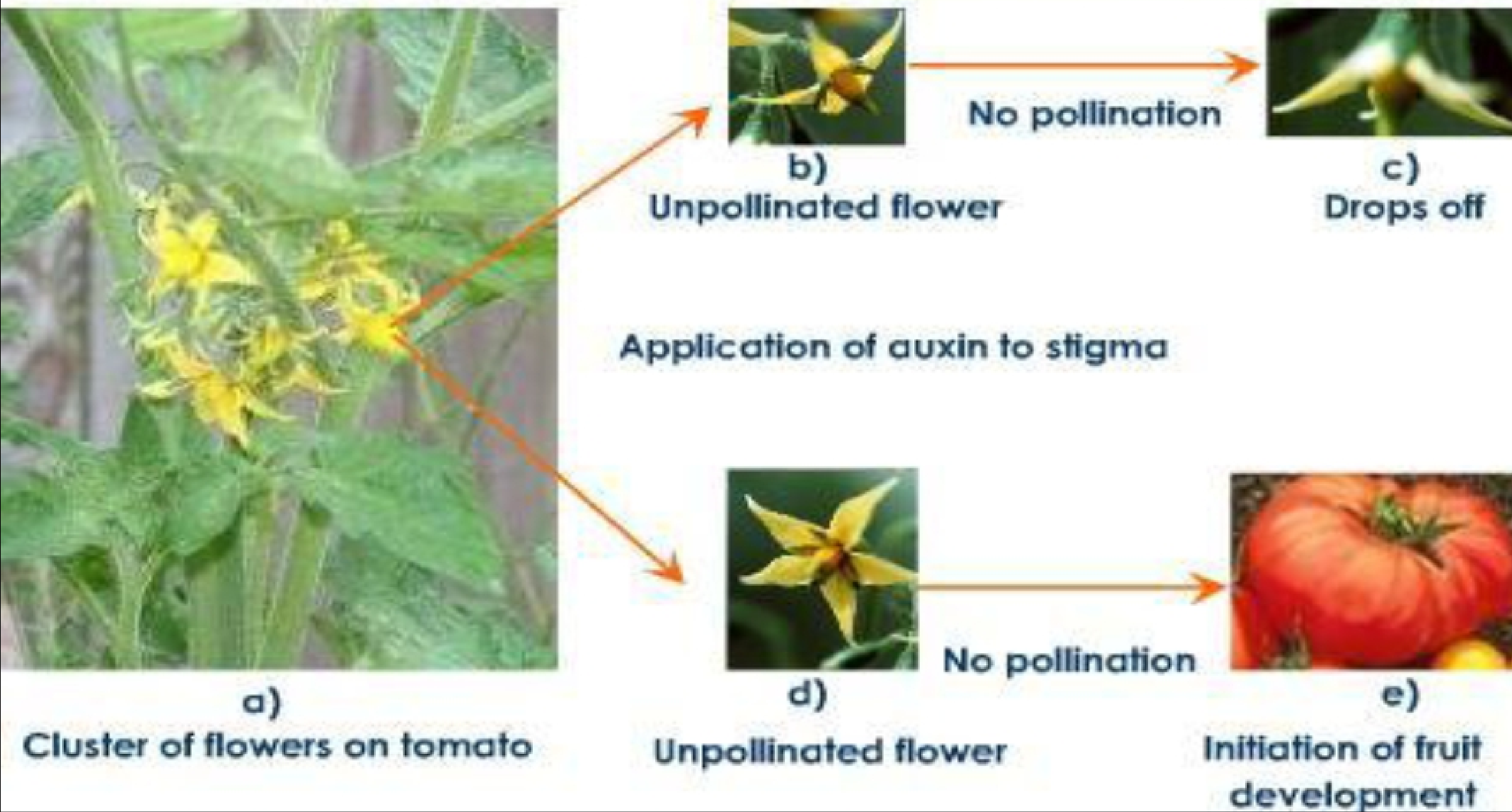
Increase parthenocarpy

Prevention of sprouting by inhibition of buds

Increase fruit sets

Weedicides

Flowering in pineapple


No pollination
b)
Unpollinated flower
c)
Drops off
Application of auxin to stigma
No pollination
a)
Cluster of flowers on tomato
d)
Unpollinated flower
e)
Initiation of fruit development

Characteristics of Auxins

- Polar translocation
- Apical bud dominance
- Variable behaviour of root and shoot growth
- Root initiation
- Delay in abscission
- Differentiation of xylem elements

Gibberellins

Discovered in association with bakanae or foolish seedling disease of rice (*Gibberella fujikuroi*)

- Gibberellins are named after the fungus *Gibberella fujikuroi* which causes rice plants to grow abnormally tall.
  - synthesized in apical portions of stems and roots
  - important effects on stem elongation
  - in some cases, hastens seed germination

Yabuta and Sumuki

Isolated and named it as Gibberellin

>120 compounds of Gibberellins

But all compounds have not biological activity

Only 15 Gibberellins have biological activity

Commercially available Gibberellins GA3, GA4 & GA7

The first higher plant Gibberellin was isolated from immature bean seeds

Di Terpenoid Compounds

Abbreviated as GA_1 ……….. GA_n

GA_1 & GA3 – Most active GA

GA_3 – Gibberellic Acid

Gibberellins Are Synthesized via the Terpenoid Pathway in Three Stages

Gibberellins are tetracyclic diterpenoids made up of four isoprenoid units. Terpenoids are compounds made up of five-carbon (isoprene) building blocks

GIBBERELLIN BIOSYNTHESIS

Acetyl CO A → Mevalonic Acid

↓

Isopentanyl Pyro PO_4

↓

Geranyl Pyro PO_4 (GPP)

↓

GGPP → Kaurene → **Gibbrellins**

Site of synthesis:

- All growing differentiated tissues
- Developing fruits and seeds
- Transported in the phloem and xylem

Role of GAs:

- Role in sub apical region
- Cell elongation
- Flowering
- Seed germination
- Mobilisation of food in seed storage cells

Breaking bud dormancy

Buds produced in winter

Remain dormant

Require High Temperature

Dormancy can be broken by GA

Substitute for High Temperature

PHYSIOLOGICAL EFFECTS

1. Induce Cell Division and Cell Elongation
2. Induce Stem elongation
3. Responsible for production of Amylase Enzyme

   Seed Germination

4. Overcomes Dormancy in seeds and buds
5. Involved in Parthenocarpic fruit development

Induce flowering in LD plants

Substitute for Cold treatment, Light and High Temperature

Induce male flower production in Cucumber

Induce female flower production in Maize

. Increase the size of Seedless Grapes

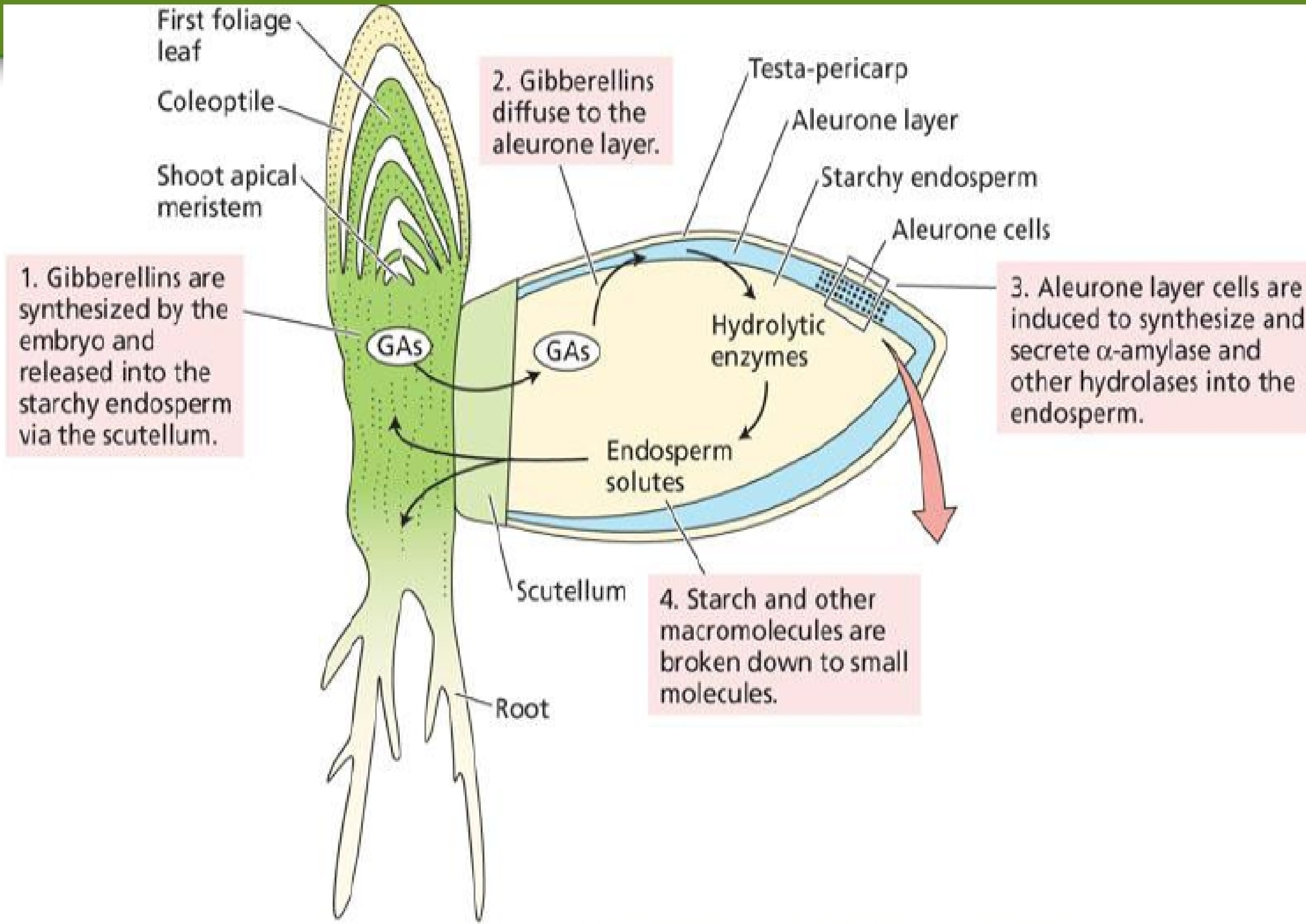
ANTI GIBBERELLINS

1. AMO - 1618
2. Cycocel (CCC)
(2 –Chloroethyl Trimethyl Ammonium Chloride)
3. Phosphon D
4. Paclo butrazol
5. SADH (Succinic Acid Dimethyl Hydrazide)
(B – Nine) (Alar)

Commercial Applications

- Increase size of grapes (spray at time of blooming and fruit set stage
- Increase distance between grapes in a cluster to minimize fungi/disease
- Breweries - increase starch digestion for malting process
- sugar cane – increased growth and yields
- Staminate flower
- Dormancy break

FIGURE 20.2 Cabbage, a long-day plant, remains as a rosette in short days, but it can be induced to bolt and flower by applications of gibberellin. In the case illustrated, giant flowering stalks were produced. (© Sylvan Wittwer/Visuals Unlimited.)


First foliage leaf
Coleoptile
Shoot apical meristem
1. Gibberellins are synthesized by the embryo and released into the starchy endosperm via the scutellum.
GAs
GAs
2. Gibberellins diffuse to the aleurone layer.
Testa-pericarp
Aleurone layer
Starchy endosperm
Aleurone cells
3. Aleurone layer cells are induced to synthesize and secrete α-amylase and other hydrolases into the endosperm.
Hydrolytic enzymes
Endosperm solutes
Scutellum
4. Starch and other macromolecules are broken down to small molecules.
Root

Auxins and Gibberellins :

Response	Auxins	GAs
Polar Translocation	YES	NO
Root initiation	YES	NO
Apical dominance	YES	NO
Abscission delay	YES	NO
Prevention of Dwarfism	NO	YES
Seed germination and Dormancy break	NO	YES
Induction of flowering in LDP	NO	YES
Cell elongation	NO	YES
	NO	

Characteristics of GA

1. **Prevention of genetic dwarfism**
2. **Breaking dormancy**
3. **Induction of flowering in LDPs**
4. **Increase of amylase activity**

Cytokinins

Called "cytokinins" because they stimulate cell division (*i.e.*, cytokinesis adenine derivatives (amino purines)

occur as: (a) the free nitrogenous base; (b) a nucleoside (base + ribose); (c) a nucleotide (base + ribose + phosphate); or (d) glycosides

The free base is the active form.

approximately 40 different structures known.

Zeatin (Z), which was first isolated from maize (*Zea mays*) is the most common cytokinin.

Other naturally occurring cytokinins include, dihydrozeatin (DHZ) and isopentenyladenosine (IPA).

Synthetic CKs

6 aminopurine

BAP

Benzimadazole, 1 benzyladenine etc

Site of synthesis :

Root tip

Developing seeds and cambial tissue

Translocation: Xylem stream

Role :

Control morphogenesis

Delay senescence

Promote lateral bud development

Dormancy breaking

MORPHOGENESIS

Depends upon Auxin and Cytokinin concentration

High Auxin + Low Kinetin → Root growth

Low Auxin + High Kinetin → Shoot growth

DELAY OF SENESCENCE (Richmond –Lang)

Ageing process in plants

↓

Loss of chlorophyll → Yellowing of leaves

↓

Senescence

By Cytokinin Treatment → Senescence postponed

Effect of Cytokinin in delaying the senescence is called as 'Richmond Lang effect'

Commercial application:

Shelf life of fruits

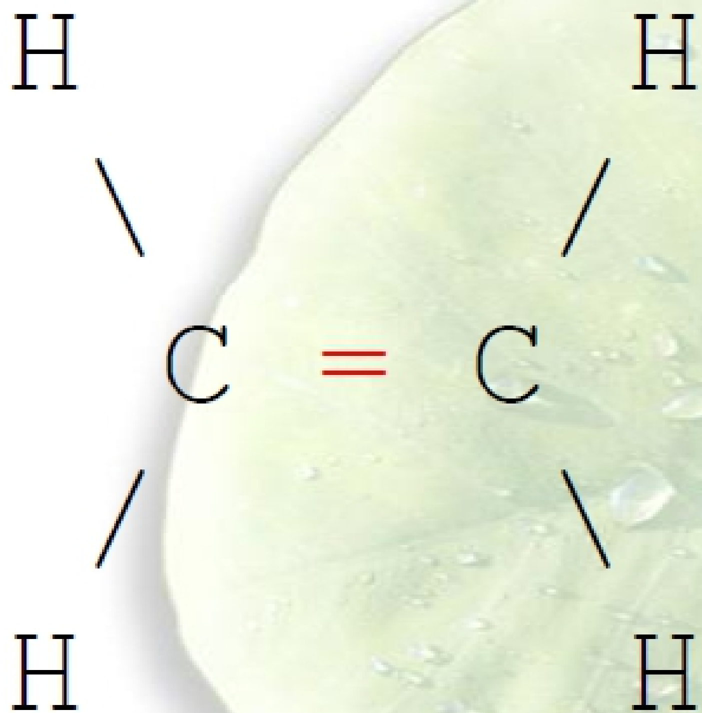
Quickening of root induction

Increasing oil and yield in groundnut

Braking dormancy

Delaying senescence

ETHYLENE



Discovery

Biosynthesis:

- All plant parts
- Node makes more ethylene than internodes
- Stimulated by stress
- Fruit ripening

Methionine + ATP

↓

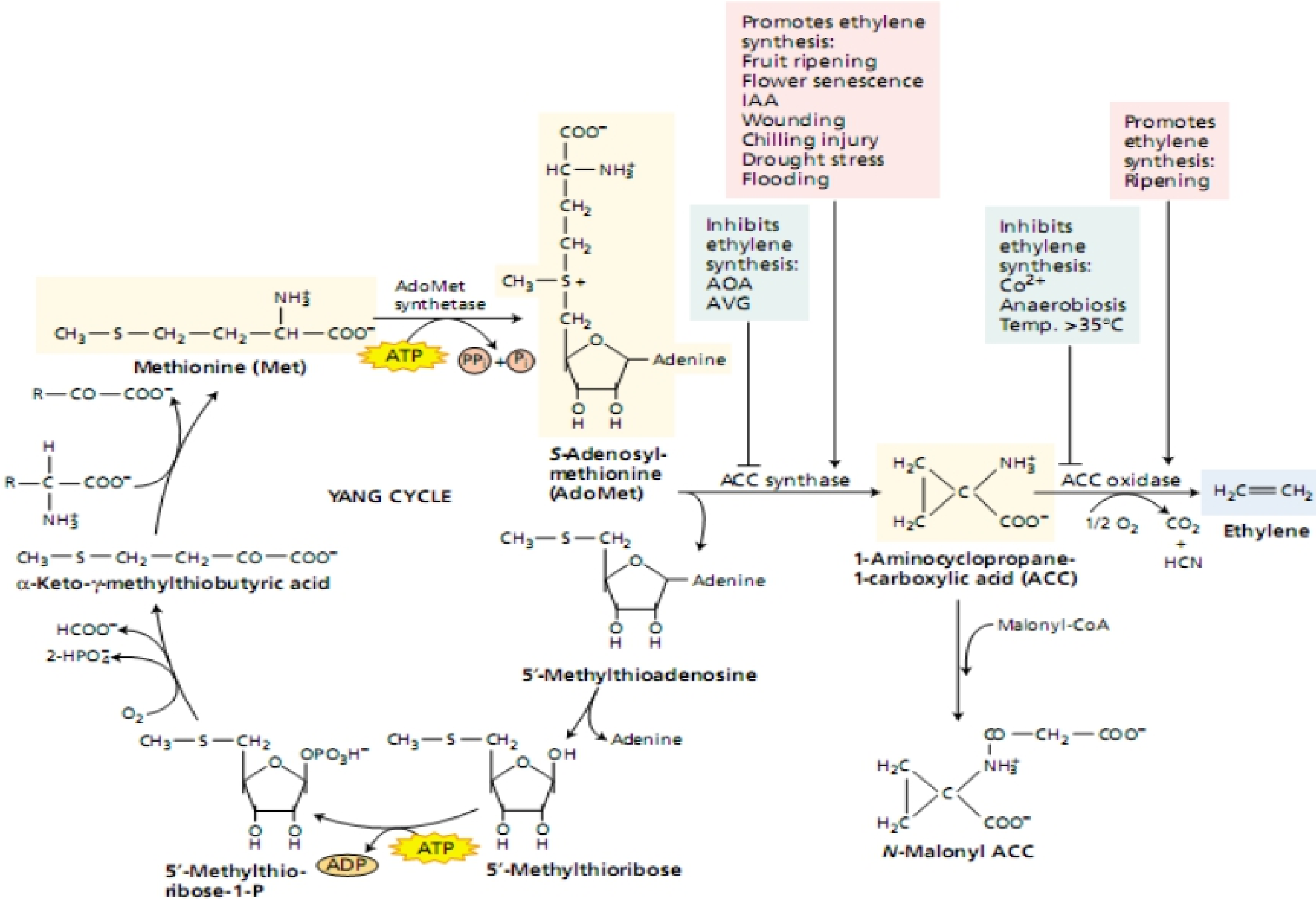
S- adenosyl methionine

↓ ← ACC Synthase

ACC

↓ ← ACC Oxidase

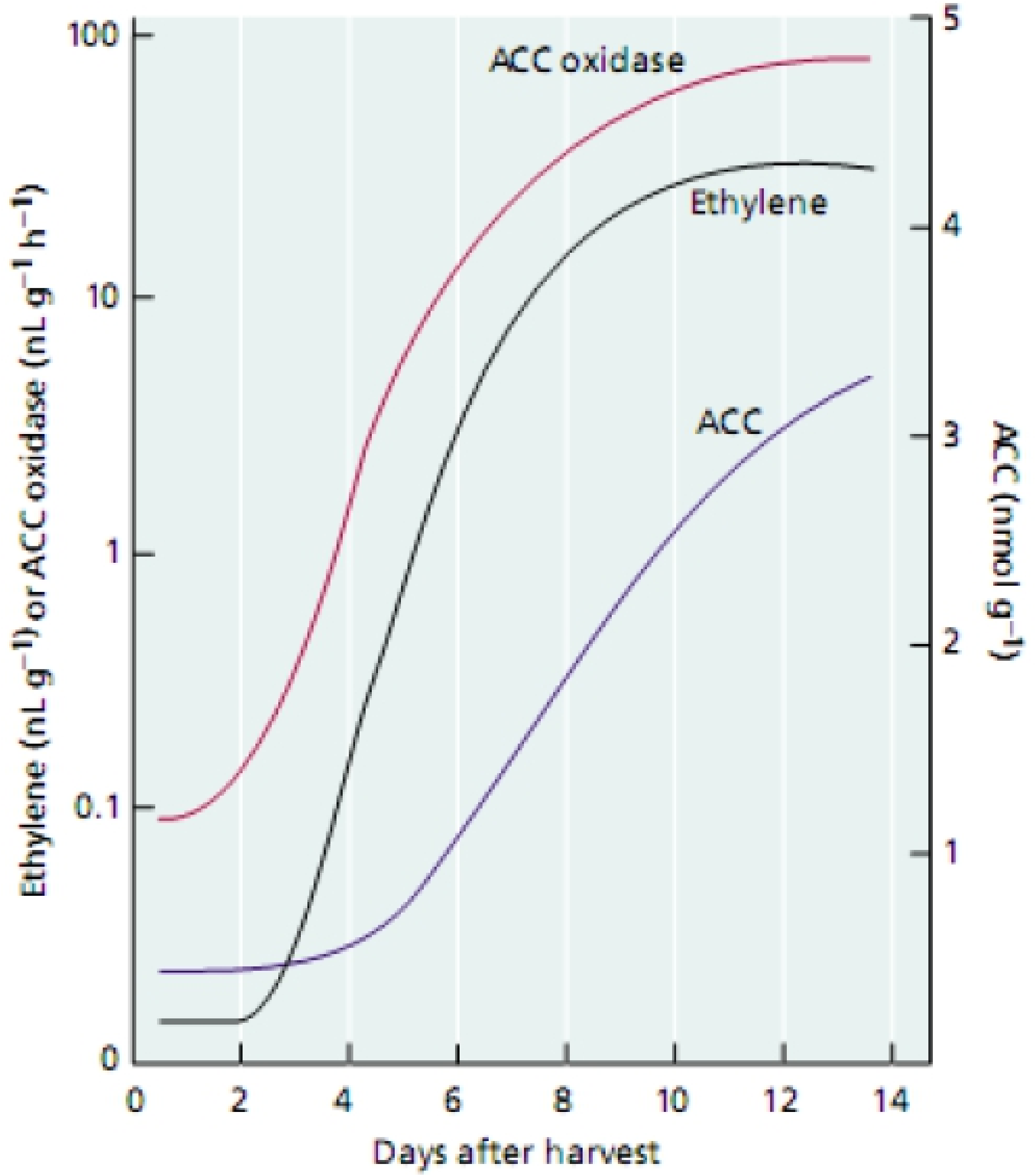
Ethylene



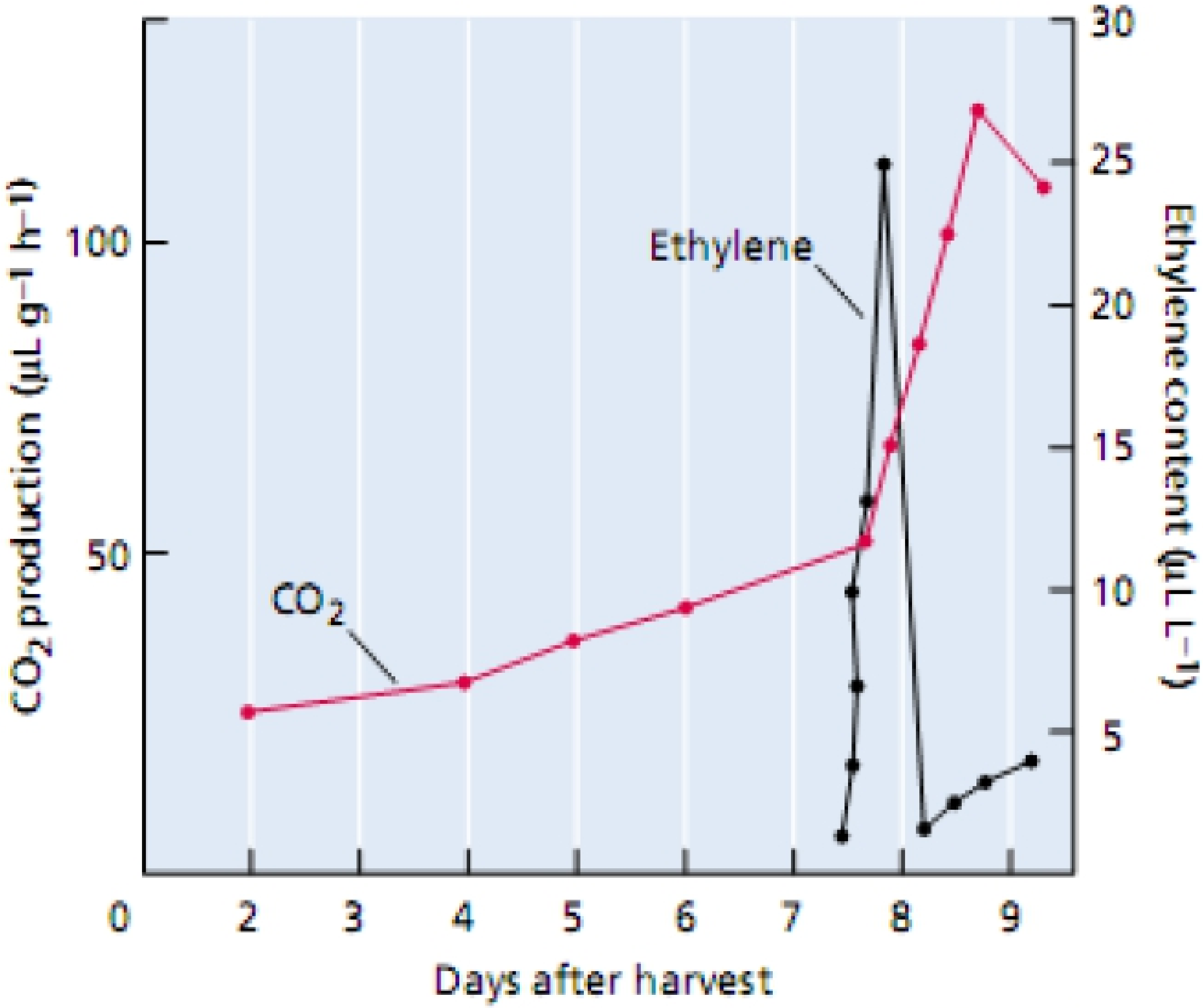
Promotes ethylene synthesis:
Fruit ripening
Flower senescence
IAA
Wounding
Chilling injury
Drought stress
Flooding
Promotes ethylene synthesis:
Ripening
Inhibits ethylene synthesis:
AOA
AVG
Inhibits ethylene synthesis:
Co2+
Anaerobiosis
Temp. >35°C
AdoMet synthetase
ATP
PPi + Pi
Methionine (Met)
S-Adenosyl-methionine (AdoMet)
Adenine
YANG CYCLE
ACC synthase
ACC oxidase
1/2 O2
CO2 + HCN
Ethylene
1-Aminocyclopropane-1-carboxylic acid (ACC)
Malonyl-CoA
N-Malonyl ACC
5′-Methylthioadenosine
α-Keto-γ-methylthiobutyric acid
HCOO−
2-HPO3 2−
O2
5′-Methylthio-ribose-1-P
ADP
ATP
5′-Methylthioribose

Physiological response

Fruit Ripening

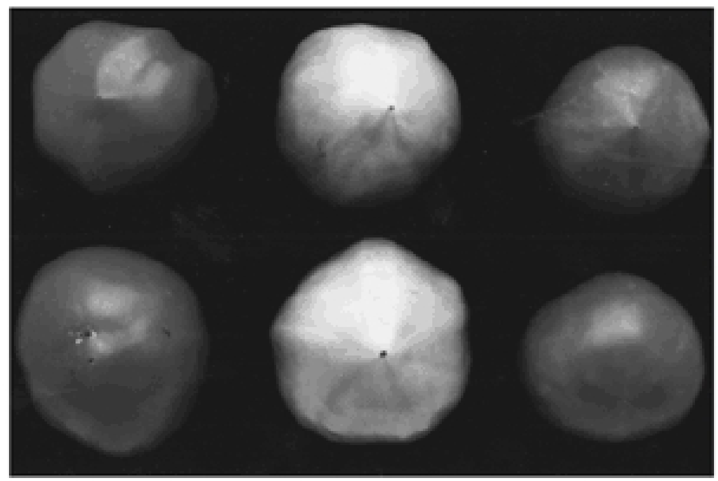


ACC oxidase
Ethylene
ACC
100
10
1
0.1
0
5
4
3
2
1
0
2
4
6
8
10
12
14
Days after harvest
Ethylene (nL g−1) or ACC oxidase (nL g−1 h−1)
ACC (nmol g−1)



Ethylene
CO2
CO2 production (µL g−1 h−1)
Ethylene content (µL L−1)
Days after harvest
0
2
3
4
5
6
7
8
9
50
100
5
10
15
20
25
30

Flavr saver

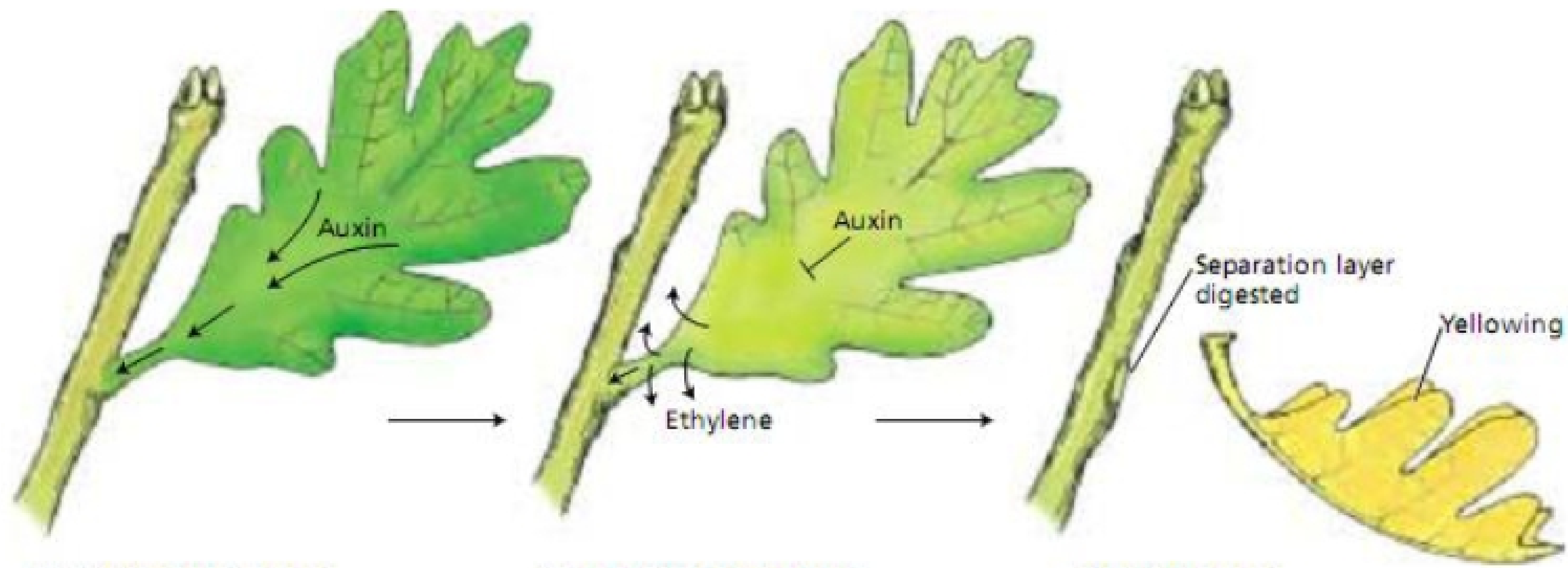


ACC-Anti-sense fruit + ethylene | ACC-Anti-sense fruit | Normal fruit

Triple response

Epinasty

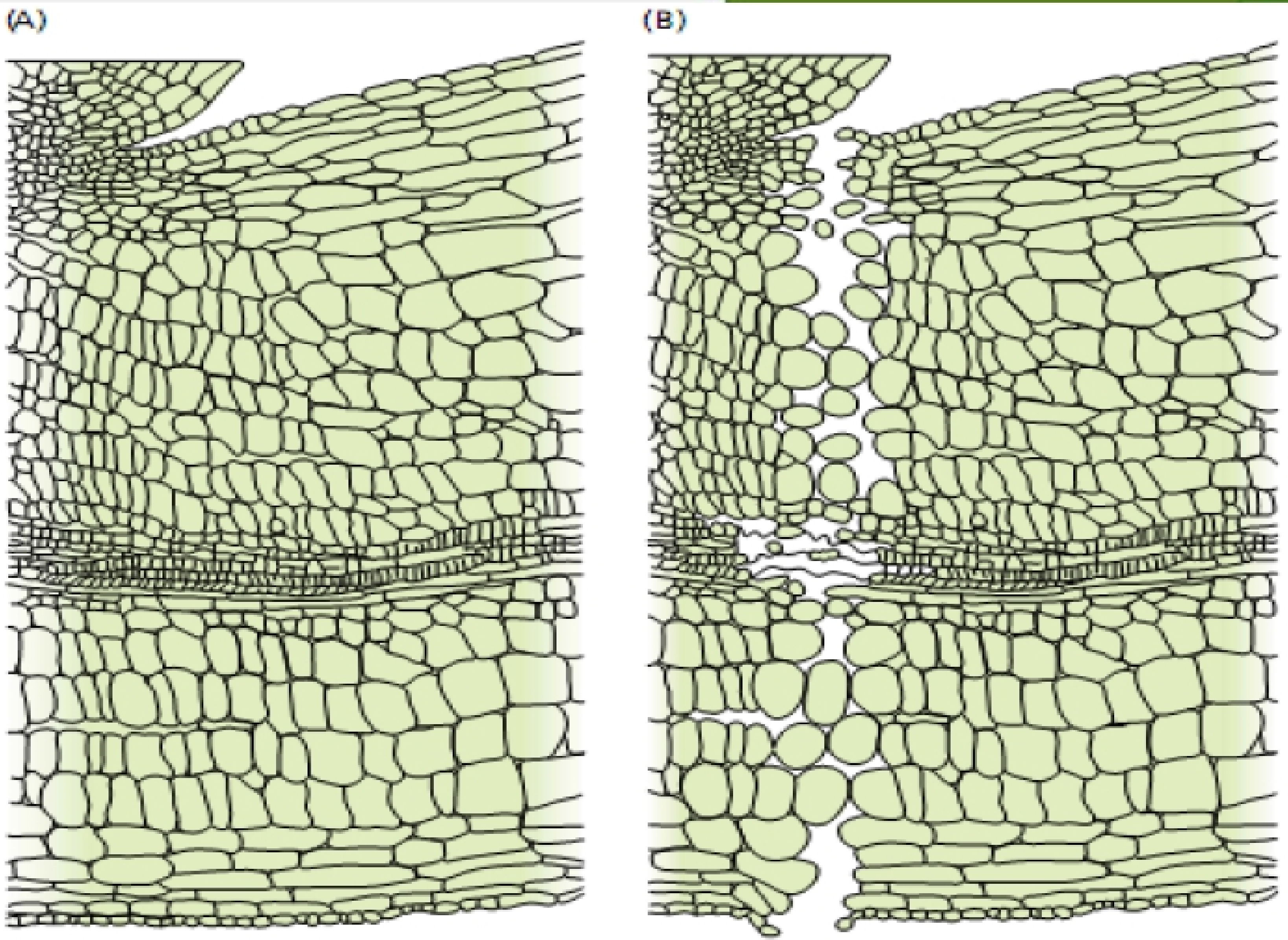
Abscission



Leaf maintenance phase
High auxin from leaf reduces ethylene sensitivity of abscission zone and prevents leaf shedding.

Shedding induction phase
A reduction in auxin from the leaf increases ethylene production and ethylene sensitivity in the abscission zone, which triggers the shedding phase.

Shedding phase
Synthesis of enzymes that hydrolyze the cell wall polysaccharides, resulting in cell separation and leaf abscission.



(A)
(B)

Commercial application :

Fruit ripening

Degreening of citrus

Synchronize flowering and fruit set in pineapple

Fruit thinning and fruit drop in cotton, cherry and walnut

ABSCISSIC ACID

‘STRESS HORMONE’

For many years, plant physiologists suspected that the phenomena of seed and bud dormancy were caused by inhibitory compounds,

1. Cornforth (1964)

Isolated substance causes Dormancy of Seeds

↓ DORMIN

2. Addicott (1965)

Isolated the substance from Cotton Fruit

↓

Abscission II

Both are same. They were jointly given the name Abscissic acid (ABA)

ABSCISSIC ACID

1. Terpenoid Compounds

2. Close link to Carotenoids

3. Natural Growth Retarding Hormone

4. Synthesis from Mevalonic Acid and Xanthophyll

BIO SYNTHESIS

1. From Mevalonic Acid

Mevalonic acid → Isopentanyl Pyro Phosphate

↓

Farnesyl Pyro Phosphate

↓

Abscissic Acid

2. From Carotenoids

Vialoxanthin

↓ Lipoxygenase

Xanthoxin

↓ Dehydrogenase

ABA aldehydes → (Oxidation) → ABA

SITE OF SYNTHESIS

Mostly – Chloroplasts of matured Leaves

Matured seeds

Translocated to other parts of plant
Through Phloem

More ABA found in Fruits and Seeds

PHYSIOLOGICAL ROLES

1. Inhibit seed germination

Inhibit the Enzymes Protease, Amylase and Peptidase

2. Inhibit the seedling growth

By decreasing water potential

3. Counteraction of Auxins, GA and Cytokinin

4. Specific antagonist to GA – 'Anti Gibbrellin'

5. Induce Dormancy of Seeds and Buds

Maintains the quality of Potato by inhibit sprouting

Sprouting makes potato sweet

6. Accelerates Senescence & Abscission of Leaf, Flowers and Fruits

7. Favours Stomatal closure

Reduce the TPN rate

Regarded as good ‘Anti Transpirant’

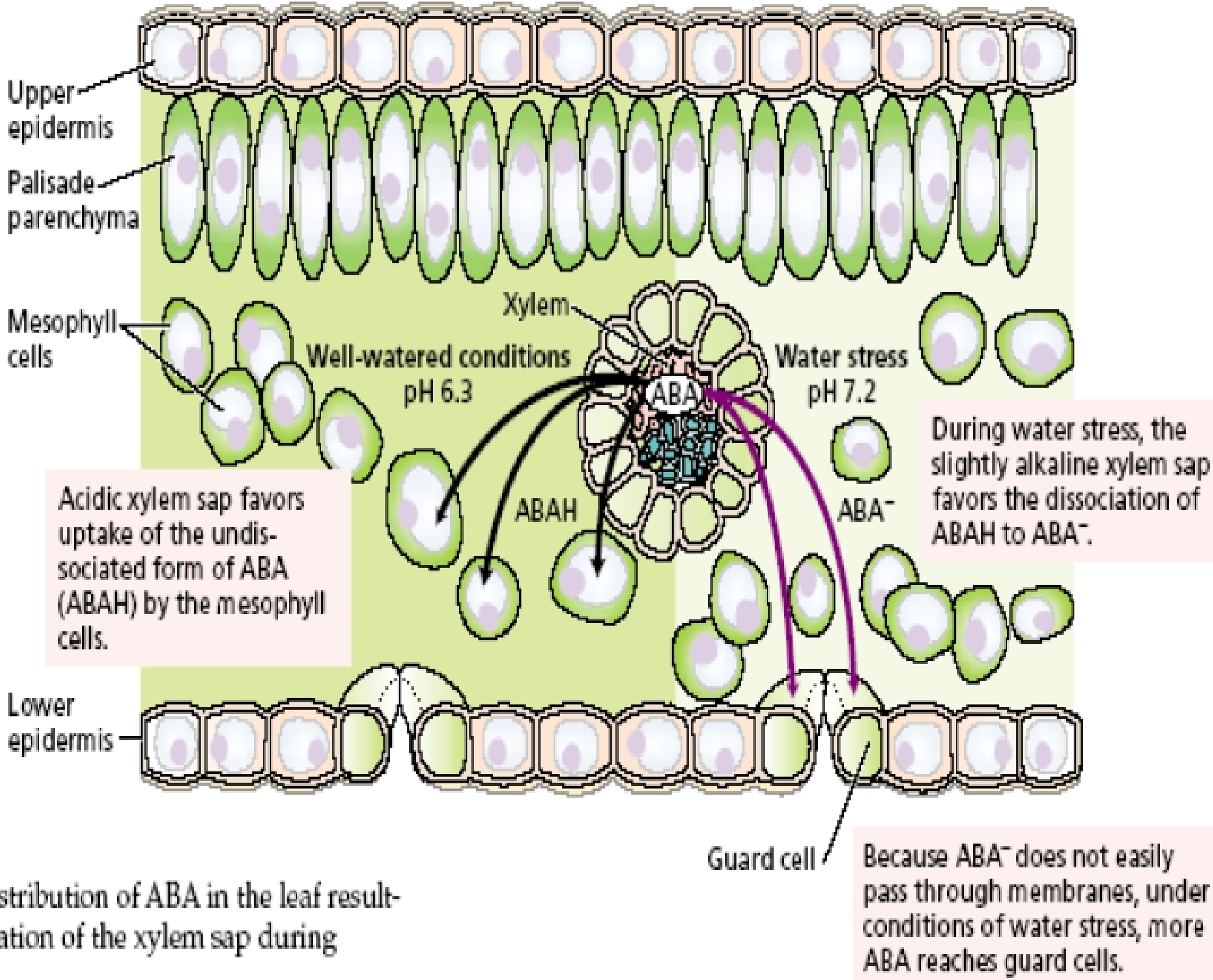


FIGURE 23.4 Redistribution of ABA in the leaf resulting from alkalinization of the xylem sap during water stress.

Commercial Uses of Growth Regulators

1. Rooting and Plant Propagation

IBA, NAA, 2,4-D, 2,4,5-T

IBA produces strong fibrous root system

2. Germination & Dormancy

GA – germination promoter

Inhibitor – Anti Gibberellin

3. Fruit Set and Development

Fruit setting → 2,4,5 - T

Fruit size increment in Grapes → GA

Shelf life increment in fruits & Flowers → CK

Good Fruit shape → GA + CK

Parthenocarpic Fruit

Gibberellins

IAA

4. Sex Expression

Production of Male flowers

Gibberellins

Production of Female flowers

Auxins & Gibberellins

5. Abscission

Control of Abscission → **NAA & IAA**

Induce Abscission → **Ethrel**

6. Morphogenesis

Auxin & Cytokinin

7. Weed Control

2,4 D and 2,4,5 T

8. Plant Organ & Size

Increases plant height → GA

Shorten the Plant Height → TIBA

Increases Tillering → BAP & TIBA

9. Anti Transpirant — ABA

10. Papaya Latex Flow → Ethephon

11. Rubber Latex Flow → 2,4, D & 2,4,5 T

12. Fruit Ripening → Ethrel

13. Sugarcane Ripeners → Glyphosate

Thank You