

HORMONES

Hormone - an endogenous or naturally-occurring compound that is produced or synthesized in one part of the plant and causes a change in physiology, growth or development in another part of the plant; usually present in very small quantities.

Elicitor Molecule - a compound which, when introduced in small concentrations to a living cell system, initiates or improves the biosynthesis of specific compounds; a compound with hormone-like activity.

Growth Substance - all naturally-occurring or synthetically produced compounds that affect the physiology, growth and development of plants.

References

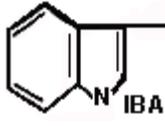
Moore, T.C. 1979. Biochemistry and Physiology of Plant Hormones. Springer-Verlag, NY.

Plant Hormones and Elicitor Molecules

Classically, plants have been known to contain five **hormones**, which are auxin, cytokinin, gibberellic acid, ethylene and abscisic acid. Recently, other endogenous compounds have been shown to elicit hormone-like reactions, which are brassinosteroids, jasmonic acid, salicylic acid and polyamines. Some do not elevate these to the status of one of the five classical hormones, so often they are called **elicitor molecules**.

- 1) **Auxin**
- 2) **Cytokinin**
- 3) **Gibberellic Acid**
- 4) **Ethylene**
- 5) **Abscisic Acid**
- 6) **Brassinosteroid**
- 7) **Jasmonic Acid**
- 8) **Salicylic Acid**
- 9) **Polyamines**

AUXIN

Naturally-Occurring	Synthetic	Structure	Site of Production
indoleacetic acid (IAA)	indolebutyric acid (IBA) naphthaleneacetic acid (NAA) 2,4-dichlorophenoxy-acetic acid (2,4-D)		shoot tips, embryos

SYNTHESIS

tryptophan → indoleacetic acid

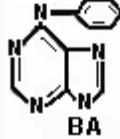
TRANSPORT

- 3:1 basipetal transport
- primarily in phloem parenchyma

EFFECTS

- 1) **Cell elongation** - causes acid induced cell wall growth
- 2) **Cell division** - stimulates
- 3) **Tropism** - response of plants to environmental or physical stimuli.
 - a) **phototropism** - response to light
 - b) **geotropism** - response to gravity
 - c) **thigmotropism** - response to touch
- 4) **Apical dominance** - determined by **correlative inhibition** of apical bud, partly due to auxin produced
- 5) **Sprout Inhibitors** – retard basal branching.
- 6) **Branch angle** - causes wide branch angles
- 7) **Fruit set** - low concentrations stimulate
- 8) **Fruit or flower thinning** - high concentrations cause
- 9) **Herbicides** - 2,4-D at high concentrations
- 10) **Adventitious root formation** -
 - a) stem and leaf cuttings
 - b) tissue culture

CYTOKININ

Naturally-Occurring	Synthetic	Structure	Site of Production
zeatin kinetin (not in plants)	benzyladenine (BA) pyranylbenzyladenine (PBA)		root tips, embryos

SYNTHESIS

adenine → zeatin

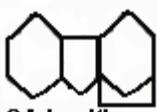
TRANSPORT

- xylem transported, found in root exudates
- primarily acropetal, but not necessarily polar

EFFECTS

- 1) **Cell division** - stimulates cell division; named after **cytokinesis**
- 2) **Nutrient mobilization** - nutrients transported towards high cytokinin concentration.
- 3) **Apical dominance** - high cytokinin/low auxin may overcome apical dominance
- 4) **Chlorophyll breakdown** - decreases chlorophyll breakdown
- 5) **Leaf Aging or abscission** - may delay
- 6) **Seed germination** - may overcome dormancy or stimulate germination
- 7) **Adventitious shoot formation** -
 - a) leaf and root cuttings
 - b) tissue culture
- 8) **Root growth** - may be inhibitory to root growth

GIBBERELLIC ACID (GA)

Naturally-Occurring	Synthetic	Structure	Site of Production
over 50 (named by consecutive numbers)	none	 GA backbone	shoot tips, root tips, embryos

SYNTHESIS (see next page)

mevalonate → farnesyl pyrophosphate →

→ geranylgeranyl pyrophosphate → copalyl pyrophosphate → kaurene → GA

growth retardants - chemicals that block synthesis of GA; most block the ring closure steps between geranylgeranyl pyrophosphate → copalyl pyrophosphate → kaurene.

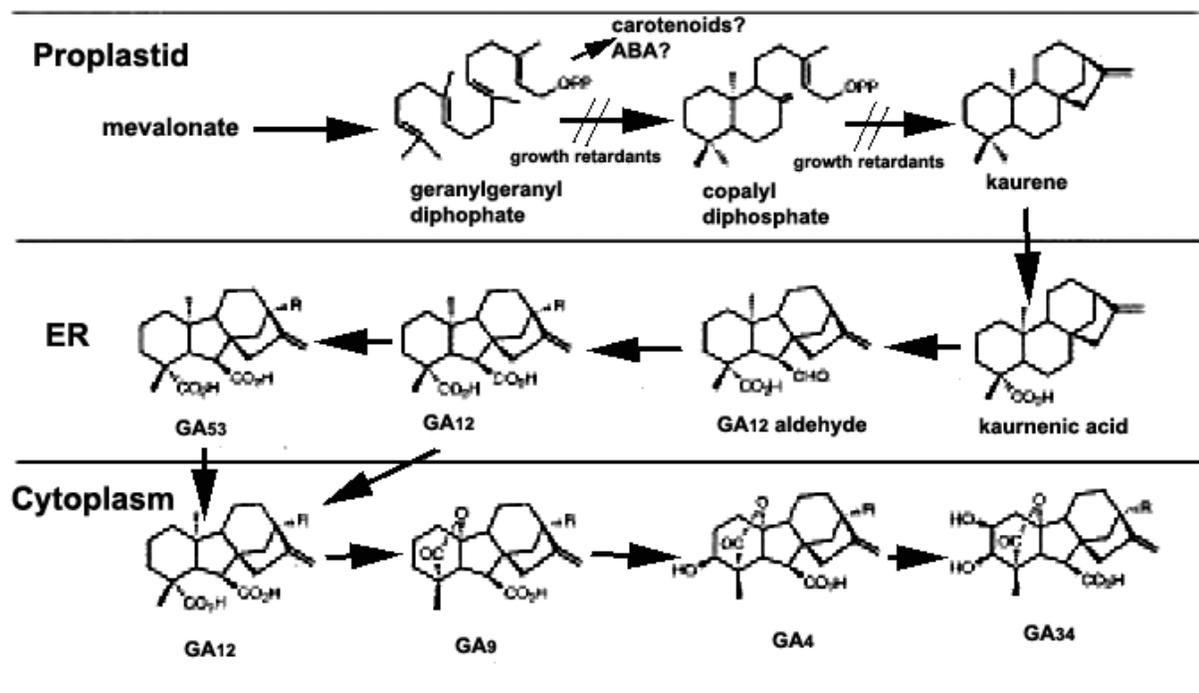
TRANSPORT

- no polarity
- in phloem or xylem

EFFECTS

- 1) **Protein synthesis** - triggers *de novo* synthesis of some proteins, ex. α -amylase.
- 2) **Cell elongation** - primary stimulus for cell elongation
- 3) **Rosette or dwarf plants** - lack of endogenous GA often contributes to decreased height.
- 4) **Height control**
 - GA used to increase height
 - growth retardants used to decrease height
- 5) **Flowering** - may cause bolting in biennials
- 6) **Fruit size** - increases size of seedless grapes
- 7) **Bud dormancy** - may overcome and substitute for cold treatment
- 8) **Seed germination** - may increase or speed up
- 9) **Sex expression** - favors staminate flower formation on monoecious plants

Biosynthetic Pathway of Gibberellic Acid (from Moore, 1979)



Mode of Action of Growth Retardants

- block ring closure between geranylgeranyl pyrophosphate and copalyl pyrophosphate
- block ring closure between copalyl pyrophosphate and kaurene

ETHYLENE

Naturally-Occurring	Synthetic	Structure	Site of Production
ethylene	ethephon or ethrel (release ethylene inside plant)	$\text{H}_2\text{C}=\text{CH}_2$ ethylene	ripening fruits, aging flowers, germinating seeds, wounded tissue

SYNTHESIS

methionine → s-adenosylmethionine → 1-aminocyclopropane-1-carboxylic acid → ethylene
(SAM) (ACC)

ETHYLENE INHIBITORS

ethylene inhibitors - chemicals that inhibit the synthesis or action of ethylene

Synthesis Inhibitors (block synthesis of SAM → ACC)

- **AVG** - aminoethoxyvinyl glycine
- **MVG** - methoxyvinyl glycine
- **AOA** - aminoacetic acid

Action Blockers (ethylene → block action)

- **STS** - silver thiosulfate
- **CO₂** - carbon dioxide
- **Ni** - nickel
- **Co** – cobalt
- **MCP** – 1-methylcyclopropane
 - it is a gas that can saturate the receptor sites, and block action for several days
 - EthylBloc – commercial compound

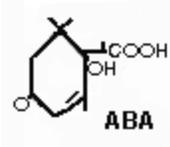
TRANSPORT

- diffusion as a gas throughout plant (in and out)

EFFECTS

- 1) **Auxin transport** - alters basipetal transport
- 2) **Membrane permeability** - increases
- 3) **Respiration** - increases
- 4) **Cell elongation** – decreases
- 5) **Aerenchyma formation** – induces aerenchyma formation under anaerobic or hypoxic conditions (i.e. under low oxygen or flooded conditions)
- 6) **Fruit ripening** - stimulates in many fruits, ex. banana
- 7) **Flowering** - triggers flowering in some bromeliads, ex. pineapple
- 8) **Flower fading** - increases
- 9) **Flower longevity** - causes senescence (death) of cut flowers
- 10) **Fruit color** - decreases green, increases other colors
- 11) **Seed germination** - increases in some seeds
- 12) **Leaf abscission** (leaf drop) - causes in some plants
- 13) **Leaf epinasty** (curling and contortion of leaves) - causes in some plants
- 14) **Sex expression** - favors pistillate flower formation on monoecious plants

ABSCISIC ACID (ABA)

Naturally-Occurring	Synthetic	Structure	Site of Production
abscisic acid	none	 <chem>CC1=C(O)C(=O)C=C(O)C1</chem> ABA	plastids, especially chloroplast

Historically also called:

abscisin - because early investigators found caused leaf abscission

dormin - because early investigators found caused dormancy

SYNTHESIS

mevalonate → farnesyl pyrophosphate → ABA

EFFECTS

- 1) **Dormancy** - causes bud or seed dormancy
- 2) **Leaf abscission** (leaf drop) - may cause in some plants
- 3) **Stoma** - causes stomata to close (a response to drought stress)

ELICITOR MOLECULES

Brassinosteroid

Effects:

- pollen tube growth
- stem elongation
- unrolling/bending grass leaves
- orientation of cellulose microfibrils
- enhanced ethylene production

Jasmonic Acid

Effects:

- defense mechanisms, promotes antifungal proteins
- growth inhibitor
- inhibit seed and pollen germination
- promotes curling of tendrils
- induces fruit ripening

Salicylic Acid

Effects:

- blocks ethylene synthesis
- induces flowering in some long day plants
- induces thermogenesis in voodoo lily
- defense mechanisms, promotes antifungal proteins

Polyamines

Effects:

- elicit cell division, tuber formation, root initiation, embryogenesis, flower development and fruit ripening
- may not have a truly hormonal role; rather participate in key metabolic pathways essential for cellular functioning.