Unit Two:
Chemical Control

Chapter Three:
Plant Hormones

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Introductory Biology 2
BIO 202

3.1 Plant growth and development are regulated by hormones

- **Tropism** is a biological phenomenon in which plants **grow** toward or away from an environmental stimulus, such as light, heat or gravity.
- Stems grow toward light and away from gravity, while roots grow away from light and toward gravity.
- These responses ensure that the plant maximizes light capture and is correctly oriented in space.

- In **positive tropism,** the growth will be toward the **stimulus**, while the reverse happens in **negative tropism.**
- In **phototropism**, the stimulus is light, and in **geotropism** (or **gravitropism**) the stimulus is gravity. While in **thigmotropism** the stimulus is mechanical such as adherence to something solid.
- Tropism is one category of plant growth and development in which **auxins** have a central role in directing growth in response to an environmental stimulus.

- Auxins are one important group of plant hormones that have numerous effects on plant growth and development.
- A **plant hormone** is a chemical substance that is made in one part of the plant and transported to another where it brings about responses in target part. Small amounts of hormone can be extremely effective.
- Hormones affect all features of plant growth and development.
- Five major categories of plants hormones have been known for many years, **(Auxins, gibberellins, cytokinins, ethylene, and abscisic acid)**

- But recently new hormones have been discovered as additional new possible categories (Table 3).
- While these hormones have different and distinctive roles in plant growth and development, they also interact in an integrated way.
- Hormone interactions can be cooperative or antagonistic. Many of their roles are summarized in Table (3).

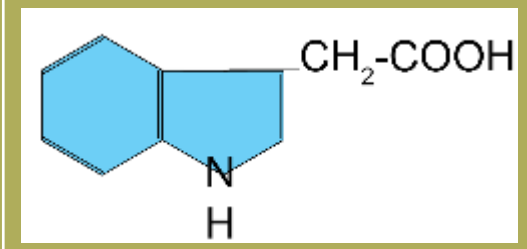
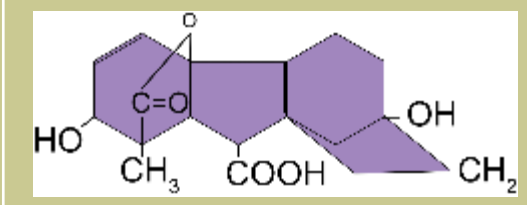
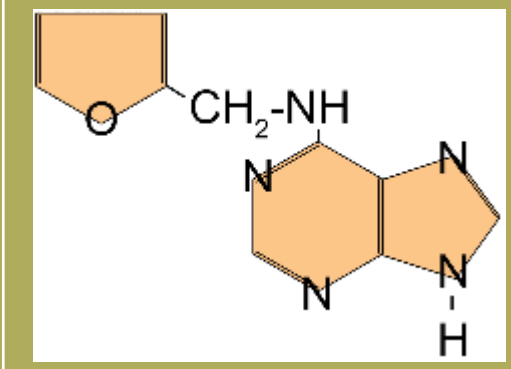
Table (3): Major Functions of Plant Hormones			
Hormone	**Production Site**	**Function**	**Chemical structure**
Auxins	Seeds embryo, shoot apical meristems, young leaves.	Cells elongation, root and stem phototropism and geotropism, root initiation, apical dominance, vascular tissues development, fruits development, delay of leaves and fruits senescence, ethylene production in fruits.	
Gibberellins	Young leaves and shoots apical meristems and embryo in seed.	Seeds germination, budding, stem elongation, flowering, fruit development	
Cytokinins	Produced in roots and transported to various sites in plants.	Lateral budding production, prevention of leaf senescence, cell division, stimulates flower, embryo and endosperm development.	

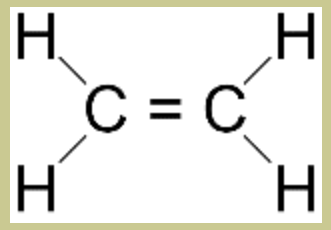
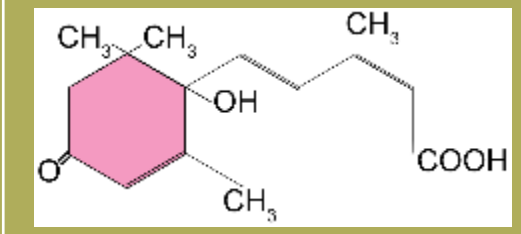
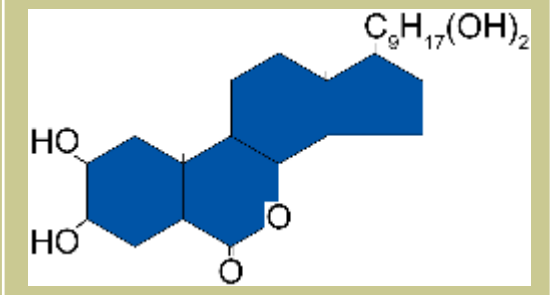
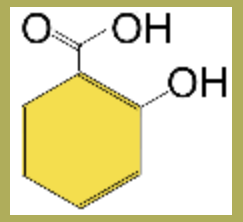
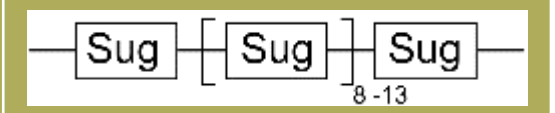
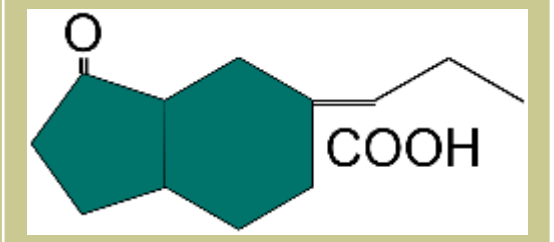
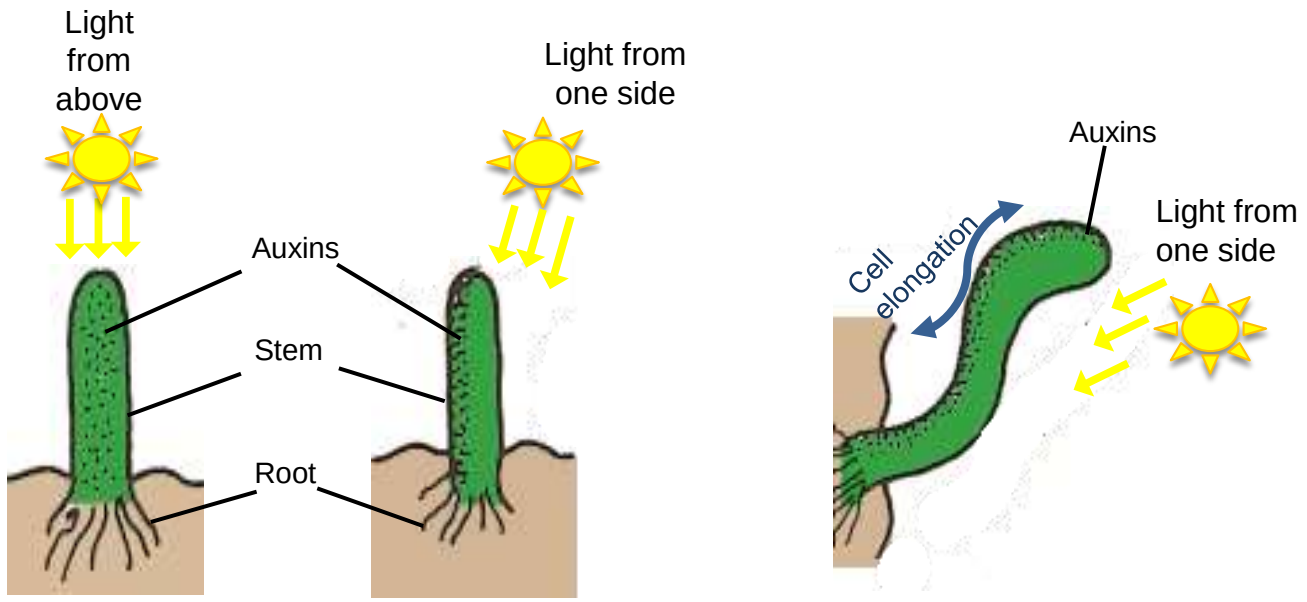
Table (3): Major Functions of Plant Hormones			
Hormone	**Production Site**	**Function**	**Chemical structure**
Ethylene	Ripening fruit tissues, stem nodes, leaves, damaged senescing tissue.	Fruit ripening, abscission in flowers and leaves, inhibits stem elongation, development of seedling primordia.	
Abscisic acid	Leaves, stems, roots, green fruits	Stomatal closure, seed dormancy, bud dormancy.	
Brassinosteroids	Shoots (leaves and flower buds), seeds, fruits.	Light-required gene expression, cell division, stem elongation, fruit ripening, leaves senescence.	

Table (3): Major Functions of Plant Hormones			
Hormone	**Production Site**	**Function**	**Chemical structure**
Salicylic acid	Wounds(site of microbial infection)	Resistance to pathogens.	
Systemin	Wounds (site of infection, animal or microbial attacks).	Initiation of defenses against predators (herbivores) or pathogens.	
Oligosaccharins	Unknown.	Many functions in plant growth and development; defense responses to pathogens.	
Jasmonates	Leaves, possibly some other tissues.	Initiation of defense against predators or pathogens.	

3.2 Auxins generally affect cells elongation

- **Auxins** are produced in seeds embryo, stem apical meristems, young leaves.
- Auxins play an important role in all tropisms.
- Their role in **phototropism** can be summarized as follows:
- When a stem is irradiated from one side only, the light causes the transfer of auxin from the “sunny” side to the darker side.
- The greater concentration of auxin on the shady side causes the cells on that side to elongate more than those on the illuminated side and the stem “bends” toward the light (Fig. 3-1).



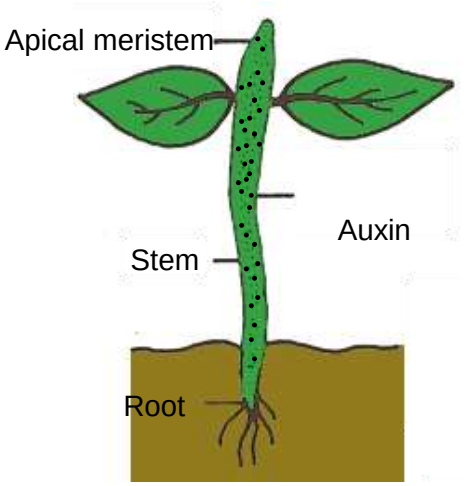
(A) When a stem is directly under light, the auxins produced by the stem apical meristem, and transported downward through the plant then distributed equally.

(B) When a stem is irradiated from one side only, light causes the transfer of auxins from the sunny side and become concentrated on the shady side of the plant

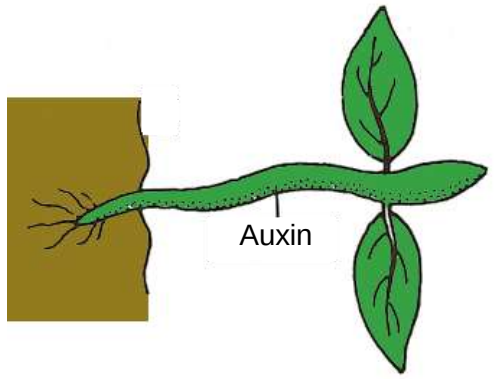
(C) The greater concentration of auxin on the shady side causes the cells on that side to elongate more than those on the illuminated side and the stem “bends” toward the light. Concentration of auxins in root cells in the illuminated side is suitable for cell elongation in that side, and root will bend away from light .

Fig. 3-1. Demonstration of Phototropism in Plants

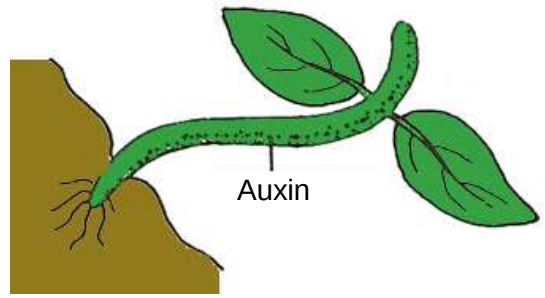
- The effect of auxins on cell elongation is a function of its concentration and site of activity:
  - Promotion of stem cells elongation is brought about by **moderate** concentrations of the auxin.
  - Reduction of stem cells elongation is brought about by **high** concentrations of the auxin.
  - Promotion of root cell elongation is brought about by **lower** concentrations of the auxin refer to (Fig. 3-2).



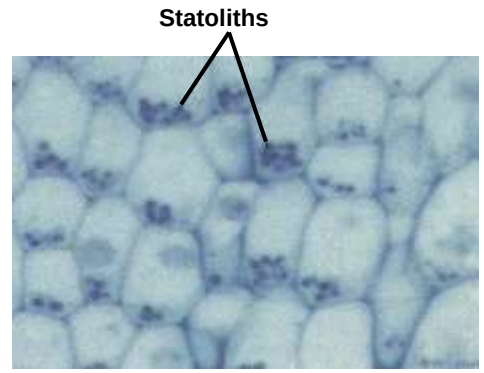
(A) When a plant is upright, auxin produced in the apical meristem moves downward through the plant



(B) When a plant is laid on its side, auxin gather in the lower half of the stem and root by action of gravity



(C) Concentration of auxin in the lower part of the stem brings about cell elongation thus curving stem growth upward (against gravity). Root grows downward (toward gravity) because cells in the upper part of the root elongate thus curving root growth downward due to concentration of the auxins in those cells is higher than that of the lower side cells of the root



(D) Photographic microscopic section showing statoliths that sense gravity in plant cells

Fig. 3-2. Demonstration of Geotropism in Plants

- Auxins also cause a similar mechanism in geotropism, but involves starch granules or **statoliths** (Fig. 3-2). Statoliths are important in gravity sensing:
  - Growth of the stem is against gravity **(negative geotropism)**
  - Growth of the root is toward gravity **(positive geotropism)**
- Auxins stimulate root initiation, a characteristic that is practiced in transplantation.

- Auxins practice the phenomenon of **apical dominance** which is the inhibition of axillary buds formation by apical meristems thus contributing to the control of branching of the plant
- Auxins play an important role in **flowering** and fruit development because upon fertilization, pollens release auxin that lead to the release of ovular auxins which prevent the formation of abscission layer thus encouraging the completion of fruit development and ripening

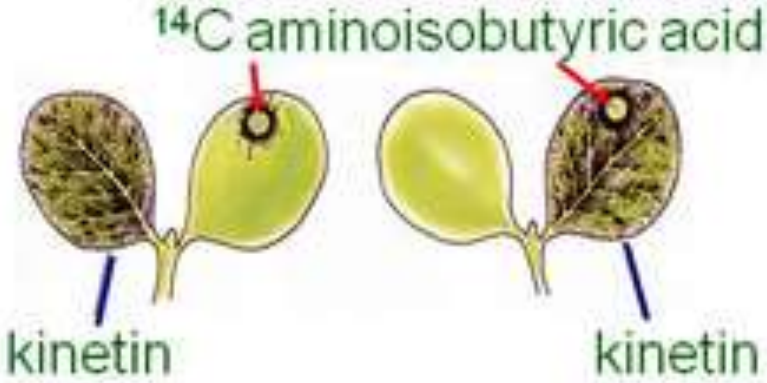
3.3 Gibberellins promote the elongation of the stem

- **Gibberellins** are produced in Young leaves, stem apical meristems and seed embryo.
- Gibberellins were named after a genus of fungi called *Gibarella fujikuroi* where discovered for the first time.
- They affect stem elongation by promoting cell division and elongation.
- They encourage seed germination and fruit development.
- They break seed and buds dormancy.
- Gibberellins antagonise the action of abscisic acid.

3.4 Cytokinins promote cell division

- **Cytokinins** are produced in roots and transported to various sites in plants. They are also produced in actively growing embryos and fruit.
  - Promote lateral budding production, in contrast to auxins that inhibit lateral budding. Therefore they interact to control apical dominance through their ratio to each other.
  - Prevention of leaf senescence (in contrast to abscisic acid)
  - Promote cell division
  - Stimulates flower, embryo and endosperm development (Fig. 3-3)

Delay senescence[4]



Sink/Source Relationships[5]

Light-mediated development[6]

Nodulation[3]

Meristem function[7]

- Nutrient response
- Apical dominance
- Vascular development
- Pathogen interactions

Organogenesis[2]

Promote cell division[1]

Adapted from: http://labs.bio.unc.edu/Kieber/Cytokinin%20page.htm

Fig. 3-3. Summarizing the main functions of cytokinins

3.5 Abscisic acid is a growth inhibitor

- **Abscisic acid (ABA)** is produced in leaves, stems, roots, green fruits.
  - High concentration of ABA in wilted leaves promotes stomatal closure thus preventing water loss by decreasing transpiration under severe drought conditions
  - ABA promotes seed dormancy at high concentrations. For germination to occur ABA must be eliminated and the ratio of ABA to gibberellins must be adjusted so that germination will take place providing that all environmental conditions required for germination are prevailing
  - Promotes bud dormancy

3.6 Ethylene promotes fruit ripening and abscission

- **Ethylene** is produced in leaves, ripening fruit tissues, stem nodes and damaged senescing tissue.
  - Promotes fruit ripening and commercially used for ripening fruits on one hand, and on the other hand ethylene production can be inhibited using CO_2 that inhibit ripening in fruit storage.
  - Promotes abscission in flowers and leaves that lead to their separation and falling down in Autumn which greatly decrease water loss in the tree to withstand prevailing environmental conditions
  - Inhibits stem elongation
  - Development of seedling primordia.

3.7 Practical applications of plant hormones in agriculture

- Production of seedless fruits by the integrative action of auxins and gibberellins
- Killing of weeds by means of auxins
- Regulation of fruit and flower production and maturation by the integrative action of more than one hormone

3.8 Photoperiodism

- The phenomenon of **photoperiodism** also has an important impact on plant growth and development.
- Photoperiodism refers to the length of the light and dark cycles that the plant is exposed to.
- In many plants, **flowering** is regulated by photoperiod, although what is actually important is the length of the dark period, not the light period.
- Plants classified as “short-day/long-night” plants with respect to flowering have a minimum requirement for time in dark (a critical night) before they flower and will not flower if given even a short light exposure during the dark period.

- Other plants are classified as long-day/short-night plants. In this case, the night must be shorter than some critical time. Some plants are day neutral and flowering is independent of photoperiod. Because of the importance of the dark period rather than the light period, some biologists suggest that the flowering categories described above should be classified as **long-night**, **short-night,** and **neutral**, and the length of the “day” should not be mentioned.

- Photoperiod regulates many aspects of plant growth and development as well as flowering.
- Photoperiodic effects are brought about by a plant pigment, **phytochrome (P)** that responds to the quality of red light received by changing its form.
- In daylight, P is in its **far-red** form (**P_{fr}**), while it is converted to its red form (**P_r**) in the dark.
- These two forms have different effects on plant growth and development, which confers photoperiod sensitivity. Of interest, when P_r is the dominant form, stem elongation is enhanced, so P_r would seem to be related to auxin levels.

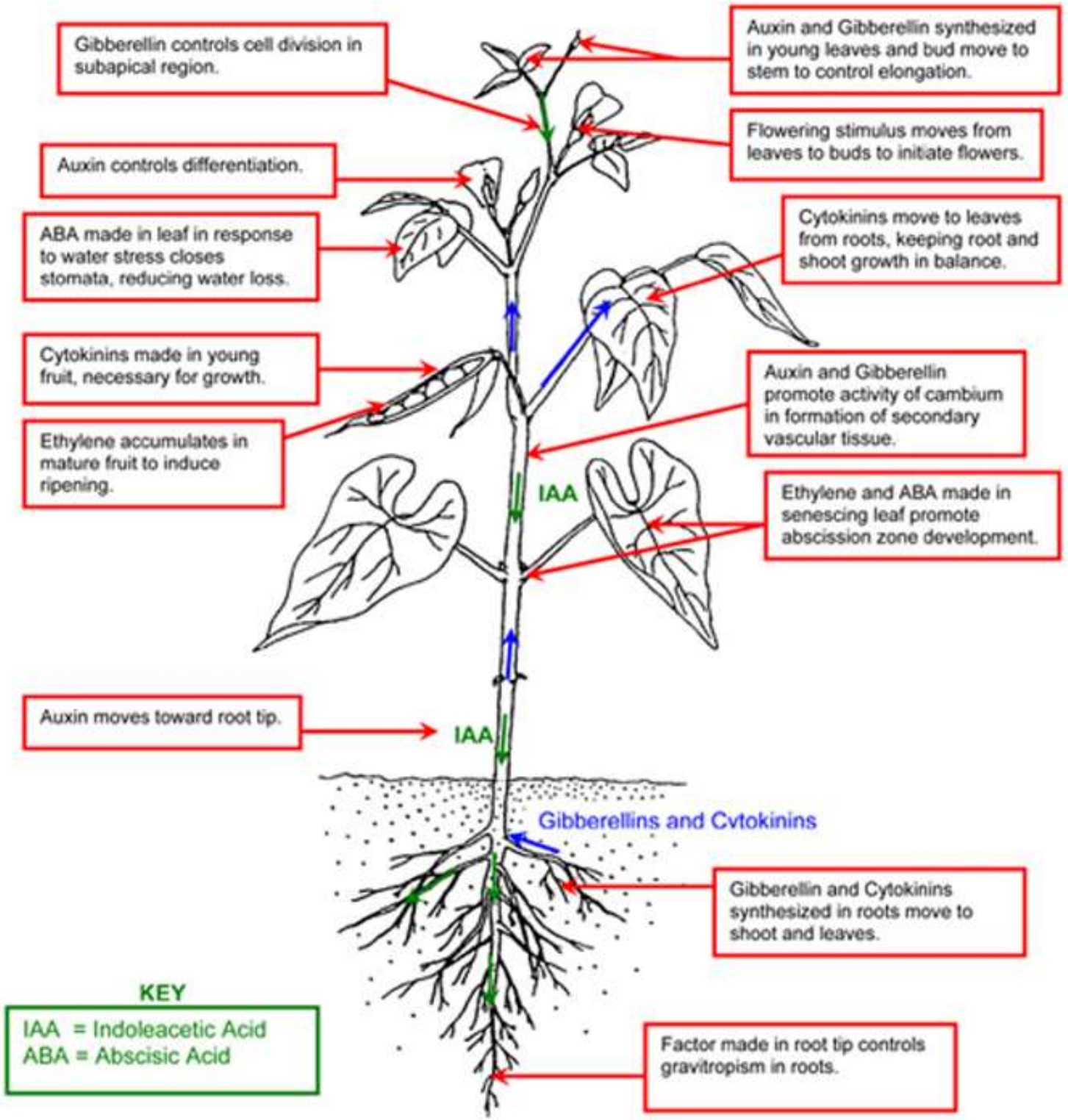
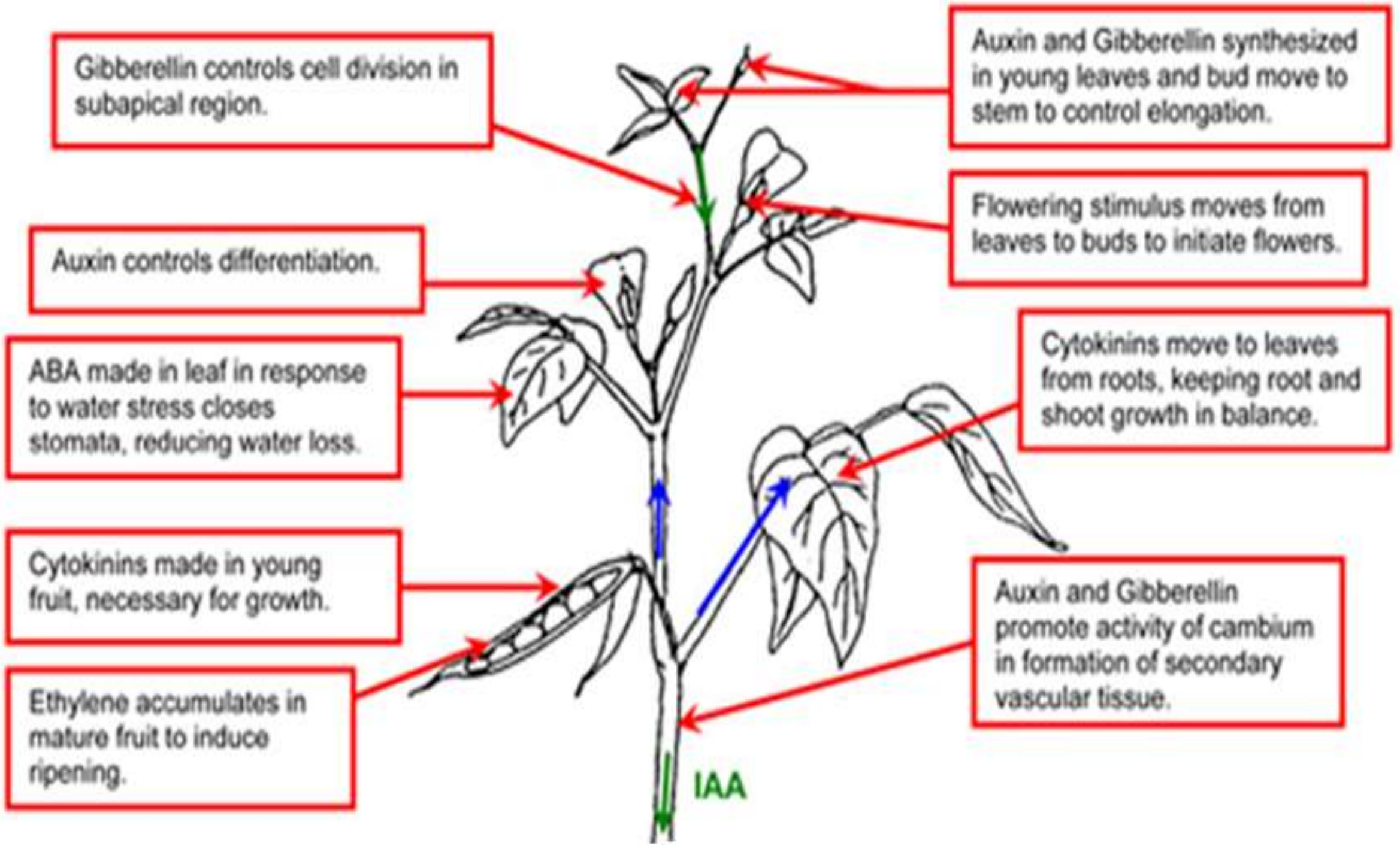
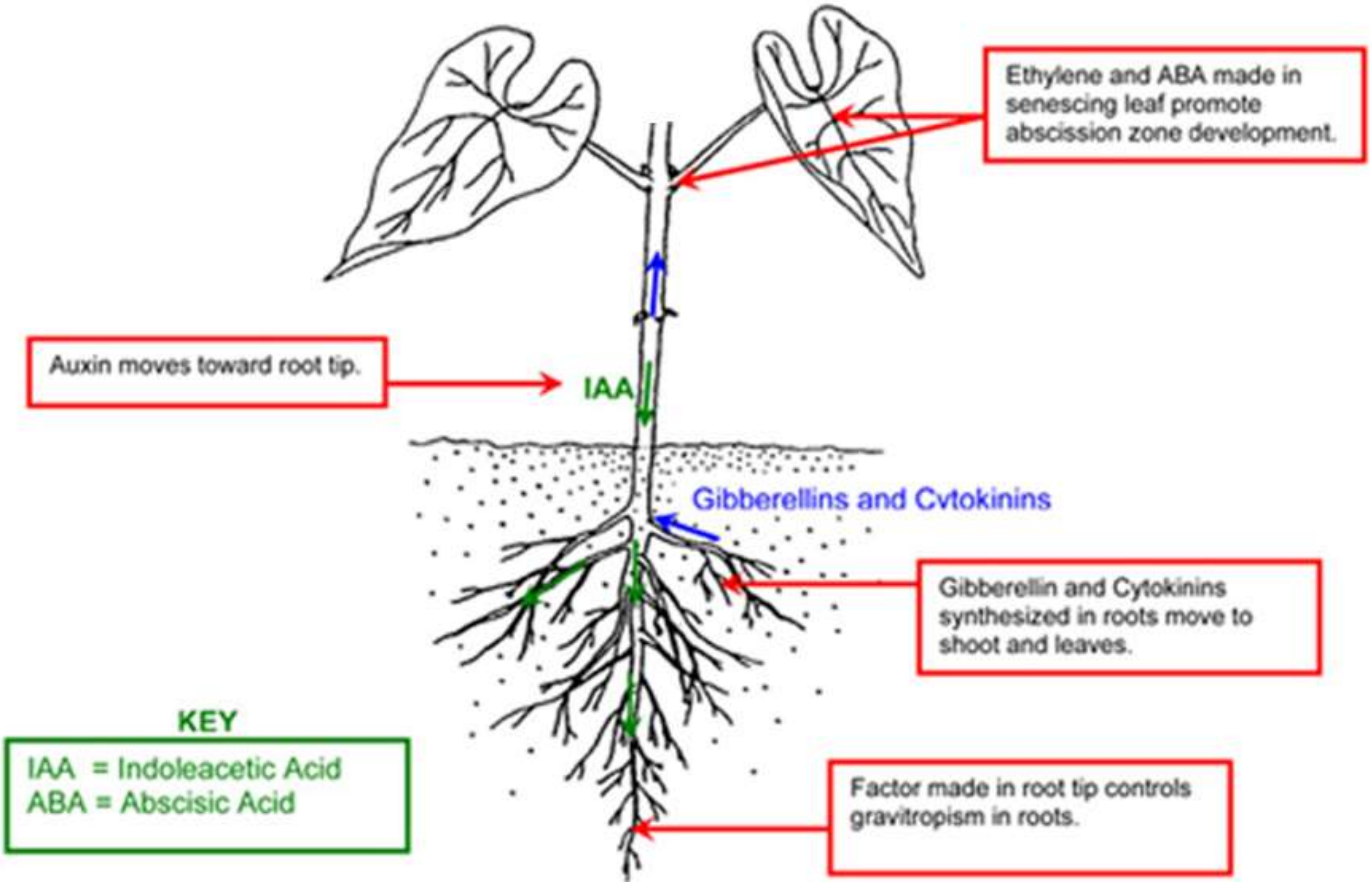


Fig. 3-4. Diagrammatic Representation of Major Functions and Sites of Production of Plant Hormones


Gibberellin controls cell division in subapical region.
Auxin and Gibberellin synthesized in young leaves and bud move to stem to control elongation.
Auxin controls differentiation.
Flowering stimulus moves from leaves to buds to initiate flowers.
ABA made in leaf in response to water stress closes stomata, reducing water loss.
Cytokinins move to leaves from roots, keeping root and shoot growth in balance.
Cytokinins made in young fruit, necessary for growth.
Auxin and Gibberellin promote activity of cambium in formation of secondary vascular tissue.
Ethylene accumulates in mature fruit to induce ripening.
IAA


Ethylene and ABA made in senescing leaf promote abscission zone development.
Auxin moves toward root tip.
IAA
Gibberellins and Cytokinins
Gibberellin and Cytokinins synthesized in roots move to shoot and leaves.
Factor made in root tip controls gravitropism in roots.
KEY
IAA = Indoleacetic Acid
ABA = Abscisic Acid

APPENDIX

Key terms

Abscisic acid (ABA)	حامض الأبسيسيك
Abscission layer	الطبقة الإنفصالية
Apical dominance	السيادة القمية
Auxin	الأوكسين
Brassinosteroids	الاستيرويدات البرونزية
Cytokinin	السايتوكين
Ethylene	الإثيلين
Flowering	الإزهار
Gibberellin	الجبيريلين
Jasmonates	هرمون الياسمين
Gravitropism (geotropism)	الإنتحاء الجاذبي
Long-day plants	نباتات طويلة اليوم
Long-night plants	نباتات طويلة الليل
Negative geotropism	الإنتحاء الجاذبي السالب
Negative Tropism	الإنتحاء السالب
Neutral plants	نباتات محايدة
Oligosaccharins	قليل التعدد السكري
Photoperiodism	ظاهرة التوقيت الضوئي

Phototropism	الإنتحاء الضوئي
Phytochrome	صبغة نباتية أو فايتوكروم
Phytochrome far-red (Pfr)	فوق أحمر الفايتوكروم
Phytochrome red (Pr)	أحمر الفايتوكروم
Plant hormone	هورمون نباتي
Salicylic acid	حامض السليسليك
Positive geotropism	الإنتحاء الجاذبي الموجب
Positive Tropism	الإنتحاء الموجب
Short-day plants	نباتات قصيرة اليوم
Short-night plants	نباتات قصيرة الليل
Statolith	حصاة الإتزان
Stimulus	المؤثر أو المنبه
Systemin	الهرمون النظامي
Thigmotropism	الإنتحاء اللمسي
Tropism	ظاهرة الإنتحاء
Phototropism	الإنتحاء الضوئي
Phytochrome	صبغة نباتية أو فايتوكروم