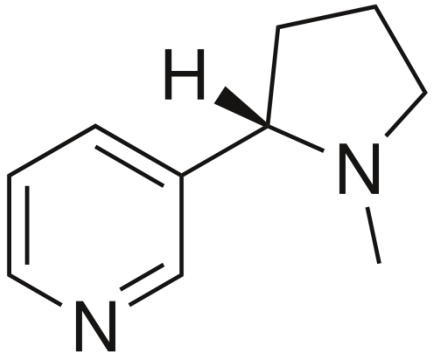
- Roots are the places in which secondary metabolites and hormones are produced in plants. For example:

- They produce gibberellins and cytokinins. These hormones are transferred to shoots with the help of xylem and stimulate plant growth and development.

- An alkaloid, nicotine is produced in the roots of *Nicotiana tabacum (tobacco)* plant and then carried to the leaves. Nicotine accumulated in the leaves serves as a toxin against herbivores that result in nervous system disorders. It is also an insecticide.



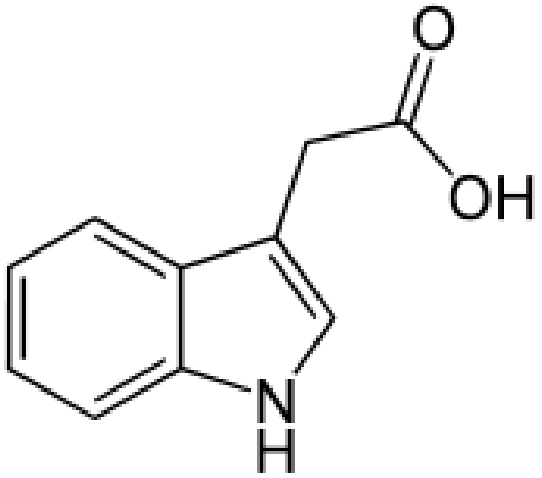
Plant Hormones

- Plant hormones are chemicals such as auxin that regulate plant growth. Plant hormones are signal molecules produced at specific locations in the plant, and occur in extremely low concentrations. The hormones cause altered processes in target cells locally and at other locations. They affect which tissues grow upward and which grow downward, leaf formation and stem growth, fruit development and ripening, plant longevity and even plant death. Hormones are vital to plant growth and, if they were to lack them, plants would be mostly a mass of undifferentiated cells.

- In general, it is accepted that there are **five major classes** of plant hormones, some of which are made up of many different chemicals that can vary in structure from one plant to the next.. Each class has positive as well as inhibitory functions, and most often work in tandem with each other to regulate growth and other responses.

Auxins:

Auxins promote stem elongation, inhibit growth of lateral buds (maintains apical dominance). They are produced in the stem, buds, and root tips. Example: Indole Acetic Acid (IA). Auxin moves to the darker side of the plant, causing the cells there to grow larger than corresponding cells on the lighter side of the plant. This produces a curving of the plant stem tip toward the light, a plant movement known as phototropism.



- Auxin also plays a role in maintaining apical dominance. Most plants have lateral (sometimes called axillary) buds located at nodes (where leaves attach to the stem). Buds are embryonic meristems maintained in a dormant state. Auxin maintains this dormancy. As long as sufficient auxin is produced by the apical meristem, the lateral buds remain dormant. If the apex of the shoot is removed (by a browsing animal or a scientist), the auxin is no longer produced. This will cause the lateral buds to break their dormancy and begin to grow. In effect, the plant becomes bushier. When a gardener trims a hedge, they are applying apical dominance.

- It also stimulates the development of fruit, inhibits falling of the leaves and the fruits, stimulates ethylene synthesis.

Cytokinins

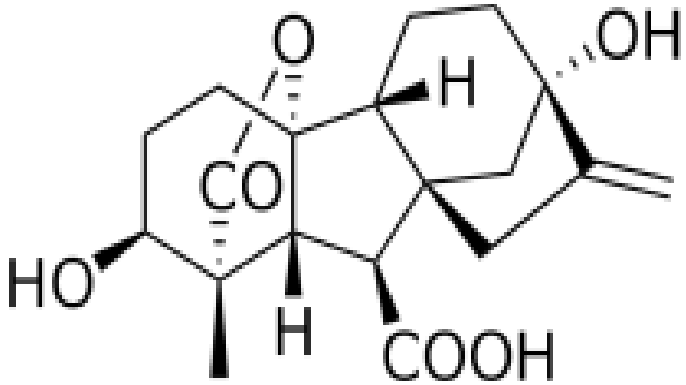
Cytokinins work together with auxin to promote growth and development, by promoting cell division and shoot formation. They are produced in the roots and travel. They counter the apical dominance induced by auxins, promoting the development of buds. In conjunction with ethylene they promote abscission (drop) of leaves and fruit.

Cytokinins regulate root apical meristem size and promote lateral root elongation. They influence the development of vessels; delay aging of the leaves.

Gibberellins

Gibberellins play an important role in germination, initiating the mobilization of nutrients stored within the seed. Absorption of water by the seed causes production of GA. They also promote the elongation of stems, flowering and cell division (growth). Gibberellins also reverse the inhibition of shoot growth and seed dormancy induced by ABA.

- They also stimulate flowering in some plants.

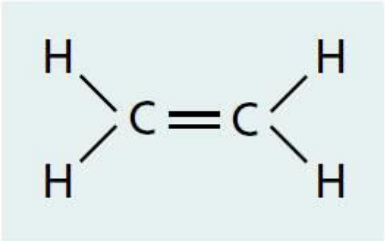


Ethylene

- Ethylene ("the ripening hormone") is a gas that promotes fruit ripening and abscission (drop) of leaves and fruit. Ethylene production increases when the seeds are mature, ensuring the fruit is released when only when the seeds are capable of germination. Fruit often releases ethylene gas as it ripens (this is why storing unripen fruit with a ripening apple will accelerate the ripening process).

- It also affects cell growth and cell shape; when a growing shoot hits an obstacle while underground, ethylene production greatly increases, preventing cell elongation and causing the stem to swell. The resulting thicker stem can exert more pressure against the object impeding its path to the surface. If the shoot does not reach the surface and the ethylene stimulus becomes prolonged, it affects the stem's natural geotropic response, which is to grow upright, allowing it to grow around an object.

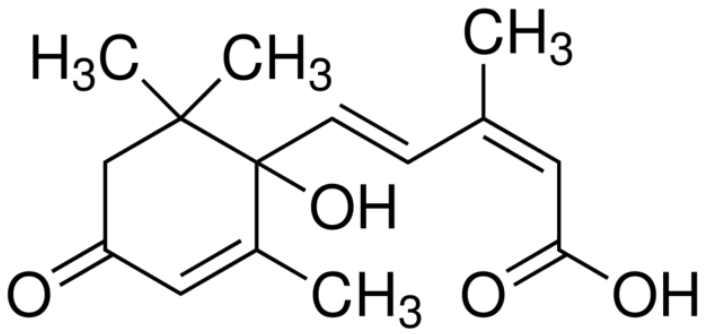
- It also allows the perception of mechanical stress and pathogenic attacks by the plant and cause them to react.



Ethylene

Abscisic acid (ABA)

- Abscisic acid (also called ABA) is one of the most important plant growth regulators. In general, abscisic acid inhibits growth / germination. Abscisic acid induces bud and seed dormancy, preventing germination during winter. As summer approaches abscisic acid dissipates, but this occurs slowly and it takes some time for it's effects to wear off. This prevents seeds from germinating on warmer winter days and ensures they only germinate once the temperature is consistently warmer. Abscisic acid also prevents seeds from germinating within the fruit, slows growth in more "mature" parts of the plant and closes stomata (tiny pores on the undersides of the leaves) in response to a lack of water.



Secondary Metabolites

Secondary Metabolites

- Food plants are important since they provide primary metabolites to other living beings. These metabolites are carbohydrates, lipids, proteins, minerals and vitamins. They may also provide secondary metabolites, with various chemical structures.

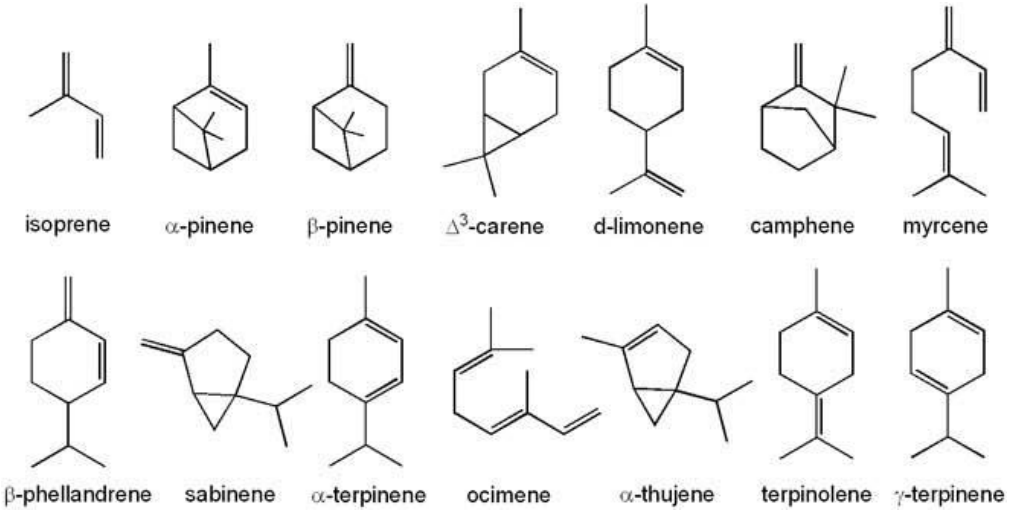
- Secondary metabolites do not have a direct role in the growth and development of plants. They serve for the purpose of protection against herbivorous animals and pathogenic microorganisms. Since plants can not run away from these agressors, they rely on chemicals for protection and they have became experts in chemical war.

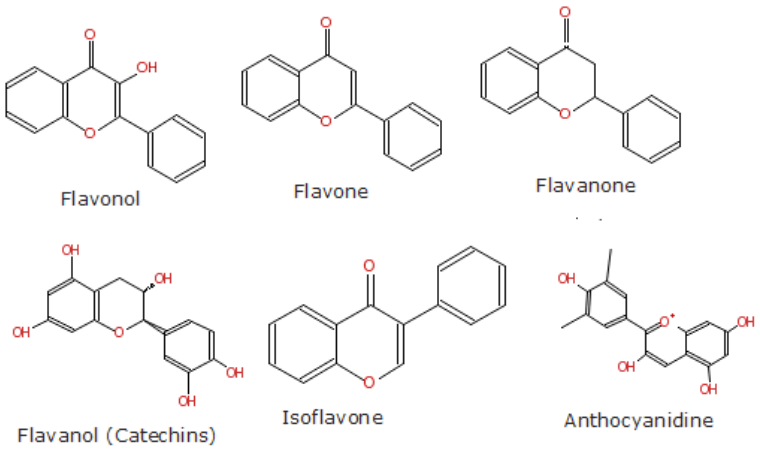
- Plants are surrounded by harmful pests, fatal microorganisms and hungry herbivores, however they still can survive. This is due to their chemical defenses. And also since plants can not move actively, they frequently use animals and birds to have their seeds carried elsewhere. In this case, secondary metabolites give color to the flowers and fruits and attract animals, birds and insects and result in the distribution of pollens and seeds.

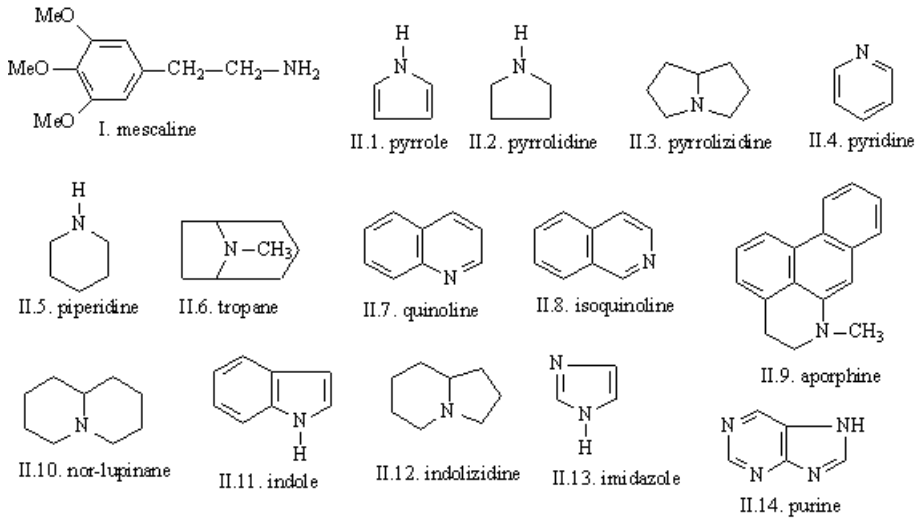
- Plants require various types of chemical defenses to deal with their enemies. Plants living in tropical rain forests where pests and disease forming microorganisms show great biodiversity have more secondary metabolites compared to plants that live in places where the requirement for defending themselves are less. Therefore, tropical regions are important in respect to finding new medicinal plants and also in respect to ethnobotanical knowledge.

Types of Secondary Metabolites

- Main classes of secondary metabolites are terpenes and terpenoids, phenolic substances including flavonoids and alkaloids.

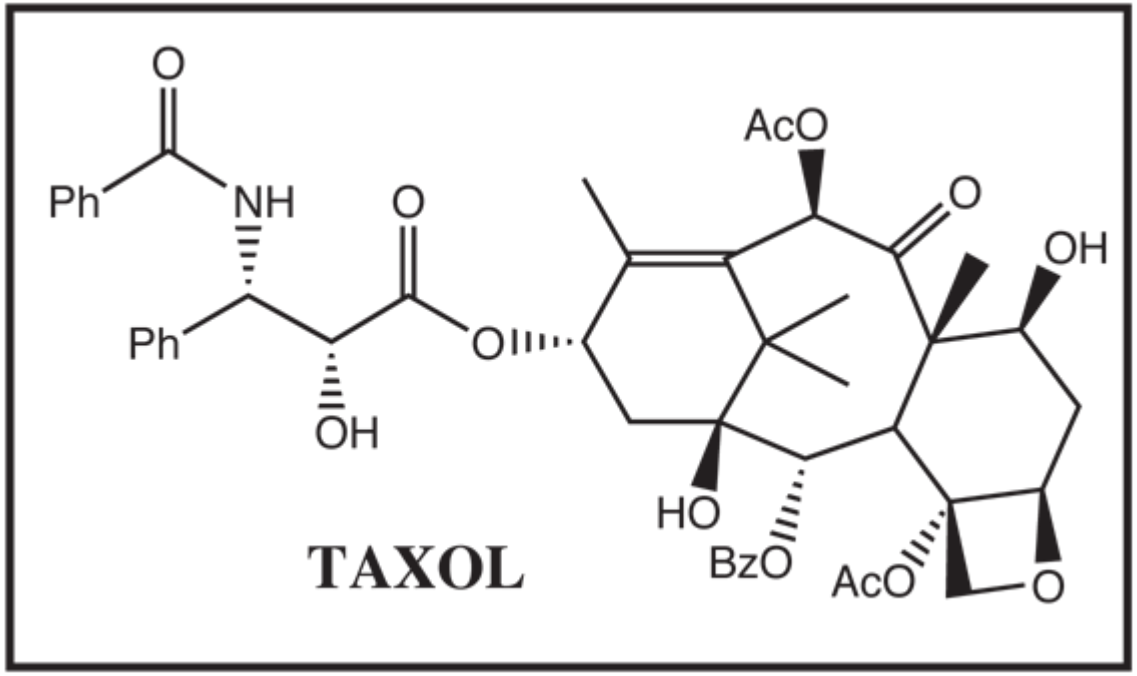






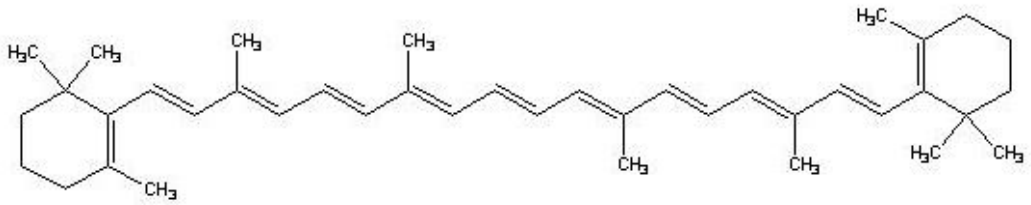
TERPENES AND TERPENOIDS

Terpenes and terpenoids are secondary metabolites that have various activities. For example, taxol (paclitaxel) that is used in cancer treatment is a terpene.



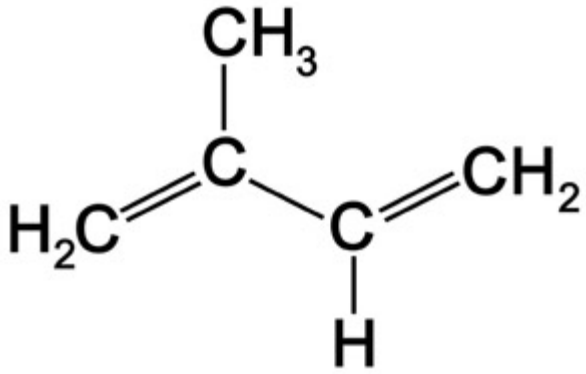
TAXOL

Carotenoids that give orange color to carrots and to leaves in the fall have a role in photosynthetic reactions and prevent damages due to excessive light.

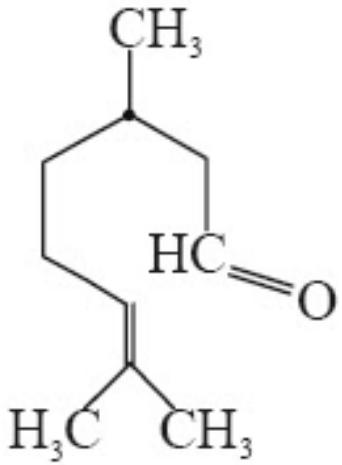


β-carotene

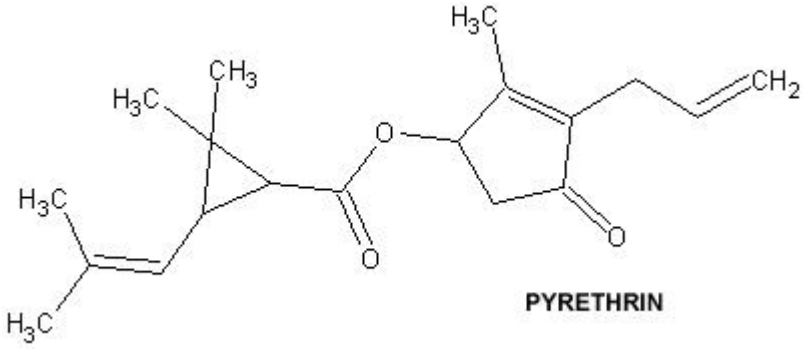
- Terpenes and terpenoids have nearly 25.000 different types that show great variety in respect to their sizes and complexities. However, all of them consist of the main building blocks that look like isoprene units. Different number of isoprene units come together to form different structures. Some of them have beautiful odors and attract insects for pollination. These can also be used in the perfume industry.



- Other terpenes play a role in repelling disease producing organisms or insects. For example citronellal is used by humans to repel biting insects.
- Pyrethrin obtained from a plant (*Pyrethrum* sp.) belonging to Asteraceae family is a natural terpene which is very potent as an insecticide.



Citronellal



PYRETHRIN

- Sunflower and wormwood plants produce terpenes in their glands that they have on their leaves. When disturbed by animals, they release these compounds in order to repel the disturbing animal.